Aeronautics and Space Report of the President

Fiscal Year 2001 Activities

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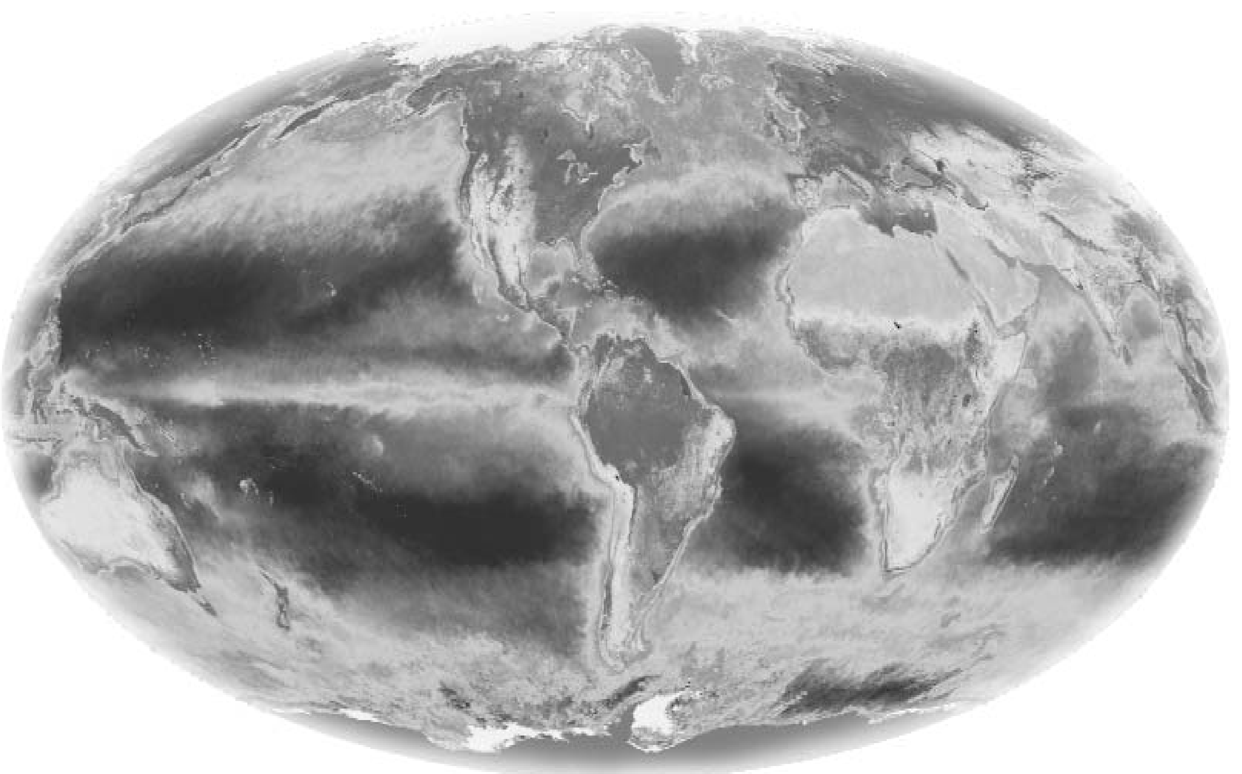

Fiscal Year 2001 Activities

National Aeronautics
and Space Administration

Washington, DC 20546

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 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, 2000, through September 30, 2001.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

In FY 2001, NASA's safety quest continued to build momentum. In the past year, NASA continued its successful plan for reducing injuries to a rate of 0.75 occurrences per 100 workers, well below the goal specified by the President's direction arising from the Federal Worker 2000 Presidential Initiative. To continue this positive trend, NASA's Centers are working to be certified under the Occupational Safety and Health Administration's Voluntary Protection Program (VPP). NASA has set a goal for all of its Centers to be VPP certified. By the end of FY 2001, 2 of the 10 Centers had been certified. NASA safety and mission assurance experts provided assessment, oversight, and critical evaluation for NASA Space Shuttle missions, International Space Station missions and operations, and NASA spacecraft missions. In addition, NASA conducted several focused assessments including operational and engineering reviews of the Jet Propulsion Laboratory microdevices laboratory and Unitary Wind Tunnel at the Ames Research Center; a critical facilities maintenance assessment to determine the safety and mission support posture of critical facilities across NASA; an assessment of X-37 safety and mission assurance processes and design features; the United Space Alliance Ground Operations workforce survey; and the Boeing Seal Beach onsite assessment and review. NASA instituted an Aviation Safety Board to oversee aviation safety programs. To strengthen the Agency's safety and mission assurance capabilities, NASA introduced the following two new tools: the Systems Analysis Program for Hands-On Integrated Reliability Evaluations (SAPHIRE), a Probabilistic Risk Assessment (PRA) software application developed for the Nuclear Regulatory Commission, which now serves as the baseline PRA tool for NASA; and the Process-Based Mission Assurance Web resource, which provides

NASA's program managers with the framework to help build the right level of safety and mission assurance activity into their program.

In the human space flight area, NASA successfully accomplished seven Space Shuttle missions in support of complex International Space Station (ISS) assembly operations during FY 2001. From the launch of STS-98 in February 2001 to the landing of STS-105 in August 2001, NASA flew five flights in six months, maintaining a vehicle in orbit for more than one third of that time. The ISS had its first permanent occupants in FY 2001, beginning with the launch of the Expedition 1 crew aboard a Russian Soyuz rocket on October 31, 2000. The Expedition 2 and 3 crews also began their stays on the ISS during FY 2001.

The STS-92 mission, which launched on October 11, 2000, was the 100th Shuttle mission. For STS-92, during its 12-day mission to the ISS, all assigned objectives to install the Zenith Z1 Truss structure and the third pressurized mating adapter (PMA3) for use as a docking port on subsequent Shuttle missions were completed. On flight day three, Japanese astronaut Koichi Wakata deftly maneuvered *Discovery's* robotic arm to lift the Zenith Z1 Truss from the Shuttle's payload bay and berthed it to a port on the Unity connecting module. Inside Unity, pilot Pam Melroy and crewmate Jeff Wisoff opened the hatch where the new truss was attached and installed grounding connections between the framework and the Station. *Discovery's* five mission specialists performed a total of four extravehicular activities (EVAs) during the STS-92 mission. The crew also successfully completed testing of the four control moment gyroscopes that will be used to orient the ISS as it orbits Earth.

On November 30, 2000, the STS-97 mission was successfully launched. For STS-97, an 11-day mission, the astronauts completed three spacewalks to deliver and connect the first set of U.S.-provided solar arrays to the ISS, prepare a docking port for arrival of the U.S. Laboratory Destiny, install a sophisticated instrumentation package to measure electrical potential surrounding the Station, install a camera cable outside the Unity module, and transfer supplies, equipment, and refuse between *Endeavour* and the ISS. The successful checkout of the extravehicular mobility units (EMUs), the Simplified Aid for EVA Rescue (SAFER) units, the Remote Manipulator System RMS, the Orbiter Space Vision System (OSVS), and the Orbiter Docking System (ODS) were all completed nominally. Also, the ODS centerline camera was installed smoothly.

The STS-98 mission launched on February 7, 2001. On STS-98, after docking to the ISS, Station and Shuttle crews opened hatches and unloaded supplies: bags of water, a spare computer, cables to be installed inside the Station to power up the Destiny Laboratory, and various personal items for the Station crew. The U.S. Laboratory Destiny was successfully installed on the ISS using the RMS and concurrent EVAs. Shuttle and Station astronauts also activated air systems, fire extinguishers, alarm systems, computers, and internal communications, plus continued equipment transfers from the Shuttle to the Station. They also filmed onboard scenes using an IMAX camera.

On March 8, 2001, the STS-102 mission launched at sunrise and carried the second resident crew (Expedition 2) to the ISS, as well as the first Multi-Purpose Logistics Module, Leonardo, full of supplies and equipment plus science racks for transfer to the U.S. Laboratory Destiny. Joint operations between the Shuttle and the Station crews resulted in unloading almost 5 tons of experiments and equipment from Leonardo and packing almost 1 ton of items for return to Earth. *Discovery's* spacewalkers—James Voss, Susan Helms, Andrew Thomas, and Paul Richards—set the stage for continued expansion of the Station by installing a platform that will eventually be used to mount a Canadian-built robotic arm, the Space Station Remote Manipulator System (SSRMS), to the Station on a future mission. They also removed a Lab Cradle Assembly from *Discovery's* cargo bay and installed it on the side of the U.S. Lab Destiny, where it will form the base for the SSRMS that was delivered on a mission in April 2001.

The STS-100 mission launched on April 19 and docked with the ISS 2 days later. The advanced robotic arm, called Canadarm2, was attached to a pallet on the outside of Destiny. It later was directed to "walk off" the pallet and grab onto an electrical grapple fixture on the Lab, which would provide data, power, and telemetry to the arm. Days later, the arm was used to hand off the cradle, on which it rested inside *Endeavour's* payload bay during launch, to the orbiter's arm. The exchange of the cradle from Station arm to Shuttle arm marked the first-ever robotic-to-robotic transfer in space. Other crew activities during the mission included attaching an ultra-high-frequency antenna on the outside of the Station and, inside, calibrating the Space Vision System, an alignment aid for operating the robotic arm, plus helping repair the Space Station's treadmill and filming for IMAX.

For STS-104, liftoff occurred on July 12, 2001. The primary mission goal was to deliver the joint airlock Quest module to the ISS. This mission marked the end of the second phase of Station assembly. After docking with the ISS on July 13, both *Atlantis* and ISS crews prepared for the planned three EVAs. In a series of three spacewalks, the joint airlock module was attached to the Unity Node an high-pressure gas tanks attached to the airlock. Both Station and Shuttle crews checked out and activated the new Quest airlock, conducting a dry run before the inaugural event. This mission was the first launch of the Block II Space Shuttle Main Engine. Approximately a month later, on August 10, 2001, the STS-105 mission launched. Part of the mission was to bring the next resident crew, Expedition 3, to the ISS and return Expedition 2 to Earth. The payload included the Early Ammonia Servicer (EAS), to be installed on the outside of the ISS, and Multi-Purpose Logistics Module (MPLM) Leonardo. During the time docked with the ISS, crews unloaded 7,000 pounds of supplies, equipment, and science racks from the MPLM Leonardo, storing it on the Space Station. This was the second flight of the Leonardo to the ISS. Mission specialists completed the first of two EVAs to install the EAS on August 16, 2001.

The Expedition 1 crew began their stay on the ISS in November 2000, following an October 31 launch (Flight 2R). The outfitting of the ISS continued with the delivery of supplies via a Russian Progress supply vehicle (2P) in mid-November. The STS-97 crew then launched on November 30, 2000, delivering the first U.S. solar array and radiator (Flight 4A), the 11th flight in the ISS assembly sequence. Next, the Expedition 1 crew received the 12th flight in the ISS assembly sequence, 5A, the delivery of the U.S. Lab on STS-98 in February 2001. This mission was followed by the third Russian Progress supply mission and the 13th ISS flight (3P) on February 25, 2001. The Station's first permanent crew spent more than 4 months on the ISS and supported four assembly and logistics missions before the arrival of the Expedition 2 crew.

Increment 2 crew operations were initiated on STS-102, the premier launch of the first Italian-made MPLM Leonardo (Flight 5A.1) on March 8. It was the first docking with the ISS under U.S. Orbital Segment (USOS) attitude control and the first ISS crew rotation. On April 16, the Progress M-244 resupply ship (3P) was jettisoned from the Service Module (SM) aft port, after having delivered approximately 2 metric tons of goods and propellants, and conducted three reboost maneuvers of the ISS. On April 19, 2001, STS-100 lifted off on ISS mission 6A with a crew of seven (including one Russian) to deliver the second Italian-built MPLM “Raffaello” and the Canadian space station remote manipulator system “Canadarm2” to the ISS. The first Soyuz (crew return vehicle) exchange (2S) was accomplished with an April 28 launch to provide the replacement Soyuz and return the “spent” Soyuz TM-31 (2R) to Earth.

Following this mission, the fourth Progress logistics flight (4P) was launched to the ISS on May 20. On July 12, STS-104 was launched with five crewmembers on assembly mission 7A to conduct joint operations with the Expedition 2 crew and, in three spacewalks, to install the Joint Airlock “Quest” and outfit it with four high-pressure gas tanks.

As NASA has accelerated the transition from ISS development work into operations, all elements for ISS assembly flight elements through 12A have been delivered either to orbit (Node 1 Unity, the FGB, the first solar arrays, thermal radiators, the Z1 Truss, Control Moment Gyros (CMG) attitude control systems, PMA-1, 2, and 3, and the U.S. Laboratory, Destiny) or to KSC (the remaining truss segments, communications system, integrated electronics, and the U.S. Airlock). NASA determined that it is in the best interest of the Government to concentrate resources on assembly planning, operations, and utilization readiness, and on the on-orbit assembly of the ISS.

From an operational perspective, the communications systems with Mission Control Center (MCC)-Houston, MCC-Moscow, and the U.S.-led international control teams have been vigorously exercised as they worked anomaly resolution, avoidance maneuvers, Soyuz and Progress dockings, and redocking tests at different ISS ports, as well as ISS reboosts as required. Mission Control was officially handed over to MCC-Houston after the 5A.1 mission in March 2001.

The establishment of a permanent human presence on the ISS created remarkable opportunities for the Space Medicine Program. While traditional support continued for astronaut healthcare, medical certification, and Shuttle medical operations, the space medicine emphasis at the Johnson Space Center (JSC) shifted to worldwide long-duration operations, onorbit deconditioning countermeasures, onorbit medical certification and intervention, and comprehensive rehabilitation services postflight. In addition, the planning process was begun to integrate exciting new capabilities such as the onorbit ultrasound to improve both astronaut healthcare and research possibilities.

The Space Medicine Program successfully implemented many changes to medical operations that included 24-hour-per-day medical support at multiple sites such as JSC, the Kennedy Space Center (KSC), the Gagarin Cosmonaut Training Center, and in Kazakhstan. Preflight, inflight, and postflight medical support was provided for seven Shuttle missions and ISS Expeditions 1, 2, and 3. Preparation for each mission included preflight medical screening, crew training on the use of medical, exercise, and environmental monitoring hardware, cross-cultural and isolation- coping techniques training, contingency medical procedures training, medical kit preparation, strength and endurance physical training, and ground crew mission-specific preparation.

Initial ISS support operations were conducted from Moscow utilizing an integrated medical team approach developed between the Russian and U.S. support staff. The integrated medical team continued daily communication and planning when flight control shifted to Houston during Expedition 2. All of the ISS International Partners participated in multilateral flight crew certification and in integrated flight readiness program reviews. An integrated catalog of all Russian and U.S. medical systems and hardware was also developed.

The Crew Health Care System (CHeCS) comprised of the Environmental Monitoring System, Health Maintenance System, and Countermeasure System was launched and operationally deployed. Medical systems for ISS are unique in that components of CHeCS can be commanded from the ground. These commands can implement a verification of onorbit systems or initiate data downlink operations. Data within JSC are transferred using a file transfer protocol server with virtual private network (VPN) connectivity to MCC-Houston and JSC Medical Lab facilities.

Medical services were enhanced with the implementation of an electronic medical record, replacing the paper-based system in the flight medicine clinic. Data are now automatically entered into the Longitudinal Study of Astronaut Health (LSAH) database. The LSAH project provides data for evidence-based decisionmaking for the development of selection standards and appropriate Earth and space-based prevention and treatment capabilities within the Space Medicine Program.

A critical new part of the Space Medicine Program is the physical training, preflight conditioning, and postflight rehabilitation of the astronauts. The

Astronaut Strength, Conditioning, and Rehabilitation (ASCR) program was implemented for long-duration ISS crewmembers. EVA-assigned crewmembers received physical training specifically to address conditioning for the required task of EVA. ISS crewmembers exercise activities were monitored and specific exercise prescriptions uplinked weekly. As a result, ISS crewmembers returned to Earth with acceptable performance margins to be able to exit the Shuttle with minimal assistance. The postflight program is designed to return the astronauts to their normal state of health while providing safety factors to prevent injury during their rehabilitation.

Upgrading the onboard space medicine preventive, diagnostic, and treatment capabilities is an ongoing process. Among many new developments this year, an important concept was improving telepresence techniques to optimally utilize Earth-based resources and expertise to extend crewmember capabilities. One example this year was the development of procedures to use ultrasound techniques to provide high-quality diagnostic imaging with nonmedical personnel. Using this technique, onorbit crew can be guided by a remotely located flight surgeon and Earth-based experts via the ISS telecommunications infrastructure.

It has also become clear that the crewmembers on long-duration missions need considerable support for psychosocial considerations. Behavioral health programs were implemented in 2001 to support the ISS crewmembers and their families. These support elements included cross-cultural training, cognitive self-assessment, and fatigue self-assessment tools to enable maximum performance and safety of the crew.

The primary goal of the Space Shuttle Safety Upgrade Program continued to be the improvement of crew flight safety and situational awareness, protect people both during flight and on the ground, and increase the overall reliability of the Shuttle system. During FY 2001, NASA continued working on improving existing Space Shuttle operational mission assurance and reliability through several safety and supportability upgrade initiatives. To improve Shuttle safety, an effort was initiated to proactively upgrade the Shuttle elements and keep it flying safely and efficiently through FY 2012 and beyond to meet Agency commitments and goals for human access to space. The suite of high- priority safety upgrades included the Cockpit Avionics Upgrade (CAU), the Space Shuttle Main Engine (SSME), Advance Health Management System (AHMS), Electric Auxiliary Power Unit (EAPU), and the Solid Rocket Booster Advance Thrust Vector

Control system. CAU, which will enhance crew situational awareness and reduce crew workload by providing automated control of complex procedures, is currently underway. The EAPU would have replaced the hydrazine-powered units by using battery-powered electric motors, but, due to technology development required before initiating the implementation, this project was cancelled. In addition, the Solid Rocket Booster Advance Thrust Vector Control upgrade, which if implemented could replace the hydrazine-powered turbines, was delayed due to budget constraints.

FY 2001 included the first flight of the upgraded SSME designated Block II on the STS-104 flight. The Block II Maine Engine configuration included a new Pratt & Whitney high-pressure fuel turbopump. The main modification to the engine was the elimination of welds by using a casting process for the housing and in integral shaft/disk with thin-wall blades and ceramic bearings. These changes doubled the reliability of the engine. This modification should increase the number of flights between major overhauls.

The operational character of the Space Shuttle Program places a significant burden on NASA resources. Although “operational” by NASA standards, the Space Shuttle requires significant specialized skills and facilities to maintain and operate at appropriate safety levels. Over the past 6 years, NASA has reduced the annual operation cost of the Space Shuttle by almost 40 percent. NASA has already made significant strides toward privatization of the Space Shuttle by completing a series of contract consolidations. In 1997, NASA turned over daily operations of the Shuttle to a jointly owned corporation called United Space Alliance (USA). During FY 2001, however, the Shuttle program still required about 1,800 highly skilled civil service personnel to carry out the remaining Government operational and oversight responsibilities. Additionally, for continued safe operations of the Space Shuttle until the middle of the next decade, significant investments are required to maintain Space Shuttle flight system and aging ground infrastructure assets.

The challenges to complete Space Shuttle privatization continued to be centered on ensuring that safety is not compromised while at the same time achieving further cost benefit to the Government. During FY 2001, NASA began the current Space Shuttle privatization effort by chartering an internal task team to perform a review and assessment of options for privatizing the Shuttle, developing screening criteria for all privatization options, and providing recommendations on the best options to senior Agency officials.

In the area of space communications, NASA's Space, Deep Space, Ground, and Wide-Area Networks successfully supported all NASA flight missions and numerous commercial, foreign, and other U.S. Government agency missions. Included were the launch of ISS hardware, Mars Odyssey, Microwave Anisotrophy Probe, Genesis, Artemis, and GOES-M. Emergency support of spacecraft anomalies were provided to Artemis, GOES, Solar and Heliospheric Observatory, Mars Global Surveyor, Terra, Tropical Rainfall Measuring Mission, and Cassini. Other support included the NEAR landing on the asteroid Eros, Deep Space-1 encounter with comet Borrelly, Astro-D re-entry with impact in the Pacific Ocean, and Landsat-4 end-of-life maneuvers.

The Consolidated Space Operations Contract (CSOC) completed its 33rd month of a 5-year basic period of performance. Operations support continued at Johnson Space Center, Jet Propulsion Laboratory, Goddard Space Flight Center, Marshall Space Flight Center, and Kennedy Space Center.

Other significant activities included installation of Ka-Band uplink capability at Goldstone Deep Space Communications Complex to support the Cassini mission; installation of 70-meter X-Band uplink capability at the Madrid, Spain, and Canberra, Australia, stations; completion of the mechanical life extension study for the Deep Space Network's 70-meter antennas; automation of the 26-meter antenna operations at Goldstone station; automation of the packet telemetry processing facility that supports the Hubble Space Telescope; installation of a 5-meter Ka-Band antenna at Wallops Flight Facility to support flight demonstrations; initiation of construction of a new 34-meter antenna at Madrid, to be operational for the armada of spacecraft arriving at Mars in late 2003/early 2004; and preparations for the launch of TDRS-I and TDRS-J.

There were 18 U.S. Expendable Launch Vehicle launches in FY 2001. Seven of the 18 launches were NASA-managed missions, 9 were Department of Defense (DoD)-managed missions, and 2 were FAA-licensed commercial launches. In addition, NASA flew one payload as a secondary payload on one of the FAA-licensed commercial launches. The last launch of the fiscal year was a NASA-managed launch from the Alaska Spaceport on Kodiak Island, the first orbital launch from the new commercial Spaceport. There was one launch failure this year. An FAA-licensed launch of the Orbital Sciences Corporation (OSC) Taurus with a NASA secondary payload onboard did not achieve orbit due to a launch vehicle first-stage failure.

NASA began a new Spaceport and Range Technology Development Initiative to develop and demonstrate advanced spaceport and range technologies to keep pace with the upgrades of current and the development of new launch vehicles. This initiative was an outgrowth of an Administration interagency study on the primary Federal launch ranges. The Kennedy Space Center is leading the initiative. Throughout FY 2001, NASA continued to define potential human/robotic exploration architectures and technologies through the efforts of an interagency planning team. As reported in FY 2000, the Decadal Planning Team (now known as the NASA Exploration Team or NEXT) focused upon science-driven and technology-enabled capabilities for future applications and destinations. These studies have changed the way NASA has approached exploration, and, at the end of the fiscal year, NASA planned to continue them.

To tackle the many technical challenges, the HEDS Technology and Commercialization Initiative (HTCI) was initiated following a 6-month program formulation involving numerous NASA Enterprises, Field Centers, universities, and companies. The focus of this initiative was to identify new concepts and develop new technologies to enable the future human/robotic exploration and commercial development of space. In February 2001, HTCI issued a Cooperative Agreement Notice that yielded 152 proposals, from which 43 were recommended for funding in May 2001. Unfortunately, however, a few months later, HTCI funds were frozen, and then the funds were transferred to the ISS Program to cover budget issues.

In lieu of HTCI as a means of implementing technology research in the near term, efforts to foster development continued by cooperative interaction among the NASA Enterprises and Centers. The cooperation encompasses a continuing specific focus in the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. The SBIR/STTR programs in the Advanced Programs Office are geared to support HEDS technology research with focused topics in high-priority technologies. In addition, the programs have been given a push in nontraditional research avenues via the Historically Black Colleges and Universities (HBCU) outreach activity. This activity resulted in a new STTR phase one contract in FY 2001 and is expected to generate additional contracts in FY 2002. The HBCU research institutions represent a far underutilized resource that could form a new approach toward meeting the HEDS technology challenges.

In the space science arena, NASA successfully launched three spacecraft in FY 2001: the 2001 Mars Odyssey, the Microwave Anisotropy Probe (MAP), and Genesis. In addition, the many spacecraft already operating delivered a wealth of scientific data.

The launch of Odyssey in April 2001 represented a milestone for space science: the rebirth of the Mars program after the devastating losses of Mars Climate Orbiter and Mars Polar Lander in late 1999. Odyssey was the first Mars mission designed under the newly renovated Mars program, so naturally all eyes were focused closely on this particular mission. From the beginning, the spacecraft operated beautifully, but the proof would not come until the spacecraft successfully achieved Mars Orbit Insertion after the close of FY 2001.

In June 2001, NASA launched the Microwave Anisotropy Probe, a mission designed to measure the temperature of the cosmic background radiation over the full sky with unprecedented accuracy. This map of the remnant heat from the Big Bang will provide answers to fundamental questions about the origin and fate of our universe. Immediately after the end of FY 2001, MAP arrived safely at its permanent observing station at L2 Lagrange Point, some 1.5 million kilometers from Earth, and scientists eagerly await the data it will deliver over its 2-year prime mission.

In August 2001, NASA launched a unique Sun-Earth Connection mission called Genesis. Genesis is designed to collect particles of solar wind in an attempt to answer two fundamental scientific questions: What is the Sun made of? Are the Earth and other planets made of the same stuff? At the end of FY 2001, the spacecraft was on its million-mile journey toward the Sun.

NASA's other orbiting spacecraft continued to deliver many new scientific discoveries and fascinating images. The Hubble Space Telescope—now in orbit for 12 years—discovered a supernova blast in the early universe that greatly bolsters the case for the existence of a mysterious form of "dark energy" pervading the universe. The concept of dark energy, which shoves galaxies away from each other at an ever-increasing speed, was first proposed—and then discarded—by Albert Einstein early in the last century. The Hubble discovery also reinforces the startling idea that the universe only recently began to speed up.

The Near Earth Asteroid Rendezvous (NEAR) Shoemaker spacecraft achieved an unprecedented feat in FY 2001. It conducted the first soft landing on an asteroid following a year-long orbital mission at the asteroid Eros, during which the mission returned enormous quantities of scientific data and images.

The Chandra X-Ray Observatory celebrated 2 years in orbit and continued unlocking secrets of mysterious high-energy astrophysical events. Chandra enhanced our understanding of black holes on many fronts. It took the deepest x-ray images ever and found the early universe teeming with black holes, it probed the theoretical edge of a black hole known as the event horizon, and it captured the first x-ray flare ever seen from the supermassive black hole in the center of the Milky Way.

The Submillimeter Wave Astronomy Satellite (SWAS) made news when a stellar apocalypse yielded the first evidence of water-bearing worlds beyond our solar system. The SWAS observations provided the first evidence that extra-solar planetary systems contain water, an essential ingredient for known forms of life.

The Mars Global Surveyor continued to send back tens of thousands of surface images over the past year that featured dust storms, dust devils, 3-D sand dunes, a recent image of “the face,” and dark streaks that may have been caused by dust avalanches. Other images revealed evidence of ground ice on Mars as recently as 10 million years ago.

With more than 30 space science missions currently in operation, these highlights represent only a fraction of the scientific discoveries and insights that the Office of Space Science gained over the past year. At the end of FY 2001, the Space Science Enterprise planned to launch seven new missions before the end of 2002, covering a wide variety of new scientific objectives.

FY 2001 was the most successful year to date for NASA’s Earth Science Enterprise (ESE) in fulfilling its mission to develop a scientific understanding of the Earth system and its response to natural and human-induced changes so as to enable improved prediction of climate, weather, and natural hazards for present and future generations. ESE’s unique vantage point of space allowed unprecedented global views of the Earth system’s atmosphere, land, oceans, ice, and life. ESE combines space observations with airborne and in situ measurements, data analysis, and modeling to conduct basic research and provide validated data products. In FY 2001, ESE more than doubled its output of top-rated scientific discoveries compared to previous years. Together with its partners, ESE enhanced the availability of Earth science results to decisionmakers, providing a sound, scientific basis for economic investment and policy decisions. ESE’s strategic goals in

FY 2001 were to expand scientific knowledge by characterizing the Earth system, disseminate information about the Earth system, and enable the productive use of ESE science and technology in the public and private sectors.

On November 21, 2000, ESE successfully launched the Earth Observing-1 (EO-1) technology demonstration satellite, its first New Millennium Program mission. EO-1 included the world's first space-based hyperspectral sensor. At one-quarter the weight and one-third the cost of traditional Landsat satellites, EO-1 demonstrated its ability to produce Landsat-like imagery at a fraction of the mission costs. EO-1 flies in formation with the Earth Observing System Terra (EOS-Terra) satellite, Landsat 7, and the joint U.S.-Argentina SAC-C satellite, and has demonstrated the satellite constellation concept in which the combined capabilities create a super-satellite. Once validated, several of the EO-1 technologies will be turned over to the private sector for commercial development.

Two international collaborations in FY 2001 provided new tools that should allow policymakers and scientists to identify major sources of air pollution and to track the movement of pollution globally. ESE and its partners tracked hazardous smoke and smog around the globe using the Total Ozone Mapping Spectrometer Earth Probe (TOMS-EP). By examining data from Indonesian and African fires in 1997, researchers discovered that smoke and smog move through the atmosphere in different ways. In the second collaboration, ESE developed the most complete view of the world's air pollution using new observations from the Canadian Measurements of Pollution in the Troposphere (MOPITT) instrument on the Terra spacecraft. Analysis of the new data revealed that plumes of carbon monoxide travel across the world, and that air pollution therefore is not just a local issue. Early warning of pollution events can help to mitigate their potentially hazardous effects on human health.

ESE successfully conducted an international field experiment, the Transport and Chemical Evolution over the Pacific (TRACE-P) airborne campaign. During the 45-day campaign in March/April 2001, ESE scientists combined data collected by two specially equipped NASA airplanes flying near Hong Kong and Japan with satellite and ground station measurements. By studying the seasonal airflow from Asia across the Pacific, researchers gained insight into the way in which natural and human-induced changes affect our global climate and contributed to our understanding of the dynamics of atmospheric chemistry.

Using 3 years of continuous, daily observations of ocean algae and land plants from the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) launched in 1997, ESE created the most comprehensive global biological record of the Earth ever assembled. Researchers are using the record, which ESE plans to extend to 10 years or more, to study the fate of carbon in the atmosphere, the length of growing seasons, and the vitality of the ocean's food web. Other uses include monitoring the health of coral reefs, tracking harmful "red tides" and algae blooms, and improving global climate models.

In FY 2001, ESE made advances in understanding seasonal to interannual climate change. The Clouds and Earth's Radiation Energy System (CERES) instrument on the Terra spacecraft provided the most accurate and first complete year of global radiation measurements. Using Terra's ability to collect data twice per day over the entire planet, the new measurements captured both incoming and outgoing energy globally. The results from a second NASA-funded study suggested that solar activity affects the jet stream over North America, possibly causing a change in cloud cover patterns. In years of increased solar activity, more ultraviolet radiation is absorbed by stratospheric ozone, which warms the stratosphere and may affect circulation in the troposphere. Researchers found that the U.S. is on average 2 percent cloudier in years of solar maximum. Understanding the links between solar radiation, atmospheric chemistry, cloud cover, and atmospheric circulation will help narrow the uncertainties in predictions of both weather and future climate change. ESE and the Canadian Space Agency (CSA) completed the second Antarctic Mapping Mission that was begun in FY 2000. By precisely navigating the CSA's RADARSAT-1 satellite to obtain data from six passes, researchers created detailed topographic maps and were able to measure the speed of moving glaciers. The first-ever velocity map of the Lambert Glacier revealed that the ice stream reaches speeds of more than 1 kilometer per year. By comparing the new map of Antarctica with the first map made in 1997, researches found that some glaciers are retreating while others are advancing. The full map should be completed in FY 2002. ESE researchers also monitored the development of a crack 15 miles long in Antarctica's Pine Island Glacier—evidence of the imminent birth of a massive iceberg—using images from Landsat 7, Terra, CSA's RADARSAT, and the European Space Agency's radar imager. These results are giving scientists a better understanding of long-term change in the polar regions, a very sensitive component of the Earth system.

ESE was also highly successful in disseminating Earth science data and information. The Earth Observing System Data and Information System (EOSDIS) manages data from NASA's past and current Earth science research satellites and field measurement programs. The EOSDIS network was very successful in FY 2001, distributing more data faster as the median product delivery time was reduced to less than 1 day. EOSDIS distributed approximately 1.2 million data products per month in response to approximately 150,000 user requests. In addition, ESE conducted 482 workshops training K–12 teachers on Earth science education products, reaching 9,295 educators (K–12). Schools participating in Global Learning and Observation to Benefit the Environment (GLOBE) increased to 13,800, and participating countries increased to 97.

Finally, FY 2001 was also a successful year for enabling productive use of ESE science and technology. Using a newly developed 512-node Silicon Graphics, Inc., supercomputer, ESE researchers simulated more than 900 days of the Earth's climate in 1 day of computer time. Previous capability had been limited to the simulation of 70 days. Researchers demonstrated experimental seasonal climate predictions using ESE data sets from the TOPEX/Poseidon, SeaWiFS, TRMM, and Terra satellites. The combination of a faster computer, more accurate climate models, and the use of more global satellite observations will result in more accurate prediction of climate change for policy makers.

To improve access to and understanding of remote-sensing data, ESE hosted five workshops around the United States. The workshops demonstrated the use of ESE science and technology to over 550 decisionmakers representing nearly every state. A survey conducted during the workshops found that 35 percent of respondents had never used satellite data. A follow-up survey after the workshops demonstrated that the number fell to 20 percent.

In FY 2001, ESE worked to extend the benefits of remote sensing to policymakers in urban and rural areas. Researchers at the Mid-Atlantic Regional Earth Science Applications Center produced more accurate and detailed maps of major cities around the country using Landsat-7 data. These maps should help urban planners studying city growth and how rainfall runoff over paved surfaces impacts regional water quality. ESE also provided imagery from the EOS-Terra satellite to the Rapid Response Project for tracking and combating wildfires in the Western United States. Federal, State and local Governments, and firefighters used the data to help mitigate this natural disaster. In a third effort, ESE created a commercial partnership that will place advanced Global Positioning Satellite technologies in tractors, giving American farmers access to precision farming technologies. Precision farming helps farmers use less water, fertilizer, and weed control, reducing the environmental impacts of agriculture and increasing efficiencies in food and fiber production.

Through a collaborative project with the Department of Defense, ESE continued to monitor and predict disease outbreaks in an effort to reduce their impact on society. Using near-real-time satellite vegetation measurements and associated climate data sets, scientists developed the capability to make predictions about emerging Rift Valley Fever (RVF) epidemics in East Africa several months before an outbreak occurs. Additionally, ESE investigators provided data support to the Walter Reed Army Institute for Research during an RVF outbreak in Saudi Arabia and Yemen.

In the area of aeronautics and aerospace technology, NASA's Office of Aerospace Technology (OAT) continued to manage a portfolio of technology development activities designed to improve air travel, making it safer, faster, and quieter, as well as more affordable, accessible, and environmentally sound. It also continued working to develop more affordable, reliable, and safe access to space; improve the way in which air and space vehicles are designed and built; and ensure new aerospace technologies are available to benefit the public.

In the area of aviation safety, there were a number of significant accomplishments. NASA demonstrated a "daisy-chain flight control allocation scheme," based on a second-generation neural flight control architecture applied to generic transport aircraft simulation. The daisy-chain scheme utilizes remaining operational surfaces and the propulsion system in an unconventional manner (e.g., symmetric ailerons or symmetric throttles for pitch control and rudder or differential throttles for yaw-based roll control) in order to compensate for more severe failures. These simulations showed that the system provided redundant control power in the event of the loss of actuator control, additional control authority in the event of actuator control saturation, and demonstrated ability to provide improved handling qualities for severe failures in a reduced flight envelope that would otherwise result in a catastrophic event.

The aviation safety program system selected design concepts that showed the greatest promise for accident prevention in the areas of fire prevention, fire detection, synthetic vision, and an integrated vehicle health management for continued development. One of these, the tactical Synthetic Vision System (SVS) is a technology that has the potential to eliminate low-visibility conditions as a causal factor to civil aircraft accidents, as well as replicate the operational benefits of flight operations on a clear, sunny day, regardless of the outside weather condition or time of day. Flight demonstration of conventional media head-up and head-down tactical SVS display concepts intended for retrofit in commercial and business aircraft were conducted over a three-week period in August and September 2001. Seven evaluation pilots representing Boeing, the FAA, and three major airlines conducted 11 research flights for a total of 106 airport approaches. The concepts were evaluated in flight tests designed to evaluate pilot acceptability/usability and terrain awareness benefits. Early results indicated that pilot terrain awareness was higher when using the selected SVS display concepts compared to present-day displays.

Studies have shown that 5 to 10 percent of rotorcraft accidents are the result of gear failure and drive train failure. NASA personnel established design guidelines to prevent catastrophic rim fractures. This work should enable ultra-safe gears to be designed, eliminating nearly all catastrophic failure modes for lightweight thin-rimmed aircraft gears. The model accurately predicts crack propagation paths and has been validated using the NASA Gear Fatigue Test Rig.

During FY 2001, NASA developed the Collaborative Arrival Planner (CAP) tool to exchange real-time air traffic control information with Airline Operational Control (AOC) centers such that decisions made by AOCs regarding their aircraft operations could be based on the most up-to-date information possible. This increased arrival prediction accuracy in the AOCs has enabled airlines to make better decisions regarding flight diversions, gate utilization, and push-back times, leading to improved operational efficiency and financial savings. In addition, an en route decision support tool for efficient, conflict-free routing was also developed. The “Direct-to” (D-2) decision support tool underwent field testing in the Fort Worth Air Route Traffic Control Center. The D-2 controller tool identifies aircraft that can save flight time by flying directly to a down-stream fix along its route of flight. This technology has demonstrated the ability to save several minutes per flight, with commensurate reductions in fuel consumption and emissions. Finally, NASA personnel developed and flight tested an Air Traffic Control (ATC)/cockpit information exchange capability. Software tools that support decisionmaking by ATC require an ability to accurately predict future aircraft positions during flight. To perform long-range trajectory predictions, Center TRACON Automation System (CTAS) relies on the availability of aircraft state, aircraft performance, flight plan intent, and atmospheric data. The ATC/cockpit information exchange successfully demonstrated the capability to downlink aircraft state and intent information from the cockpit directly to CTAS by means of a real-time air-to-ground data link. A comparison of climb predictions at 15,000 feet to actual radar tracks showed that the direct downlink predictions reduced the peak altitude error by over 3,000 feet from the standard system.

NASA continued conducting a balanced effort at making major advances in aircraft noise reduction. Previously, NASA had demonstrated technologies that resulted in a 5-decibel reduction in aviation noise. In FY 2001, researchers tested additional technologies including a Pratt & Whitney 4098 engine and improved inlets. NASA personnel also conducted tests to separate and assess core noise. Airframe noise-reduction concepts (flap edge, slat cove, flap and slat trailing edge treatments, and landing gear modifications) were validated on the Subsonic Technology Assessment Research model, a detailed 26 percent Boeing 777, which was tested in the 40 x 80-foot tunnel at NASA's Ames Research Center. Two flight tests were conducted to validate engine system noise reduction. A "chevron" nozzle and other jet noise-reduction concepts were validated on a Lear 25, and both jet and fan noise-reduction concepts were validated on a Falcon 20. A system analysis of the test results demonstrated an additional 2-decibel reduction for large transport aircraft and 3 decibels for regional and business classes of aircraft.

In the area of technology innovation, NASA set a new world altitude record for a solar-powered aircraft, reaching an altitude of 96,863 feet on August 13, 2001 from the U.S. Navy's Pacific Missile Range Facility (PMRF) on the Hawaiian island of Kaua'i. Although short of the 100,000-foot altitude that project officials hoped for, the altitude is the highest ever flown by a nonrocket-powered aircraft in sustained horizontal flight and well above the current world altitude record of 85,068 feet for sustained horizontal flight by a conventional aircraft, set by a U.S. Air Force Lockheed SR-71A reconnaissance aircraft in July 1976. It also surpassed the existing altitude record for propeller-driven aircraft, 80,201 feet, set by the Helios Prototype's predecessor, the Pathfinder-Plus, in August 1998. The 96,863-foot record altitude remains unofficial, however, until certified by the Fédération Aéronautique Internationale.

The Helios Prototype flew for more than 40 minutes above a 96,000-foot altitude before beginning its descent. It was in the air for almost 17 hours on the record flight, having lifted off the PMRF runway at 8:48 a.m. and landing at 1:43 a.m. the following morning after a 9.5-hour descent. Electrical power for post-sunset flight was provided by the generating capability of the motors using the windmill effects of the propellers as the aircraft glided down.

Production variants of Helios might see service as long-term Earth environmental monitors, disaster monitoring, as well as communications relays, reducing dependence on satellites and providing service in areas not covered by satellites. The record altitude flight also provided NASA and AeroVironment with information on how an aircraft would fly in a Mars-like atmospheric condition, since the atmosphere at that altitude above the Earth is similar to the atmosphere near the Martian surface.

Another aircraft mission was not as successful. The X-43A is designed to be the first scramjet-powered vehicle, capable of attaining speeds as high as Mach 10. The X-43A mission on June 2, 2001 was lost moments after the X-43A and its launch vehicle were released from the wing of the NASA B-52 carrier aircraft. Following launch vehicle ignition, the combined launch vehicle and X-43A experienced structural failure, deviated from its flight path, and was deliberately terminated. A Mishap Investigation Board (MIB) was immediately formed and began conducting a thorough review of the failure. The MIB results were released in April 2002 and will be addressed prior to scheduling the next X-43 flight.

With the cessation of the X-33 and the X-34 programs, the Aerospace Technology Enterprise has taken a new approach toward developing reusable launch vehicle (RLV) technologies to enable the eventual routine access to space. This effort is called the Second-Generation RLV Program. In FY 2001, NASA awarded contracts valued at $767 million to 22 contractors, including large and small companies, to allow maximum competition. The money will be used to develop concepts and the technologies needed to pioneer this extraordinary effort, which is expected to make the vehicle at least 10 times safer and crew survivability 100 times greater, all at one-tenth the cost of today's space launch systems.

At the beginning of FY 2001, NASA created the Biological and Physical Research Enterprise (BPR) to strengthen NASA's interdisciplinary program of research in space. As humans make the first steps off Earth and into space, we enter a new realm of opportunity to explore profound questions, new and old, about the laws of nature. At the same time, we enter an environment unique in our evolutionary history that poses serious physiological, psychological, and environmental challenges. NASA's Biological and Physical Research Enterprise addresses the opportunities and challenges of space flight through basic and applied research on the ground and in space. BPR seeks to exploit the rich opportunities of space flight for fundamental research and commercial development, while conducting research to enable efficient and effective systems for protecting and sustaining humans in space.

The Biological and Physical Research Enterprise (BPRE) closed its first fiscal year with a significant record of accomplishment. The Enterprise initiated a program of research on the International Space Station to take advantage of available resources during the construction phase, released three NASA research announcements, and strengthened its research investigator community.

BPR established a new Memorandum of Understanding with the U.S. Department of Agriculture, conducted a joint research solicitation with the National Cancer Institute, and continued work under 18 other agreements with the National Institutes of Health. In a truly auspicious sign of things to come, a BPRE investigator received the Nobel Prize in physics for ground-based research that he plans to extend and expand on the International Space Station.

FY 2001 also included major efforts to restructure International Space Station research. These efforts respond to substantial reductions in available budgets for research equipment (facilities), support, and operations. In addition, BPR continued working to address potential reductions in available onorbit resources for research. While this restructuring is of central importance for the future of ISS research, it did not materially affect resources necessary for executing BPR's planned research program in fiscal year 2001.

ISS outfitting for research began with the delivery of the Human Research Facility in March 2001. NASA delivered two research equipment racks in mid-April and an additional two at the beginning of Expedition 3 in August 2001. At the end of the fiscal year, the Agency is on track to deliver another five research equipment racks by the end of 2002. Despite underestimation of Station maintenance requirements and a greater-than-expected volume of "off-normal" activities during Expeditions 1 and 2, the ISS team was able to meet the minimum research objectives of these increments.

The Expedition 1 crew initiated a small number of U.S. research activities, including crew Earth observations, the Educational SEEDS experiment (plant growth in microgravity), biological crystal growth (structural biology), space technology motion and vibration experiments, and human research baseline data collection.

With Expedition 2, completed in July, the research program on the ISS was underway. Eighteen experiments were conducted. The Expedition focus was on biomedical research and included studies of biological effects of space radiation, characterization of the ISS radiation environment, bone loss and spinal cord response during space flight, and interpersonal influences on crewmember and crew-ground interactions. Other experiments included plant germination and growth; Earth observations; and experiments aimed at resolving the exact structures of important biological molecules.

Research on Expedition 3 included 8 new and 10 continuing experiments. New Expedition 3 experiments included investigation of the mechanism that causes space travelers to suffer from dizziness and an inability to stand on returning to Earth (a condition called orthostatic intolerance); a study of heart and lung function in space and as affected by spacewalks; a study of the risk factors associated with kidney stone formation during and after space flight; new techniques for structural biology in space; and a study of materials passively exposed to the space environment around the ISS to better define changes in material properties and onorbit degradation trends.

Research results from the ISS will be forthcoming as data are collected and analyzed. Results reported in FY 2001 based on earlier research missions and ground-based experiments support continued progress in understanding and controlling the negative effects of space travel.

Research published in 2001 suggests that the human brain contains an internal model of gravity and that this model may be very difficult or potentially even impossible to "unlearn." (*Nature Neuroscience*, *4*, 693–694, 2001). Astronauts quickly adjust to many of the challenges of orientation and movement associated with space flight, but the new results suggest there may be limits to this adaptability. Astronauts attempted to catch a "falling" object moving at different constant speeds. The test subjects proved unable to adjust to the fact that such objects do not "fall" faster and faster in space. The expectation that a "falling" object would accelerate proved impossible to unlearn over the course of this brief experiment. This experiment raises the possibility that the nervous system may contain a "hardwired" model of gravity. If confirmed, this would be a fundamental discovery that could influence medical treatments for people with damaged or impaired nervous systems. In addition, this finding has important implications for the design of safe and efficient environments and systems for human space flight.

In what may be a breakthrough for astronauts and osteoporosis victims alike, researchers were able to prevent bone loss using mild vibrations (*FASEB J*, October 2001). Normally, rats lose bone when their hind limbs are suspended and no longer support the weight of the body. BPRE researchers were able to counteract this bone loss by exposing the rats to mild vibrations. This study opens the door to a new method for controlling the 1% per month loss of bone that astronauts experience in space, and clinical studies are planned to determine the usefulness of vibration for treating or preventing osteoporosis on Earth.

In addition to research aimed at controlling the physical challenges of space flight, BPR exploits the space environment to conduct unique experiments in physics, chemistry, and biology that would be impossible to conduct on Earth. A broader program of ground-based research supports research progress in space and develops new hypotheses for testing.

2001 was a banner year for BPRE basic physics research. Early in the year, BPRE researchers reported that they had "brought light to a full stop, held it, and then sent it on its way." (*Physical Review Letters*, January 29, 2001, Vol. 86, Issue 5). Researchers used lasers they developed under BPRE funding to bring a beam of light to a complete stop in a specially designed trap, and then released it again.

Another team of BPRE researchers created a gas cloud riddled with tiny whirlpools like those that cause "starquakes." (*Science*, Vol. 292, No. 5516, 20 April 2001). The researchers used an ultra-cold cloud of sodium gas and quantum effects to create a physical model of phenomena that take place deep inside distant stars.

The importance of this kind of low-temperature physics research was reinforced at the end of 2001 when Dr. Ketterle was awarded the Nobel Prize in physics for his seminal BPRE-funded work on Bose-Einstein Condensate, a new state of matter in which individual atoms merge into each other.

These experiments represent substantial milestones in physicists' quest to study quantum phenomena (physical phenomena that are ordinarily only observable at microscopic scales) in macroscopic systems. This research could have far-reaching implications for the future of information and communication technologies.

In biotechnology research, a research group at the Massachusetts Institute of Technology grew heart tissue with "significantly improved" structural and electrophysiological properties using NASA bioreactor technology (*Journal of Physiology-Heart and Circulatory Physiology*, Jan. 2001). Unlike tissue grown using more conventional technology, the tissue grown in the NASA bioreactor was actually made to beat like native heart tissue. The NASA bioreactor allows researchers to grow tissues in the laboratory that much more faithfully reproduce the properties of natural tissues in the body. These tissues allow researchers to explore mechanisms of disease and may ultimately improve processes for creating engineered tissue for use in treatment and transplant.

Twenty-four cell cultures, including colon, kidney, neuroendocrine, and ovarian cell cultures, were grown aboard the ISS in 2001. This represents our first opportunity to use a sophisticated bioreactor to grow cells in space. Bioreactor cell growth in microgravity permits cultivation of tissue cultures of sizes and quantities not possible on Earth. Cells may grow in low gravity more like they grow in the human body, increasing research capability in areas pertinent to the study of human diseases.

BPR provides knowledge, policies, and technical support to facilitate industry investment in space research. BPR enables commercial researchers to take advantage of space flight opportunities for proprietary research. FY 2001 included continued growth in the number of commercial partners participating in the program and an initial set of 5–6 experiments conducted aboard the ISS.

In fiscal year 2001, StelSys (a joint venture of FVI and In Vitro Technologies) signed an agreement with NASA to explore commercial applications of bioreactor technology research specifically in areas related to biological systems.

Bristol-Myers Squibb and the Center for BioServe Space Technologies reported that production of antibiotics is substantially greater in microgravity than on the ground with more antibiotic produced in flight samples. They are working to apply this research to ground-based processes.

BPR's Center for Biophysical Sciences and Engineering (CBSE) formed an exclusive partnership with Athersys, Inc., a premier genomics company. Genomics is the science of describing the proteins that are encoded by the genes in our DNA. CBSE has developed a world-class capability to determine the exact shapes and structures of proteins through the process of protein crystallography. Precise information on the protein structure is critical to the design of highly specific and effective new drugs.

BPR seeks to use its research activities to encourage educational excellence and to improve scientific literacy from primary school through the university level and beyond. We deliver value to the American people by facilitating access to the experience and excitement of space research. BPRE strives to involve society as a whole in the transformations that will be brought about by research in space.

During FY 2001, BPR held its first interactive education and public outreach broadcast as part of a technically oriented Pan Pacific Microgravity Workshop. BPR revamped its material on the Worldwide Web to reflect our new NASA Enterprise status and mission, and to group material specifically for public, educational, and technical audiences. The Enterprise had requests for and distributed over 4,000 interactive CDs explaining space flight and space research to the layperson and educator as a result of our electric light tower exhibit touring the country. In collaboration with the USAF Academy Department of Biology, we completed development of an undergraduate-level course in Space Biology.

During FY 2001, NASA continued its international activities, expanding cooperation with its partners through new agreements, discussions in multilateral fora, and support for ongoing missions. NASA concluded over 90 cooperative and reimbursable international agreements for projects in each of NASA's five Strategic Enterprises. These agreements included ground-based research, aircraft campaigns, and satellite missions in the fields of Earth science, space science, and human space flight and research. Significant international agreements signed during FY 2001 include several government-to-government framework agreements, under which future cooperation will be carried out, and agency-to-agency Memoranda of Understanding for specific projects.

In the area of framework agreements, the Agreement Between the United States of America and the Republic of Hungary on Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes was signed on May 14, 2001. This agreement establishes the foundation for future bilateral cooperation between the U.S. and Hungary in the areas of space science, Earth and atmospheric science, and human space exploration. The Agreement Between NASA and the National Commission for Space Activities of the Argentine Republic for Cooperation in the Civil Uses of Space was extended on August 2, 2001, for an additional l5 years.

This agreement provides the framework for strengthening cooperation in the uses of space for research in Earth science and global climate change.

In space science, specifically in the area of solar system exploration, NASA and the Russian Aviation and Space Agency (Rosaviakosmos) signed an Implementing Agreement for Flight of the Russian High-Energy Neutron Detector (HEND) instrument to fly on NASA's Mars 2001 Odyssey mission. This mission was launched by NASA on April 7, 2001 and entered the orbit of Mars after the end of FY 2001. The HEND instrument will provide unique data to scientists to assist in the ongoing search for water on Mars. NASA also signed project-level agreements for scientific participation by Germany and Denmark in NASA's Mars Exploration Rover mission, to be launched in 2003. In the area of space physics, NASA signed project-level agreements covering the participation of several nations in NASA's planned Solar-Terrestrial Relations Observatory mission: Germany, Italy, the United Kingdom, France, Switzerland, and Hungary, and the European Space Agency (ESA). In astrophysics, NASA signed initial project-level agreements with the ESA and the Canadian Space Agency (CSA) for cooperation in the Next-Generation Space Telescope mission, NASA's planned follow-on to the highly successful Hubble Space Telescope mission. In addition, NASA signed a series of project-level agreements with ESA covering U.S. participation in several future ESA astrophysics and planetary missions: the International Gamma-Ray Astrophysics Laboratory, the Laser Interferometer Space Antenna, the International Rosetta mission (an in situ investigation of the Comet Wirtanen), and Mars Express. The NASA Astrobiology Institute accepted two new international affiliate members during FY 2001, the United Kingdom Astrobiology Forum and the Australia Centre for Astrobiology.

In Earth science, NASA and the CSA signed a Memorandum of Understanding (MoU) for the SciSat-1 Atmospheric Chemistry Experiment (ACE) mission on October 24, 2000. As of the end of FY 2001, the SciSat-1 ACE mission was scheduled for launch no earlier than December 2002. The objective of the SciSat-1 ACE mission is to improve our understanding of the chemical processes involved in the depletion of the ozone layer, with particular emphasis on the processes occurring over Canada and the Arctic. On May 29, 2001, NASA and The Netherlands Agency for Aerospace Programmes signed an MoU for the Dutch-built Ozone Monitoring Instrument (OMI) to fly on NASA's Earth Observing System (EOS) Aura spacecraft, scheduled for launch in mid-2003. OMI will measure total column ozone, ozone profiles, and other atmospheric constituents, such as clouds and aerosols. These important measurements will help scientists determine how the Earth's ozone layer and ultraviolet radiation is responding to the phase-out of ozone-destroying chemicals, as well as to the increasing concentrations of greenhouse gases and atmospheric particulates (e.g., dust and soot) caused by human activity.

Also in Earth science, NASA and the Israel Space Agency signed an MOU for cooperation related to the Mediterranean Israeli Dust Experiment (MEIDEX) in Tel Aviv, Israel, on August 16, 2001. Both agencies are now completing work on the Israeli instrument, which is scheduled for flight as a secondary payload on the Space Shuttle *Columbia* in 2002. The primary objective of the MEIDEX payload is to investigate the geographical variation of the optical, physical, and chemical properties of desert aerosols, including the location and temporal variation of its sinks, sources, and transport. An Israeli payload specialist, Colonel Ilan Ramon, who will be the first Israeli to fly in space, will conduct the MEIDEX experiment in flight. NASA established a series of agreements with institutes from Japan, China, Taiwan, and Germany in support of the NASA Transport and Chemical Evolution over the Pacific atmospheric science experiment. This experiment, which included NASA aircraft and ground-validation sites, was conducted in March and April 2001 in Hong Kong, Japan, and Taiwan.

In addition, NASA and the Argentine Space Commission (CONAE) signed an agreement for an airborne validation campaign on December 27, 2000, to complement cooperation between NASA and CONAE under the Memorandum of Understanding for the Scientific Applications Satellite-C (SAC-C) Earth Observing Mission (signed October 28, 1996). Under this agreement, the NASA Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) was deployed to Argentina to conduct calibration and validation activities for the EO-1 and SAC-C satellites shortly after their joint launch in November 2000.

In human space flight and research, the NASA Administrator led a NASA delegation to witness the historic launch of the first crew (Expedition 1) to the International Space Station (ISS), which took place at the Baikonur launch facility in Kazakhstan on October 31, 2000. Following approval procedures in the U.S., Japan, and Russia, the Inter-Governmental Agreement (IGA) Concerning Cooperation on the Civil International Space Station entered into force on March 28, 2001. The International Space Station Partners approved the flight of the first space flight participant, Mr. Dennis Tito, to the ISS in April 2001 aboard a Soyuz taxi mission. In December 2000, as part of the U.S. Government team, NASA successfully concluded discussions with the government of Japan that clarified and updated the 1995 Agreement Between the United States and the Government of Japan Concerning Cross-Waiver of Liability for Cooperation in the Exploration and Use of Space for Peaceful Purposes. This agreement ensures that Japan and the United States agree to waive liability claims for cooperative U.S./Japan space activities.

Also during FY 2001, NASA participated in numerous multilateral fora and meetings designed to review ongoing cooperation or to foster new cooperation. These included: the Inter-Agency Consultative Group for Space Science and its International Living with a Star Task Group; the Committee on Earth Observing Satellites; the United Nations Committee on Peaceful Uses of Outer Space and its subcommittees; the ISS IGA Triennial Review; the ISS Forum 2001; and the International Astronautical Federation. NASA senior management engaged in bilateral discussions with current and potential future international partners, hosting meetings with space officials from around the world, and visiting foreign space officials and facilities. One of the developments in this regard was the initiation of preliminary discussions between the U.S. Government and the government of Turkey on potential civil space cooperation. A Turkish Space Symposium was held in May 2001 in Ankara, Turkey, and senior NASA management participated in this meeting. Several months later, a high-level Turkish delegation visited NASA Headquarters and several NASA Field Centers in August 2001 to continue the exploratory discussions.

DEPARTMENT OF DEFENSE

DoD

During FY 2001, the Department of Defense (DoD) engaged in a wide variety of aerospace activities. In terms of environmental monitoring, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), a tri-agency program of NASA, DoD, and the Department of Commerce (DoC) that converges the DoD and DOC/NOAA polar-orbiting weather satellite programs, continued to progress. In FY 2001, the NPOESS Integrated Program Office (IPO) extended the two Program-Definition and Risk-Reduction (PDRR) contracts by 6 months and down-selected development contract awards for all remaining major sensors. The NPOESS Preparatory Project (NPP), an IPO/NASA joint mission to provide a crucial early-flight and risk-reduction opportunity for several major NPOESS sensors, also continued to progress in FY 2001. The PDRR contractors each held several promising early demonstrations of system concepts and designs to accommodate the planned 2005 NPP mission launch.

DoD, NASA, NOAA, and other Federal agencies continued to make good progress in FY 2001 on implementing activities for the Space Weather Architecture Transition Plan. DoD participated in a new NASA initiative, Living with a Star, a systems approach to studies of Sun-Earth connections. In 2001, DoD participated fully in the LWS Science Architecture Team to help develop a definition of the LWS program. The objectives of LWS connect the scientific understanding of the Sun-Earth system with an ultimate operational forecasting capability, a major DoD concern.

The Geostationary Operational Environmental Satellite (GOES)-M spacecraft was launched successfully on July 23, 2001. This DoD/NOAA/NASA spacecraft continued a series of capabilities in weather imagery and sounding data to support operational weather forecasting and meteorological research. New on this mission was the DoD/NOAA/NASA-sponsored Solar X-ray Imager, the first operational instrument for monitoring x rays that originate in the atmosphere of the Sun. Solar forecasters now get a real-time downlink of images that helps them make more accurate predictions of geomagnetic storms on Earth. Some affected activities and impacts that benefit from these forecasts are GPS navigation errors, radio communication blackouts, radiation danger to high-flying crews and passengers, and interruptions to satellite operations.

Regarding the highly protected SatCom systems, Milstar Flight 4 was launched from the Eastern Range during February 2001. This was the first successful medium data rate EHF satellite on orbit for the DoD.

In the area of positioning and navigation, two Global Positioning System (GPS) Block IIR satellites were launched and subsequently declared operational. At the end of the fiscal year, the GPS constellation consisted of a total of 28 satellites providing unprecedented levels of accuracy in support of national security, as well as worldwide transportation safety, scientific, and commercial interests. Development efforts continued on the GPS modernization program to add new military signals (known as the M-code) to Block IIR and IIF satellites, a second civil signal on IIR satellites, and a third civil signal (L5) on IIF satellites. As the first step in a major effort over the next several years to modernize GPS to enhance its ability to meet both military and civil needs for the foreseeable future, System Architecture and Requirements Development (SA/RD) contracts were awarded to Boeing and Lockheed Martin. The yearlong SA/RD contracts, also called Concept Exploration, are intended to evaluate military and civil utility, as well as define the system performance trade space for the subsequent phases of GPS III development.

As part of the DoD restructure of its Evolved Expendable Launch Vehicle (EELV) program, DoD sought and won congressional approval of a Heavy Lift Vehicle demonstration launch as a risk-reduction step. Launch was scheduled for 2003.

In the areas of intelligence, surveillance, and reconnaissance, the Space-Based Infrared System (SBIRS) made progress toward fielding the follow-on system to the Nation's Defense Support Program (DSP) missile launch early warning satellites. SBIRS is fielded in three increments. The technical difficulties in 1999 that had set back the transition to a new mission control station were resolved. Increment 1 consolidated the DSP's overseas ground stations, located in Europe and Australia, with the old U.S. ground station into a single mission control station located at Buckley Air Force Base, Colorado. The overseas sites were replaced with minimally staffed relay ground stations in order to realize savings in staffing, operations, and maintenance. The addition of the SBIRS high component, also known as “SBIRS Increment 2,” has encountered difficulties, however, and first launch will probably be slipped from FY 2005 to FY 2007. The Highly Elliptical Orbit sensor payload and the mobile multimission processors both passed successful critical design reviews, paving the way to begin fabrication of HEO flight payloads and SBIRS mobile ground stations. The DoD has also continued with the risk-reduction and program definition phase for SBIRS low.

The DoD Space Test Program (STP) teamed again with NASA in launching the Kodiak Star mission on an Athena I launch vehicle—the first orbital launch out of Kodiak Island, Alaska. In addition to NASA's Starshine III spacecraft, this mission included three small DoD spacecraft (PICOSat, PCSat, and Sapphire) which tested a variety of new space technologies, including flexible polymer batteries, ionospheric occultation measurements, and advanced command and control techniques. At the end of the fiscal year, STP and the Naval Research Laboratory were progressing well toward the 2002 Titan II launch of Coriolis, a risk-reduction effort for NPOESS, acquired under NASA’s Rapid Satellite Acquisition process. STP awarded a contract to Spectrum Astro to build and launch the Communication/Navigation Outage Forecasting System mission, which will test the ability to forecast communications outages due to ionospheric scintillation. STP teamed with the Air Force Research Laboratory’s Space Vehicles Directorate to develop a secondary payload adapter ring for the Evolved Expendable Launch Vehicle (EELV), which can host up to six 400-pound micro satellites. STP also worked closely with NASA and the U.S. Navy on the Geosynchronous Imaging Fourier Transform Spectrometer/Indian Ocean Meteorology and Oceanography Imager project.

STP had two successful Shuttle/ISS missions in FY 2001 as well. STS-105 delivered and successfully deployed the Materials International Space Station Experiment (MISSE) externally on the ISS. MISSE, a passive materials exposure experiment, is the first external experiment on ISS. In addition, STS-105 retrieved and returned MACE II (Middeck Active Control Experiment II) from the ISS. MACE II was the first experiment on ISS and was operated for nearly a year. Through the efforts of Commander Bill Shepherd and astronaut Susan Helms, Mace II surpassed all anticipated data results.

DoD continued to coordinate and oversee a wide array of space control initiatives spanning all four space control mission areas: surveillance of space; protection of space assets; prevention; and negation. Particular emphasis was placed on space surveillance programs leading to an approved modernization and investment strategy that will transform the existing surveillance network from a track-based system to a search-based system that will eventually be able to provide true space situational awareness. Plans were also made for a new Space Situational Awareness Integration Office within the Air Force Space Command to serve as an advocate for space surveillance and improve program management and collaboration among DoD components and other interested Government agencies. In the area of space system protection, the U.S. Space Command led an effort to develop a new analytic tool to assist decisionmakers in establishing protection priorities for space systems. The results of this effort will be used to help develop a Space Protection Roadmap that will ensure the availability of critical space capabilities during all levels of conflict. Research also continued on a number of space prevention and negation concepts in response to emerging DoD requirements.

Federal Aviation Administration

FAA

The FAA continued in its mission to ensure a safe, secure, efficient, and environmentally friendly civil air navigation and commercial space transportation system. During FY 2001, the agency performed and sponsored research and development programs to enhance the effectiveness of its mission; issued regulations and guidelines for better flight standards, operations, and maintenance; and provided equipment and training for a modernized air traffic control system.

In the area of airport safety and pavement technology research, the FAA completed the first set of full-scale trafficking tests at the National Airport Pavement Test Facility during FY 2001.These tests involved subjecting nine test pavements to simulated B-747 and B-777 loading at speeds of 2.5 and 5 mph. The FAA worked closely with the Boeing Company and an international working group in planning these tests. Researchers recorded the pavement response instrumentation data and stored it in a database for future retrieval.

The FAA, in cooperation with the Air Force, conducted a study on vehicle stability enhancements for heavy airport rescue and firefighting vehicles, since a number of these vehicles have suffered rollover accidents in recent years. The study focused on active and reactive suspension systems and shock-dampening systems. Technicians conducted testing to establish more stringent static and dynamic testing criteria for newly manufactured vehicles. As a result, the FAA incorporated changes into the latest revision of the advisory circular for heavy airport rescue vehicle design in the areas of performance testing and vehicle suspension systems. These changes will help prevent rollover accident by ensuring that future airport rescue and firefighting vehicles have the new suspension technology, as well as allowing for retrofitting the existing fleet.

The FAA also initiated research to prevent new large aircraft wingtips from intruding in the safety areas of adjacent taxiways, runways, and terminal areas. In particular, the FAA selected Anchorage International Airport for this research due to its large number of Boeing 747 traffic and availability of varying weather conditions. FAA specialists completed the first phase of data collection in August 2001, with a second phase beginning in September 2001. The FAA expected to begin analysis of the data in FY 2002.

In the area of fire safety research, the FAA has emphasized fuel tank safety since the TWA flight 800 accident in July 1996. One proposed method of reducing the flammability of fuel tanks is fuel tank inerting, which is commonly used by the military. However, the systems weight, resource requirements, and low dispatch reliability have indicated that military fuel tank inerting systems would not be practical for application in transport airplanes. The Aviation Rulemaking Advisory Committee (ARAC) Fuel Tank Harmonization Working Group, commissioned by the FAA to evaluate various concepts for preventing fuel tank explosions in commercial transport aircraft, concluded that the most potentially cost-effective method of fuel tank flammability reduction is ground-based inerting (GBI). Ground-based inerting is defined by inerting fuel tanks during ground operations, when the threat of explosion is perceived to be the greatest.

FAA and Boeing personnel therefore performed a series of aircraft flight and ground tests to evaluate the effectiveness of GBI as a means of reducing the flammability of fuel tanks in the commercial transport fleet. Boeing made available a model 737-700 for modification and testing. A series of 10 tests were performed (five flight, five ground) under different ground and flight conditions to demonstrate the ability of GBI to reduce fuel tank flammability. Results with low fuel loads showed that, under quiescent conditions, the oxygen concentration in the fuel tank remained somewhat constant, keeping the CWT inert (below 10- to 12-percent oxygen by volume) for relatively long periods of time. Results were in reasonably good agreement with predictions, and the FAA planned to continue this research in FY 2002.

Aircraft cargo compartments' fire-detection systems currently consist of either ionization or photoelectric smoke detectors. However, the ratio of false alarms to actual fires detected by U.S.-registered airlines during the previous 5 years is approximately 200 to 1. There are no certification criteria for new multisensor detectors employing algorithms that attempt to discriminate between real fires and nuisance alarm sources. The FAA conducted research to standardize the fire that cargo fire-detection systems must detect and to provide technical data to develop certification guidelines for multisensor fire detectors.

Two fire sources were initially developed as proposed standards and the FAA-conducted testing was done at its William J. Hughes Technical Center. Concurrent with the development and testing of fire sources, under NASA funding, Sandia National Laboratories developed a computational fluid dynamics (CFD) model to predict the transport of smoke, heat, and gases throughout an aircraft cargo compartment. NASA also contributed to the research by expanding an ongoing project on miniature gas sensors for space applications into use on aircraft. The FAA planned to conduct further related tests to evaluate detector placement and alarm algorithms on detection times and possibly reduce some of the required certification tests.

Regarding suppression of inflight cargo compartment fires, FAA personnel conducted full-scale tests to investigate the effectiveness of several types of water spray systems. Water spray is being considered an alternative agent for Halon 1301, which is no longer being produced because it depletes stratospheric ozone. Because water spray technologies have proven effective in other applications and because water is environmentally friendly, nontoxic, and abundant, it is being considered as a halon-replacement agent for use in cargo compartments.

During FY 2001, FAA personnel also investigated ways to reduce the flammability of seat cushions and other sources of rubber and foam in aircraft. New materials that were developed with the assistance of industry such as polyphosphazene and polysilphenylene-siloxane provide as much as a 50-percent reduction in flammability compared to the best commercial semi-inorganic rubbers and an order-of-magnitude reduction in flammability compared to the polyurethane currently used in aircraft seating. FAA specialists planned to explore the use of relatively low-cost expandable graphite technology in semi-inorganic rubber compounds to obtain a fireproof (zero heat release rate) seat cushion foam by 2005.

The FAA's Fire Research Program continued to seek ways to predict the fire resistance of new polymers from their chemical structure without the time and expense (about 6 months and $50,000 per material) of synthesis, purification, characterization, and fire testing. To this end, the FAA has been developing computer programs to simulate the molecular-level fuel generation process of polymers in fires. FAA scientists measured over 100 polymers of known chemical structure for heat-release capacity using a special FAA-developed technique. A comparison of calculated to measured heat release capacities for 80 polymers showed good agreement, indicating that the fire hazard of a polymer in an aircraft cabin is proportional to its heat-release rate in flaming combustion. Thus, the potential fire resistance of polymers can be simply calculated a priori from the chemical structure without the need for synthesis and/or testing.

In terms of crash research, FAA researchers conducted a vertical drop test of a B737-100 fuselage section at its Atlantic City, NJ, facility. The airframe section was configured to simulate the load density at the maximum takeoff condition and contained cabin seats, dummy occupants, overhead stowage bins with contents, and cargo compartment luggage. The test article was fully instrumented. The objective of the test was to evaluate the response behavior of the overhead stowage bin installations when subjected to a severe, but survivable, impact condition. Of particular interest was a comparison of the pretest static, steady state forces to which the bins were subjected during their calibration versus the dynamic forces generated during the impact test.

Researchers at Wichita State University used an FAA grant to study the use of composite materials in commercial and general aviation aircraft. In particular, scientists investigated impact damage states. It is crucial to understand the effects of impact damage on static ultimate strength and damage tolerance criteria in terms of safety, as well as the implications to maintenance.

The FAA also funded researchers at Syracuse University who developed a methodology to address the problem of delamination growth, a common failure mode in laminated composite aircraft structures. This methodology has the potential of profoundly affecting design, analysis, and certification procedures for composite aircraft structures. First, it will allow a relatively rapid assessment at a large number of possible locations, under a wide range of loadings, whether delamination growth is likely. This will provide an early identification of possible failure sites that may not be found by the current selective testing approach, resulting in improved flight safety. Second, knowledge of the critical size and location of delaminations will reduce aircraft maintenance activity as it will serve as a guide for repair actions. Finally, this methodology may allow the implementation of a more economic certification procedure based on a mix of analysis and testing to assure a damage-tolerant structure similar to that presently in use for metallic structures.

A virtue of fabricating aircraft components from composite materials is that the designer is afforded significant flexibility to vary materials and adhesives to optimize the component's weight and load-carrying performance. The same wide range of variables that is so appealing to the designer, however, can cause significant concern to the nondestructive inspection (NDI) practitioner who must buy or fabricate calibration standards for each type of structure encountered when conducting comparative-type NDI tests. Thus the FAA developed some important new reference standards in this regard, and a number of aircraft manufacturers said they would comply.

To predict crack growth and residual strength of riveted joints subjected to widespread fatigue damage (WFD), accurate stress and fracture analyses of corner and surface cracks emanating from a rivet hole are needed. To address this need, the FAA expanded the existing database of three-dimensional stress-intensity factor solutions and modeled bulging factors.

The FAA also developed a methodology to assess the development of WFD and its effect on the residual strength of aircraft structure. WFD in a structure is characterized by the simultaneous presence of cracks at multiple structural components where the cracks are of sufficient size and density that the structure will no longer meet its damage-tolerance requirement. The approach developed by the FAA is a combination of analytical methodology development and experimental validation. Advanced analytical methods were developed and validated over the past decade by the FAA with the support and sponsorship of NASA and the U.S. Air Force Research Laboratory.

In a related area, the FAA funded the development of an analytical methodology to provide stress-intensity factors to predict fatigue crack growth for rotorcraft applications. The methodology (Automated Global, Intermediate, and Local Evaluation) is a suite of software tools developed for the automation of hierarchical analysis of complex structures.

The FAA Operational Loads Monitoring Research Program continued to collect and analyze both flight and landing loads data on civil transport aircraft. FAA personnel added airplane models A-320 and Cessna-172 to the research program in FY 2001, and models B-747 and B-777 were scheduled to be incorporated into the program in FY 2002.

In partnership with the Naval Air Systems Command and the Office of Naval Research, the FAA continued research and development of arc fault circuit breakers (AFCB) intended to replace existing thermal circuit breakers used in aircraft today. AFCBs detect electrical arcing and rapidly remove power to the affected circuit, drastically reducing the chances of fire and other damage. During FY 2001, the FAA successfully fabricated and tested these AFCB prototypes. In addition, the FAA initiated an extensive program to evaluate the condition of aging circuit breakers.

In the area of aviation security research, the FAA continued to develop and deploy products that prevent explosives, weapons, and other threat material from being introduced onto aircraft. Major areas of concentration include: certification testing, checked and carry-on baggage screening using bulk and trace explosives detection, human factors, aircraft hardening, aviation security technology integration, and airport deployment of systems by the Security Equipment Integrated Product Team.

The Aviation Security Laboratory (ASL) conducted certification tests on the InVision CTX 9000Dsi Explosives Detection System (EDS) production unit, the CTX-2500, and the L3 eXaminer 3DX 6000 unit. All these systems passed. FAA researchers also continued their advanced work in bulk-detection techniques such as x-ray diffraction. In the area of personnel screening, the FAA evaluated several explosive detection prototypes. In the weapons detection area, the ASL evaluated the response of metal detector systems to additional types of weapons in anticipation of upgrading the standard. The ASL also evaluated several large cargo inspection systems and a large bulk EDS for break-bulk cargo.

The human factors program continued to enhance the performance of screeners through the development of Threat Image Projection software. This software, which continued to be installed on systems for both carry-on and checked baggage, improves screener training and enhances awareness. The program also developed a networked Screener Readiness Test.

The Aircraft Hardening Program conducted a series of explosive tests on 737s, 747s, and Airbus aircraft under pressurized conditions for the purpose of refining the vulnerability criteria for carry-on luggage. The program also evaluated liners to protect the overhead bin area and performed additional tests to determine the least risk bomb location.

In FY 2001, human factors and aeromedical scientists conducted research to provide the FAA and industry with human performance information critical to the design, operation, regulation, and certification of equipment, training, and procedures, thereby facilitating safe and efficient National Airspace System (NAS) operations and reducing operator error as an accident-causation factor. Specifically, the FAA conducted aeromedical research with a focus on improving the health, safety, and survivability of aircraft crews and passengers.

The air transportation human factors research program conducted investigations to collect and analyze data on the antecedents and responses to crew error. The results of these investigations were used by the air carriers to modify current line operations and pilot training programs to enhance safety. Researchers completed a survey of over 12,000 U.S. air carrier pilots regarding the effectiveness of current pilot training programs. The results revealed that pilots view their training as effective and important in preparing them to fly in the NAS. Researchers also continued the development of a training analysis and development system that is used by air carriers and local FAA offices in designing pilot training simulator scenarios and other tests that are challenging, fair, and operationally relevant when evaluating pilot performance. This system allows air carriers to design an Advanced Qualification Program (AQP) using performance data collection and analysis. Phase 2 of the Model AQP was completed in 2001.

General aviation researchers completed an analysis of causal factors in accidents and incidents attributed to human error using the military Human Factors Analysis and Classification System. Aviation maintenance researchers also continued their investigation of methods and guidelines that can be used to reduce fatigue-producing factors in the maintenance environment. The results of both of these research projects will facilitate development of regulatory and certification guidance material.

In FY 2001, the FAA researched a new incident-investigation technique that assesses underlying causal factors of operational errors in air traffic control. This project was coordinated with a similar European project. Research also examined human-factor issues in runway incursions, including development of a new booklet for controllers and pilots entitled “Runway Safety: It’s Everybody’s Business,” that provides helpful information on memory, pilot-controller communication, and situational awareness.

In terms of aircraft occupant safety, the FAA completed the largest cabin evacuation study ever conducted evaluating aircraft design and human factors affecting passenger egress through Type III (over wing) emergency exits in transport aircraft. The FAA also completed an altitude research study evaluating the physiological protection provided by three different types of continuous-flow oxygen masks used with portable oxygen bottles for flight attendants. The 747 Aircraft Environmental Research Facility was completed and is in service supporting a variety of safety, security, training, and testing functions and programs. Researchers also conducted investigations to address the FAA's goal for an equivalent level of safety for all aircraft occupants, with targeted areas including seats/restraints/inflation devices for infants and small children, and side-facing seats in corporate aircraft. In addition, three research studies aimed at providing information on 1) the accessibility of under-seat life preservers on transport aircraft, 2) the tension average passengers apply to their seatbelts during normal and emergency conditions, and 3) the optimum lever motion for rapid seatbelt release were completed. Researchers also continued to investigate the nature of inflight medical emergencies and the use of defibrillators on commercial flights, as well as perform epidemiological assessment of biochemical and toxicological factors from fatal civilian aviation accidents.

The FAA and private industry continued to collaborate on the Safe Flight 21 Program, an initiative to validate the capabilities of advanced communication, navigation, and surveillance technologies and related air traffic procedures. During FY 2001, the FAA continued to demonstrate the uses of Automatic Dependent Surveillance-Broadcast (ADS-B) technologies at various airports across the country. ADS-B has been identified in the FAA "Blueprint for NAS Modernization" as a key surveillance technology to supplement, and possibly replace, radar. On January 1, 2001, FAA began initial operations using ADS-B in Alaska for air traffic control representing the first-ever use of this technology to provide radar-like services.

To accomplish these results, the FAA conducted extensive testing to validate the suitability for use of ADS-B to provide air traffic control services similar to radar-based air traffic control services. Problems were identified and solutions developed. New air traffic and certification procedures for using ADS-B were developed and implemented. The FAA's en route automated radar tracking system in Anchorage, Alaska, was upgraded to receive, process, and display ADS-B reports. In October 2000, an operational evaluation involving 17 aircraft from the

Cargo Airline Association, the FAA, and avionics manufacturers was conducted in Louisville, Kentucky, to demonstrate the use of ADS-B in final approach spacing, airport surface situational awareness, and moving map applications. A demonstration of surface safety applications was also conducted in Memphis, Tennessee, in June 2001. In addition, four ADS-B safety assessments were completed in September 2001. The Alaska Capstone Program continued its work in Bethel, Alaska, and the Yukon Kuskokwim (Y-K) Delta region, and began expansion into southeast Alaska. On January 1, 2001, the Anchorage Air Route Traffic Control Center began using ADS-B to provide radar-like services in the Bethel, Alaska, area. During the year, avionics were installed in 140 aircraft operating in Bethel and the Y-K Delta. Pilots use this equipment, in conjunction with six ground stations, to receive weather data, a NEXRAD map, and other traffic data. Program expansion to southeast Alaska also began. A useable Instrument Flight Rules (IFR) infrastructure is planned to address the terrain challenges presented by Juneau, Alaska, and the surrounding area. During the year, a request for proposal (RFP) was released to solicit vendors for upgraded avionics suites. Approximately 200 commercial service airplanes and helicopters will be equipped with the enhanced ADS-B systems in southeast Alaska.

The FAA awarded six contracts in February 2001 under the initial Surface Technology Broad Agency Announcement which is designed to explore new/emerging lower cost technology options to reduce runway incursions at the Nation's airports. Two proposed solutions, ground markers and addressable signs, showed promise and were being considered for functional and operational testing in an airport environment. The FAA also continued to pursue surveillance-controlled runway status light solutions for both large and small airports.

In FY 2001, the FAA continued progress toward implementation of the Wide Area Augmentation System (WAAS) that will provide availability, integrity, and accuracy for the Global Positioning System (GPS) to be used for en route navigation and precision civilian navigation. During the fiscal year, WAAS employees performed data collection and analyses using the National Satellite Test Bed (NSTB). The FAA developed interference detection and mitigation techniques, collected and analyzed ionospheric data, analyzed satellite alternatives for WAAS final operating capability, and researched satellite navigation issues for Alaska. Researchers from Stanford University used FAA funding to provide key support to the WAAS Integrity and Performance Panel and Independent Review

Board. The FAA continued pursuing a North American Satellite Augmentation System with Mexico and Canada. These agreements may significantly cut the FAA's expenses by reducing the agency's need to field WAAS reference stations along the southern and northern U.S. borders.

In addition, the FAA assisted the International Civil Aviation Organization (ICAO) with plans and strategies for the development of a WAAS-based Global Navigation Satellite System (GNSS) test bed capability for the Caribbean South American region. The FAA expected that the resulting South American test bed would pave the way for an operational system in the region that is completely compatible with the U.S. systems. This future capability, based on U.S. technology, may also provide cost-sharing opportunities on Geostationary Earth Orbit satellite services, significantly reducing projected FAA leasing expenses for satellites. The successful completion of all flight tests and other activities helped to demonstrate U.S. technological leadership in satellite navigation, ensure the seamless transfer from one regional satellite-based navigation system to another, and promote the adoption of satellite navigation in regions where improved navigation capability will increase the safety of flight for U.S. citizens traveling abroad. The FAA expected it to provide the groundwork necessary to achieve the ICAO's vision of a future, worldwide, seamless navigation capability. In FY 2001, FAA researchers made significant progress in the quest to use the Local Area Augmentation System to achieve Category I and Category III precision approaches. The FAA cooperated with private companies such as United Parcel Service (UPS) and Federal Express (FedEx) in successful tests using this system.

During the fiscal year, the FAA worked with the aviation industry to increase the level of detail contained in the National Airspace System Plan. The plan provides the communities strategic plan for Air Traffic Management through 2015. The plan is based on the "Free Flight" operational concept in which pilots may choose the most efficient and economical routes to their destinations. As part of these modernization efforts, the FAA delivered all the domestic Terminal Doppler Weather Radars. The radar and its associated display are important safety features for helping to identify hazardous weather such as wind shear and microbursts.

During FY 2001, the FAA's William J. Hughes Technical Center worked in partnership with NASA's Ames Research Center as the cosponsors of a technology transition initiative. The purpose of this initiative was to acquire technical knowledge of new technologies developed by NASA early in the concept and prototype development phases. The knowledge acquired through joint development participation will potentially assist in reducing the time it takes to go from concept development to field implementation. In support of this effort, the team at the Technical Center recruited and hired subject-matter experts to participate in the technology transition initiative. The success of the technology transition initiative was validated by an increase in the number of implementation plans, which provide the formal agreement between NASA and the FAA for collaborative joint development and technology transition efforts.

The Technical Center team has also supported the mission of the Interagency Air Traffic Management Integrated Product Team by providing technical experts to serve as coleads for joint research projects and project leads for those projects that have shown some benefit for the NAS. In addition, the key team members were active participants in the Interagency Air Traffic Management Integrated Management Team.

In FY 2001, the FAA completed development of an advanced tool to calibrate and certify many secondary radars in the NAS, including the new Airport Surveillance Radar, the Air Traffic Control Beacon Interrogator upgrade, and existing Mode S radars. The Technical Center conducted tests verifying the performance envelope and the electromagnetic inference and environmental characteristics of this new test set. Subsequently, the FAA accepted the first five production units for use at operational sites around the Nation.

The Hughes Technical Center also completed a study of the Airport Movement Area Safety System intersecting runways alert parameters. The purpose of the study was to determine a recommended set of parameters to initiate alerts of potential runway collisions for aircraft operating on intersecting runways at various airports. After collecting live data at these airports and thorough analysis of the data, the study recommended a set of parameters that maximize safety benefits while minimizing the number of nuisance alerts generated.

In partnership with the Department of Defense and the National Oceanic and Atmospheric Administration, the Technical Center initiated research on the feasibility of using multifunction-phased array radars to perform weather detection and warning, and to track aircraft. The ultimate goal of this project was to provide much earlier warning of impending severe weather conditions. The FAA expected that this project would create a research facility in the aptly named "Tornado Alley" at the National Severe Storm Laboratories in Norman, Oklahoma.

Airborne laboratories in the FAA's Research and Development Flight Program participated in unique flight-test and high-altitude data collection to support development of new procedures and technology to improve navigation and safety for our Nation's pilots and their passengers. The wide variety of programs included GPS navigation and precision approach development, air traffic control circuit breakers tests, human factors, WAAS, and the Traffic Alert and Collision Avoidance System (TCAS). These tests utilized a specially modified Boeing 727, a Sikorsky helicopter, and a Convair 580 aircraft.

The Technical Center established an advanced differential GPS test bed in Brazil. Under a memorandum of understanding between FAA and the aviation authority in Brazil, Technical Center engineers procured and installed hardware and software for the test bed and provided training on the fundamental concepts of GPS wide-area differential systems and how to operate and maintain the test bed.

The safe operation of our Nation's airspace depends on reliable communications and navigation signals, but radio frequency interference (RFI) can damage or cancel those signals. The Technical Center supported several high-visibility RFI projects such as innovative training courses for FAA inspectors and personnel at ATC facilities. In FY 2001, FAA instructors reached out to over 300 FAA regional, flight inspection, and international technicians, inspectors, and engineers.

The Technical Center completed the final phase of an air traffic control simulation study designed to reduce delays into Newark International Airport. More than 100 air traffic controllers from four facilities in the eastern region participated in a series of simulations. They tested different procedures along existing flight paths to better enable controllers to sequence aircraft into the busy New York metropolitan area. The completion of this study represented more than a year of development and testing involving hundreds of hours of simulation, and involved airspace in four air traffic control facilities: New York Center, Washington Center, Philadelphia Air Traffic Control Tower, and the New York TRACON. Separate standalone simulations were conducted for each facility, and these simulations were conducted using the high-fidelity equipment in the air traffic labs at the Technical Center. The controllers, programmers, airspace specialists, union representatives, and managers all worked together throughout the year to overcome the many challenges faced by the participants, and the final phase of simulations was completed in May 2001. The Administrator also initiated a unique study in the fall of 2000 to identify several points of congestion in the NAS and provide relief in an expeditious manner.

Human factors researchers at the Technical Center conducted rapid prototyping efforts, early user involvement events, and computer-human interface (CHI) validation simulations on multiple new or upgraded systems for the NAS. In addition, they revised the Human Factors Design Guide to reflect the most current research and information.

Human factors scientists at the Technical Center also examined the effects of automation tools on air traffic controllers' workload and situational awareness. The first study investigated the effect of increasing levels of decision support automation. A second study, conducted in collaboration with the Civil Aeromedical Institute, explored the potential benefits and information requirements of an operational position, airspace coordinator, which could more strategically plan traffic through airspace sectors. Finally, researchers examined the potential human factors issues associated with collocating three Free Flight automation tools.

FAA's Office of the Associate Administrator for Commercial Space Transportation (AST) continued to license and regulate U.S. commercial space launch activity, ensuring public health and safety, and the safety of property, and protecting national security and foreign policy interests of the United States. AST also licensed operation of non-Federal launch sites and facilitated and promoted commercial space launches by the private sector.

During fiscal year 2001, AST licensed six orbital space launches. Three launches were conducted by Sea Launch (Zenit 3SL vehicle), two by Orbital Sciences Corporation (Pegasus and Taurus), and one by International Launch Services (Atlas IIAS). AST also established the System Engineering and Training division to define safety standards for existing and emerging space launch systems, launch sites, re-entry systems, and re-entry sites. The new division responds to the training needs of AST employees.

Several reports were released, including "The Economic Impact of Commercial Space Transportation on the U.S. Economy." The first-ever U.S. study of its kind, the report showed that in a single year (1999), the U.S. commercial launch industry was responsible for yielding more than $61.3 billion in economic activity and for supporting nearly half a million jobs in the United States. The "2001 Commercial Space Transportation Forecasts" were released by AST and FAA's Commercial Space Transportation Advisory Committee. The forecasts projected an average demand for 32 worldwide commercial space launches per year through 2010.

The Air Force and the FAA signed a Memorandum of Understanding on Safety for Space Transportation and Range Activities. AST completed the draft and preliminary versions of the Rulemaking Project Record for the Reusable Launch Vehicle Operations and Maintenance Notice of Proposed Rulemaking (NPRM). In addition, AST participated on a committee to advise NASA in selecting initial contracts for the Space Launch Initiative (second-generation Reusable Launch Vehicle), revised and updated its environmental guidelines, and began preparation on licensing new Atlas V and Delta IV launch vehicles.

Department of Commerce

DoC

In FY 2001, the Department of Commerce (DoC) engaged in a wide variety of activities that furthered U.S. interests in aeronautics and space, including satellite operations and licensing, technology development, trade promotion, and civilian and commercial space policy support. Most notably, DoC joined other U.S. Government agencies in applying airborne and space-based resources to the relief efforts following the September 11 terrorist attacks on the World Trade Center and the Pentagon. Specifically, a number of National Oceanic and Atmospheric Administration (NOAA) line offices contributed significantly to these efforts, namely the Office of Marine and Aviation Operations (OMAO), National Ocean Service (NOS), and Oceanic and Atmospheric Research (OAR). The OMAO's Aircraft Operations Center (AOC) provided support to NOS's Remote Sensing Division. Teaming with NOS, Optech, Inc., and the University of Florida, AOC made available and operated NOAA's Citation jet, and coordinated its flights with the Federal Aviation Administration (FAA) and North American Aerospace Defense Command (NORAD). The Citation flew over both sites at the request of the Army's Joint Precision Strike Demonstration project, collecting high-resolution aerial photography and LIDAR (Light Detection and Ranging) data from a system provided by Optech, Inc., of Canada.

NOS's National Geodetic Survey (NGS) directly supported search and recovery efforts at both the World Trade Center and the Pentagon disaster sites by using its mapping and remote-sensing capabilities. The Army Joint Precision Strike Demonstration coordinated a highly detailed mapping mission at both disaster sites using LIDAR technology. LIDAR is an active remote-sensing system used to profile or scan terrain elevations. NOS, the NOAA Office of Marine and Aviation Operations, Optech, Inc., and the University of Florida teamed up to fly the LIDAR in NOAA's Cessna Citation. The images, which were created by the LIDAR system and produced by NOAA, were provided as digital surface models that offered an accurate bird's eye view of the scene. They provided three-dimensional positioning of the building structures and the surrounding area, at 15cm accuracy, which helped the rescuers and engineers locate original support structures, stairwells, elevator shafts, and basements. The LIDAR data, traditional high-resolution aerial photography, and accurate Global Positioning System (GPS) measurements are all connected to the National Spatial Reference System (NSRS), which serves as a base reference for location information, and proved to be invaluable to the rescue efforts. In this way, the rescuers had one base reference system to efficiently locate utilities and building structures, which had been rendered indistinguishable as a consequence of the attacks. NOAA later returned to the World Trade Center site to provide data for change analysis. The crews were able to pinpoint their recovery efforts by using photographs that revealed the degree of the damage and the distribution of debris.

LIDAR data was also used to monitor structural movement of damaged buildings in the area of the disaster and to calculate the volume of rubble. For example, as the recovery efforts descended into the World Trade Center Tower basements, LIDAR images provided very accurate height measurements that could be used to mitigate potential flooding from the surrounding rivers. NOAA also flew a mission over the Pentagon site to map it with LIDAR for reconstruction purposes.

A NOAA pilot on temporary duty with NASA flew an aircraft equipped with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) system at the request of the Environmental Protection Agency (EPA) in order to identify and locate asbestos fallout from the WTC plume. NOAA/OAR scientists also assisted EPA efforts to assess ground-level air pollution problems in New York that were primarily associated with asbestos released as the buildings fell.

On July 23, 2001, NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) launched the Nation's newest Geostationary Operational Environmental Satellite-12 (GOES-12). GOES-12 is the first in the GOES series to carry a new Solar X-Ray Imager (SXI) capable of producing images of the Sun at 1-minute intervals. The SXI provides a continuous sequence of coronal x-ray images that will be used by NOAA's Space Environment Center

(NOAA/SEC) and the broader community to monitor solar activity for its effects on the Earth's upper atmosphere and near space.

GOES-8 continued to view environmental events over the East Coast of North and South America and over the Atlantic Ocean; GOES-10 continued to view the West Coast and the Pacific Ocean, including Hawaii. Similar to the other operational GOES, GOES-11 and GOES-12 are in place to be used to monitor Earth's atmosphere and surface to support NOAA's forecasting and warning programs.

GOES-2 was de-orbited in May 2001 after 24 years of onorbit operations. Launched in 1977, the satellite was initially used for imaging operations and later supported the Pan-Pacific Education and Communication Experiment (PEACESAT) administered by the University of Hawaii. In addition, NOAA-10 was deactivated in August. Since its launch in 1986, the satellite was fully operational for almost 5 years, and served secondary functions until its deactivation.

NESDIS continued to operate two polar-orbiting environmental satellites, NOAA-15 and NOAA-16, to provide a continuous flow of data to support weather forecasting and monitoring of environmental events around the world. In the U.S., NOAA's National Weather Service (NWS) used the data primarily for long-range weather and climate forecasts. These satellites are the first of 2 in a series of 5 polar-orbiting satellites with improved imaging and sounding capabilities that will operate over the next 12 years. The new microwave instruments on NOAA-15 and NOAA-16 have enabled NOAA short-term weather forecasting and warning programs to measure moisture in the atmosphere for identifying heavy precipitation conditions. The direct broadcast, on a free and open basis, of Advanced Very High Resolution Radiometer (AVHRR) instrument data provides imagery to scientific, commercial, and educational groups throughout the world. In addition, the search and rescue instruments on these satellites continue to support a global community that has established ground stations that "listen" for distress beacons relayed through the NOAA polar-orbiting and Russian Cospas satellites.

As part of NOAA's interagency activities, it represented the DoC interests in several subteams under the National Security Council Space Policy Coordinating Committee. NOAA also continued its work with the Department of Defense (DoD) and NASA as part of the Integrated Program Office (IPO) that is managing the development of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) commenced 7 years ago. NPOESS represents a major step toward the merger of U.S. civilian and military operational meteorological satellites into a single, integrated, end-to-end satellite system. NPOESS is designed to replace the current NOAA Polar-orbiting Operational Environmental Satellites (POES) and the Defense Meteorological Satellite Program (DMSP) systems.

Under a robust sensor risk-reduction effort that has been focused on early development of the critical sensor suites and algorithms necessary to support NPOESS, the IPO has awarded contracts for design and development of the following NPOESS instruments: Ozone Mapping and Profiler Suite (OMPS); Cross-track Infrared Sounder (CrIS); Global Positioning System Occultation Sensor (GPSOS); and the Visible/Infrared Imager Radiometer Suite (VIIRS). In August 2001, preliminary design efforts were completed for the last of five critical advanced technology imaging/sounding instruments for NPOESS, and an instrument development contract was awarded for the Conical-scanning Microwave Imager Sounder (CMIS). In 2001, the IPO continued work on competitive Program Definition and Risk Reduction contracts to define the requirements for the NPOESS total system architecture, including space, ground processing, and command, control, and communications components, as well as to develop specifications for sensor/spacecraft integration.

The IPO continued to support its partners in final development of the joint DoD/IPO WindSat/Coriolis mission that is designed to provide a space-based test and demonstration of passive microwave polarimetric techniques to derive measurements of ocean surface wind speed and direction. This 3-year mission will continue the development of improved microwave measurement capabilities from the Special Sensor Microwave Imager and Sounder (SSMI/S) on DMSP to CMIS on NPOESS. In addition, the IPO continued to comanage development of the NPOESS Preparatory Project (NPP) designed to reduce the potential risks incurred during the transition from POES and DMSP to NPOESS. NPP is also designed to provide continuity of the calibrated, validated, and geo-located NASA EOS Terra and Aqua missions systematic global imaging and sounding observations for NASA Earth Science research. As part of the convergence of the DoC and DoD meteorological satellite programs (POES and DMSP) into

NPOESS, the IPO and NESDIS continued to operate the DMSP satellites and prepared for the launch of the next replacement satellite (DMSP F-16). During the course of the year, four DMSP satellites continued to contribute atmospheric, ocean, and space weather measurements to DoD and NOAA operational forecast centers.

NOAA/NESDIS continued to lead the National Hazard Information Strategy (NHIS), which is an interagency initiative to reduce disaster losses through better information. Under this initiative, efforts to develop the Hazard Mapping System (HMS) succeeded in achieving progress on applications for smoke and fire detection for State and Federal agencies. The HMS is an interactive processing system that allows analysts in the NESDIS Office of Satellite Data Processing and Distribution to integrate data from various sources, such as GOES, polar-orbiting data (AVHRR), detection of fire from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS), and Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS) nighttime lights detection technique. This composite data set is used to compile a quality-controlled display of fire locations for the continental United States.

In FY 2001, the national Search and Rescue Satellite-Aided Tracking (SARSAT) and international Cospas-Sarsat programs, led by NOAA/NESDIS in collaboration with the U.S. Coast Guard, U.S. Air Force, and NASA, contributed to the rescue of 178 lives in the U.S. and more than 1,000 worldwide. The SARSAT program uses search and rescue payloads on NOAA and Russian satellites to detect emergency beacons used by aviators and mariners in distress. During the year, South Africa and Nigeria joined the Cospas-Sarsat program, bringing the total number of member States to 33. Planning also continued for placing search and rescue payloads on the European Meteosat Second Generation and Indian Insat-3 geostationary satellites.

In FY 2001, the NESDIS/National Climatic Data Center (NCDC) archived 2.3 terabytes of POES data and 16.2 terabytes of GOES data. Approximately 300 customers requested satellite products. A data set of surface temperatures was recently developed from a combination of in situ, satellite, ship, and buoy observations. This blended source of information provides a comprehensive analysis of surface temperature anomalies throughout the globe. In support of NOAA efforts to improve access to GOES retrospective data, NCDC awarded a contract to Marada Corporation in June 2001 to conduct a 1-year study of design options for online access to GOES data.

NCDC supported the International Satellite Cloud Climatology Project (ISCCP) by serving as the Sector Processing Center (SPC) for both operational morning and afternoon NOAA polar orbiter satellites and, secondly, as the ISCCP Central Archive (ICA). In its role as the SPC, NCDC provided ISCCP level B2 data, which consists of a spatially sampled version (approximately 30 km resolution) of the Global Area Coverage (GAC) data routinely produced by NOAA from the AVHRR instrument onboard the operational NOAA polar orbiters. In its role as the ICA, NCDC acted as the official archive of ISCCP data, serviced customer orders from this archive, and also provided correlative data to some of the ISCCP participants.

Throughout FY 2001, NCDC responded to data requests from customers supporting the NOAA mission. The Great Lakes Environmental Research Lab, which is part of NOAA, ordered approximately 1,000 GOES images to study the El Niño-induced weather patterns from Central America and South America. The National Centers for Environmental Prediction (NCEP) acquired GOES-8 data to help map aerosol distribution from space. Scientists developed new algorithms to study the effects of aerosols on regional climate patterns and used aerosol properties retrieved from the GOES-8 Imager to compare against ground-based Sun photometer measurements.

Space environment monitoring data from the geostationary and polar-orbiting operational satellites were processed and archived at the NOAA/NESDIS National Geophysical Data Center (NGDC). Space environment, atmospheric, and oceanic monitoring data recorded on operational Defense Meteorological Satellite Program (DMSP) satellites were also processed and archived. Analyses of the DMSP archives produced the first global database of visible-to-near-infrared emissions. The emission database was used to produce a map of changes in emission intensity from 1992 to 2000, which are then related to analysis of urban sprawl. NOAA personnel developed a new Satellite Archive Browse and Retrieval system to provide a variety of online, automated services from imagery browsers to high volume, full resolution data transfers. This archive and access system was modified to accept moderate resolution imagery collected on NASA's Earth Observing Satellite (EOS) as a joint venture with NASA to address the long-term archive of EOS data.

In conjunction with the GOES-12 satellite launch and the Solar X-ray Imager (SXI) that it carries, the first new instrument in over 20 years designed to improve space weather forecasting and monitoring, NGDC helped to develop a real-time system that will provide data to commercial space weather vendors, scientists, educators, and the public. NGDC worked in close cooperation with NOAA's Space Environment Center to produce the software to process, archive, and access SXI data within minutes of the recording.

Charged under the 1992 Land Remote Sensing Policy Act to license private remote-sensing satellite systems, NOAA approved four new licenses for commercial systems in FY 2001, including second-generation electro-optical/multispectral systems, and high-resolution synthetic aperture radar. NOAA also approved 6 foreign agreements of its licensees, totaling an investment of up to $110 million in U.S. systems.

Additionally, NOAA and DoC's International Trade Administration (ITA) commissioned a remote-sensing policy study from the RAND Corporation. This study was conducted with the aim of better understanding the role that U.S. Government policies and regulations play in shaping prospects for the commercial remote-sensing satellite industry. The study provided recommendations to U.S. Government and industry to mitigate technical, market, policy, and regulatory risks.

In the international space arena, NOAA/NESDIS continued to improve and enhance its ongoing activities in FY 2001. NOAA participation in the United Nations Committee on Peaceful Uses of Outer Space (COPUOS) played a key role in facilitating negotiations that established the U.N. COPUOS Action Team on Disaster Management. State Department Environmental Defense Funding was awarded to NOAA through its role as the Chair of the Committee on Earth Observation Satellites (CEOS) Disaster Management Support Group (DMSG). This funding, together with assistance from the United Nations Office of Outer Space Affairs (OOSA) and the European Space Agency (ESA), is to be used in support of disaster workshops to bring together practitioners and space agencies that have developed space technology solutions for disaster management in developing countries. NOAA managers also negotiated a renewal of the Radarsat-1 Memorandum of Understanding resulting in signature by the NOAA and NASA Administrators and the Director-General of the Canadian Space Agency. This agreement maintains NOAA access to Radarsat-1 data until Radarsat-2 becomes operational. NOAA's ongoing space relations with Japan also continued in 2001, with completion of a new proposal to NASDA for cooperation on their Advanced Land Observing Satellite (ALOS) mission. NOAA continued to provide, as the sole DoC representative, overall responsibility for observational issues on the U.S. delegations to the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Commission on Sustainable Development (CSD).

NESDIS's significant multilateral space activities also continued through its prominent activities in the Integrated Global Observing Strategy (IGOS). NOAA developed, with an IGOS visibility team, IGOS-related language and concepts for endorsement at the April 2001 intergovernmental Commission on Sustainable Development (CSD) at the United Nations Headquarters in New York City. In particular, they worked to insert language in support of full and open data sharing, and to find an integrated global observing strategy for documents being prepared for the World Summit on Sustainable Development (WSSD). NOAA also organized, with its IGOS Partners, an IGOS exhibit and side-event in connection with the CSD.

In coordination with the French, Canadian, and European Space Agencies, the DoS, and other U.S. agencies, NOAA became a member to the International Charter on Space and Major Disasters. NOAA also worked closely with the DoS to obtain an Export License for four-line elements and perturbation software to allow EUMETSAT to calibrate and validate NOAA instruments on their METOP satellites. In addition, the NOAA/DoS collaboration helped to expedite approval of a Technology Assistance Agreement between EUMETSAT and ITT. European cooperation with NOAA was further enhanced through an energetic effort to refocus NOAA and U.S. Government polar satellite cooperation with EUMETSAT. NOAA obtained EUMETSAT funds, in agreement with NASA, for testing NOAA instruments scheduled to fly in a changed METOP-1 launch environment. NOAA, with NASA and DoD, its partners in the NPOESS, drafted a new Joint Polar Transition Agreement for negotiation with EUMETSAT.

The NOAA Assistant Administrator for Satellite and Information Services participated in a July 26, 2001, inaugural ceremony in San Jose, Costa Rica, that celebrated the NOAA-facilitated transfer to Costa Rica of a satellite ground station that brings high-resolution digital imagery from GOES satellites to the Central American region. The imagery is collected through RAMSDIS units installed in Costa Rica, Nicaragua, and Guatemala. NOAA has commenced efforts to establish agreements with Belize, El Salvador, Guatemala, Honduras, Nicaragua, and Panama for installation of RAMSDIS systems.

In addition, Australia and NOAA signed a historic Science and Technology Arrangement for collaboration on coral reef research. The Acting NOAA Administrator signed the Arrangement in January 2001 to establish a Coral Reef Virtual Laboratory that will help researchers better understand and monitor coral reef health. Excessive temperatures can cause bleaching of the corals that are detrimental to island reef structures and the attendant marine ecosystem. The health of the coral reefs will be monitored by using satellite-observed sea surface temperatures and will contribute to mitigation activities under the arrangement.

NOAA/NESDIS worked with NASA, the French space agency, and EUMETSAT to fashion cooperation for the eventual transitioning of research satellite altimetry missions of the follow-on Jason series of satellites to operational status. The four agencies also received recognition for preparing to commit resources to the identified satellite altimetry requirements in the Oceans Theme of the IGOS. NOAA/NESDIS also focused efforts of the Assistant Administrator, in coordination with NASA and NOAA/NWS counterparts, to represent U.S. interests in the January 2001 World Meteorological Organization (WMO) Consultative Meeting on High-Level Policy on Satellite Matters. This effort also included NOAA inputs to a new WMO Technical Document on the role of satellites in WMO programs. NOAA/NESDIS contributed, and prompted contribution by other foreign space agencies, to a May 2001 University of Miami international infrared radiometer calibration and inter-comparison exercise in connection with the CEOS Working Group on Calibration and Validation.

In FY 2001, the NOAA/NESDIS Office of Research and Applications (ORA) and NASA established the Joint Center for Satellite Data Assimilation (JCSDA) to accelerate the use of satellite data in weather-prediction models. The JCSDA is a “virtual center,” involving scientists from NASA and NOAA who work in tandem to transition research, algorithms, and techniques in satellite data assimilation. The objective is to maximize the significant investment that has been put into current observing systems and prepare for the explosion of data that will be available from future systems, such as the convergence of the NPOESS constellation of satellites.

NOAA's AOC supported hurricane research and surveillance, winter storms research, coastal mapping, snow surveys (for hydrological forecasting), air chemistry studies, and global climate research by providing specially designed and instrumented aircraft for operations. Highly trained pilots, scientists, engineers, and technicians operate these aircraft. In FY 2001, AOC also made significant improvements to NOAA's "hurricane hunter" technology. In conjunction with flights of the NOAA G-IV hurricane surveillance jet far out over the Pacific Ocean, a WP-3D Orion flew into winter storms off the West Coast, collecting meteorological data for computer models to improve forecasts of severe Pacific storms approaching the United States. An Inmarsat communications system was installed on the P-3 for this mission that enabled immediate, real-time storm data and voice transmissions to forecasters. The system was later installed on NOAA's other P-3, giving both aircraft the capability to transmit immediately to the National Hurricane Center during missions flown over the course of the 2001 hurricane season.

NOAA's NOS continued to use GPS and remote-sensing technology to meet its mission of mapping the national shoreline, producing airport obstruction charts, and monitoring and analyzing coastal and landscape changes. NOS/NGS continued work on advancing centimeter-level positioning accuracy of GPS through its National Continuously Operating Reference Stations (CORS) program. It added 31 new stations to the National CORS network during FY 2001. At the end of the fiscal year, the network contained 229 sites. NOS continued upgrading the sampling rate of all Nationwide Differential GPS (NDGPS)/DGPS sites from 30 seconds to 5 seconds to better serve those involved in Geographical Information Systems (GIS) development and/or kinematic applications. In another effort to better serve those in the GPS and GIS communities, NOS hosted a CORS Industry Forum in March 2001. The Forum presented the current status of the CORS program and solicited input from existing and prospective partners to determine the future direction of CORS. A joint effort was undertaken between NOS and the FAA Tech Center in Atlantic City, NJ, to establish a T1 Internet connection to download GPS data from approximately 50 sites contained in the Wide Area Augmentation System/National Satellite Test Bed (WAAS/NSTB) network. Many of these sites are being incorporated into the CORS network. This software will allow the streaming of FAA data into hourly files. CORS was also utilized in the response and recovery efforts of the World Trade Center disaster. The New Jersey Institute of Technology and the U.S. Coast Guard increased the data collection rate at nearby stations to better position the airplanes that were mapping the affected area via remote-sensing techniques.

Also in the past year, NOS developed the Online Positioning User Service (OPUS) as a means to facilitate GPS users' access to the NSRS. OPUS allows users to submit their GPS data files to NOS, where the data will be processed to determine a position using NOS computers and software. Each submitted file is processed with respect to three CORS sites. While it is not a real-time feedback, it is very valuable for checking data that is brought in from the field.

NGS continued its effort as a key partner in the NASA Synthetic Vision System (SVS) program by providing essential data and information to be incorporated into this system. NASA is working with industry to create Synthetic Vision, a virtual reality display system for the cockpit. This program could offer pilots a clear, electronic picture of what is outside their windows, regardless of the weather or time of day.

NOS continued to provide access to data it currently collects and maintains within the Aeronautical Survey Program (ASP). It also continued to derive specialized data to support the SVS. These data include obstruction data, runway positional information, digital terrain models, and orthorectified imagery. In FY 2001, two test sites were selected, Dallas-Fort Worth, Texas, and Eagle County, Colorado. This data provides the backbone of the SVS system, which is used to provide the required positional accuracy and the scene replication data needed for safe air navigation in low-visibility situations.

NOS has collaborated with the FAA Aviation Systems Standards (AVN), the University of Florida Geomatics Department, and Optech Inc. to test the feasibility of using an Optech 33 kHz Airborne Laser Terrain Mapper (ALTM) for FAA programs (AVN-Flight Check/National Aeronautical Charting Office (NACO)-Flight Edit) and the NOS Aeronautical Survey Program.

NOS continued to participate in the Safe Flight 21 program, which is led by the FAA. This is a joint Government/industry initiative designed to demonstrate and validate, in a real-world environment, the capabilities of advanced surveillance systems and air traffic procedures that will move the national airspace system forward in the 21st century. Enabling technologies include Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Services-Broadcast (TIS-B). The NOS role is to provide accurate data referenced to the NSRS. It provides orthorectified imagery and then generates a highly detailed digital map of the test airports. The data sets include runways, taxiways, vehicle roads, signs, centerline paint stripes, all movement areas, and other detailed information to help air traffic controllers safely move aircraft and ground vehicles around the airfield.

The NOS Coastal Services Center (CSC) continued to expand its efforts to make remote-sensing data, information, and technology accessible to the coastal resource management community in FY 2001. One of CSC's most significant efforts was to manage the NOS coral mapping efforts in the Pacific Ocean. This effort is based primarily on remote-sensing technology, using satellite and airborne platforms to develop the coral reef map products. This is an ongoing collaborative activity and includes the participation of many program offices within NOS, as well as contracts with the private sector for product development.

Another significant activity included the beginning of outsourcing efforts for remote-sensing products and services. NOS released a contract to private industry for the development of satellite-based, land cover and "change" data sets in the coastal areas of the Great Lakes region. These products will meet the guidelines and standards of the NOAA Coastal Change Analysis Program (CCAP). In FY 2001, NOS also developed these products for the main eight islands of Hawaii. Commercial, high-resolution satellite data were purchased to support various land-based resource management projects in the Pacific Islands and coastal regions of the mainland. Other outsourcing activities included the initiation of a contract to collect elevation data from LIDAR technology for the Willapa Bay region of Washington.

NOS also continued to support remote-sensing and GIS activities in partnership with the coastal management community. These data were used to support the land cover mapping of the main eight islands of Hawaii, to verify historical logging activities for an ecological characterization project in Alaska, and to estimate visitor use for two National Marine Sanctuaries located off the coasts of Georgia and Texas.

NOS outreach and educational activities included the development of a remote-sensing training course for GIS professionals, Web-based materials that focus on the coastal applications of remote sensing, and CD-ROM products that demonstrate how remote-sensing technology is being used in specific State and local coastal resource management applications. NOS continued to develop its internal NOAA relationships and to foster its relationships with other civil agencies that have mutual interests in remote-sensing and Earth observation technologies within the coastal zone, such as the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), EPA, and NASA's Earth Science Enterprise.

The NOAA/National Marine Fisheries Service (NMFS) Office of Habitat Conservation has been interacting with the Naval Oceanographic Office at Stennis Space Center in Mississippi for several years on a project to acquire high-resolution imagery of the Sacramento River. The aim is to monitor areas along the river that are accessible by threatened and endangered species of interest to NMFS. Previously, the Navy collected very-high-quality imagery along the Sacramento River, from Shasta Dam downstream to the Delta (i.e., the entire portion of the river accessible to resources of interest to NMFS). That imagery was processed by the Naval Oceanographic Office and sent to NMFS as 2 sets of a 6-volume series of hard-copy images of the Sacramento River. The last volume was received during summer 2001. Copies were then sent to the NMFS field office in Santa Rosa, California, for immediate use in assessments for both the Endangered Species Act and the Sustainable Fisheries Act. The imagery has allowed NMFS staff engineers and biologists to examine details of the river that have enhanced project planning, impact assessment, and evaluation of potential restoration activities.

During FY 2001, following completion of a NMFS-led restoration effort to enhance lateral growth of the Atchafalaya River Delta under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA), the NMFS Office of Habitat Conservation used National Imagery Systems and other data to track changes in the delta from 1998. Louisiana has 40 percent of the wetlands in the continental U.S., yet the State experiences 80 percent of the loss (the CWPPRA was instituted to combat this loss). The imagery collected under this project was utilized by the USGS and analyzed by NMFS. This imagery has revealed observations of large areas of accretion on the lateral edges of the delta, which demonstrates the success of the NMFS-led restoration effort.

NOAA's Special Agents and Fisheries management officials leveraged high-tech tools to assist them in their work of protecting and managing the Nation's marine living resources. One of these tools is a national Vessel Monitoring System (VMS), which routinely uses satellite-based monitoring systems to monitor compliance with domestic and international fishing regulations, as well as receive real-time catch data. NOAA's Fisheries Office for Law Enforcement (OLE) continued to expand its national VMS program. This program is the vehicle to provide infrastructure, economies of scale and coordination across NOAA Fisheries' regions and offices. It is designed to ensure standards-based consistency for enacting national policies concerning fishing data confidentiality, systems security, and legal evidence handling. The current regional VMS systems are designed to be linked to OLE HQ servers and use standardized hardware, communications software, and formats. An integral part of the national VMS program is the ability to afford wide-area network connectivity for all of the major enforcement and VMS monitoring offices.

NOAA's SEC, the Nation's official source of space weather alerts and warnings, continued to monitor continually and forecast Earth's space environment by providing accurate, reliable, and useful solar-terrestrial information.

SEC conducted research into phenomena affecting the Sun-Earth environment, including the emission of electromagnetic radiation and particles from the Sun, the transmission of solar energy to Earth via solar wind, and the interactions between the solar wind and Earth's magnetic field, ionosphere, and atmosphere. In conjunction with the U.S. Air Force, SEC continued to conduct Space Weather Operations (SWO) to monitor solar and geomagnetic activity 24 hours a day; disseminate information on the solar-terrestrial environment; alert private, commercial, Government, and military users to possible disruptive or dangerous changes in the space environment; issue daily forecasts of space environment conditions; and act as the World Warning Agency for the space environment. The SEC continued to operate a Data Acquisition and Display System to gather current space weather data for distribution to Government and private sector users and for subsequent archiving by NOAA's NGDC.

More than 20 years of joint effort between the U.S. Air Force, NASA, and NOAA culminated in the development of a real-time image processing system, to improve space weather alerts and forecast the effects of such disturbances. The system, installed on one of NOAA's geostationary satellites (GOES-12), includes a flexible "movie" player for visualization and assessment of dynamic changes in the sun's corona, as provided by the new SXI data. Data from the instrument was first recorded on September 7, 2001. The images, which revealed solar details such as coronal holes, active regions, flare locations, and a wealth of other detail, achieved all expectations. The instrument is being tested and calibrated to optimize products that will come out of the images.

Real-time tracking of NASA's Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) commenced from NOAA's Fairbanks ground station. IMAGE is the first mission dedicated to "seeing" Earth's space environment and watching solar activity drive space weather. Through a partnership between NASA, NOAA, and the Communications Research Laboratory in Japan, the IMAGE satellite broadcasts images of space weather in real time, and ground stations receive the images and transfer them to the SEC.

SEC collaborated with NASA in planning *Living with a Star*, a guide providing K–12 educators with materials and resources that are useful for understanding connections between the Sun and Earth. The two primary goals of this effort are to disseminate educational resources about the Sun and to facilitate the involvement of space scientists in education.

DoC also engaged in a variety of non-NOAA aerospace activities. The Technology Administration (TA) engaged in a number of space-related activities through the Office of Space Commercialization (OSC) and the National Institute of Standards and Technology (NIST). OSC continued to serve as the principal coordinating unit within the DoC on space-related issues, coordinating positions with and disseminating information to various bureaus with separate space-related responsibilities and authorities, including NIST, NOAA, the International Trade Administration (ITA), the National Telecommunications and Information Administration (NTIA), and the Bureau of Export Administration (BXA).

In June, OSC published the *2001 Trends in Space Commerce* report, providing an overview of the commercial space market and projections for future growth. The analysis included highlights on competitiveness comparing the U.S. with other nations in the fields of space commerce, space transportation, satellite communications, remote sensing and the Global Positioning System. The report projected a $93.4 billion worldwide market for the space industry in 2001, with $77.74 billion in revenue expected from satellite communications, the largest and fastest growing segment of the industry.

OSC assumed an active role in interagency space matters under the Space Policy Coordinating Committee (PCC) established by the National Security Council. OSC cochaired the Space PCC Sub-Team on commercial space issues, overseeing the development of strategies for the use of commercial remote-sensing satellite systems by the military and for commercial use of the International Space Station. OSC also participated in Space PCC Sub-Teams focused on space transportation, spectrum, and international issues.

Within the White House-led Interagency Working Group on the Future Use and Management of the U.S. Space Launch Bases and Ranges, OSC collaborated with the U.S. Air Force and the FAA Office of the Associate Administrator for Commercial Space Transportation (AST) to assure full consideration of the needs of commercial users of the two major Federal space launch facilities. As part of a separate effort, OSC, FAA/AST and IT's Office of Aerospace worked closely to coordinate industry positions on outside funding for Federal launch bases and ranges.

Through OSC and NOAA, DoC continued to promote the interests of commercial, scientific, and Government users of GPS as a key member of the Interagency GPS Executive Board. OSC played a critical role in defending GPS radio spectrum from encroachment by ultra-wideband emitters and other potential interference sources, working with the NTIA as well as civil and military Federal agencies. OSC also continued to host the offices and meetings of the IGEB, to engage in international outreach missions to promote GPS, and to participate in the GPS modernization program.

OSC continued to represent U.S. industry interests during bilateral negotiations with the European Commission on satellite navigation. OSC also participated in bilateral consultations with Japan led by the DoS to affirm the two nations' mutual commitment to promote and use GPS as an international standard for satellite navigation and timing.

In the area of satellite remote sensing, OSC, NOAA, and IT's Office of Aerospace (OA) continued to represent commercial interests as part of the

Remote Sensing Interagency Working Group (RSIWG). Led by the DoS, the RSIWG is charged with coordinating policy for the export of U.S. remote-sensing satellite systems and negotiating government-to-government agreements covering the safeguarding of those systems' technology.

During FY 2001, NIST performed a broad range of measurements and standards-related research, technology transfer, and industry support in the areas of aeronautics and space. NIST continued to provide radiometric calibration support for NASA's EOS program to ensure the accuracy of the sensors used in global remote sensing. NIST also provided the radiometric calibration of NOAA's Marine Optical Buoy (MOBY), which furnishes accurate data necessary to calibrate and validate satellite ocean color measuring instruments such as the Sea-Viewing Wide Field-of-View Sensor (SeaWifs) and MODIS. NIST started a multi-year effort to improve calibration techniques for radiometers used for remote sensing. These new developments should provide greater measurement accuracy in satellite applications such as measuring Earth's temperature, wind speed over the ocean, sea salinity, and locating resource position.

The NIST Manufacturing Extension Partnership (MEP) helped hundreds of U.S. aerospace parts and systems manufacturers increase sales and productivity and reduce costs through adoption of lean manufacturing and other competitive processes. As one example, RoBrad Tool & Engineering, Inc., an 80-employee machine shop that supplies precision subassemblies for Boeing and Honeywell, came to the Arizona extension center to reengineer its setup processes. Conversion techniques prescribed by the Arizona center reduced RoBrad's setup times by 42 percent and saved $300,000 a year in setup costs.

To improve the security of communications between space-based and ground-based operations, NIST's Cryptographic Module Validation Program worked with NASA to develop and use new cryptographic modules and cryptographic algorithm implementations. To reduce interference between aircraft navigation systems, external radiation, and onboard laptops and cell phones, the Naval Surface Warfare Center provided funding to NIST to compare alternatives and to deliver efficient techniques and methodologies for measuring aircraft radiation shielding. With funding from FAA, NIST helped set interference measurement policy. To reduce potential interference between ultra-wideband broadcast signals and GPS systems, NIST and the NTIA worked on characterizing ultra-wideband emissions for simulated interference studies.

NIST continued to work with the NASA Jet Propulsion Laboratory on the Condensate Laboratory Aboard the Space Station (CLASS) project, which will develop microgravity measurement instruments for Bose-Einstein condensates, an atomic-level phenomenon for which a NIST scientist received the 2001 Nobel Prize in physics. NIST scientists also prepared a Shuttle experiment involving the rapid stirring of xenon in microgravity, a process that decreases its viscosity, something never seen before in such a simple fluid. Results from this experiment should help predict flows occurring in the manufacture of ordinary plastics.

NIST continued to provide the tools, methodologies, standards, and measurement services needed by aerospace parts manufacturers and assemblers to maintain their accurate and traceable use of the International System of Units (SI) of length, mass, and time, as well as their derived units (force, acceleration, sound pressure, and ultrasonic power). For example, NIST provided calibration services in the areas of electrical measurements and microwave parameters to numerous aerospace corporations such as Boeing, General Dynamics, Lockheed Martin Astronautics, McDonnell Douglas Corporation, Northrop Grumman, and TRW Space and Electronics.

NIST's Advanced Technology Program supported efforts of an industry team at the Ohio Aerospace Institute of Cleveland to develop technologies that make product design concurrent with manufacturing, thereby reducing design time, improving quality, and potentially reducing the cost of creating new products in a range of industries. Demonstration of the technology will focus on a jet engine, nacelle, and fuel nozzle.

NIST continued its NASA-funded research on microgravity-based fires and fire suppression. NIST studied flame extinction in microgravity in order to improve methods for ensuring fire safety during long-duration space missions. To characterize the size distribution of smoke generated in microgravity, NIST and NASA researchers measured and compared the output of approved spacecraft smoke detectors with 1-g results and model predictions. A computer program was developed to simulate the effects of g-jitter on small combustion experiments being conducted in NASA drop towers, the Space Shuttle, and the International Space Station.

NIST worked with aerospace manufacturers to develop “predictive process engineering” models, metrology, and standards, intelligent manufacturing control systems, and product interoperability protocols and knowledge representation schemes for Computer-Aided Design (CAD) systems. NIST developed software for testing the Air Transport Association’s IGExchange, a specification that allows the aerospace industry to develop Extensible Markup Language (XML)-based dynamic graphics. In collaboration with NASA, NIST helped deploy on a telescope in Hawaii a unique infrared-imaging instrument similar to NIST systems aerospace companies have commercialized for space missions.

NIST worked with NASA to develop an optics metrology laboratory and capability for NASA optics. NIST also developed optical disk image and storage standards for NASA, which is interested in using optical tape for storing satellite imagery. With funding from NASA and in collaboration with Stanford University, NIST deployed a new class of optical detectors with sufficient speed and resolution to provide entirely new information from space, such as the detailed characterization of light being emitted from pulsars.

NIST scientists developed tools to accelerate the introduction of new materials and processes in the manufacture of aerospace engine components; these include multi-component alloy thermodynamics, phase diagrams, solidification, and diffusion. Additionally, NIST cooperated with the NASA Glenn Research Center to broaden the use of advanced ceramic materials that, due to their brittleness, currently have limited applications. The two agencies developed standard test methods for quantifying the fracture resistance of brittle, monolithic ceramics in a manner suitable for use by aerospace designers. NIST also developed object-oriented finite element software to enable virtual measurements of the thermal conductivity of ceramic thermal barrier coatings used to extend the operating temperature and life of jet turbine blades.

NIST continued to support the Primary Atomic Reference Clock in Space (PARCS), a laser-cooled cesium clock being developed for deployment on and use with the International Space Station’s onboard scientific and technical applications. The PARCS project has completed its first two NASA reviews and is scheduled to fly in early 2005. NIST also continued to provide synchronization support for NASA’s Deep Space Network, used for space navigation and tracking. NIST provided a number of key NIST facilities to NASA science missions, including NIST’s synchrotron (SURF III), the Solar Radiation and Climate Experiment

(SORCE), and the TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) spacecraft. SURF III was used as a source of soft x rays and vacuum ultraviolet light to calibrate mirrors, detectors, and spectrometers used in spacecraft that study solar flares and astronomical bodies.

NIST completed the radiometric calibration of the NIST Advanced Radiometer (NISTAR) and Earth Polychromatic Imaging Camera (EPIC), both planned for deployment on the NASA Triana satellite. NISTAR will measure the absolute irradiance of the Earth. EPIC will provide hourly, spatially resolved measurements of cloud properties, and ozone and aerosol levels of the Earth's atmosphere.

In FY 2001, ITA's OA played a central role in the organization and coordination of the Commission on the Future of the United States Aerospace Industry, established by Congress to study issues associated with the future of the industry in the global context, particularly in relation to national security. The Commission is required to issue a report for the President and Congress in late 2002 recommending actions by Federal agencies to maintain a robust industry in the future. OA contributed a staff member to colead a team on global issues and assist the Commission in developing recommendations on issues including export control, technology transfers, subsidies/offsets, trade agreements and policies, regulations and standards, and international mergers and teaming.

OA worked closely with other U.S. agencies to renew the Czech government's 1-year tariff waiver on imports of U.S. large civil aircraft, helicopters, and certain spare parts through December 31, 2002. The DoS, the office of the U.S. Trade Representative (USTR), and the U.S. Embassy in Prague joined efforts in convincing Czech officials to eliminate the tariff differential between U.S. and EU aircraft by renewing the tariff waiver. Without the waiver, the Czech Republic levies a 4.8 percent tariff on U.S. aircraft, while no tariff is assessed on EU aircraft. The Czech government confirmed its intention to join the World Trade Organization (WTO) Trade in Civil Aircraft Agreement (which, among other things, binds tariffs on aircraft and parts to zero) as part of any future multilateral trade negotiations. OA encourages as many countries as possible to sign the WTO Agreement on Trade in Civil Aircraft as part of their WTO accession process.

Efforts by OA, USTR, and the DoS to open Russia's highly protectionist aerospace market met with some success during FY 2001. In August 2001, the

Russian government repealed Resolution #716, which had linked obtaining tariff waivers for imported aircraft to purchases of Russian-made aircraft.

OA continued to monitor and address European government loans to Airbus for the development of the A380 super jumbo jet. In January 2001, a U.S. interagency team, led by USTR and DoC, held consultations with the EU in Washington. U.S. officials expressed concern about Government loans and the extent to which they are compatible with the WTO. The EU responded that any Government loans would be compatible with the 1992 U.S.-EU Large Civil Aircraft Agreement, which allows for direct Government loans that match up to 33 percent of total aircraft development costs. In April 2001, the EU provided information about the loans as required in the 1992 agreement. OA personnel continued analyzing this data, and the U.S. Government requested further information from the EU to better understand their compatibility with both the 1992 Agreement and WTO disciplines.

OA organized a number of aerospace-related activities under the U.S.-China Joint Commission on Commerce and Trade (JCCT) aimed at fostering greater bilateral trade in this sector. The Chinese participated in training programs sponsored by the FAA and offered by the American Association of Airport Executives. Delegations of Chinese from various disciplines in the aviation community visited the United States and participated in the annual meetings of the Airports Council International, the National Business Aviation Association, and the General Aviation Manufacturers Association.

OA continued to play a critical role in the U.S. Government team seeking resolution of the dispute over the European Union regulation that restricts the registration and operation in the EU of aircraft modified with noise suppression technology, including aircraft engine "hushkits" and replacement engines. OA and other agency representatives participated in bilateral discussions with EU officials under the mediation of the International Civil Aviation Organization (ICAO) Council President. The U.S. Government team also vigorously supported the recommendation for a new aircraft noise standard and related procedures by an ICAO technical working group and subsequent adoption of the standard by the ICAO Council. Through extensive technical discussions and negotiations with other ICAO members, the U.S. Government successfully achieved the key objective of endorsement by all ICAO members of new aircraft-noise-related policy guidance. ICAO adoption of this policy guidance is anticipated to significantly contribute to resolution of the “hushkit” dispute. The U.S. Government will continue bilateral negotiations with European officials to seek withdrawal of the hushkit regulation prior to April 2002.

During discussions with European officials in FY 2001, OA and other Federal agencies raised concerns over the European Commission’s plans to establish a European Aviation Safety Agency (EASA) to regulate civil aircraft safety in the EU and other European states. OA has concerns with provisions that link aircraft safety to international trade considerations. DoC championed a proposal to amend the EASA regulation in a way that would remove the linkage between trade considerations and the oversight of aircraft safety.

OA and TA’s OSC continued to participate in efforts led by USTR to monitor Chinese compliance with the quantitative restrictions and pricing provisions of the U.S.-China Commercial Space Launch Agreement. Ongoing and new proliferation-related sanctions on China have limited the ability of foreign satellite manufacturers and operators to select a Chinese launch vehicle, thereby reducing China’s participation in the commercial market. China had relatively few new commercial contracts, and the interagency working group discovered no new violations of the agreement.

In FY 2001, OA continued to assist the U.S. aerospace industry through trade promotion events. To promote the export of U.S. aerospace products, ITA sponsored Aerospace Product Literature Centers at five major international exhibitions and air shows in Australia, China, France, Taiwan, and the United Kingdom. More than 4,000 trade leads were generated through this program. Working with the American Association of Airport Executives, OA sponsored the 6th Annual Eastern European Airport and Infrastructure Conference and Trade Show in Budapest, Hungary. The office also cosponsored, with Senator Rockefeller, Congressman Oberstar, and Federal agencies, a China seminar that showcased a variety of U.S. products and services.

With support from OA, Secretary Evans visited the Paris Air Show in June 2001. In meetings with representatives of leading U.S. aerospace exporters and with his counterparts in foreign governments, Secretary Evans called for improvements in the international trade regime to facilitate U.S. export sales. OA arranged visits to the U.S. Pavilion by more than 20 delegations from outside the United States. Those visits helped generate sales leads for U.S. exhibitors.

OA, in coordination with ITA's Advocacy Center and overseas offices, provided advocacy to support U.S. companies in international aerospace competitions. The competitions include commercial aircraft sales for the Boeing Company, helicopters, airport construction, commercial space projects, and air traffic management projects.

Secretary Evans oversaw the official signing ceremony for the sale of 30 Boeing aircraft worth over $1.6 billion to four Chinese airlines. The contract and signing ceremony, coordinated by OA, highlighted the importance of international cooperation in this sector, especially in the wake of the September 11 terrorist attacks and their toll on the U.S. aircraft industry.

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 (INTELSAT) Organization and the International Mobile Satellite (INMARSAT) Organization. The restructuring has been successfully completed. NTIA continued to manage the Federal Government's use of the radio spectrum, including assignments for NASA, DoD, NOAA, and other Government satellite programs. NTIA worked closely with other U.S. regulatory authorities and commercial satellite users to prepare for U.S. participation at the ITU World Radio Conference (2003) to protect spectrum allocations for GPS.

DEPARTMENT OF THE INTERIOR

DoI

The U.S. Geological Survey (USGS) and NASA continued their partnership to manage the Landsat-7 satellite, providing important new data to the global science and operational user communities. USGS assumed complete mission operation responsibility for Landsat-7 from NASA in October 2000, and USGS continued to have responsibility for Landsat-7 data collection, archiving, and distribution. NASA shared its expertise in mission management with USGS staff and conducted research in the technical characteristics and the potential uses of Landsat data. At the end of FY 2001, nearly 200,000 scenes of Landsat-7 Enhanced Thematic Mapper Plus (ETM+) data were collected for the U.S. archive at the USGS Earth Resources Observation Systems (EROS) Data Center. Total Earth coverage, including record amounts of repetitive coverage, exceeds 6.2 billion square kilometers. USGS successfully supported the Landsat-7 International Cooperator Network by downlinking approximately 350 scenes per day to 16 operational Landsat-7 ground receiving stations. Eight ground stations are now submitting metadata on a regular basis.

The commercial operator of the Landsat-5 satellite officially relinquished commercial rights to market Landsat Thematic Mapper (TM) data on July 1, 2001. The operator had informed USGS earlier that it would no longer support the operation of Landsats 4 and 5 at no cost to the Government. Because USGS manages Landsat-7 operations, it assumed responsibility for Landsat-5 operations and continued to operate Landsat-5 through FY 2001. Landsat-4 was decommissioned in June 2001 because it was no longer able to provide useful data.

The Land Remote Sensing Policy Act of 1992 requires U.S. Government Landsat Program Management (NASA and USGS) to “assess options for a successor land remote-sensing system to Landsat 7.” NASA and the USGS proceeded with a two-step procurement strategy for the Landsat Data Continuity Mission (LDCM) under which the private sector would provide multispectral digital image data for global coverage of the Earth's land mass on a seasonal basis and in a manner that ensures continuity with the Landsat-7 mission. In FY 2001, NASA requested industry comment on a draft Request for Proposals (RFP) for a set of Formulation Phase contracts. In response to the final RFP for this phase, NASA may award several contracts in FY 2002 to companies that will develop plans for a mission that is mutually beneficial to the Government and the private sector. The winning contractor for the Implementation Phase will deliver data as specified in the LDCM Data Specification for the 5-year period starting in 2006, with an option to extend the contract for a second 5-year period.

Landsat data were used in many studies of human-induced and natural alterations to the Earth during FY 2001. For example, USGS collected Landsat-7 ETM+ data over Siren, Wisconsin, on June 18, 2001, the day after a tornado destroyed much of the community; the data clearly showed the geographic extent of the affected area. State and Federal emergency response agencies used the data to study the path of the tornado and to assess its effects on the communities involved by comparing that scene with one collected shortly before the storm.

The Land Cover Trends project is a 4-year collaborative research project between USGS, the U.S. Environmental Protection Agency, and NASA to use Landsat and other data to document the rates, driving forces, and consequences of land use and land cover change over the past 30 years for the conterminous United States. The project is based on the hypothesis that land cover changes unevenly over time and space. In order to understand and manage the consequences of the change, it is necessary to have reliable information on the forces that cause change and the actual rates of change from time-to-time and from place-to-place. During FY 2001, project scientists began to determine the rates of change for 84 regions of the conterminous United States, using a probability sample methodology with over 800 20-km by 20-km sites and Landsat data covering five dates from 1972 to 2000. Preliminary results showed that land cover has changed little between 1972 and 1992 in some regions such as North Central Appalachia in Pennsylvania and New York. In other areas, such as the Northern Piedmont stretching from New Jersey through Virginia, there has been significant conversion of agricultural land to urban cover.

With funding support from NASA, primary team members from the USGS Astrogeology Program had outstanding success supporting several missions in the FY 2001 NASA Planetary Science Program, and they hold leadership roles on several future missions. USGS is part of the imaging team on the Galileo spacecraft's continuing survey of Jupiter's largest moons. Galileo returned image and geophysical data as it closed to within 180 km of Jupiter's moon, Io, passing through the sulfurous snowflakes of one of its volcanic plumes. The Mars Global Surveyor collected spectacular images of Mars with the Mars Observer Camera and the Thermal Emission Spectrometer, especially of the largest global dust storm on Mars in over 20 years. As Mars 2001 Odyssey reached orbit, USGS team members collected data to help determine the distribution of minerals on the surface of Mars and how that relates to its geological landforms.

USGS leads the combination camera-and-spectrometer instrument on the Deep Space 1 probe that had a successful encounter with comet Borrelly, returning images of the 10-km-long “bowling-pin-shaped” nucleus of that comet from only 2,200 kilometers away. USGS leads the micro-imager camera team on the Mars Excursion Rover mission that will be launched in 2003. Astrogeology scientists are also part of the primary camera team for the ultra-high spatial resolution (25 cm) camera on the Mars 2005 orbiter.

The Office of Surface Mining Reclamation and Enforcement (OSMRE) used IKONOS 1-meter-resolution pan-sharpened multispectral stereo satellite imagery covering active western and eastern coal mines for regulatory purposes, including review of coal mining permits, making topographic measurements at active coal mines, and ensuring that mine operators comply with regulations. OSMRE successfully orthorectified this imagery by collecting high-accuracy global positioning system (GPS) ground control and generating digital elevation model products from the IKONOS stereo pairs on a photogrammetric workstation.

OSMRE used its Technology Information Processing System to distribute Landsat orthorectified imagery mosaics (imagery from approximately 1990) of the conterminous 48 States to over 70 State agencies, tribes, and OSMRE field offices involved in surface coal mining to promote the use of remote sensing. OSMRE installed a terabyte imagery server in Denver and began testing software to distribute the data to agencies and tribes involved in surface coal mine permitting issues. OSMRE personnel conducted briefings and training sessions during the year to expand the use of remotely sensed data within the agency and to stimulate its full integration with geographic information systems (GIS), GPS, and mobile computing activities.

OSMRE continued to acquire and successfully use Light Detection and Ranging (LIDAR) imagery for detailed topographic mapping at abandoned mine land sites and active coal mines. OSMRE also acquired standard aerial photography products from commercial vendors and used airborne GPS and Inertial Measurement Unit data to lower the overall cost of internal production of orthophotography. OSMRE used GPS technology in FY 2001 in surface mine reclamation verification, technical assistance projects, and training. OSMRE mine inspectors routinely used GPS on large western surface mines for navigation and field verification of mine features such as channels, surface depressions, and reclaimed topography. OSMRE used GPS in Midwestern States to map acid mine drainage discharges and to locate and inventory abandoned mine entries. In the Eastern States, OSMRE technical staff mapped domestic wells and home sites to aid in resolving complaints of water loss due to the impact of mining activities on ground water flow.

Bureau of Land Management (BLM) resource specialists used a wide variety of remote-sensing technologies in FY 2001 to inventory and monitor public lands that were under increased pressure for energy and mineral resource extraction, as well as urban growth. Data from traditional and digital aerial cameras, and multispectral and hyperspectral sensors were supplemented by GPS and GIS to support management activities associated with wildlife habitat, wilderness, recreation, rangeland, timber, fire, minerals, and hazardous materials.

In FY 2001, BLM specialists used Landsat TM data to map a variety of landscape components, including: vegetation and invasive species for five Southwestern States—Arizona, Colorado, Nevada, New Mexico, and Utah (in partnership with USGS); leafy spurge, an invasive plant species in Wyoming; increased soil detail throughout the Western U.S.; sage grouse habitat as an input to conservation planning for the 11 BLM-managed Western States; and riparian wetland areas in South Park, Colorado. Landsat TM data were also used to map hazardous fuels in the 11 Western States that BLM manages, and to develop hydrologic and terrain landscape models to support identification of rangeland health indicators in western Colorado. BLM personnel analyzed NOAA

Advanced Very-High-Resolution Radiometer (AVHRR) satellite data for detection of cheatgrass, an invasive species, in the Great Basin region to support vegetation restoration efforts following wildland fire.

BLM used digital orthophoto quadrangles to identify off-highway vehicle routes for land use assessments on BLM-managed lands. Color-infrared and black-and-white aerial photographs were used to assess riparian conditions in numerous Western States. BLM personnel mapped historical changes in pinyon-juniper communities in western Utah to support site-specific fuels management. Airborne Data Acquisition and Registration (ADAR) multispectral camera data were used to monitor vegetation succession following wildland fire in northern Wyoming. AURORA hyperspectral data were collected to develop a hazardous waste materials inventory for remediation efforts on BLM-managed lands; for coal bed methane inventory in Colorado, Montana, and Wyoming; and to inventory an invasive plant species in Wyoming.

The National Park Service (NPS) used Landsat, SPOT, and IKONOS satellite data, along with conventional aerial photography, LIDAR data, and digital orthophotography to map and monitor land cover, vegetation, cultural features, and other specific features in many national parks. Approximately 400 GPS receivers were used for mapping and navigation to support a variety of NPS resource management and park maintenance applications.

NPS continued to work with USGS to map vegetation and obtain uniform baseline data on the composition and distribution of vegetation types for 270 U.S. national park units. Vegetation mapping was completed in FY 2001 for Badlands (South Dakota), Theodore Roosevelt (North Dakota), Voyageurs (Minnesota), Isle Royale (Michigan), and Rock Creek (District of Colombia) National Parks. The pace of mapping increased substantially in FY 2001, with work beginning in 29 new park units. For comparison, mapping was performed in a total of only 30 parks since the program began in 1994.

Bureau of Reclamation (BOR) and USGS personnel used NASA Advanced Visible and Infrared Imaging Spectrometer (AVIRIS) hyperspectral data of a portion of the Owyhee Basin in eastern Oregon to map surface minerals and identify source areas of mercury within the basin that are contributing to the high levels of mercury found in Reclamation's Owyhee Reservoir. These high mercury levels exceed standards set for fish and wildlife populations, and have resulted in advisories being placed on the consumption of fish taken from the reservoir. Preliminary maps of mercury source areas have been produced; when these maps are finalized, they could be used to institute land-management practices to retard the influx of mercury into the reservoir.

The California Central Valley Project Improvement Act Biological Opinion requires that data on wildlife habitat change be used in water-related negotiations with irrigation districts and with the U.S. Fish and Wildlife Service (FWS). BOR image analysts used multitemporal Landsat TM data of the Central Valley to identify such areas of change between 1993 and 2000. Areas that changed between 1993 and 2000 will be mapped again using 1:120,000-scale aerial photography acquired in 2001. This two-tiered approach reduced overall costs by focusing more expensive high-resolution image acquisitions on specific areas identified using the Landsat data. These data will also be incorporated into the Statewide change detection project being coordinated by the U.S. Forest Service and the California Department of Forestry.

BOR continued to use Landsat TM, Indian Remote-Sensing Satellite multispectral and panchromatic data, and USGS digital orthophoto quarterquads to map agricultural crops in the Colorado River basin, the Lahontan Basin in Nevada, and the Central Valley of California. Water managers used irrigation status and crop-type data with crop water use coefficients and locally varying climate data to calculate agricultural consumptive water use.

BOR continued mapping flood inundation perimeters and depths below reclamation dams. Image analysts developed high-accuracy digital elevation models (DEMs) from multireturn airborne LIDAR data. Hydraulic engineers used these DEMs in conjunction with one- or two-dimensional hydraulic models to predict flood water perimeters and depths for specific time intervals that would result from a theoretical dam breach or spill event. GIS analysts overlaid maps of maximum wetted area and maximum depth onto geographically referenced population and infrastructure data derived from USGS, the Census Bureau, Department of Transportation, Federal Emergency Management Agency, and other Federal agencies to determine the human and economic impacts of the modeled flood events.

During FY 2001, the Bureau of Indian Affairs (BIA) used remote sensing and GPS to support BIA and tribal initiatives to map land use, inventory natural resources, conduct environmental assessments, support Safety of Dams program initiatives, and map and inventory irrigation systems. Application specialists used digital orthophotography, National Aerial Photography Program (NAPP) aerial photography, National Elevation Dataset (NED) data, Digital Raster Graphics (DRG), and IKONOS satellite imagery as backdrops for modeling inundation zones associated with the potential catastrophic failure of earthen dams. BIA personnel also collected GPS data on high-priority dams under BIA jurisdiction. BIA personnel developed inundation maps for input to Emergency Action Plans for five dams during the reporting period.

Commercial GPS receivers were used to collect data for 1,539 ditch miles and 19,518 associated structures in BIA-managed irrigation systems. In addition, digital aerial photographs with GPS coordinates were collected for all structures. These data sets were combined to map irrigation system and structure condition on seven major BIA Irrigation Projects on Indian Reservations in the Western United States. Aerial photos and satellite data were also key components in the mapping process in both the Irrigation and Safety of Dams Projects. The BIA also continued its use of the Precision Lightweight GPS Receivers (PLGRs) to access the DoD Navstar GPS Precise Positioning Service (PPS), primarily at the field office level. The PLGRs are being phased out, where appropriate, in favor of commercial systems as the life span of PLGRs is being reached.

The Minerals Management Service (MMS) supported University of Colorado scientists in research on satellite altimetry using the TOPEX/Poseidon and European Remote Sensing-2 (ERS-2) satellites. This work has improved estimates of sea surface height and ocean currents, particularly for the large Loop Current eddies in the Gulf of Mexico. Accurate ocean currents are important for estimating oil spill trajectories and can affect offshore oil and gas operations.

MMS continued to use GPS data to assist in determining baseline points that are used to delineate offshore boundaries in the U.S. Virgin Islands. Accurate boundaries were needed to support Territorial Submerged Lands jurisdictions, as well as a proposed national monument for protection of coral reefs around the islands of St. Thomas and St. Croix.

The USGS and BLM used Landsat-7, RADARSAT-2 synthetic aperture radar (SAR) images to investigate glacier dynamics and change at Bering Glacier, Alaska. The observations are used to map the retreat of the glacier terminus as it undergoes large-scale calving in Vitus Lake. Vitus Lake is now expanding, and a marine ecosystem is rapidly evolving. The stability of the ice dam that impounds water in Berg Lake remained under study to assess potential hazards should the dam fail.

The USGS and the French Space Agency (CNES) have developed multi-sensor techniques to estimate snow pack thickness and water equivalent from microwave instruments. The combination of passive microwave observations obtained by the Special Sensor Microwave Imager (SSM/I) on the Defense Meteorological Satellite and the dual frequency TOPEX/Poseidon radar altimetry measurements have yielded more accurate snow depths than previously attained by SSM/I observations when the technique was applied to the U.S. Northern Great Plains, with the heavy snow year of 1997 used as a test case.

Cleveland Volcano in the Aleutian Islands, Alaska, sent ash plumes across the air lanes of the North Pacific three times in February and March 2001. Scientists at the USGS Alaska Volcano Observatory detected the ash clouds by using data from meteorological satellites, Landsat 7, and other sources, and quickly informed Federal and State agencies, including the Federal Aviation Administration, the National Weather Service, and local Air Force installations, of the hazard. These ash clouds disrupted international air traffic in the busy North Pacific corridor during the first 48 hours after each of the explosions. Timely information on the position of ash clouds helps minimize both the cost of such eruptions to the airlines and the danger and inconvenience they pose to the public. Satellite data was the main monitoring tool for this eruption because Cleveland Volcano (which has erupted at least 11 times since 1893) was not yet monitored seismically at the end of the fiscal year.

In FY 2001, USGS scientists used SAR data from the ERS satellites and the interferometric SAR (InSAR) technique to detect uplift of the ground surface over a broad area centered 5 kilometers west of South Sister Volcano in the Three Sisters region of the central Oregon Cascade Range. The initial uplift, which occurred between 1996 and 2000, covers an area about 15 to 20 km in diameter, with the maximum amount of uplift being about 10 centimeters. Close aerial inspections of the area revealed no unusual surface features. Scientists from the Cascades Volcano Observatory installed a seismometer near the center of the area to see if there are any earthquakes associated with the deformation. The uplift, which is most likely caused by intrusion of magma, appeared from InSAR analysis results to be continuing. The USGS continued to monitor the area to assess the probability of an eruption. This was the first successful use of the InSAR technique in the Cascades region.

USGS also used the InSAR technique to study land surface deformation associated with natural recharge in the San Bernardino ground water basin of Southern California. Several centimeters of uplift were detected during the first half of 1993 in two areas of the basin based on InSAR analysis of ERS-1 and ERS-2 images. This uplift correlates with unusually high runoff from the surrounding mountains and increased ground water levels in nearby wells. The deformation of the land surface identifies the location of faults that restrict ground water flow, maps the location of recharge, and suggests the areal distribution of fine-grained aquifer materials. Preliminary results demonstrate that naturally occurring runoff and the resultant recharge can be used with interferometric deformation mapping to help define the structure and important hydrogeologic features of a ground water basin. This approach may be particularly useful in investigations of remote areas with limited ground-based hydrogeologic data.

USGS, in collaboration with the University of Washington, tested the feasibility of using helicopter-mounted radar equipment that is to measure river discharge. River discharge traditionally has been measured by using sounding weights to determine average river depth and rotating cups to determine river velocity. For these experiments, standard ground-penetrating radar measured river cross-sectional areas, and microwave radar developed by the Applied Physics Laboratory, University of Washington, measured river velocity. Preliminary analysis indicates that discharge can be measured within +/-10 percent of the discharge value computed from stage readings at streamflow-gaging stations. Discharge measurements using the radar method were made in an average of about 45 seconds each, compared with several hours using the traditional method. The radar method may have an important application during large regional floods when discharge measurements are needed at many streamflow-gaging stations in a short period of time, or for other applications in which the physical properties of a river need to be defined.

USGS scientists used key predator bird species as part of long-term contaminant monitoring systems to assess the health of large river systems, bays, and estuaries in the United States. In the past, scientists have used bird banding to track where one such species, the American osprey, spent the winter and the routes used to reach wintering sites. Scientists from USGS and the University of Minnesota used NOAA satellites to track osprey migration routes by using small radios. Knowledge about the speed of migration and the location of wintering grounds gained in this way provides a better understanding of contaminant exposure away from the nesting grounds in the United States.

Sandhill cranes migrate through the Platte River valleys of Nebraska, but much is not known about their habitat use and ultimate destinations. During FY 2001, researchers marked 51 cranes with satellite-monitored transmitters attached to plastic leg bands and tracked them continuously from their staging area along the Platte and North Platte Rivers in Nebraska, to their breeding grounds. At the end of the fiscal year, results showed that lesser sandhill cranes staging along the North Platte River breed mostly in Siberia and western Alaska. Data show that most of the midcontinent population was present in late March when the FWS conducted their annual population survey, providing managers with key information on reliability of population size estimates derived from the survey.

USGS biologists completed a pilot study of the year-to-year movements of snowy owls in the Arctic. They used satellite telemetry to map the annual flight paths of adult female snowy owls from Barrow, Alaska, through remote areas and during periods of Arctic darkness. These data would have been impractical or impossible to obtain with traditional tracking methods.

USGS biologists developed methods to predict brood and duckling survival across the extensive Prairie Pothole region of the upper Great Plains by analyzing habitat information in a GIS. They also used satellite radiotelemetry to monitor mallard and gadwall duckling survival rates in relation to wetland and upland habitat conditions. They collected imagery from a digital color-infrared camera to monitor the availability of seasonal wetland habitat and to estimate the percentage of the landscape in perennial vegetation cover. USGS biologists used similar satellite telemetry techniques to determine the survival, dispersal, and long-range movements of prairie falcons from the Snake River Birds of Prey National Conservation Area, Idaho.

In FY 2001, the USGS Grand Canyon Monitoring and Research Center collected digital, high-resolution black-and-white and color-infrared aerial imagery over approximately two thirds of the Colorado River Ecosystem between Lake Powell and Lake Mead. The USGS has collected aerial imagery annually since 1990 to monitor change in the natural and cultural resources within the ecosystem resulting from the operation of the Glen Canyon Dam. This information is used by the Glen Canyon Adaptive Management Program to make informed decisions on the operation of the dam that improve the values for which the Grand Canyon National Park and the Glen Canyon National Recreation Area were created.

USGS scientists cooperated with the U.S. Army Corps of Engineers (USACE) and a private firm to complete initial high-definition airborne mapping of glacial and bedrock outcrop sites in northern Lake Michigan that are used by lake trout as spawning habitat. Mapping was done with the USACE/Navy Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS) system that uses a LIDAR sensor to make lake-floor maps in areas too shallow for practical use of conventional sonar systems, such as reefs and near-shore areas. Fishery resource management agencies used this information to determine whether degraded spawning habitat is one of the factors adversely affecting the rehabilitation of trout populations in Lake Michigan.

USGS scientists regularly used GPS in FY 2001 to support scientific research conducted in the Great Lakes basin. Side-scan sonar surveys conducted throughout the Great Lakes basin and habitat-mapping projects in the St. Claire-Detroit River System required GPS technology to locate sample sites and provide geographic reference for biological data. Larval fish habitat preference studies in Lake Erie used GPS to guide repetitive sampling procedures and simplify navigation in open water. GPS was also used for locating field sites while conducting native clam research in several NPS national parks and lakeshores in Michigan and wetland restoration projects in cooperation with FWS on national wildlife refuges in Michigan and Ohio.

USGS scientists used GPS to conduct annual fish stock assessments in all five Great Lakes in cooperation with the international Great Lakes Fishery Commission and State, tribal, and Canadian fishery management agencies. These data are used to make management decisions on fish stocking and harvest quotas to promote the ecological and economic sustainability of Great Lakes commercial, sport, and tribal fisheries. USGS scientists also used GPS to guide studies on the recovery of the burrowing mayfly (Hexagenia) populations in western Lake Erie, Saginaw Bay (Lake Huron), and Green Bay (Lake Michigan). Hexagenia is an important food source for many kinds of Great Lakes fishes, and its increasing numbers in recent years is an indicator of improving Great Lakes water and bottom sediment quality. In contrast, another important fish food organism is the deep-water amphipod, Diporeia, and its declining numbers were investigated at sites located by GPS in Lakes Ontario and Huron.

USGS scientists on the NASA Earth Observing-1 (EO-1) satellite Science Validation Team worked to determine whether data from the EO-1 satellite could be used to detect and map leafy spurge, an invasive plant species in Theodore Roosevelt National Park, North Dakota. Preliminary analysis of multiple data sets collected during the 2001 growing season with the EO-1 Hyperion hyperspectral sensor indicated the feasibility of delineating stands of leafy spurge larger than 30 m in diameter in grassland and badland environments of the park.

USGS scientists used high-spatial-resolution IKONOS satellite data and NASA's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) multispectral satellite data to map small but important and sensitive bird habitat types such as pockets of forested wetlands on islands in the Great Lakes. These features were essentially unidentifiable with other commercially available spaceborne sensors. Protection of Great Lakes island habitats is one of the highest management priorities of the FWS in the Great Lakes region. Landsat ETM+ images were used for project planning and wetland research at Seney National Wildlife Refuge, a very large refuge on the Upper Peninsula of Michigan where a USGS/FWS wetland restoration project is ongoing.

USGS and a private company began developing new techniques to monitor infestations of water hyacinth, an exotic aquatic weed infestation that is causing major damage to the ecosystem and economy of the Lake Victoria basin of East Africa. They used RADARSAT, Landsat, and IKONOS satellite data to provide timely information to aquatic plant managers in East Africa. USGS scientists documented a major infestation in Winam Gulf, Kenya, which peaked at 180 km2 of areal extent in November 1998, and subsequently declined to under 1 km2 by February 2000. USGS and the company are helping East African governments to implement an operational monitoring system.

Since 1975, the USGS has chaired the Civil Applications Committee, chartered by the Office of the President, to facilitate the use of classified imagery for applications that are central to many agency missions, such as environmental monitoring, resource management, homeland security, natural hazards, and emergency response applications. USGS continued to support this growing demand through the National Civil Applications Project (NCAP). NCAP staff employed a network of secure national and regional facilities to help users acquire these data for science investigations, and to generate custom and derived products. FY 2001 applications of classified data included glacier monitoring and delineation of glacial karst features; tracking of migration and breeding patterns of animals in remote locations; determining the surface characteristics of sea ice melt ponds; gathering river stage information for flood forecasting; and water quality monitoring.

Federal Communications Commission

FCC

All FCC accomplishments in space during FY 2001 were related to communications and Earth observation satellites. The FCC formulates rules to facilitate and regulate the U.S. domestic satellite industry and the licensing of all stations and satellite launches. Internationally, the FCC continued to coordinate satellite placement with other countries. FCC specific accomplishments are outlined for FY 2001.

The FCC issued construction authorizations and authorized a number of launches of communications satellites. There were 34 Ka-band Geostationary Orbit/Fixed Satellite Service (GSO/FSS) satellites authorized for construction. In the C/Ku bands, the FCC authorized SES Americom for two satellites which were launched in October and December 2000.

The FCC granted operational licenses to The Boeing Company, Celsat America, Inc., Constellation Communications Holdings, Inc., Globalstar, L.P., Iridium LLC, Mobile Communications Holdings, Inc., ICO Services Ltd., and TMI Communications and Company, L.P., in the 2 GHz band. An Earth Exploration Satellite Service (EESS) license was granted to AstroVision, and the DirecTV 5 space station license was granted in November 2000. In addition, 34 Ka-band GSO/FSS satellites were licensed to 11 companies.

Several satellites authorized by the FCC became operational during FY 2001. These were VITA, a little LEO licensee; and EarthWatch, an EESS licensee. Also, XM Radio began providing Satellite Digital Audio Radio Service broadcast in September 2001.

During FY 2001, the FCC was also active in international satellite coordination with Argentina, Brazil, Canada, ESA, INTERSPUTNIK, Mexico, Netherlands, Papua New Guinea, United Arab Emirates, United Kingdom, Uruguay, and Venezuela in the C/Ku-band. Other coordination meetings were also concluded with Japan, Norway, and the Russian Federation.

Department of Agriculture

USDA

During FY 2001, several USDA agencies regularly used remotely sensed data to support operational and research activities. These agencies include, but are not limited to, the Agricultural Research Service (ARS), Foreign Agricultural Service (FAS), Farm Service Agency (FSA), Forest Service (FS), National Agricultural Statistics Service (NASS), and Natural Resources Conservation Service (NRCS). Following are brief summaries from these six agencies describing how remotely sensed data were used to accomplish departmental goals and objectives during FY 2001.

The ARS research program used remotely sensed data and related technologies to develop techniques and methodologies to monitor, assess, and administer agricultural, rangeland, and natural resources. ARS identified eight areas for research of the application of remotely sensed information to agricultural and natural resource problems. These areas encompassed 1) soil properties and assessment, 2) hydrometeorology, 3) crop management, 4) range management, 5) land use evaluation, 6) water quality and aquatic ecosystems, 7) sensor development and calibration, and 8) development of analytical tools for remotely sensed data. ARS scientists were involved in a broad remote-sensing research program that involved more than 30 laboratories. These laboratories cooperated extensively with other Federal and State agencies, in this country and abroad, to extend the applications of remotely sensed data for agricultural and natural resources management. This research resulted in the development of new and cost-effective methods to assess agricultural and natural resources at local, regional, and global scales. The following examples epitomize the breadth and depth of remote-sensing research in ARS.

ARS scientists used remote-sensing data from ground, aircraft, and satellite platforms to develop methods to monitor, assess, and manage the Nation's waters on small and large scales. For example, at the Kika de la Garza Subtropical Agricultural Research Center in Weslaco, Texas, scientists used aerial photography and videography to detect water-lettuce infestations in Texas waterways. Similarly, scientists at the Northwest Watershed Research Center in Boise, Idaho, used very-large-scale, color-infrared aerial photography of stream segments to quantify stream shading by riparian vegetation. Stream shading was under consideration by the Environmental Protection Agency as a possible remotely sensed surrogate for direct stream temperature measurements because it is logistically impossible to use ground-based techniques to characterize the spatial dynamics of stream temperature within extensive and remote rangeland stream systems. Researchers in Louisiana, Maryland, Mississippi, and Texas used remote sensing to develop methods to monitor water quality. A prototype submersible sensor to monitor harmful algal species, such as those responsible for red tide and dead zones, was being tested in the St. John's River in collaboration with other regional, State, and Federal agencies.

ARS scientists in Arizona, Georgia, Idaho, Iowa, Maryland, New Mexico, Mississippi, Oklahoma, and Texas collaborated with personnel from NASA and other Federal and international agencies to study interactions between the Earth's surface and atmosphere, and how these interactions influence climate change and the management of agricultural and natural resources. For example, researchers from the ARS Hydrology and Remote Sensing Laboratory and the University of Virginia, Department of Environmental Sciences, explored the coupling between the land and the atmospheric boundary layer using a three-dimensional turbulence large eddy simulation model and remotely sensed land surface images. An analysis of the results revealed the existence of scale-dependent earth/atmosphere interactions, suggesting that significant changes in regional land use or agricultural practices could affect local and regional climate. This research was a fundamental step in addressing the effects of climate change on agricultural resources and will help in the development of mitigation strategies.

In Arizona, California, Colorado, Iowa, Maryland, Missouri, Nebraska, and Texas, ARS scientists worked on developing remote sensors and techniques to monitor crop growth, soil conditions, and plant water and fertilizer requirements.

These sensors and techniques have helped in the development of precision farming techniques that enable farmers to maximize crop production while minimizing agricultural effects on the environment. Work also focused on sensor calibration. ARS scientists from the U.S. Water Conservation Laboratory in Phoenix, Arizona, and from the Southwest Watershed Research Center in Tucson, Arizona, teamed with personnel from NASA Stennis Space Center and the National Imaging and Mapping Agency to perform a multiple-platform calibration in July 2001. Images of the University of Arizona's Maricopa Agricultural Center were acquired via sensors aboard IKONOS, Landsat 7, and NASA Earth Observing System (EOS) satellites, as well as aircraft ranging from a Learjet to a powered parachute. Ground crews measured plant and soil parameters, surface properties, and atmospheric conditions in support of this project. ARS scientists used these data to evaluate each sensor's suitability for helping growers make better informed management decisions related to the water and nutrient needs of their crops.

ARS personnel applied remote sensing in recent studies of insect, weed, and disease infestations and rangeland conditions. One goal of this research was to develop new remote-sensing tools and techniques to help decisionmakers better manage pests and weeds affecting agriculture and natural resources. For example, the ARS Screwworm Research Program found that screwworm population densities were highest in edges between mature forests and open fields in the tropics. Researchers developed methods to identify these habitats using Landsat Thematic Mapper (TM), SPOT, and RADARSAT satellite data. The ability to locate probable screwworm populations using remotely sensed data would increase the efficiency and effectiveness of USDA's biological control of screwworm.

The FAS remote-sensing program is administered by the Production Estimates and Crop Assessment Division (PECAD). PECAD is the focal point within FAS and USDA for assessing global agricultural production and conditions that affect world food security. PECAD is the world's most extensive and longest running (20 years) operational user of commercial satellite data, using numerous satellite platforms to evaluate agronomic situations worldwide. This basic market intelligence effort was mandated in the legislation, establishing the agency in 1954 (Title VI of the Agricultural Act of 1954). PECAD is the only operational unit of its type in the world.

PECAD was responsible for global crop condition analysis and estimates of world grain, oilseed, and cotton production. Satellite remote-sensing data are a critical components used in making crop production and condition estimates for key markets and competitors, providing reliable, repeatable, and comparable observations. In 2001, the division confirmed and enhanced remote-sensing data by incorporating economic, weather, crop model, and field observation data in a "convergence of evidence" methodology. These data came from public and private sources. Remote sensing enabled PECAD to obtain information in regions where such information is often difficult to obtain. Satellite data were frequently more timely and reliable, and often more complete, than conventional sources. Furthermore, satellite data were quite inexpensive compared to the cost of maintaining staff in overseas offices or continually funding travel for U.S.-based analysts.

PECAD helped USDA and other agencies "right size" food aid and other emergency response efforts by providing unbiased assessments of the influence of weather and other events on food supplies. Two division analysts provided full-time support to the USDA Farm Service Agency (FSA) by providing crop condition assessments and early warnings of crop disasters through the FSA/FAS Center for Remote-Sensing Analysis. FAS also shared data and analyses with other USDA and U.S. Government agencies to meet national security requirements and assess global food security needs. In 2000, USDA designated FAS as the repository and manager of the USDA Satellite Imagery Archive. FAS purchased, archived, and shared satellite data with six other USDA agencies, substantially reducing individual agency costs. All high- and medium-resolution and some low-resolution satellite data were purchased commercially. Some low-resolution data was acquired from NASA and NOAA. NOAA and the U.S. Air Force Weather Agency (AFWA) provided the satellite weather data.

FSA completed a three-state pilot that compared alternative methods for collecting aerial photography for farm program compliance. During FY 2001, FSA acquired most of the U.S. agricultural area data using light aircraft equipped with 35-millimeter cameras and color slide film. FSA tested approaches to replace this methodology with a program that delivered 1 to 2 m geo-referenced digital imagery. FSA challenged the private sector to collect, rectify, package by county, and deliver, within 60 days of the flying window, usable products. Data for 51 counties in Kansas and Nebraska were collected through this project, and the result was an amazing achievement for inexpensive, high-quality digital images. As an added benefit, FSA had the color film, similar to that available through the National Aerial Photography Program (NAPP), stored at the Aerial Photography Field Office in Salt Lake City, Utah. The film was capable of being scanned to create 1-meter Digital Orthophoto Quadrangles.

As a result of the Kansas and Nebraska pilots, FSA began a major paradigm shift. FSA began redirecting its $500,000 NAPP cost-share money to contract internally to create digital products that can serve FSA compliance requirements. These products were anticipated to be a great national asset, used by Federal, State and local Governments, as well as the public, to obtain low-cost, high-resolution digital images of domestic agricultural areas. FSA spent about $2 per square mile to acquire film for the 35- millimeter compliance program. In contrast, this new digital acquisition method required $12 to $14 per square mile. The FSA FY 2002 and 2003 budgets would not allow this innovation to be fielded.

The FSA also tested a lower cost alternative in Minnesota. Here, companies flew small aircraft with digital sensors and 35-millimeter film-based cameras. These products were not geo-referenced as well and, combined with a small footprint, were more difficult to use. This new digital acquisition method required $4 to $8 per square mile.

FS continued to manage 191 million acres of public lands in national forests and grasslands, and provided technical and financial assistance to State and private forestry agencies. FS also continued its role as the largest forestry research organization in the world. Wildfires in 2000 and 2001 were larger, more frequent, and more numerous than those seen in recent years. The number and severity of these fires severely taxed Federal and State wildfire management resources. The FS Remote Sensing Applications Center (RSAC) collaborated with staff at NASA Goddard Space Flight Center and the University of Maryland to develop the Moderate-Resolution Imaging Spectroradiometer (MODIS) Land Rapid Response System, providing a range of time-critical data to the National Interagency Fire Center (NIFC) and other Federal and State users. Staff at the RSAC used MODIS data to generate cumulative and daily active fire maps, and disseminated the maps to users via an Internet Web-based system. The Federal wildfire community used this near-real-time data to assist in the strategic allocation of assets and in post-fire rehabilitation efforts. Before the end of the fiscal year, technicians installed an antenna at the RSAC facility in Salt Lake City, Utah, to receive Direct Broadcast MODIS data that was expected to become operational in FY 2002.

NASA also supported FS by acquiring high-altitude color photography over the nearly 1,600,000 acres of the Deschutes National Forest. The imagery included large format camera 9 x 18-inch color-infrared photography at 1:30,000 scale and 9 x 9-inch color-infrared photography at 1:60,000 scale. FS staff used this photography for a wide range of resource management applications, including recreational planning and forest health management.

The mission of NASS continued to be the provision of timely, accurate, and useful statistics describing U.S. agriculture. These statistics cover virtually every facet of domestic agriculture, from the production and supply of food and fiber to the prices paid and received by farmers and ranchers.

During FY 2001, NASS personnel used remote-sensing data to construct area frames for statistical sampling, estimate crop area, and create crop-specific land-cover data layers for geographic information systems (GIS). For area frame construction, NASS staff combined digital Landsat and SPOT data with U.S. Geological Survey (USGS) digital line-graph data, enabling users to assign a category to each piece of land in a State based on the percentage of cultivated land and other variables. NASS implemented a new remote-sensing-based area frame and sample for Tennessee and Wisconsin. The remote-sensing acreage estimation project analyzed Landsat data from the 2000 crop season in Arkansas, Illinois, Indiana, Iowa, Mississippi, New Mexico, and North Dakota. These data were used to produce crop acreage estimates for major crops at State and county levels, and to develop a crop-specific categorization of a digital mosaic of TM scenes, which was distributed to users on a CD-ROM. For the 2001 crop season, NASS headquarters and several NASS field offices continued partnership agreements with State organizations, working to decentralize Landsat processing and analysis tasks, and expanding into the boot heel of Missouri and a pilot area in southeastern Nebraska. The pilot area in southeastern Nebraska was a joint project with FSA to examine the accuracy of NASS crop-specific categorizations. Data for 2001 acreage estimation analyses were collected in Arkansas, Illinois, Indiana, Iowa, Mississippi, Missouri, New Mexico, and North Dakota. NASS, in conjunction with ARS, began studying data obtained from the MODIS sensor on the NASA

Terra satellite for use as an additional input for setting yield estimates and as a possible replacement for Advanced Very-High-Resolution Radiometer (AVHRR) data in generating vegetation condition images.

NRCS is the primary Federal agency working with private landowners to help them protect their natural resources. Much of the land management business conducted by NRCS requires the use of good science and practical technology, such as remote sensing. NRCS has used aerial photography and related remote-sensing products for over 50 years to conduct agency programs and business.

In FY 2001, aerial photography and orthoimagery (1-meter resolution) were used extensively nationwide for conducting soil surveys as part of the National Cooperative Soil Survey program. Soil scientists used digital orthoimagery to map and digitize soils at their true map positions on the ground. NRCS personnel also used digital orthoimagery for conservation planning, wetland delineations, watershed planning, and to provide technical assistance to landowners and communities. NRCS acquired and used high-quality (1-foot resolution) aerial photography to conduct the annual continuous National Resources Inventory (NRI). In FY 2001, the agency expanded use of GIS to most county field offices. As a result, the need for digital orthoimagery for use as a mapping and planning base map also increased.

NRCS obtained all of its aerial photography and digital orthoimagery from commercial sources. NRCS coordinated with USDA and other Federal agencies in the purchase of aerial photography and digital orthoimagery. Much of the aerial photography was obtained through NAPP, a partnership of Federal and State agencies. Digital orthoimagery was coordinated and obtained through the National Digital Orthophoto Program (NDOP), a partnership of Federal and State agencies having common imagery requirements. All of the data developed through these national imagery programs became part of the public domain, permitting agencies to share these data and imagery internally and externally without licensing or use restrictions.

The NRI program required high-resolution imagery over confidential statistical sampling sites. In FY 2001, NRCS purchased high-quality imagery for approximately 72,500 sites nationwide. The USDA Aerial Photography Field Office of FSA contracted for the imagery. The FSA office had responsibility for contracting aerial photography in the USDA.

Compared to the purchase and use of aerial photography and digital imagery derived from airborne systems, NRCS purchased and used only a modest amount of satellite imagery. Most NRCS programs and activities required high-resolution imagery from airborne systems. Satellite systems were not able to provide high-resolution imagery to NRCS at a cost comparable to airborne systems.

NRCS was well represented on Federal mapping, remote sensing, GPS, and geodata committees. Significant time and resources were devoted to supporting the work of the Federal Geographic Data Committee, NAPP, NDOP, Interagency GPS Executive Board, and other groups. Coordination efforts within these committees resulted in partnerships to cost share in the development, acquisition, and sharing of imagery and geodata.

NRCS has actively used GPS for more than six years as a tool in support of carrying out conservation programs and technical assistance. Over 1,000 GPS receivers were in use at county field offices. In FY 2001, NRCS led a GPS modernization team of USDA county service center agencies to develop business application requirements, equipment configuration specifications, and to provide contact support to the department for the awarding of an USDA-wide GPS contract for commercial off-the-shelf GPS receivers.

National Science Foundation

NSF

NSF continued to serve as the lead Federal agency for the support of ground-based astronomy and space science, and sponsored a broad base of observational, theoretical, and laboratory research aimed at understanding the states of matter and physical processes in the solar system, our Milky Way galaxy, and the universe. NSF also supported advanced technologies and instrumentation, and optical and radio observatories that maintain state-of-the-art instrumentation and observing capabilities accessible to the community on the basis of scientific merit.

NSF-supported researchers extended their work to measure the very faint fluctuations in the microwave light emitted by the hot gas in the early universe, from a time before stars and galaxies formed. These additional data have strengthened the conclusion that the universe is nearly spatially flat and added information about the higher order peaks in the power spectrum of primordial sound waves, which have been used to estimate cosmological parameters, such as the expansion rate, the age, and the total mass of the universe, and how much of that mass is comprised of normal (baryonic) matter. Models of the universe which have a "flat" geometry are dominated by (up to 90 percent) "dark" matter and fit the standard nuclear physics models for the generation of the elements hydrogen and helium during the big bang, and have been shown to be consistent with the observations.

Researchers involved in the Sloan Digital Sky Survey discovered, in the spectrum of the most distant quasar known, the signature of neutral hydrogen in the intergalactic medium, indicating that their observations are probing redshifts before large numbers of quasars and galaxies formed. Recent observations of the highest redshift quasar yet discovered showed the signature of a high optical depth of neutral hydrogen. The existence of this neutral hydrogen indicates that in this distant epoch, the universe had not yet been flooded with a substantial density of ionizing photons from stars and quasars.

Recent radio observations of the prototypical starburst galaxy M82 revealed a complex and dynamic system. NSF-funded researchers used the Owens Valley Radio Observatory array to map the large-scale structure of molecular gas in M82. The sensitivity and area coverage of the resulting high-angular-resolution data was an order of magnitude better than previous interferometric observations. Their images showed tidal stripping of the molecular gas along the plane of the galaxy and coincident with streams of neutral hydrogen. The distribution of molecular gas also coincides with the dramatic dust features seen in optical absorption. As much as 25 percent of the total molecular mass of M82 is situated at large galactocentric radii. Researchers with the Five College Radio Astronomy Observatory used the 14-meter telescope and the focal plane array system to identify molecular gas located as high as 3 kiloparsecs above the plane of the disk of M82. Some of the carbon monoxide (CO) emission is clearly associated with neutral hydrogen tidal features that arise from the interaction of M82 with the large, neighboring spiral galaxy M81. The molecular gas in these tidal features may have been directly extracted from the molecular gas rich reservoir of M82 or formed in situ within the tidal streams.

The large, spherical halo component of our own galaxy is believed to harbor a substantial amount of unseen dark matter. NSF researchers recently observed microlensing events toward the nearby Magellanic Clouds, indicating that 10 to 50 percent of this dark matter may be in the form of very old white dwarfs, the remnants of a population of stars as old as the galaxy itself. A team of astronomers used the Cerro Tololo InterAmerican Observatory 4-meter telescope to carry out a survey to find faint, cool white dwarfs in the solar neighborhood that would be members of the halo. The survey revealed a substantial population of white dwarfs, too faint and cool to have been seen in previous surveys. The newly discovered population accounts for at least 2 percent of the dark matter, or about an order of magnitude larger than previously thought, and represents the first direct detection of galactic halo dark matter. The objects are also found in astrometric survey photographs with other telescopes, and spectra taken at the Cerro Tololo InterAmerican Observatory confirmed their white dwarf nature.

Research into the birth and the death of stars and their planetary systems continued to be an active area of investigation and discovery. Radio and infrared studies revealed protostars in the process of formation and extended structures around them that indicate preplanetary disks. Young stars at different evolutionary stages show complex outflows of wind and jets. High-resolution images of CO emission show shell structures and reveal close associations between the morphologies of CO and molecular hydrogen emission features. The CO kinematics show evidence of bow-shock interactions in a number of sources and evidence for wide-angle wind interactions. Scientists running simulations found that neither of the current popular models for stellar outflow, pure jet wind, or wide-angle wind adequately explain all morphologies and kinematics.

A major impetus to the observational and theoretical studies of the formation of stars and their planetary disks has been provided in the last few years by the discovery of extra-solar planets. NSF has supported much of this work. A recent discovery, again by the team of Marcy, Butler, Fischer, and Vogt, found a planet three-quarters the mass of Jupiter in a circular orbit around the solar-like star 47 Ursa Majoris. Although 70 extra-solar planets have been found thus far, this is the first system with two planets in circular orbits—at distances that make the planetary system similar to our own.

Brown dwarfs are cool, dim objects with masses between that of Jupiter and the Sun, so small that their cores never become hot enough to burn hydrogen into helium. Only the slow cooking of the limited amount of deuterium in the stellar interior is possible. Progress in the discovery and study of brown dwarfs has been possible through the large coordinated efforts of the 2 Micron All Sky Survey and Sloan Digital Sky Survey, both of which have been supported partly by NSF. Individual researchers have been following up these discoveries and investigating the physical properties of these new objects. Under an award in a joint NSF-NASA grants program, investigators from New Mexico State University and Washington University have developed cool cloud models appropriate to the cool, substellar temperatures found in brown dwarf atmospheres. Their new models explain the color changes seen in the spectral sequence of brown dwarfs, and their thermochemical calculations have wide application to the derivation of temperature and pressure indicators for gas giant planets, as well as brown dwarfs. Their models also predicted that large grains precipitate out of the brown dwarf atmospheres, just as rain does on Earth.

The national astronomy centers generate substantial databases and archives of observational data, often through coordinated surveys, which enable research beyond the scope of a single researcher. A recent example was the National Optical Astronomy Observatory's Deep Wide-Field Survey, an extensive, multi-year, multicolor survey using the 4-meter telescopes at Kitt Peak and at Cerro Tololo. The first results, covering an area of 1.15 degrees square, and with it over 300,000 faint galaxies and stars, were released in January 2001. When the survey is completed in spring 2002, the full area will be 15 times this size and will provide deep images in both the visible and infrared. With it, astronomers will be able to study large-scale structures in the universe, the formation and evolution of galaxies and quasars, rare stellar populations, and the structure of the Milky Way.

Among the areas of development supported by instrumentation programs at NSF is optical interferometry, which will enable diffraction-limited imaging using aperture synthesis methods to create images from telescopes with effective apertures up to 1 kilometer in diameter. Recent results from the Infrared Stellar Interferometer, under development by Townes at UC Berkeley, show the potential of such instrumentation—measurements of nearby stars indicate that our previous understanding of stellar sizes has been confused by the dust and gas surrounding evolved stars. New measurements with ISI show stellar radii some 10 to 25 percent larger than previous measurements, changes that have implications for our models of stellar structure and atmospheres, temperature, and ultimately distance scales.

NSF continued a joint activity with the Air Force Office of Scientific Research to provide the U.S. astronomical community with access to state-of-the-art facilities at the Advanced Electro-Optical System (AEOS) telescope, in Maui, Hawaii. The capability of this 3.76-meter advanced technology telescope for scientific research is illustrated with its recent observations of Jupiter's satellite Ganymede. Images obtained with AEOS resolve details only 270 km in size, performing significantly better than the Hubble Space Telescope.

NSF also supported technological development in the field of radio astronomy that involves the real-time adaptive cancellation of unwanted radio interference using adaptive digital filters and special signal-processing algorithms. Researchers at the National Radio Astronomy Observatory, Brigham Young University, Ohio State University, and the University of California at Berkeley have begun a program of recording high-speed data samples of signals that are known to cause interference to radio astronomical observations. With these samples in hand, tests of canceling algorithms were underway at the end of the fiscal year and have proven to be very successful for certain kinds of well-characterized and predictable signals, as in the cancellation of a signal from the GLONASS satellite.

Department of State

DoS

The Department of State (DoS) conducted successful negotiations with the Japanese government to resolve issues related to the 1995 U.S.-Japan Agreement Concerning Cross-Waiver of Liability for Space Cooperation that had been impeding successful implementation of the agreement.

During FY 2001, the Department of State led U.S. Government participation in the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS). Over the past year, the committee undertook significant work in areas such as addressing the problem of orbital space debris, global navigation satellite systems, meteorology, astronomy and astrophysics, space transportation, human space flight, planetary exploration, and environmental monitoring. The committee also considered legal issues related to international liability and responsibility of launching nations, international financial security interests in space equipment, and the equitable access to the geostationary orbit.

The Department of State provided funding for a series of four regional Global Navigation Satellite Systems (GNSS) Workshops and one Plenary Session to be held during 2001–2002. These workshops are being held under the auspices of the United Nations and the United States. The first two workshops were held in Kuala Lumpur, Malaysia, for the Asia Pacific regions, and in Vienna, Austria, for the Eastern European region. Both workshops were highly successful in bringing together regional experts and decisionmakers to advance awareness and support for use of GNSS applications for sustained growth, transportation safety, and environmental management.

In addition to the GNSS workshops, the DoS led GPS international outreach efforts for the interagency GPS Executive Board Secretariat. As a result, the

GPS exhibit and support team carried the U.S. message to such venues as the International Civil Aviation Organization General Assembly in Montreal and the Working Party 8D of the International Telecommunication Union in Geneva.

The Department of State also presented a draft framework agreement between the United States and the European Community on Satellite Navigation Systems in October 2000. This led to two negotiation sessions with the European Community based on the draft.

DEPARTMENT OF ENERGY

DoE

DoE's Office of Nuclear Energy continued to support NASA's Space Exploration Program by providing radioisotope power sources and heater units, and developing new advanced power systems covering the range of power levels required to meet more stringent power system requirements for future missions. DoE personnel provided safety analyses to support the NASA Environmental Impact Statement for the potential use of radioisotope heater units on the Mars 2003 mission. DoE conducted competitive procurements with several potential system contractors for development of conceptual designs for a Stirling radioisotope power system. A Stirling engine is one in which work is performed by the expansion of gas at high temperature to which heat is supplied through a wall. At the end of the fiscal year, DoE specialists were evaluating these contractor designs and expected to select one for further development. Additionally, DoE initiated actions to procure a system contractor to develop a multimission radioisotope thermoelectric generator (RTG) suitable for use in a variety of environments such as the surface of Mars and deep space. Finally, following a bench-scale demonstration in 2000, DoE proceeded to install a full-scale process to recover Plutonium-238 scrap for reuse as an energy source for radioisotope power systems for future NASA missions.

In FY 2001, DoE's Office of Science cooperated with NASA in a wide variety of activities, such as bringing the experimental techniques of fundamental physics for use in outer space, using the science and technology plasma science to devise new propulsion systems, joint efforts to understand atmospheric and environmental phenomena, and a working partnership in advanced computing research. These activities were carried out under a Memorandum of Understanding between NASA and DoE signed by NASA Administrator Goldin and DoE Secretary Watkins in 1992.

Through an Implementing Arrangement with NASA signed in 1995, the Office of Science continued in 2001 to build the Alpha Magnetic Spectrometer (AMS) for use on the International Space Station. The AMS is an international experiment designed to use the unique environment of space to search for and measure, with a much greater sensitivity than heretofore possible, various unusual types of matter. AMS will study the properties and origin of cosmic particles and nuclei, including antimatter and dark matter. Discovering the presence of either material will increase scientists' understanding of the early universe and could potentially lead to a clearer understanding of the actual origin of the universe. Funding in FY 2001 was used for analysis of data acquired during a 10-day Shuttle flight in 1998, and for planning and fabrication for an upcoming Shuttle flight, for the eventual deployment on the International Space Station in 2003.

DoE's Office of Science and NASA's Office of Space Science worked together in FY 2001 to build the Large-Area Telescope (LAT), the primary instrument for the Gamma-ray Large-Area Space Telescope (GLAST) project. This device, using the techniques of experimental particle physics research, detects gamma rays emitted by the most energetic objects and phenomena in the universe. Stanford University and the Stanford Linear Accelerator Center (SLAC) are responsible to the Office of Science and to NASA for overall project direction. SLAC, a DoE facility at Stanford University, is responsible for the assembly and integration of the complete instrument, data acquisition system management, as well as software development for GLAST's flight system and science analysis. DoE provided funding in FY 2001 for R&D, design, and fabrication of the telescope, in conjunction with NASA and international partners. At the end of FY 2001, the launch was anticipated to take place in 2004.

DoE's Oak Ridge National Laboratory (ORNL) and NASA's Johnson Space Center collaborated in FY 2001 on the development of an advanced rocket technology that could cut in half the time required to reach Mars. Called the Variable-Specific Impulse Magnetoplasma Rocket (VASIMR), the technology is a precursor to fusion rockets and was developed in DoE's magnetic fusion program. The VASIMR concept could provide a powerful means of propulsion by utilizing plasma as the propellant. A key to the technology is the capability to vary the plasma exhaust to maintain optimal propulsive efficiency.

Some of the new fusion technologies being developed for VASIMIR include magnets that are super-conducting at space temperatures, compact power generation equipment, and compact and robust radio-frequency systems for plasma generation and heating. ORNL's Fusion Energy Division continued to play a key role in developing and adapting these technologies for use on the VASIMR plasma thruster. NASA's Johnson Space Center provided direct support to ORNL to fund technology development specific to the VASIMR. In addition, DoE's Office of Science complemented the NASA effort by supporting related research on creating high-density plasmas by radio-frequency heating.

The Office of Science also worked with NASA to evaluate the responses of ecosystems to increasing concentrations of atmospheric carbon dioxide and to make predictions of future climate variation due to such increases. In FY 2001, the Office of Science made available to NASA its models of carbon dynamics in terrestrial ecosystems developed under the Terrestrial Carbon Processes Program. Scientists began to use these models as a basis for comparison with a variety of models developed under NASA's Vegetation Model Analysis Program.

DoE's Office of Science and NASA also worked together to calculate the biweekly primary productivity of various representative regions in the United States. In FY 2001, the AmeriFlux Program of the Office of Science provided real-time meteorological and solar radiation data for these calculations, and NASA provided data on leaf-area and photosynthetically active radiation. This joint work made possible continental-scale estimates of seasonal and geographic patterns of productivity. The AmeriFlux Program produced unique measurements of net ecosystem production from about 25 locations across the U.S. These results provided an independent calibration of NASA's productivity calculations.

The Atmospheric Radiation Measurement program of the Office of Science conducted a joint field campaign with NASA that is designed to provide accurate measurements of water vapor in the upper troposphere. Data on water vapor in the upper troposphere are one of the key elements required to improve the performance of large-scale weather and climate-prediction models. The Office of Science and NASA provided ground and airborne instrumentation for water vapor measurements for the campaign. In addition, NASA provided the new Proteus aircraft, an airborne platform designed for high-altitude and long-endurance research flights. This campaign represented the most extensive study of upper-level water vapor to date—a critical step forward in climate model improvements.

The Office of Science and NASA also collaborated in a joint effort to measure water vapor in the lower troposphere. Both agencies provided ground-based instruments, which enabled researchers to compare two sets of data. This research has led to new algorithms for the instruments that will be used by each agency as standards for specific measurements.

The Office of Science's Low-Dose Radiation Research Program continued to have an ongoing interaction with the Space Radiation Health Program in NASA's Office of Biological and Physical Research. The focus of research in the DoE Low-Dose Radiation Research Program continued to be on doses of radiation that are at or below current workplace exposure limits. The primary area of emphasis of the NASA Space Radiation Health Program continued to be understanding the biological effects of space radiation that account for radiation risks.

In FY 2001, NASA and DoE developed a Memorandum of Agreement (MoA) to better coordinate their common interests that were pending final approval at the end of the fiscal year. This close collaboration between NASA and DoE is to enhance progress in understanding and predicting the effects and health risks resulting from low-dose radiation. In addition to the MoA, DoE and NASA jointly sponsored a radiation investigators workshop in FY 2001 that included presentations by representatives of all radiation biology research projects funded by DoE and NASA. DoE and NASA also issued a joint Request for Applications in FY 2001 for research that addresses both DoE and NASA needs to understand the human health effects and risks of exposures to low doses of radiation.

The Office of Science continued to make available to NASA the Alternating Gradient Synchrotron (AGS), part of the Relativistic Heavy Ion Collider (RHIC) complex at Brookhaven National Laboratory. The AGS is the only accelerator in the United States capable of providing heavy ion beams at energies of interest for space radiobiology. Since the fall of 1995, experiments in radiobiology have been performed using beams of iron, gold, or silicon ions from the AGS. NASA funded these experiments as part of its Space Radiation Health Program. A new NASA-funded facility is under construction at the RHIC complex, the Booster Applications Facility. This new user facility, scheduled for completion in 2003, will be used to more effectively continue NASA's radiation biology studies. The Office of Science and NASA continued working together to expand the range of technical resources available for experimentation and analysis of experimental results at BNL.

In the computing area, the Office of Science and NASA continued their collaboration on "Grids," an innovative way to transfer data among geographically disbursed computer systems at rates of a gigabyte per second and higher. Disciplines that are benefiting from Grid technology include multidisciplinary aerospace system design, high-energy physics data analysis, climate analysis and prediction, and large-scale remote instrument operation. The Office of Science and NASA also conducted the Global Grid Forum, a technology definition and standards organization that is providing an invaluable contribution to the field.

Most users of Grids will access Grid services via discipline-specific frameworks that are built from services that use the World Wide Web. The Office of Science supplied and continued working on various technologies that made Grid services available in the Web environment. The Office of Science has developed a range of basic Grid services for reliable movement of terabyte-sized datasets, data replication, and location management techniques to minimize data access times, etc. Two Office of Science laboratories, the Lawrence Berkeley National Laboratory and the Argonne National Laboratory, set up experimental Grids with NASA's Ames Research Center in order to identify and resolve the technical and configuration issues that arise from cross-institutional operation of the authentication and security infrastructure, and cross-operation of the directory services that are the central information service for Grids.

Smithsonian Institution

The Smithsonian Institution continued to contribute to national aerospace goals through the activities of the Smithsonian Astrophysical Observatory (SAO), which is joined with the Harvard College Observatory in Cambridge, Massachusetts, to form the Harvard-Smithsonian Center for Astrophysics (CfA). Here, over 300 scientists engage in a broad program of research in astronomy, astrophysics, and science education. The Smithsonian National Air and Space Museum (NASM) in Washington, DC, also contributed to national aerospace goals through its research and education activities.

SAO continued to operate NASA's Chandra X-ray Observatory, which completed its second year of observations in FY 2001 with a series of widely reported results and discoveries. During FY 2001, Chandra observations led to an enhanced understanding of black holes. Chandra took the deepest x-ray images ever and found the early universe likely to be teeming with black holes, probed the theoretical edge of a black hole known as the "event horizon," observed the x-ray afterglows of gamma-ray bursts, and captured the first x-ray flare ever seen from the massive black hole in the center of the Milky Way. Chandra data also shed light on the distribution of dark matter by yielding the most accurate estimate to date of the amount of dark matter in galaxy clusters. In the field of supernova research, Chandra associated a pulsar with a supernova recorded by Chinese astronomers in 386 AD (only the second pulsar to be associated with a historically observed supernova), and a team of three high school students using x-ray data from Chandra and radio data from the National Radio Astronomy Observatory's Very Large Array discovered a neutron star within a nearby supernova remnant.

SAO also continued its role as the leader of another NASA satellite, the Submillimeter Wave Astronomy Satellite (SWAS), a space telescope used to study the chemistry and dynamics of the interstellar gas clouds in the Milky Way galaxy. In FY 2001, SWAS observed massive amounts of water vapor surrounding an aging giant star about 500 light years from Earth. The SWAS observations provided the first evidence that extrasolar planetary systems contain water. Scientists concluded that this water likely comes from a swarm of icy comets surrounding the star which are gradually being vaporized. This result was the subject of a NASA Space Science Update news conference held at NASA Headquarters in Washington, DC.

In FY 2001, using ground-based observations, SAO scientists discovered high-energy gamma-ray emissions from so-called “extreme” galaxies and created the first large-scale map of the galactic center using emissions from carbon monoxide molecules at submillimeter wavelengths. They also discovered a young star repeatedly emitting spheres of gas into space. An international team of astronomers including a member from SAO discovered dusty disks surrounding young brown dwarfs in the Orion Nebula, indicating that brown dwarfs probably form in a manner similar to stars. SAO scientists set new limits on the amount of material in the outer reaches of the solar system by studying the diffused light from Kuiper Belt Objects too small to be seen directly. Their data set constraints on theories of planet formation in our solar system.

Solar scientists at SAO continued to study the electrically charged atoms (ions) that the Sun expels into the solar system via coronal mass ejections. New observations from SAO’s UltraViolet Coronagraph Spectrometer (UVCS) aboard the Solar and Heliospheric Observatory (SOHO) spacecraft allowed scientists to: 1) probe physical processes in the explosive coronal mass ejections that can have a strong impact on Earth’s local space environment, and 2) observe, for the first time, the properties of the sources of the high-speed solar wind as these sources reform in conjunction with the Sun’s switch in magnetic polarity. These measurements are coordinated with other SOHO instruments and with the extreme ultraviolet images from the Transition Region and Coronal Explorer satellite. UVCS ultraviolet spectra of sungrazing comets indicated that the nuclei of those comets are in the range of 10–20 meters in diameter. These spectra also provided unique probes of the density and speed of the solar wind.

The Science Education Department (SED) at CfA continued to host teachers from across the United States at sessions designed to train them in the use of the department's many curriculum programs for grades 3–12. SED activities included the "MicroObservatory Program," which enables classrooms to control small telescopes located around the world. Using MicroObservatory, students can plan observations, take data, and share their results with other schools. SED worked with a consortium of teachers from across the Nation to develop the "From the Ground UP!" program—a series of investigations in physical science for middle and high school students using the MicroObservatory network.

SED's Science Media Group produced four television workshops and documentaries, ranging from a 1-hour special on science and sports to an eight-part workshop exploring the science of force and motion. SED also continued managing the Annenberg/CPB Channel, a satellite/Web service broadcasting free educational programming nationwide for schools, colleges, and communities. The channel's reach has grown over the past year to 62,000 schools and 38 million households.

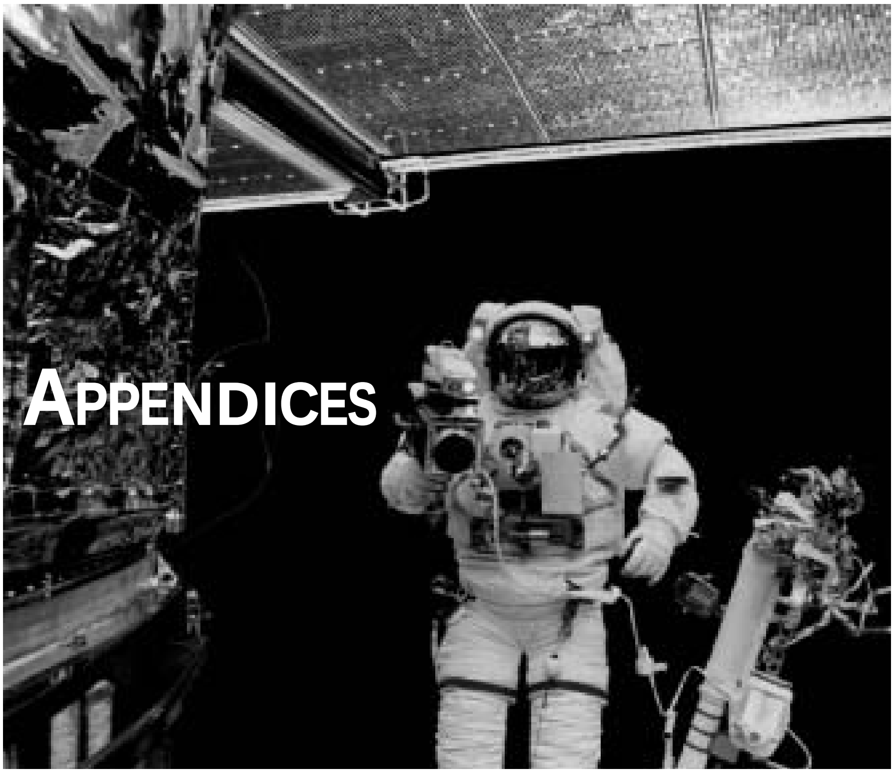
SAO continued to offer its popular Observatory Night lectures and telescope observing to the public on a monthly basis. Lectures aimed at general audiences drew more than 100 people to most events. A new program of monthly "Sci-Fi Movie Nights" was introduced, offering attendees the chance to learn about science in a fun way by comparing what Hollywood got right versus what it got wrong. A CfA scientist introduced each film by discussing the science shown and the social context in which the film was made. These movie nights, with the theme "Everything we learned about science, we learned at the movies," proved extremely popular, with attendances of up to 100 people, and were frequented by science and science-fiction enthusiasts of all ages. SAO also continued to offer "Children's Night" programs aimed at younger audiences.

Staff of the Center for Earth & Planetary Studies (CEPS) at the National Air and Space Museum were selected as science team members for the 2005 Mars Reconnaissance Orbiter. Dr. John Grant is a co-investigator for the HiRISE High-Resolution Imager, which will be capable of color and stereo imaging with about six times higher resolution than any current images of Mars. This imagery will be crucial for understanding the evolution of Mars and the changing role that water has played in shaping the surface of the planet. CEPS chairman Dr. Bruce

Campbell is a member of the science team for the Shallow Subsurface Sounding Radar. This system will use radio waves to penetrate the upper kilometer of the Martian crust, map subsurface geologic layering, and search for buried ice and water deposits. Dr. Campbell was also selected as one of 10 principal investigators to receive NASA funding for a 6-month concept study of the Mars Scout Radar instrument proposed for the Mars Scout missions. CEPS staff were further involved in planetary mission planning through co-chairing the Mars Landing Site Steering Group, participating in the Mars Exploration Payload Analysis Group, serving on the Messenger Science Team, and working on numerous other NASA evaluation groups.

CEPS continued its active research program in planetary and terrestrial geology and geophysics using remote-sensing data from Earth-orbiting satellites and manned and unmanned space missions. The scope of research activities included work on Mercury, Venus, the Moon, and Mars, and corresponding field studies in terrestrial analog regions. CEPS staff studied a variety of geologic processes such as volcanism, cratering, tectonics, and sand movement.

As a NASA Regional Planetary Imagery Facility, CEPS continued to house an extensive collection of images of the planets and their satellites. In addition, CEPS staff participated in the development and presentation of exhibits and public programs, including teacher workshops, special events, and outreach activities in the community. Staff continued to be responsible for developing and maintaining the National Air and Space Museum Web site, including innovative online exhibit materials, interactive educational programs, research highlights, and virtual tours of the museum's galleries.


APPENDICES

APPENDIX A-1

U.S. Government Spacecraft Record

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

Calendar	Earth Orbit[a]		Earth Escape[a]	
Year	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2
1962	55	12	4	1
1963	62	11	0	0
1964	69	8	4	0
1965	93	7	4	1
1966	94	12	7	1[b]
1967	78	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1
1972	33	2	8	0
1973	23	2	3	0
1974	27	2	1	0
1975	30	4	4	0
1976	33	0	1	0
1977	27	2	2	0
1978	34	2	7	0
1979	18	0	0	0
1980	16	4	0	0
1981	20	1	0	0
1982	21	0	0	0
1983	31	0	0	0
1984	35	3	0	0
1985	37	1	0	0
1986	11	4	0	0
1987	9	1	0	0
1988	16	1	0	0
1989	24	0	2	0
1990	40	0	1	0
1991	32[c]	0	0	0
1992	26[c]	0	1	0
1993	28[c]	1	1	0
1994	31[c]	1	1	0
1995	24[c, d]	2	1	0
1996	30	1	3	0
1997	22[e]	0	1	0
1998	23	0	2	0
1999	35	4	2	0
2000	31[f]	0	0	0
2001 *(through September 30, 2001)*	16	0	3	0
TOTAL	1,499	153	97	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.
f. Counts OCS, OPAL, FALCONSAT, and ASUSAT microsatellites as one set, and The Picosats 4-8 as another set.

APPENDIX A-2

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

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

Calendar Year	United States	USSR/ CIS	France[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	37	19			2	6			11	1	
1998	36	25			2	6			11		
1999	30	29				4			10	1	
2000	29	36				5			12		
2001 *(through September 30, 2001)*	18	23				1			7		
TOTAL	1,233	3,657	10	8	54	64	1	1	137	11	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, 2000–September 30, 2001

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Oct. 9, 2000 HETE 2* 2000-61A Pegasus	Science	637 km 594 km 97 min 2°	
Oct. 11, 2000 STS-92/*Discovery* 2000-62A Space Shuttle	ISS Assembly	381 km 380 km 92 min 51.6°	
Oct. 20, 2000 USA 153 2000-65A Atlas 2A	Military Communications	Orbital Parameters unknown	
Oct. 21, 2000 Thuraya 1* 2000-66A Zenit 3SL/Sea Launch	Communications	Geosynchronous	United Arab Emirates satellite
Nov. 10, 2000 Navstar 49 (USA 154) 2000-71A Delta 2	GPS navigation	20,498 km 20,177 km 724.3 min 55.1°	
Nov. 21, 2000 EO-1 2000-75A Delta 2	Earth Science	700 km 690 km 98.7 min 98.2°	
Nov. 21, 2000 SAC-C 2000-75B Delta 2	Earth Science	701 km 682 km 98.7 min 98.2°	International mission
Nov. 21, 2000 Munin 2000-75C Delta 2	Earth Science	1,794 km 693 km 110 min 95.4°	Swedish auroral research nanosatellite
Nov. 30, 2000 STS-97/*Endeavour* 2000-78A Space Shuttle	ISS Assembly	365 km 352 km 91.7 min 51.6°	
Dec. 6, 2000 USA 155 2000-80A Atlas 2AS	Military reconnaissance	Orbital parameters unknown	

APPENDIX B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2000–September 30, 2001

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jan. 30, 2001 Navstar 50 (USA 156) 2001-4A Delta 2	GPS navigation	20,390 km 158 km 357 min 39.1°	
Feb. 7, 2001 STS-98/*Atlantis* 2001-6A Space Shuttle	ISS assembly	378 km 365 km 92 min 51.5°	
Feb. 7, 2001 Destiny module 2001-6B Space Shuttle	ISS module	ISS orbital parameters	
Feb. 27, 2001 USA 157 2001-9A Titan 4/Centaur	Military communications	Geosynchronous	
March 8, 2001 STS-102/*Discovery* 2001-10A Space Shuttle	ISS crew and supplies	ISS orbital parameters	
March 18, 2001 XM 2* 2001-12A Zenit 3SL/Sea Launch	Radio broadcast satellite	Geosynchronous	Also known as XM Rock
April 7, 2001 Mars Odyssey 2001-14A Delta 2	Space Science	Interplanetary mission	
April 19, 2001 STS-100/*Endeavour* 2001-16A Space Shuttle	ISS crew and assembly	394 km 377 km 92.3 min 51.6°	
May 8, 2001 XM 1* 2001-18A Zenit/Sea Launch	Radio broadcast satellite	Geosynchronous	Also known as XM Roll
May 18, 2001 USA 158 2001-20A Delta 2	Military communications	Geosynchronous	Reportedly a laser communications technology demonstrator

APPENDIX B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2000–September 30, 2001

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
June 19, 2001 ICO-F2* 2001-26A Atlas 2AS	Communications	10,216 km 10,104 km 351 min 45°	British relay satellite
June 30, 2001 MAP 2001-27A Delta 2	Space Science	Initial "parking" at second Lagrangian point	Microwave Anisotropy Probe astrophysics spacecraft
July 12, 2001 STS-104/*Atlantis* 2001-28A Space Shuttle	ISS assembly	390 km 372 km 92.2 min 51.6°	
July 23, 2001 GOES 12 2001-31A Atlas 2A	Weather	Geosynchronous	
Aug. 6, 2001 USA 159 2001-33A Titan 4B	Military reconnaissance	Geosynchronous	Defense Support Program (DSP)-21 satellite
Aug. 8, 2001 Genesis 2001-34A Delta 2	Space Science	Varying parameters	
Aug. 10, 2001 STS-105/*Discovery* 2001-35A Space Shuttle	ISS crew and assembly	402 km 373 km 92.3 min 51.6°	
Sept. 8, 2001 USA 160 2001-40A Atlas 2AS/Centaur	Military reconnaissance	Orbital parameters unknown	
Sept. 30, 2001 Starshine 3 2001-43A Athena-1	Science	472 km 472 km 94 min 67°	First launch from the Kodiak Launch Complex in Alaska
Sept. 30, 2001 Picosat 9 2001-43B Athena-1	Science	794 km 794 km 101 min 67°	British-built, U.S. DoD-funded satellite to test electronic components

APPENDIX B
(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles
October 1, 1998–September 30, 2001

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Sept. 30, 2001 PCSat 2001-43C Athena-1	Science	794 km 794 km 101 min 67°	Prototype communications satellite built by midshipmen at U.S. Naval Academy as relay for amateur radio transmissions
Sept. 30, 2001 Sapphire 2001-43D Athena-1	Science	794 km 794 km 101 min 67°	DoD-funded microsatellite built by Stanford University students and faculty, with voice synthesizer

* Commercial launch licensed as such by the Federal Aviation Administration.
More launch data is available at *http://ast.faa.gov/launch_info/launch/history.cfm* on the Web.

APPENDIX C

U.S. and Russian Human Space Flights
1961–September 30, 2001

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 (with Vostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	2:22:50	First woman in space; within 5 km of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Boris G. Yegorov	1:0:17	First three-person crew.
Voskhod 2	Mar. 18, 1965	Pavel I. Belyayev Aleksey A. Leonov	1:2:2	First extravehicular activity (EVA), by Leonov, 10 min.
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	0:4:53	First U.S. two-person flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, II	4:1:56	21-min. EVA (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	7:22:55	Longest duration human flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	13:18:35	Longest human flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	1:1:51	Rendezvous within 30 cm of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	0:10:41	First docking of two orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	3:0:21	EVA; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	2:22:47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sep. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	2:23:17	First initial-orbit docking; first tethered flight; highest Earth-orbit altitude (1,372 km.).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	3:22:35	Longest EVA to date (Aldrin, 5 hrs.).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	1:2:37	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	10:20:9	First U.S. three-person mission.
Soyuz 3	Oct. 26, 1968	Georgiy T. Beregovoy	3:22:51	Maneuvered near uncrewed Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	6:3:1	First human orbit(s) of Moon; first human departure from Earth's sphere of influence; highest speed attained in human flight to date.
Soyuz 4	Jan. 14, 1969	Vladimir A. Shatalov	2:23:23	Soyuz 4 and 5 docked and transferred two cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris V. Volynov Aleksey A. Yeliseyev Yevgeniy V. Khrunov	3:0:56	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	10:1:1	Successfully simulated in Earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.

Appendix C

(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 2001

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. Kubasov	4:22:42	Soyuz 6, 7, and 8 operated as a group flight without actually docking. Each conducted certain experiments,
Soyuz 7	Oct. 12, 1969	A. V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4:22:41	including welding and Earth and celestial observation.
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 Lunar Module as "lifeboat" until just before reentry.
Soyuz 9	June 1, 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17:16:59	Longest human space flight to date.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	9:0:2	Third human lunar landing. Mission demonstrated pinpoint landing capability and continued human exploration.
Soyuz 10	Apr. 22, 1971	Vladimir A. Shatalov Aleksey S. Yeliseyev Nikolay N. Rukavishnikov	1:23:46	Docked with Salyut 1, but crew did not board space station launched Apr. 19. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy T. Dobrovolskiy Vladislav N. Volkov Viktor I. Patsayev	23:18:22	Docked with Salyut 1, and Soyuz 11 crew occupied space station for 22 days. Crew perished in final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James B. Irwin	12:7:12	Fourth human lunar landing and first Apollo "J" series mission, which carried Lunar Roving Vehicle. Worden's inflight EVA of 38 min., 12 sec. was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly II	11:1:51	Fifth human lunar landing, with roving vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	12:13:52	Sixth and final Apollo human lunar landing, again with roving vehicle.
Skylab 2	May 25, 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	28:0:50	Docked with Skylab 1 (launched uncrewed May 14) for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	59:11:9	Docked with Skylab 1 for more than 59 days.
Soyuz 12	Sep. 27, 1973	Vasiliy G. Lazarev Oleg G. Makarov	1:23:16	Checkout of improved Soyuz.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 2001

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	Aleksey 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.

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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 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	May 14, 1981	Leonid I. Popov Dumitru Prunariu	7:20:41	Docked with Salyut 6. Prunariu first Romanian cosmonaut to orbit.
Space Shuttle *Columbia* (STS-2)	Nov. 12, 1981	Joe H. Engle Richard H. Truly	2:6:13	Second flight of Space Shuttle; first scientific payload (OSTA 1). Tested remote manipulator arm. Returned for reuse.
Space Shuttle *Columbia* (STS-3)	Mar. 22, 1982	Jack R. Lousma C. Gordon Fullerton	8:0:5	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 F. Story Musgrave	5:0:24	Sixth flight of Space Shuttle; launched TDRS-1.

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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	Vladimir Lyakhov Aleksandr Aleksandrov	149:9:46	Docked with Salyut 7 station.
Space Shuttle *Challenger* (STS-8)	Aug. 30, 1983	Richard H. Truly Daniel C. Brandenstein Dale A. Gardner Guion S. Bluford, Jr. William E. Thornton	6:1:9	Eighth flight of Space Shuttle; launched one commercial satellite (Insat 1-B); first flight of U.S. black astronaut.
Space Shuttle *Columbia* (STS-9)	Nov. 28, 1983	John W. Young Brewster W. Shaw Owen K. Garriott Robert A. R. Parker Byron K. Lichtenberg Ulf Merbold	10:7:47	Ninth flight of Space Shuttle; first flight of Spacelab 1; first flight of 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 Robert 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 Francis 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. Resnik 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
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Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Discovery* (STS 51-A)	Nov. 8, 1984	Frederick H. Hauck David M. Walker Joseph P. Allen Anna L. Fisher Dale A. Gardner	7:23:45	Fourteenth flight of Space Shuttle; first retrieval and return of two disabled communications satellites (Westar 6, Palapa B2) to Earth.
Space Shuttle *Discovery* (STS 51-C)	Jan. 24, 1985	Thomas K. Mattingly Loren J. Shriver Ellison S. Onizuka James F. Buchli Gary E. Payton	3:1:33	Fifteenth STS flight. Dedicated DoD mission.
Space Shuttle *Discovery* (STS 51-D)	Apr. 12, 1985	Karol J. Bobko Donald E. Williams M. Rhea Seddon S. David Griggs Jeffrey A. Hoffman Charles D. Walker E. J. Garn	6:23:55	Sixteenth STS flight. Two communications satellites. First U.S. Senator in space (Garn).
Space Shuttle *Challenger* (STS 51-B)	Apr. 29, 1985	Robert F. Overmyer Frederick D. Gregory Don L. Lind Norman E. Thagard William E. Thornton Lodewijk van den Berg Taylor Wang	7:0:9	Seventeenth STS flight. Spacelab-3 in cargo bay of Shuttle.
Soyuz T-13	June 5, 1985	Vladimir Dzhanibekov Viktor Savinykh	112:3:12	Repair of Salyut-7. Dzhanibekov returned to Earth with Grechko on Soyuz T-13 spacecraft, Sept. 26, 1985.
Space Shuttle *Discovery* (STS 51-G)	June 17, 1985	Daniel C. Brandenstein John O. Creighton Shannon W. Lucid John M. Fabian Steven R. Nagel Patrick Baudry Prince Sultan Salman Al-Saud	7:1:39	Eighteenth STS flight. Three communications satellites. One reusable payload, Spartan-1. First U.S. flight with French and Saudi Arabian crew members.
Space Shuttle *Challenger* (STS 51-F)	July 29, 1985	Charles G. Fullerton Roy D. Bridges Karl C. Henize Anthony W. England F. Story Musgrave Loren W. Acton John-David F. Bartoe	7:22:45	Nineteenth STS flight. Spacelab-2 in cargo bay.
Space Shuttle *Discovery* (STS 51-I)	Aug. 27, 1985	Joe H. Engle Richard O. Covey James D. van Hoften William F. Fisher John M. Lounge	7:2:18	Twentieth STS flight. Launched three communications satellites. Repaired Syncom IV-3.
Soyuz T-14	Sep. 17, 1985	Vladimir Vasyutin Georgiy Grechko Aleksandr Volkov	64:21:52	Docked with Salyut 7 station. Viktor Savinykh, Aleksandr Volkov, and Vladimir Vasyutin returned to Earth Nov. 21, 1985, when Vasyutin became ill.
Space Shuttle *Atlantis* (STS 51-J)	Oct. 3, 1985	Karol J. Bobko Ronald J. Grabe Robert L. Stewart David C. Hilmers William A. Pailes	4:1:45	Twenty-first STS flight. Dedicated DoD mission.

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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. 26, 1985	Brewster H. Shaw Bryan D. O'Connor Mary L. Cleave Sherwood C. Spring Jerry L. Ross Rudolfo Neri Vela Charles D. Walker	6:21:4	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-Díaz Steve A. Hawley George D. Nelson Robert 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 Aleksandr Aleksandrov	9:20:13	Docked with *Mir* space station. 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.

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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-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 Norman 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-Díaz Ellen S. Baker	4:23:39	Thirty-first STS flight. Launched Jupiter probe and orbiter Galileo.
Space Shuttle *Discovery* (STS-33)	Nov. 22, 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

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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 Samuel T. Durrance Ronald A. Parise	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 Krikalev remained 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'Connor 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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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 Artsebarskiy in the TM-12 spacecraft.
Space Shuttle *Atlantis* (STS-44)	Nov. 24, 1991	Frederick D. Gregory Tom Henricks Jim Voss F. 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)	8:1:15	Forty-fifth STS flight. Carried International Microgravity Laboratory-1 in cargo bay.
Soyuz TM-14	Mar. 17, 1992	Aleksandr Viktorenko Aleksandr 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	8:22:9	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	8:21:18	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 Lawrence J. DeLucas Eugene H. Trinh	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 July 29. Tognini returned to Earth in TM-14 capsule with Aleksandr Viktorenko and Aleksandr 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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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-Díaz Franco Malerba (Italy)	7:23:16	Forty-ninth STS flight. Deployed Tethered Satellite System-1 and Eureca 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	5:23:39	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 Poleschuk	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 commercial payload module and retrieved European Retrievable Carrier in orbit since August 1992.

Appendix C
(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 2001

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 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-Díaz 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. 4, 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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 2001

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 atmospheric research. Included the first untethered spacewalk by astronauts in over 10 years.
Space Shuttle *Endeavour* (STS-68)	Sep. 30, 1994	Michael A. Baker Terrence W. Wilcutt Thomas D. Jones Steven L. Smith Daniel W. Bursch Peter J. K. Wisoff	11:5:36	Sixty-fifth STS flight. Used Space Radar Laboratory-2 to provide scientists with data to help distinguish human-induced environmental change from other natural forms of change.
Soyuz TM-20	Oct. 3, 1994	Aleksandr 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-François 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 ultraviolet telescopes called Astro-2.

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U.S. and Russian Human Space Flights

1961–September 30, 2001

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 space flight. 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 micro-gravity 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).

(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 2001

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-Díaz 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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U.S. and Russian Human Space Flights

1961–September 30, 2001

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz TM-25	Feb. 10, 1997	Vasily Tsibliev Aleksandr Lazutkin Reinhold Ewald	*	Soyuz TM-24 returned to Earth on March 2, 1997, with Reinhold Ewald, Valery Korzun, and Aleksandr 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 Aleksandr 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 Chrétien 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.

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U.S. and Russian Human Space Flights
1961–September 30, 2001

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Columbia* (STS-87)	Nov. 19, 1997	Kevin R. Kregel Steven W. Lindsey Kalpana Chawla Winston E. Scott Takao Doi Leonid K. Kadenyuk	15:16:34	Payloads included USMP-4, Spartan 201-04 free-flyer, Collaborative Ukrainian Experiment (CUE) in space biology, and several other “hitchhiker” payloads.
Space Shuttle *Endeavour* (STS-89)	Jan. 22, 1998	Terrence W. Wilcutt Joe F. Edwards, Jr. James F. Reilly II Michael P. Anderson Bonnie J. Dunbar Salizhan S. Sharipov Andrew S. Thomas** David A. Wolf***	8:19:47	Eighth Shuttle docking mission to *Mir.* Andrew Thomas replaced David Wolf on *Mir.* Shuttle payloads included SPACEHAB double module of science experiments.
Soyuz TM-27	Jan. 29, 1998	Talgat Musabayev Nikolai Budarin Leopold Eyharts	*	Soyuz TM-26 left *Mir* and returned to Earth on February 19 with Anatoly Solovyev, Pavel Vinogradov, and Leopold Eyharts.
Space Shuttle *Columbia* (STS-90)	Apr. 17, 1998	Richard A. Searfoss Scott D. Altman Richard M. Linnehan Kathryn P. Hire Dafydd Rhys Williams Jay Clark Buckey, Jr. James A. Pawelczyk	15:21:50	Carried Neurolab module for microgravity research in the human nervous system. Secondary goals included measurement of Shuttle vibration forces, demonstration of the bioreactor system for cell growth, and three Get Away Special payloads.
Space Shuttle *Discovery* (STS-91)	June 2, 1998	Charles J. Precourt Dominic L. Pudwill Gorie Franklin R. Chang-Díaz Wendy B. Lawrence Janet Lynn Kavandi Valery V. Ryumin Andrew S. Thomas***	9:19:48	Last of nine docking missions with *Mir,* this one brought home Andrew Thomas. Payloads included DoE’s Alpha Magnetic Spectrometer to study high-energy particles from deep space, four Get Away Specials, and two Space Experiment Modules.
Soyuz TM-28	Aug. 13, 1998	Gennady Padalka Sergei Avdeev Yuri Baturin	*	Docked to *Mir* using manual backup system because of prior failure of one of two automatic systems. Soyuz TM-27 left *Mir* returned to Earth with Talgat Musabayev, Nikolai Budarin, and Yuri Baturin.
Space Shuttle *Discovery* (STS-95)	Oct. 29, 1998	Curtis L. Brown, Jr. Steven W. Lindsey Scott E. Parazynski Stephen K. Robinson Pedro Duque (ESA) Chiaki Mukai (NASDA) John H. Glenn	8:21:44	Payloads included a SPACEHAB pressurized module, the Pansat communications amateur satellite, and the Spartan 201-05 solar observatory. Performed biomedical experiments on space flight and aging. Second flight of John Glenn.
Space Shuttle *Endeavour* (STS-88)	Dec. 4, 1998	Robert D. Cabana Frederick W. Sturckow James H. Newman Nancy J. Currie Jerry L. Ross Sergei K. Krikalev (RSA)	11:19:18	Payloads included Unity (Node 1), the first U.S. module of the ISS, as well as SAC-A and Mightysat 1.
Soyuz TM-29	Feb. 20, 1999	Viktor Afanasyev Jean-Pierre Haignere (ESA) Ivan Bella	*	Soyuz mission to *Mir*.

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U.S. and Russian Human Space Flights

1961–September 30, 2001

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Discovery* (STS-96)	May 27, 1999	Kent V. Rominger Rick D. Husband Daniel T. Barry Valery I. Tokarev (RSA) Ellen Ochoa Julie Payette (CSA) Tamara E. Jernigan	9:19:13	ISS supply and repair mission; also launched the Starshine student passive reflector satellite.
Space Shuttle *Columbia* (STS-93)	July 23, 1999	Eileen M. Collins Jeffrey S. Ashby Michel Tognini (CNES) Steven A. Hawley Catherine G. Coleman	4:22:50	Deployed Chandra X-ray Observatory. Collins was first female commander of a Shuttle mission.
Space Shuttle *Discovery* (STS-103)	Dec. 19, 1999	Curtis L. Brown Scott J. Kelly Steven L. Smith C. Michael Foale John M. Grunsfeld Claude Nicollier Jean-Francois Clervoy	7:23:11	Hubble Space Telescope Servicing Mission #3
Space Shuttle *Endeavour* (STS-99)	Feb. 11, 2000	Kevin Kregel Dominic Gorie Gerhard P.J. Thiele Janet Kavandi Janice Voss Mamoru Mohri	11:5:38	Shuttle Radar Topography Mission (SRTM). The main objective of STS-99 was to obtain the most complete high-resolution digital topographic database of Earth, using a special radar system.
Soyuz TM-30	Apr. 4, 2000	Sergei Zalyotin Alexander Kaleri	72:19:43	Final Soyuz mission to *Mir*.
Space Shuttle *Atlantis* (STS-101)	May 19, 2000	James Halsell, Jr. Scott Horowitz Susan Helms Yury V. Usachev James Voss Mary Ellen Weber Jeff Williams	9:20:9	Second crew visit to the International Space Station ISS (2A.2a), to deliver supplies, perform maintenance, and reboost its orbit.
Space Shuttle *Atlantis* (STS-106)	Sept. 8, 2000	Terrence Wilcutt Scott Altman Daniel Burbank Edward T. Lu Yuri I. Malenchenko Rick Mastracchio Boris V. Morukov	11:19:11	Third logistics/outfitting flight to ISS (2A.2b) to prepare the station for its first resident crew.
Space Shuttle *Discovery* (STS-92)	Oct. 11, 2000	Brian Duffy Pamela A. Melroy Leroy Chiao William S. McArthur Peter J.K. Wisoff Michael E. Lopez-Alegria Koichi Wakata	12:21:43	*Discovery's* was the 100th mission in Shuttle Program history. ISS assembly mission.
Soyuz TM-31	Oct. 31, 2000	William Shepherd Yuri Gidzenko Sergei Krikalev	140	Launch of 1st resident crew (Expedition 1) to the ISS.

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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 *Endeavour* (STS-97)	Nov. 30, 2000	Brent W. Jett Michael J. Bloomfield Joseph R. Tanner Marc Garneau Carlos I. Noriega	10:19:58	Mission to the ISS.
Space Shuttle *Atlantis* (STS-98)	Feb. 7, 2001	Kenneth D. Cockrell Mark L. Polansky Robert L. Curbeam Marsha S. Ivins Thomas D. Jones	12:21:20	Delivered U.S. Laboratory module Destiny to the ISS.
Space Shuttle *Discovery* (STS-102)	March 8, 2001	James D. Wetherbee James M. Kelly Andrew S.W. Thomas Paul W. Richards James S. Voss (up) Susan J. Helms (up) Yuri V. Usachev (up) William Shepherd (down) Yuri P. Gidzenko (down)	12:19:49	Delivered Expedition 2 crew to the ISS and returned the Expedition 1 crew to Earth.
Space Shuttle *Endeavour* (STS-100)	April 19, 2001	Kent V. Rominger Jeffrey S. Ashby Chris A. Hadfield John L. Phillips Scott E. Parazynski Umberto Guidoni Yuri V. Lonchakov	11:21:30	Mission to the ISS.
Soyuz TM-32	April 28, 2001	Talgat A. Musabaev Yuri M. Baturin Dennis Tito	7:22:4	Launch of the 1st “taxi” flight to the ISS, bringing a “fresh” Soyuz crew return vehicle for the ISS crew. This mission also carried the first commercial space tourist, U.S. businessman Dennis Tito.
Space Shuttle *Atlantis* (STS-104)	July 12, 2001	Steven W. Lindsey Charles O. Hobaugh Michael L. Gernhardt Janet L. Kavandi James F. Reilly	12:18:35	Mission to the ISS.
Space Shuttle *Discovery* (STS-105)	Aug. 10, 2001	Scott J. Horowitz Frederick W. Sturckow Patrick G. Forrester Daniel T. Barry Frank L. Culbertson (up) Vladimir N. Dezhurov (up) Mikhail Tyurin (up) Yury V. Usachev (down) James S. Voss (down) Susan J. Helms (down)	11:21:13	Returned the Expedition 2 crew to Earth.

* *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

					Max. Payload (kg)[d]			
Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[b, c]	Max. Dia x Height (m)	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	—	335	1994[g]
	1. Orion 50S-XL	Solid	743.3	1.28x10.29	350[e]			
	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	255	1,020	1994
	0. Castor 120	Solid	1,687.7	2.34x11.86	1,080[e]			
	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)[j]	Solid	433.6 (SL)	1.01x11.16				
	2. Centaur II: RL10A-4 (2)	LOX/LH_2	92.53/engine	3.05x10.05				
Athena								
	1. Athena	Solid	1450	2.36x19.8	520	245		1995

APPENDIX D

(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,
	1. LR-87-AJ-5 (2)	N204/A-50	1,045.0	3.05x21.5				Titan II SLV
	2. LR-91-AJ-5	N204/A-50	440.0	3.05x12.2				[1964, Titan II
								Gemini]
Titan III				3.05x47.3	14,515	5,000[l]	—	1989,
	0. Titan III SRM (2)	Solid	6,210.0	3.11x27.6				Titan III
	(5-1/2 segments)							[1964,
	1. LR87-AJ-11 (2)	N204/A-50	1,214.5	3.05x24.0				Titan IIIA]
	2. LR91-AJ-11	N204/A-50	462.8	3.05x10.0				
Titan IV				3.05x62.2	17,700	6,350[m]	—	1989,
	0. Titan IV SRM (2)	Solid	7,000.0	3.11x34.1	14,110[e]			Titan IV
	(7 segments)							
	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,
	0. Titan IV SRM (2)	Solid	7,000.0	3.11x34.1				Titan IV
	(7 segments)							Centaur
	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/LH_2	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,
	1. SRB:	Solid	11,790.0 (SL)	3.70x45.46				*Columbia*
	Shuttle SRB (2)							
	2. Orbiter/ET:	LOX/LH_2	1,668.7 (SL)	8.41x47.00 (ET)				
	SSME (3)			23.79x37.24[h] (orbiter)				
	3. Orbiter/OMS:	$N_2 0_4$/MMH	26.7	23.79x37.24[h]				
	OMS engines (2)							
Delta III								
	1. RS-27A	LOX/RP-1	1,043.0 (SL)	4x39.1	8,292	3,810	6,768	1998[g]
	Alliant GEM (9)	Solid	608.8	1.16x14.7				
	2. RL-10B-2	LOX/LH_2	110	4x8.8				
	3. Star 48B	Solid	66.4	1.25x2.04				

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_20_4 = Nitrogen Tetroxide

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

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

d. Inclination of 28.5˚ except where indicated.

e. Polar launch from Vandenberg AFB, CA.

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

g. First launch was a failure

h. Diameter dimension represents vehicle wing span.

i. Applies to Delta II-7925 version only.

j. Two Castor IVA motors ignited at liftoff. 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.**

APPENDIX E-1A

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[d]	DoC	DoI	Ag	NSF[a]	DoT	Total Space
1959	331	261	490	34	34						785
1960	524	462	561	43	43						1,066
1961	964	926	814	68	68						1,808
1962	1,825	1,797	1,298	199	148	51					3,294
1963	3,673	3,626	1,550	257	214	43					5,433
1964	5,100	5,016	1,599	213	210	3					6,828
1965	5,250	5,138	1,574	241	229	12					6,953
1966	5,175	5,065	1,689	214	187	27					6,968
1967	4,966	4,830	1,664	213	184	29					6,707
1968	4,587	4,430	1,922	174	145	28	0.2	1			6,526
1969	3,991	3,822	2,013	170	118	20	0.2	1	31		6,005
1970	3,746	3,547	1,678	141	103	8	1	1	28		5,366
1971	3,311	3,101	1,512	162	95	27	2	1	37		4,775
1972	3,307	3,071	1,407	133	55	31	6	2	39		4,611
1973	3,406	3,093	1,623	147	54	40	10	2	41		4,863
1974	3,037	2,759	1,766	158	42	60	9	3	44		4,683
1975	3,229	2,915	1,892	158	30	64	8	2	54		4,965
1976	3,550	3,225	1,983	168	23	72	10	4	59		5,376
TQ*	932	849	460	31	5	22	3	1	12		1,352
1977	3,818	3,440	2,412	194	22	91	10	6	65		6,046
1978	4,060	3,623	2,738	226	34	103	10	8	71		6,587
1979	4,596	4,030	3,036	248	59	98	10	8	73		7,314
1980	5,240	4,680	3,848	231	40	93	12	14	72		8,759
1981	5,518	4,992	4,828	234	41	87	12	16	78		10,054
1982	6,044	5,528	6,679	313	61	145	12	15	80		12,520
1983	6,875	6,328	9,019	327	39	178	5	20	85		15,674
1984	7,458	6,858	10,195	395	34	236	3	19	103		17,448
1985	7,573	6,925	12,768	584	34	423	2	15	110		20,277
1986	7,807	7,165	14,126	477	35	309	2	23	108		21,76
1987	10,923	9,809	16,287	466	48	278	8	19	112	1	26,562
1988	9,062	8,322	17,679	741	241	352	14	18	115	1	26,742
1989	10,969	10,097	17,906	560	97	301	17	21	121	3	28,563
1990	12,324	11,460	15,616	506	79	243	31	25	124	4	27,582
1991	14,016	13,046	14,181	772	251	251	29	26	211	4	27,999
1992	14,317	13,199	15,023	798	223	327	34	29	181	4	29,020
1993	14,310	13,064	14,106	731	165	324	33	25	180	4	27,901
1994	14,570	13,022	13,166	632	74	312	31	31	179	5	26,820
1995	13,854	12,543	10,644	759	60	352	31	32	278	6	23,946
1996	13,884	12,569	11,514	828	46	472	36	37	231	6	24,911
1997	13,709	12,457	11,727	789	35	448	42	39	219	6	24,973
1998	13,648	12,321	12,359	839	103	435	43	39	213	6	25,519
1999	13,653	12,459	13,203	982	105	575	59	37	200	6	26,644
2000	13,601	12,521	12,941	990	102	571	60	44	207	6	26,708
2001	14,230	13,304	14,326	1,073	145	576	59	49	232	12	28,703

* 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* in 1987.

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. For the years 1989–1997, this "Other" column also includes small figures for the Environmental Protection Agency (EPA).

d. DoE has recalculated its space expenditures since 1998, making them slightly different.

SOURCE: Office of Management and Budget

Appendix E-1B

Space Activities of the U.S. Government

BUDGET AUTHORITY IN MILLIONS OF EQUIVALENT FY 2001 DOLLARS
(adjusted for inflation)

FY	Inflation Factors	NASA Total	NASA Space[b]	DoD	Other[c]	DoE[d]	DoC	DoI	Ag	NSF[a]	DoT	Total Space
1959	4.8869	1,618	1,275	2,395	166	166						3,836
1960	4.7940	2,512	2,215	2,689	206	206						5,110
1961	4.7489	4,578	4,397	3,866	323	323						8,586
1962	4.6858	8,552	8,420	6,082	932	694	239					15,435
1963	4.6285	17,000	16,783	7,174	1,190	990	199					25,147
1964	4.5745	23,330	22,946	7,315	974	961	14					31,235
1965	4.5160	23,709	23,203	7,108	1,088	1,034	54					31,400
1966	4.4403	22,978	22,490	7,500	950	830	120					30,940
1967	4.2581	21,146	20,567	7,086	907	783	123					28,559
1968	4.2107	19,315	18,654	8,093	734	611	118	0.8	4			27,480
1969	4.0606	16,206	15,520	8,174	692	479	81	0.8	4	127		24,385
1970	3.8877	14,563	13,790	6,524	548	400	31	4	4	109		20,861
1971	3.6899	12,217	11,442	5,579	598	351	100	7	4	136		17,619
1972	3.5078	11,600	10,772	4,935	468	193	109	21	7	138		16,176
1973	3.3460	11,396	10,349	5,431	493	181	134	33	7	138		16,273
1974	3.1994	9,717	8,827	5,650	506	134	192	29	10	141		14,983
1975	2.9873	9,646	8,708	5,652	471	90	191	24	6	161		14,831
1976	2.7168	9,645	8,762	5,387	457	62	196	27	11	161		14,606
TQ	2.5341	2,362	2,151	1,166	109	13	56	8	3	30		3,426
1977	2.4514	9,359	8,433	5,913	474	54	223	25	15	158		14,820
1978	2.3507	9,544	8,517	6,436	531	80	242	24	19	167		15,484
1979	2.2012	10,117	8,871	6,683	546	130	216	22	18	161		16,100
1980	2.0420	10,700	9,557	7,858	472	82	190	25	29	147		17,886
1981	1.8803	10,376	9,387	9,078	441	77	164	23	30	147		18,905
1982	1.7153	10,367	9,482	11,456	536	105	249	21	26	137		21,475
1983	1.6055	11,038	10,160	14,480	525	63	286	8	32	137		25,165
1984	1.5366	11,460	10,538	15,665	607	52	363	5	29	158		26,810
1985	1.4811	11,217	10,257	18,911	865	50	627	3	22	162		30,032
1986	1.4346	11,200	10,279	20,265	684	50	443	3	33	155		31,227
1987	1.4012	15,305	13,744	22,821	653	67	390	11	27	157	1	37,218
1988	1.3650	12,370	11,360	24,133	1,012	329	480	19	25	157	1	36,504
1989	1.3224	14,506	13,353	23,679	741	128	398	22	28	160	4	37,773
1990	1.2731	15,690	14,590	19,881	644	101	309	39	32	157	5	35,115
1991	1.2265	17,191	16,002	17,394	947	308	308	36	32	259	5	34,342
1992	1.1821	16,925	15,603	17,759	943	264	387	40	34	214	5	34,305
1993	1.1561	16,544	15,103	16,308	845	191	375	38	29	208	5	32,257
1994	1.1276	16,428	14,683	14,845	713	83	352	35	35	202	6	30,242
1995	1.1022	15,270	13,825	11,732	836	66	388	34	35	306	7	26,393
1996	1.0794	14,986	13,567	12,428	894	50	509	39	40	249	6	26,889
1997	1.0590	14,518	13,192	12,419	836	37	474	44	41	232	6	26,447
1998	1.0413	14,212	12,830	12,869	874	107	453	45	41	222	6	26,573
1999	1.0282	14,037	12,810	13,575	1,010	108	591	61	38	206	6	27,394
2000	1.0150	13,804	13,134	12,708	1,071	166	584	61	45	210	6	26,914
2001	1	14,230	13,304	14,326	1,073	145	576	59	49	232	12	28,703

APPENDIX E-2

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority			Budget Outlays		
	1999 actual	2000 actual	2001 est.	1999 actual	2000 actual	2001 est.
NASA	12,459	12,521	13,304	12,466	12,427	13,197
Defense	13,203	12,941	14,326	12,453	13,207	13,046
Energy	105	164	145	103	165	143
Commerce	575	575	576	431	517	519
Interior	59	60	59	59	60	59
Agriculture	37	44	49	37	44	49
Transportation	6	6	12	6	6	12
NSF	200	207	232	216	207	213

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		
	1999 actual	2000 actual	2001 est.	1999 actual	2000 actual	2001 est.
NASA[a]	1,194	1,060	926	1,217	1,014	867
Defense[b]	5,532	6,587	6,149	5,913	6,320	6,297
Transportation[c]	2,271	2,201	2,792	2,369	2,243	2,571

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 and Acronyms

A

ACTS	Advanced Communications Technology Satellite
ADEOS	Advanced Earth Observing Satellite
ADS-B	Automated Dependent Surveillance-Broadcast
AEAP	Atmospheric Effects of Aviation Project
AGATE	Advanced General Aviation Technology Experiment
AMOS	Air Force Maui Optical Site
ARS	Agricultural Research Service (USDA)
AST	Advanced Subsonic Technology (Program)
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTP	Apollo-Soyuz Test Project
ATLAS	Atmospheric Laboratory for Applications and Science
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
AVOSS	Advanced Vortex Sensing System
AXAF	Advanced X-ray Astrophysics Facility (former name of Chandra X-ray Observatory)

B

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
BXA	Bureau of Export Administration (DoC)

C

CEOS	Committee on Earth Observation Satellites
CIS	Commonwealth of Independent States
CITEL	Commission on Inter-American Telecommunications
CME	Coronal Mass Ejections
CNES	Centre National d'Etudes Spatiales (France)
COPUOS	Committee on the Peaceful Uses of Outer Space (United Nations)
Corona	The outer atmosphere of the Sun, extending about a million miles above the surface
CORS	Continuously Operating Reference Station
Cosmic rays	Not forms of energy, such as x-rays or gamma rays, but particles of matter
COSPAR	Committee on Space Research
CrIS	Cross-track Infrared Sounder
CRISTA-SPAS	Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite
CSC	Commercial Space Center
CSOC	Consolidated Space Operations Contract
CT	Computerized Tomography
CUE	Collaborative Ukrainian Experiment

D

DAAC	Distributed Active Archive Center
DARWIN	Design Assessment of Reliability With Inspection
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
DSN	Deep Space Network
DSP	Defense Support Program

E

EELV	Evolved Expendable Launch Vehicle (program)
EHF	Extremely High Frequency
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
EOS	Earth Observing System—a series of satellites, part of NASA's Earth Science Enterprise, being designed for launch at the end of the 1990's togather data on global change
EPA	Environmental Protection Agency
EPIC	Environmental Photographic Interpretation Center (EPA)
ERAST	Environmental Research Aircraft and Sensor Technology (project)
EROS	Earth Resources Observation System (USGS)
ERS	European Remote-Sensing Satellite
ESE	Earth Science Enterprise
ESA	European Space Agency
ET	External Tank
ETM+	Enhanced Thematic Mapper-Plus (Landsat instrument)
EUV	Extreme ultraviolet
EVA	Extravehicular activity

F

FAA	Federal Aviation Administration
FACE	Free Air Carbon dioxide Enrichment
FAR	Federal Acquisition Regulation
FAS	Foreign Agricultural Service (USDA)
FCC	Federal Communications Commission
FGB	Functional Cargo Block (Russian acronym)
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)
FSS	Fixed Satellite Service
FWS	(U.S.) Fish and Wildlife Service (DoI)
FY	Fiscal Year

G

Gamma rays	The shortest of electromagnetic radiations, emitted by some radioactive substances
GDIN	Global Disaster Information Network
Geo-stationary	Traveling around the Earth's equator at an altitude of at least 35,000 kilometers and at a speed matching that of the Earth's rotation, thereby maintaining a constant relation to points on the Earth
Geosynchronous	Geostationary
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellite
GOIN	Global Observation Information Network
GPS	Global Positioning System

H

Heliosphere	The region of the Sun's influence, including the Sun and the inter planetary medium
HST	Hubble Space Telescope
Hypersonic	Faster than Mach 4; 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 (such as Earth)

I

ICM	Interim Control Module
IGEB	International GPS Executive Board
IGOS	Integrated Global Observing Strategy
IGS	International GPS Service for Geodynamics
INM	Integrated Noise Model
INMARSAT	International Mobile Satellite Organization
InSAR	Interferometric Synthetic Aperture Radar
INSAT	Indian Remote Sensing Satellite
Integrated modular avionics	Aircraft-unique avionics cabinet that replace 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 short-wave transmissions
IPO	Integrated Program Office
ISO	International Organization for Standardization
ISS	International Space Station
ITA	International Trade Administration (DoC)
ITU	International Telecommunications Union

J

JEM	Japanese Experimental Module
JPL	Jet Propulsion Laboratory (NASA)

K

K-band	Radio frequencies in the 20-gigahertz range
Ka-band	Radio frequencies in the 30-gigahertz range
KSC	Kennedy Space Center
Ku-band	Radio frequencies in the 11–12-gigahertz range

L

Landsat	Land [remote sensing] Satellite—a series of satellites designed to collect information about 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
LEO	Low-Earth Orbit—100 to 350 nautical miles above Earth
LH2	Liquid Hydrogen
LIDAR	Light Intersection Direction and Ranging
LOX	Liquid Oxygen
LVIS	Laser Vegetation Imaging Sensor

M

Mach	A relative number named after Austrian physicist Ernst Mach (1838–1916) and indicating speed with respect to that of sound in a given medium; in dry air at 32 degrees Fahrenheit and at sea level, for example, Mach 1=approximately 741 miles per hour (1,192 kilometers per hour)
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

MCC-H	Mission Control Center–Houston
MCC-M	Mission Control Center–Moscow
MCO	Mars Climate Orbiter
MHz	Megahertz
MilSatCom	Military Satellite Communications
MISR	Multiangle Imaging Spectroradiometer
MMH	Monomethyl Hydrazine
MMS	Minerals Management Service (DoI)
MODIS	Moderate Resolution Imaging Spectrometer
MPL	Mars Polar Lander
MPLM	Multi-Purpose Logistics Module

N

NAPP	National Aerial Photography Program
NAS	National Airspace System (FAA)
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency (of Japan)
NASM	National Air and Space Museum
NASS	National Agricultural Statistics Service (USDA)
NATO	North Atlantic Treaty Organization
NAWQA	National Water Quality Assessment
NCAP	National Civil Applications Program (USGS)
NDGPS	Nationwide Differential GPS
NDOP	National Digital Orthoquad Program
NESDIS	National Environmental Satellite, Data and Information Service (NOAA)
Neutron star	Any of a class of extremely dense, compact stars thought to be composed primarily of neutrons; see pulsar
NEXRAD	Next Generation Weather Radar
NGS	National Geodetic Survey
NGSO	Nongeostationary satellite
NIST	National Institute of Standards and Technology (DoC)
NOAA	National Oceanic and Atmospheric Administration (DoC); also the designation of that administration's Sun-synchronous satellites in polar orbit
Nominal	Functioning as designed
NOx	Oxides of nitrogen
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NPS	National Park Service (DoI)
NRA	NASA Research Announcement
NRCS	National Resources Conservation Service (USDA)
NRO	National Reconnaissance Office (DoD)
NSC	National Security Council
NSF	National Science Foundation
NTIA	National Telecommunications and Information Administration (DoC)—the Federal Government's radio spectrum manager, which coordinates the use of LEO satellite networks, such as those for Landsat, Navstar GPS, the Space Shuttle, and the Television and Infrared Operational Satellite (TIROS), with other countries of the world

NWRC	Northwest Watershed Research Center (ARS)

O

ODERACS	Orbital Debris Radar Calibration Spheres
OLMSA	Office of Life and Microgravity Sciences and Applications (NASA)
OMPS	Ozone Mapping and Profiler Suite
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
OSMRE	Office of Surface Mining Reclamation and Enforcement (DoI)
OSS	Office of Space Science (NASA)
OSTP	Office of Science and Technology Policy

P

PAMS-STU	Passive Aerodynamically Stabilized Magnetically Damped Satellite-Satellite Test Unit
PARCS	Primary Atomic Reference Clock in Space
Pathfinder	A program that focuses on the processing, reprocessing, maintaining, archiving, and distributing existing Earth science data sets to make them more useful to researchers; NASA, NOAA, and USGS are involved in specific Pathfinder efforts
PCB	Polychlorinated biphenyl
PEACESAT	Pan-Pacific Education and Communications Experiment by Satellite
PECAD	Production Estimates and Crop Assessment Division (FAS)
Photo-grammetry	The science or art of obtaining reliable measurements by means of photography
PMA	Pressurized Mating Adapter
POES	Polar-orbiting Operational Environmental Satellite (program)
PPS	Precise Positioning Service
PRA	Probabilistic Risk Assessment
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

Q

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
QuikSCAT	Quick Scatterometer

R

RADARSAT	Canadian Radar Satellite
Ramjet	A jet engine with no mechanical compressor, consisting of specially shaped tubes or ducts open at both ends, along with the air necessary

	for combustion being shoved into the duct and compressed by the forward motion of the engine
RFID	Radio Frequency Identification
RLV	Reusable Launch Vehicle
RPA	Remotely Piloted Aircraft
RSA	Russian Space Agency
RSML	Remote Sensing and Modeling Laboratory (ARS)

S

SAMRSS	Shafter Airborne Multispectral Remote Sensing System
SAO	Smithsonian Astrophysical Observatory
SAR	Synthetic Aperture Radar
SBIRS	Space Based Infrared System
SBS	Satellite Business Systems
Scramjet	Supersonic-combustion ramjet
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SLS	Spacelab Life Sciences
SMA	Safety and Mission Assurance
SNOE	Student Nitric Oxide Experiment
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOHO	Solar and Heliospheric Observatory
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
SPOT	Satellite Pour l’Observation de la Terre (French satellite for the observation of Earth)
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRMU	Solid Rocket Motor Upgrade
SSBUV	Shuttle Solar Backscatter Ultraviolet
SSCC	Space Station Control Center
SSCE	Solid Surface Combustion Experiment
SSME	Space Shuttle Main Engine
SSM/I	Special Sensor Microwave Imager
SSRMS	Space Station Remote Manipulator System
SSTF	Space Station Training Facility
SSTI	Small Satellite Technology Initiative
START	Strategic Arms Reduction Treaty
STS	Space Transportation System
SWAS	Submillimeter Wave Astronomy Satellite

T

TA	Technology Administration (DoC)
TATP	Triacetone triperoxide (terrorist explosive)
TDRS	Tracking and Data Relay Satellite
TERRIERS	Tomographic Experiment using Radiative Recombinative Ionospheric

	EUV and Radio Sources
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment
TRACE	Transition Region and Coronal Explorer
TRACON	Terminal Radar Approach Control (system)
TRMM	Tropical Rainfall Measuring Mission

U

UARS	Upper Atmosphere Research Satellite
UHF	Ultrahigh Frequency—any frequency between 300 and 3,000 megacycles per second
UNISPACE	United Nations Conference on the Exploration and Peaceful Uses of Outer Space
URET	User Request Evaluation Tool
U.S.	United States
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey (DoI)
USML	U.S. Microgravity Laboratory
USMP	U.S. Microgravity Payload
USWCL	U.S. Water Conservation Laboratory (ARS)

V

VCL	Vegetation Canopy Lidar
VHF	Very High Frequency—any radio frequency between 30 and 300 megacycles per second
VLBA	Very Large Baseline Array
VLSA	Very Large Scale Aerial

W

WAAS	Wide Area Augmentation System
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
WIRE	Wide-field Infrared Explorer
WRC	World Radiocommunication Conference
WSDDM	Weather Support to Deicing Decision Making
WSF	Wake Shield Facility

X-Y-Z

X rays	Radiations of very short wavelengths, beyond the ultraviolet in the spectrum
XRSIM	X-ray simulation software

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NP-2003-3-304-HQ