Aeronautics and Space Report of the President

Fiscal Year 2002 Activities

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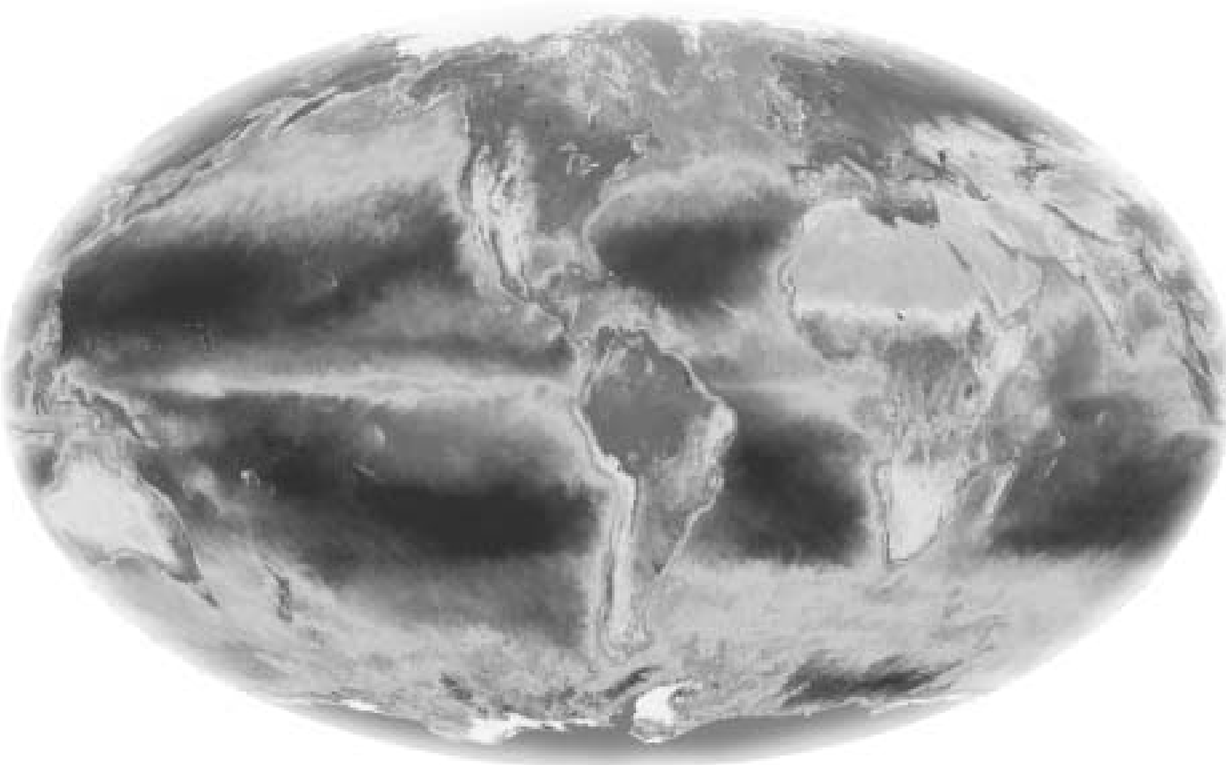

Fiscal Year 2002 Activities

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, 2001, through September 30, 2002.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

Fiscal Year (FY) 2002 brought advances on many fronts in support of NASA's new vision, announced by Administrator Sean O'Keefe on April 12, "to improve life here, to extend life to there, to find life beyond." NASA successfully carried out four Space Shuttle missions, including three to the International Space Station (ISS) and one servicing mission to the Hubble Space Telescope (HST). By the end of the fiscal year, humans had occupied the ISS continuously for 2 years. NASA also managed five expendable launch vehicle (ELV) missions and participated in eight international cooperative ELV launches.

In the area of space science, two of the Great Observatories, the Hubble Space Telescope and the Chandra X-Ray Observatory, continued to make spectacular observations. The Mars Global Surveyor and Mars Odyssey carried out their mapping missions of the red planet in unprecedented detail. Among other achievements, the Near Earth Asteroid Rendezvous (NEAR) Shoemaker spacecraft made the first soft landing on an asteroid, and the Solar and Heliospheric Observatory (SOHO) monitored a variety of solar activity, including the largest sunspot observed in 10 years. The education and public outreach program stemming from NASA's space science missions continues to grow. In the area of Earth science, attention focused on completing the first Earth Observing Satellite series. Four spacecraft were successfully launched. The goal is to understand our home planet as a system, as well as how the global environment responds to change.

In aerospace technology, NASA conducted studies to improve aviation safety and environmental friendliness, progressed with its Space Launch Initiative

Program, and explored a variety of pioneering technologies, including nanotechnology, for their application to aeronautics and aerospace.

NASA remained broadly engaged in the international arena and concluded over 60 international cooperative and reimbursable international agreements during FY 2002.

In FY 2002, the Office of Space Flight continued to support NASA's mission to understand and protect our home planet, explore the universe and search for life, and inspire the next generation of explorers by providing safe and reliable access to space for crew and a variety of payloads. NASA's space flight missions and our astronauts are the most visible face of NASA and play a key role in inspiring the public. The Space Shuttle provides transportation to the ISS, where scientific research is constantly underway. NASA's Earth and space science missions, as well as other external missions, launch aboard expendable launch vehicles and the Space Shuttle. Our Advanced Systems programs enable us to look beyond low-Earth orbit to a time when humans can explore our solar system and beyond.

NASA successfully accomplished four Space Shuttle missions during FY 2002. One mission was a spectacular and highly successful fourth servicing mission to the Hubble Space Telescope (HST). The servicing not only repaired the telescope, but also improved its capabilities, allowing us to look even deeper into the universe. Three of the missions delivered crew, supplies, and assembly hardware to the ISS. At the end of the fiscal year, the ISS had received 14 Space Shuttle dockings and had continuous human presence on board for 2 years. The Expedition Four crew broke the U.S. record for time in space with a stay of 196 days.

The three Space Shuttle missions to the ISS in FY 2002 focused on assembling the truss, which provides the primary structure and a distribution system for many of the key utilities essential for onorbit operations, and Station logistics. Wires, cables, and cooling lines will snake through the truss, circulating energy, information, and fluids throughout the ISS. Canada's Mobile Servicing System will move its robotic arm along tracks attached to the truss.

The first Space Shuttle launch in FY 2002 was in December 2001. Major elements of the STS-108 flight (ISS Utilization Flight 1) of the Space Shuttle Endeavour were a new ISS crew, the fourth flight of an Italian-built Multipurpose Logistics Module (MPLM), and an ExtraVehicular Activity (EVA) to install thermal blankets over two pieces of equipment at the bases of the Space Station's solar wings. The ISS Expedition Four crew (ISS Commander Yury Onufrienko and Flight Engineers Daniel Bursch and Carl Walz) replaced the Expedition Three crew (ISS Commander Frank Culbertson, Flight Engineer Mikhail Tyurin, and Pilot Vladimir Dezhurov), who were launched to the Station in August 2001.

The Space Shuttle Columbia was used in March 2002 as the foundation for the latest HST servicing mission (STS-109), the fourth since HST was launched in 1990. Two astronaut teams accomplished five demanding and spectacular EVAs. They installed additional durable solar arrays, a large gyroscopic assembly to help point the telescope properly, a new telescope power control unit, and a cooling system to restore the use of a key infrared camera and spectrometer instrument that had been dormant since 1999. The telescope's view of the universe has been dramatically improved with the addition of the newest scientific instrument—the Advanced Camera for Surveys (ACS). The spacewalks and specific tasks to upgrade Hubble's instruments were more intricate and challenging than astronauts had encountered in previous servicing missions, and its successful repair is a notable achievement for the U.S. space program.

In April 2002, the Space Shuttle Atlantis expanded the ISS on mission STS-110 (ISS Assembly Flight 8A), installing the initial section of a framework that eventually will hold systems needed to provide power and cooling for future research laboratories. Atlantis's mission was one of the most complex ISS assembly flights NASA has accomplished. It included four EVAs and operations with both the Shuttle's robotic arm and the Station's robotic arm. The Station's Canadarm2 robotic arm was used to hoist the 13-ton truss section, called the S-Zero (S0) Integrated Truss Structure, from Atlantis's payload bay and attach it to the ISS. The flight marked the first time that the Station's arm was used. This was also the first Space Shuttle flight in which all spacewalks originated from the ISS's airlock.

The next mission, STS-111, aboard the Space Shuttle Endeavour in June, delivered the Expedition Five crew (ISS Commander Valery Korzun and Flight Engineers Peggy Whitson and Sergei Treschev) to the ISS and returned the Expedition Four crew, who had been in space since December 2001. During docked operations, the crew transferred several thousand pounds of logistics and equipment to the ISS. There were three successful spacewalks during which the Mobile Remote Servicer Base System was removed from Endeavour's cargo bay and installed on the Mobile Transporter on the ISS. Endeavour delivered replacement parts for a faulty wrist joint on the ISS's robot arm, Canadarm2. The suspect parts were successfully replaced on this mission, enabling use of this key piece of ISS assembly hardware.

At the end of FY 2002, after 2 years of continuous occupation, the ISS had seven research racks on orbit with 25 investigations underway, representing U.S. and international partner research from government, industry, and academia. This work represents approximately 1,000 hours of crew time dedicated to research, leveraging almost 90,000 hours of experiment run time.

Basic research is being conducted in biology, physics, chemistry, ecology, medicine, manufacturing, and the long-term effects of space flight on humans. Several commercial experiments are also being conducted on bone loss treatments, plant growth, pharmaceutical production, and petroleum refining. Some of the first ISS experiments are still ongoing, and some earlier experiments have already returned to Earth. Detailed postflight analysis continues on these experiments. Additionally, a significant component of the research has involved hundreds of primary and secondary school students who loaded experiments, assigned Earth photography targets, followed science activities via the Internet, and used the results in their classroom studies.

NASA Administrator Sean O'Keefe continued to increase the Agency's emphasis on research, which is the ISS's main mission. In September 2002, he named Dr. Peggy Whitson the first NASA ISS Science Officer.

During FY 2002, NASA continued work on the Space Shuttle Safety Upgrades Program. This program's goal is to improve flight crew safety, to protect people both during flight and on the ground, and to increase the overall reliability of the Shuttle system. The Cockpit Avionics Upgrade (CAU) design will significantly improve crew performance margins in safety-critical, high-workload scenarios and mitigate risk of crew error throughout all critical flight operational phases. The CAU project completed its Preliminary Design Review in April 2002 and is proceeding toward project implementation at the end of FY 2002. The Space Shuttle Main Engine Advanced Health Monitoring System (AHMS) is proceeding on schedule for its first flight in mid-2004. AHMS will provide real-time vibration monitoring of the Space Shuttle Main Engine (SSME) and improved engine anomaly response capabilities.

The Space Shuttle Supportability Upgrade Program delivered and flew the Device Driver Unit (DDU) and the Modular Memory Unit (MMU) in FY 2002. The DDU, which flew aboard Columbia on STS-109 in March 2002, eliminates spurious outputs during power-up and power-down and simplifies crew procedures in the orbiter cockpit. The MMU, which flew aboard Atlantis on STS-110 in April 2002, replaces the old magnetic tape units in the orbiter with solid-state technology. The MMU is lighter in weight, uses less power, and provides greater storage and faster data transfers.

In March 2002, the Space Shuttle program began an assessment to identify upgrades and supportability investments that may be required to maintain the Space Shuttle fleet capability to fly safely through 2020. Evaluating and prioritizing upgrade candidates were scheduled to take place after the end of FY 2002.

As a result of the 2020 assessment, the upgrades program has been restructured, and the new name for the program is the Service Life Extension Program (SLEP). The primary objective of the SLEP is to reduce risk and to keep the Space Shuttle safe and viable until a new human space flight transportation system is available. The program is a well-integrated prioritization process aligned with NASA's goals, the Integrated Space Transportation Plan, and customer requirements. It addresses systemwide investments in safety, supportability, obsolescence, infrastructure, and ground systems. The prioritization process criteria include safety, reliability, maintainability, supportability, performance, and cost reduction. The first half of FY 2003 will be used for detailed review of potential improvement projects, each of which will be reviewed based on the nature of the identified issue and its attendant risk, the systems engineering impacts of the proposed improvements, the alternative strategies and solutions, and the cost and schedule projections and reserve strategies.

As part of NASA's implementation of the President's Management Agenda, NASA began considering competitive sourcing of Space Shuttle operations during FY 2002. To obtain a private-sector perspective, NASA commissioned the RAND Corporation to lead an independent task force of representatives from the business community to identify and evaluate possible business models for future Space Shuttle operations. The RAND study found that there is a very tight linkage among the Space Shuttle, the ISS, and the Space Launch Initiative programs. Any major decision on one program could have a profound effect on the others. In addition, a decision on the future of the Space Shuttle program could significantly alter the options available to address future human space exploration and any potential military space requirements. The RAND Study Task Force offered numerous other findings and recommendations, including the following:

- Safe operations must remain the top priority.
- Market demand for Space Shuttle exists, but is very limited.
- The transfer of civil service personnel to a private-sector company has limited viability.
- Liability concerns affect Space Shuttle asset ownership, but not operations.
- The Space Shuttle program remains structured as a development program in a form that is not conducive to independent operation by a private firm.

NASA began to factor the study findings and recommendations into its deliberations as the Agency sought to develop a preliminary Space Shuttle competitive sourcing plan at the end of FY 2002.

Of the 15 U.S. expendable launch vehicle launches in FY 2002, 5 were NASA-managed missions. The first launch of the Atlas V launch vehicle ushered in a new family of Atlas vehicles for use by commercial, civil, and national defense for the next decade. All of the U.S. launches successfully deployed their payloads; however, communication with the NASA Comet Nucleus Tour (CONTOUR) spacecraft was lost weeks after the spacecraft deployment. A spacecraft anomaly investigation was initiated and was underway at the end of the fiscal year.

NASA was involved with eight international cooperative Expendable Launch Vehicle launches in FY 2002. Six of the eight launches were Russian-provided Soyuz and Progress launches to the ISS. The remaining two launches carried NASA scientific spacecraft aboard Russian (Rockot) and Ukrainian (Zenit) launch vehicles as part of an international scientific collaboration.

NASA and the national defense organizations involved in space launch continued to build on their collaborative relationship by sharing launch vehicle technical information and resources for technical penetration into current and evolved launch vehicle systems.

In the area of Space Communications, NASA's Space Network, Ground Networks, Deep Space Network, and Wide Area Network successfully supported all NASA flight missions and numerous commercial, foreign, and other U.S. Government agency missions. Included were four Space Shuttle missions, the launch of Earth Observing System (EOS) Aqua on a Delta booster, and the launch of NOAA-M. Over 15 ELVs were supported, including Delta, Atlas, Titan, Sea Launch, Ariane, H-IIA, and Pegasus. Space Communications successfully supported 30 sounding rocket campaigns from Wallops Flight Facility's (WFF) Poker Flat Research Range and other remote sites.

The Consolidated Space Operations Contract completed the 45th month of a 5-year basic period of performance. Operations support continued at the Johnson Space Center (JSC), Jet Propulsion Laboratory (JPL), Goddard Space Flight Center (GSFC), Marshall Space Flight Center (MSFC), and Kennedy Space Center (KSC).

The first of three second-generation Tracking and Data Relay Satellite (TDRS) satellites, TDRS-H, was transitioned into operations. TDRS-I was launched in March 2002, and preparations were made for the launch of TDRS-J. The Data Services Management Center at White Sands Complex (WSC) was transitioned to operations, providing cost savings and centralized scheduling capabilities for the Space Network and Ground Network. Other cost-saving initiatives completed by Space Communications in FY 2002 included Data Services Automation at WSC, Mission Data Storage Consolidation at JSC, and Operations Support Team Automation at JSC. Several Wide Area Network services for the Space Shuttle and ISS were reengineered to reduce operations costs, including replacing a domestic communications satellite circuit between WSC and GSFC with a terrestrial circuit. Space Communications implemented a 5.4-m Ka/S-band antenna at WFF to support Ka-band technology testing and interoperability demonstrations with the U.S. Air Force. Commercialization continued in FY 2002 with expanded contracts with Space Data Services (Norway) and Honeywell/DataLynx, as well as issuance of a subcontract to a Satellite Applications Center in South Africa.

Office of Space Flight personnel also implemented several initiatives involving educational institutions, including the transition of selected mission services operations for the Wide-field Infrared Explorer (WIRE) and Fast Auroral Snapshot Explorer (FAST) spacecraft to universities (Bowie State and UC-Berkeley) and the establishment of a Space Communications contractor "storefront" presence at Prairie View A&M, University of Texas-El Paso, Oakwood College, and Alabama A&M. Each storefront involves setting up a mentoring environment near or on selected university campuses, where students are then trained and hired to perform engineering work under the supervision of one of

NASA's contractors. In FY 2002, Space Communications conducted international telemedicine demonstrations between the University of Mississippi Medical Center and doctors in Japan. Space Communications also received a Federal Energy and Water Management Award at the Merritt Island Launch Annex.

Throughout FY 2002, NASA continued to define potential human and robotic exploration architectures and technologies through the efforts of an interagency planning team. NASA's Exploration Team (NEXT) updated a family of strategic research and technology roadmaps that establish future directions, options, and opportunities for Technology for Human and Robotic Exploration and Development of Space (THREADS). NEXT also implemented a series of highly focused technology concept validation activities ranging from new planetary mobility applications, to advanced multibandgap solar arrays, to highly redundant and reconfigurable wireless avionics boards. Finally, NEXT developed new concepts and investigated prospects for applications of a wide range of emerging technologies for future human and robotic exploration and development of space. These studies have changed the way NASA approaches exploration and will be continued in FY 2003.

In partnership with NASA's Office of Space Science and Office of Aerospace Technology, the Office of Space Flight's Advanced Systems Office continued to identify and define common Agency space exploration goals and fund space research initiatives such as propulsion, communications, and space power.

The Office of Space Science (OSS) ended calendar year 2001 with the successful launch of the TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics) mission in December. TIMED is studying a region of Earth's atmosphere that has never been the subject of a comprehensive, long-term scientific investigation. As we entered FY 2002, the Microwave Anisotropy Probe (MAP) completed its 3-month journey and arrived at its L-1 destination, half a million miles from Earth. MAP is a NASA Explorer mission that is measuring 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.

On February 5, 2002, NASA launched the High-Energy Solar Spectroscopic Imager (HESSI), which is a mission to study solar flares and the gamma rays they emit. Just over 1 month after launch, HESSI made its debut by observing a huge explosion in the atmosphere of the Sun. The solar flare was equal to 1 million megatons of TNT and gave off powerful bursts of x rays. The new solar flare satellite was renamed RHESSI—the Reuven Ramaty High-Energy Solar Spectroscopic Imager—in honor of the late NASA scientist who pioneered the fields of solar-flare physics, gamma-ray astronomy, and cosmic-ray research.

A pair of spacecraft, the Mars Global Surveyor and the Hubble Space Telescope (HST), teamed up to provide astronomers with a ringside seat to the biggest global dust storm seen on Mars in several decades. The Martian dust storm, larger by far than any seen on Earth, raised a cloud of dust that engulfed the entire planet for several months. The Sun-warmed dust raised the atmospheric temperatures by 80 degrees Fahrenheit while the shaded surface chilled precipitously. The Mars Odyssey 2001 spacecraft successfully achieved orbit around Mars following a 6-month, 286-million-mile journey. (Following aerobraking operations, Odyssey entered its science-mapping orbit in February 2002 and began characterizing the composition of the Martian surface at unprecedented levels of detail.)

In March 2002, the HST got its fourth and most challenging servicing to date from the STS-109 astronaut crew. The result of their extraordinary efforts was a Hubble that was more scientifically robust than at any other time of its 12-year life. It gained new, more efficient solar arrays, a new power control unit, a resuscitated Near Infrared Camera and Multi-Object Spectrometer (NICMOS), and a powerful new resource called the Advanced Camera for Surveys (ACS). The first results from this new instrument were released on April 30, 2002, and made news around the world. The remarkable images let us see deep into the universe with unprecedented detail. One image of the Tadpole galaxy had a bonus: a background that showed approximately 6,000 other galaxies—twice the number of galaxies that are visible in the now-famous Hubble Deep Field image.

Our Far Ultraviolet Spectroscopic Explorer (FUSE) spacecraft returned to life and full operations in March 2002, when the team developed an innovative new guidance system. The system used a complex new set of procedures that let controllers use electromagnets in the satellite to push and pull on Earth's magnetic field. Experts had speculated about such an approach as a fallback for failing satellite guidance systems, but it had never been employed to steer a satellite with the exacting accuracy needed for scientific observations.

The Chandra X-Ray Observatory, launched aboard the Space Shuttle Columbia in July 1999 during STS-93, continued its impressive performance and delivered data and images, which have enhanced our current understanding of black holes on many fronts. Chandra 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 captured the first x-ray flare ever seen from the supermassive black hole at the center of our own Milky Way galaxy. The Chandra observations, together with ultraviolet observations, are a major advance in our understanding of how the universe evolved over the last 10 billion years.

The Near Earth Asteroid Rendezvous (NEAR) Shoemaker spacecraft achieved the first soft landing on an asteroid—the culmination of a yearlong orbital mission at the asteroid Eros during which it returned enormous quantities of scientific data and images.

The Sun-Earth Connections program accomplishments in 2002 included the Solar and Heliospheric Observatory (SOHO), which continued to observe the largest sunspot in 10 years—a sunspot with a surface area as big as that of 13 Earths. This area proved to be a prolific source of stormy solar activity, hurling clouds of electrified gas known as coronal mass ejections (CME) toward Earth. SOHO also provided the first clear picture of what lies beneath sunspots: swirling flows of electrified gas that create a self-reinforcing cycle, holding the sunspot together.

July 2002 began with the loss of the Comet Nucleus Tour (CONTOUR) Discovery mission that was to visit and study at least two comets. A failure review team was formed, and the team members began analyzing data to determine the cause of the loss.

Slowly rising from the Northwest region of Manitoba, Canada, near a small gold-mining town called Lynn Lake, a massive NASA balloon began a journey on August 25, 2002, that took it to the fringes of space. The balloon carried a solar and heliosphere experiment called Low Energy Electrons (LEE) that weighed 1,500 pounds (690 kg). Aside from the fact that this balloon established a new record for balloon volume (50 percent greater than NASA's standard balloon designs), this flight should help establish a new platform for science such as ultraviolet and x-ray astronomy.

With a focus on precollege education and the public understanding of science, NASA's Space Science Education and Public Outreach (E/PO) program is now one of the largest programs in astronomy and space science education ever undertaken. E/PO activities are embedded in every OSS flight mission and research program.

NASA's Aerospace Technology Enterprise sought to improve air and space travel, space-based communications, and high-performance computing through fundamental research and technology development during FY 2002. The Enterprise's technical accomplishments were organized around three of its strategic goals: revolutionize aviation, advance space transportation, and pioneer technology innovation.

Its first strategic goal was to revolutionize aviation by enabling its safe, environmentally friendly expansion. In FY 2002, Aerospace Technology examined aviation accident trends and identified technologies that would improve the safety of the national airspace system. In cooperation with the Federal Aviation Administration (FAA) and the aviation industry, Aerospace Technology looked into accidents and incidents involving hazardous weather, controlled flight into terrain, human-performance-related causal factors, and mechanical or software malfunctions. Aerospace Technology identified and assessed the situations and trends that led to accidents and then developed information technologies for building a safer airspace system.

These safety technologies included a self-paced, computer-based training program to help pilots detect, avoid, and minimize exposure to icing. The program explains the effects of icing on aircraft performance and describes how to detect and recover from icing-related wing and tail stalls (loss of lift). Pilot testimonials, animation, case studies, interactive demonstrations, and ice accretion images from NASA's icing research aircraft and icing research tunnel enhance the presentation. U.S. and European airline operators, Cessna Aircraft Company, Transport Canada, United Express, the Ohio Civil Air Patrol, and the U.S. Army Safety Center received copies of the program, which is also available online. Originally released on videotape in 2000, a computer-based training program for pilots of larger aircraft became available on compact disc in FY 2002 with additional training exercises and content for student pilots. The Agency collaborated with the FAA, the Air Line Pilots Association, and the University of Oregon on this effort.

Several weather-related safety technology demonstrations took place in FY 2002. One, a forward-looking, turbulence warning system, completed its 20th flight in NASA's commercial-transport-size research aircraft. The system's performance has been excellent, demonstrating an 81-percent probability of detecting severe turbulence more than 30 seconds before it happens and a nuisance alarm rate of only 11 percent.

In addition, Aerospace Technology demonstrated software designed to help airlines schedule flight crews for long-haul flights. Aerospace Technology based this scheduling-assistant software on neurobehavioral, subjective, and operational measurements collected during commercial long-haul flights. The software predicts the effects of acute sleep loss, cumulative sleep loss, and circadian desynchrony (disruption of the normal 24-hour cycle) on waking performance. Airlines can also use this software to minimize practices that lead to in-flight fatigue.

In FY 2002, the first tests of a low-emission aircraft engine combustor sector (a segment of a full combustor design) produced a nitrogen oxides reduction of 67 percent below 1996 International Civil Aircraft Organization standards. This result is just 3 percentage points short of NASA's goal of a 70-percent reduction, 40-percent fewer nitrogen oxides emissions than current commercial aircraft engines, and 17-percent fewer than the combustor design Aerospace Technology demonstrated last year.

A new ceramic thermal barrier coating increases the ability of turbine blades in aircraft engines to tolerate high temperatures. At higher temperatures, fuel burns more completely and with fewer emissions. Turbine blades located directly behind the engine's hot combustor section must withstand these high temperatures. In FY 2002, NASA's coated test blades withstood temperatures 300 ˚F higher than standard blades. They survived 1,200 cycles (100 hot hours) at surface temperatures of 2,480 ˚F. This new coating will significantly increase the ability of both high-pressure turbine and combustor liner components to withstand high temperatures.

The Enterprise completed two feasibility studies in FY 2002. One considered using fuel cells to power a state-of-the-art aircraft and predicted that such an aircraft would have a 54-nautical-mile range with a 140-pound payload. Fuel-cell technology developments currently on the horizon may allow a fuel-cell-powered craft to exceed the payload and range of current piston-powered aircraft. The second study considered using liquid hydrogen to fuel a transport aircraft at today's state of the art, at 2009, and at 2022 technology levels, and it predicted that by 2022, hydrogen-powered transport aircraft could have a 52-percent lower gross weight at takeoff, lower nitrogen oxides emissions, and no carbon dioxide emissions while maintaining the same payload and range as conventionally powered aircraft.

System-level noise assessments are critical to determining which technologies have the highest potential for reducing community noise. In FY 2002, a beta version of the Advanced Vehicle Analysis Tool for Acoustics Research software showed great promise in providing these assessments. The software had all the prediction capabilities of NASA's Aircraft Noise Prediction Program and ran on the Linux operating system. It also corrected for propagation of jet noise, could predict noise from advanced high-bypass ratio engines and airframe subcomponents, and accounted for wind and temperature gradient effects on noise propagation. With these enhancements and its physics-based modeling capability, the software could allow designers to treat the various airframe and engine noise sources as an interrelated system and find the best set of components for noise mitigation.

In FY 2002, Aerospace Technology conducted a simulation of the interoperability of two new graphical traffic automation tools: the Surface Management System and the Traffic Management Advisor. Both proved their worth to FAA tower controllers, including the traffic management coordinator from Dallas/Fort Worth International Airport. In the simulation, the coordinator used the tools to decide when to switch a runway from departures to arrivals. The coordinator found that the tools' timelines showing predicted arrivals and departures were the most helpful aid in determining when to change the runway configuration and in balancing departures.

The Traffic Flow Automation System, a decision-support tool for predicting traffic loads, was developed and evaluated in FY 2002. As much as a minute earlier than current tools, this tool tells FAA controllers how much air traffic will be entering their sector of the sky. The software, running on a Unix-based computer cluster, processed all of the air traffic in the national airspace system's 20 Air Route Traffic Control Centers simultaneously. The new tool predicts sector loading more accurately than the current tool and is 15 to 20 seconds faster.

New technologies to increase small aircraft safety in nearly all weather conditions can greatly increase the capacity of the Nation's air system. The Small Aircraft Transportation System project will develop such technologies. In FY 2002, the project partners (NASA, the FAA, and the National Consortium for

Aviation Mobility) began work to develop, evaluate, and demonstrate four new operating capabilities for small aircraft.

The Aerospace Technology Enterprise's second strategic goal was to advance space transportation by creating a safe, affordable highway through the air and into space. FY 2002 produced solid achievements in the development of space launch technologies. The Enterprise achieved all of its annual performance goals. The Space Launch Initiative Program, after extensive analyses, narrowed architecture designs and conducted stringent systems engineering evaluations to ensure that selected designs will be viable and that NASA's future technology investments are relevant to those designs.

In FY 2002, the Space Launch Initiative program narrowed its potential architecture designs—from hundreds to the 15 most promising—and aligned technology development investments to support them. Stringent systems engineering evaluations ensure that designs are viable and that technology investments are relevant. The Enterprise has created an advanced engineering environment to analyze and validate data in order to ensure that the Government is a smart buyer. Interrelated technology projects focus on such innovations as long-life rocket engines, robust thermal-protection materials, and sophisticated diagnostic software. Aerospace Technology has completed designs for a crew transfer/return vehicle and has several options for near-term development.

Propulsion is one of the keys to improving space access. In FY 2002, the Enterprise tested flight engine prototypes and components. A new liquid-oxygen/kerosene engine may afford quick turnaround and be fully reusable. An integrated vehicle health-management system demonstrates the potential to use model-based reasoning software to monitor the condition of the entire space launch system in every phase of operation.

In FY 2002, the Space Transfer and Launch Technology program completed critical tests and established partnerships with industry and academia. Materials scientists improved airframe materials, and research engineers established design requirements for the rocket-based combined-cycle engine. The X-43C vehicle's preliminary and systems-level requirements will provide the project's baseline goals, a decision that moves NASA closer to procuring X-43C demonstrator vehicles. Aerospace Technology awarded two University Research Education and Technology

Institute grants: the Universities of Maryland and Florida will each receive $5 million annually for work in airframe and propulsion technologies research.

In FY 2002, research engineers demonstrated a 10-kilowatt ion engine designed for use in nuclear electric propulsion systems. Such an engine, with its nearly constant propulsion, could greatly reduce trip times for interplanetary missions. The high-power ion engine with titanium ion optics increased power by a factor of four and produced a 62-percent greater specific impulse than the state-of-the-art ion engine.

The Aerospace Technology Enterprise's third strategic goal was to pioneer technology innovation to enable a revolution in aerospace systems. In FY 2002, the Enterprise developed engineering tools and computational architectures to reduce system design and analysis time, link geographically distant researchers in collaborative environments, speed software verification, provide adaptive capabilities for flight control systems, reduce mission risk, and streamline mission operations.

Several demonstrations in FY 2002 showed the potential of advanced engineering tools to reduce system design and analysis time and to streamline mission operations. Engineers rapidly redesigned a crew return vehicle (to bring back Station crews in emergency conditions) using a flight-simulation environment while pilots provided real-time feedback on handling qualities. A high-performance computing algorithm allowed mission designers to generate a database of reusable launch vehicle concepts without extensive numerical simulation. This cut the time required to evaluate vehicle concepts from several months to a week and reduced design cycle time to less than one-third that of state-of-the-art techniques. An adaptive grid generator for computational fluid dynamics analysis decreased computation time by a factor of 15.

Aerospace Technology developed a collaborative workspace to streamline mission operations for the Mars Exploration Rover. The workspace allows dispersed scientists, engineers, and mission operators to interactively develop mission plans and monitor mission status. Collaborative engineering environments could substantially reduce the time needed to conduct tests and plan mission operations.

The Enterprise conducted a successful proof-of-concept demonstration for a goal-oriented autonomous architecture tool. This software allowed prototype Mars rovers to plan their own paths and determine ideal instrument placement. The software also reduced the number of command cycles needed to direct the rover to reach objects of scientific interest. An intelligent flight-control system using adaptive neural networks—an artificial brain that learns from experience—improved aircraft performance and reconfigured the control system to maintain vehicle stability when failures occurred. Such intelligent systems will result in safer, more efficient flight.

In FY 2002, the Enterprise developed technology to make possible high-data-rate space communications from small ground stations in order to provide advanced aircraft with simplified high-lift systems using active flow control and to demonstrate nanotechnology applications for chemical sensors and high-strength composites. The 622-megabit-per-second space communications link provides direct access to scientific data from satellites in low-Earth orbit using only a small, portable ground station. The ground station uses a digital modem and is about one-fourth the size of the ground station presently required. This affordable way for users to communicate directly with spacecraft substantially reduces the time and expense needed to acquire and distribute data. These small ground stations can also supplement the existing space communications infrastructure to increase coverage or redundancy.

In FY 2002, Aerospace Technology demonstrated that an active-flow-control technology could improve lift and stability on advanced aircraft. Active flow control allows aircraft to use simpler high-lift systems that can reduce noise and allows transport-sized aircraft to access smaller airports. Because these systems are typically lighter, they can also reduce fuel use and emissions. In addition, a simulation demonstrated how flow-control technology could affect aircraft stability. This flow-control system used a porous wing, sections of which could reconfigure to maintain stability when other aircraft components failed. The porous wing may one day replace conventional control surfaces to reduce weight and improve safety.

Nanotechnology (the science of manipulating materials on an atomic or molecular scale) may change our lives in a multitude of ways. NASA is engaged in nanotechnology research with potential applications to aeronautics and aerospace. For example, in FY 2002, Aerospace Technology demonstrated that it is possible to fabricate ultrasensitive chemical sensors from carbon nanotubes by attaching nucleic acids and other probe molecules to the nanotube's tip. When specific chemicals bonded with the probe molecule, a measurable change occurred in the nanotube. Potential applications for nanosensors include the search for life on other planets, medical diagnostics such as detecting cancer cells, and the detection of biological and chemical threats to the Nation's security.

In FY 2002, the Enterprise also aligned carbon nanotubes in a polymer matrix by extrusion. This is an important first step in developing carbon-nanotube-based composite materials. Nanotube fibers are usually produced in tangled bundles. Materials scientists believe that carbon-nanotube-based composites with their fibers aligned in a single direction may be stronger than steel by a factor of 100 at one-sixth the weight. If these materials can be developed, they will significantly reduce the weight of aircraft, launch vehicles, and spacecraft.

NASA's Earth Science Enterprise (ESE) remained dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment. From the vantage point of space, NASA provides information about Earth's land, atmosphere, ice, oceans, and life that is obtainable in no other way, providing unique insights into our environment as only NASA can. NASA continued to use the measurements from satellite systems to study the interactions among these Earth system components to advance the discipline of Earth system science and contribute sound scientific knowledge for the development of environmental policy and economic investment decisions that serve our society and improve life here. In addition to purely scientific contributions, NASA continued to develop innovative technologies and science-based applications of remote sensing for solving practical societal problems in agriculture and food production, natural hazard mitigation, water resources, regional planning, and national resource management in partnership with other Federal agencies, industry, and State and local governments.

ESE science activities in FY 2002 focused on the completion of the first Earth Observing Satellite (EOS) series and characterization of the forces acting on the Earth system and its responses. The Earth Science Enterprise successfully launched four spacecraft in FY 2002. Jason-1, a joint mission with France, makes precision ocean topography measurements begun by TOPEX-Poseidon and is now employed in weather and climate forecasts. The Stratospheric Aerosol and Gas Experiment (SAGE III), launched in a joint mission with Russia, measures ozone and aerosols in the upper atmosphere. The Gravity Recovery and Climate Experiment (GRACE), a joint mission with Germany, uses a microwave beam between twin satellites to make precise measurements of Earth's gravity field, allowing for improvement in ocean topography and enabling inferences about the distribution of mass in Earth's interior. Aqua, launched in May 2002, acquires precise atmospheric and oceanic measurements to enable the study of the global water cycle, leading to the next generation of climate and weather forecasts. NASA's unique space-based observations of the variability inherent in the Earth system have enabled Earth scientists both to extend their view of previously observed global environmental parameters and to extend their measurements over a progressively longer period of time using state-of-the-art observational techniques. For the first time, NASA Earth scientists have demonstrated new global environmental observations that were not previously available. Particular advances in FY 2002 have occurred in the areas of sea ice, ocean biology, and polar ice sheets.

The extent of ice in the Arctic has been shown to have decreased by several percent per decade from 1979 to 2000, while in the Antarctic, sea ice has been shown to have increased slightly over roughly the same period. Moreover, the thicker perennial ice cover in the Arctic has been observed to be decreasing by a factor of three, which has the potential to impact ocean circulation significantly.

In the area of ocean biology, ESE gathered new data sets from two different satellite instruments and plans to combine them to improve NASA's knowledge of the phytoplankton distribution in the ocean. This microscopic organism serves as the base for the marine food chain and plays an important role in the exchange of carbon between the biosphere and the atmosphere. The exchange that takes place affects the buildup of carbon dioxide in the atmosphere that can, in turn, affect climate.

New results from aircraft-based remote-sensing campaigns over polar ice sheets in Greenland and Antarctica provided ESE with the ability to make a quantitative assessment of changes in ice cover, especially at the margins between ice sheets and the ocean. Quantitative knowledge of the behavior of ice sheets is important for testing climate models and improving our ability to provide assessments of potentially hazardous changes in sea level and sea ice distributions. In FY 2002, ESE completed development of the first space-based laser altimeter for ice sheet topographic mapping for launch in FY 2002.

NASA continued to provide global observations of some of the primary drivers of global change, including global distributions of radiatively and chemically active trace gases and aerosol particles, top-of-the-atmosphere observations of solar irradiance, and global observations of land cover and land use change.

Particular highlights of FY 2002 achievements were made in the studies of atmospheric aerosols and in land cover.

The most comprehensive evaluation of the global distribution and properties of atmospheric aerosols became available in FY 2002. Using data from several NASA spacecraft, including two instruments from the Terra spacecraft launched in 1999, the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite launched in 1997, and the Total Ozone Mapping Spectrometer (TOMS) instrument launched in 1996, an unprecedented database was created. These data also are combined with ground-based data that can help scientists understand the impact of atmospheric aerosols on the solar radiation that reaches Earth's surface and thus impacts local weather, agricultural productivity, and air quality.

Scientists used high-resolution land cover studies carried out with the Landsat series of satellites to study how land use and changes in land cover may impact regional and local economies. In the past year, several such studies focused on the Mojave Desert region, rangelands in the U.S. Southwest, and metropolitan and nonmetropolitan Michigan were completed and published. These data also form the basis for studies of how land use change can impact the distribution of carbon between the atmosphere and the biosphere and thus provide a rigorous basis for future approaches to accounting for carbon emission and uptake.

Understanding how the Earth system responds to natural and human-induced change is paramount in ESE's efforts to accurately model potential future climate change. NASA continued to provide the observational and modeling tools needed to characterize and generalize these response and feedback processes that will play such a large role in determining the future of our planet. Particular areas of substantial advances in FY 2002 have been made in NASA's studies of clouds, oceans, and the atmosphere.

One of the major uncertainties in climate change models is the way they represent clouds. In FY 2002, NASA made great progress in linking satellite and in situ measurements of clouds with their effects on atmospheric radiation. In particular, data from several cloud and radiation instruments aboard the Terra spacecraft have been useful in mapping the global distribution of clouds and their impacts on atmospheric radiation, especially for thin cirrus clouds that have been difficult to observe in the past. Detailed in situ observations of clouds were made during a NASA-led campaign carried out in Florida in the summer of 2002. One aircraft platform, NASA's WB-57F, used a suite of more than two dozen instruments to make what is the most comprehensive measurement of cloud-particle properties ever made.

Earth's oceans have been one of the most undersampled regions of the global environment because of the difficulty associated with making repeated measurements in the open ocean, away from coastal regions and islands. In FY 2002, the results of several years of observations of Earth's oceans became available and incorporated into models. Accomplishments of particular interest include the completion of more than a decade of observations of sea surface height measured with the TOPEX/Poseidon satellite and the launch of its successor, Jason-1, as well as the completion of 3 years of observations of the wind field at the ocean surface, which drives ocean circulation, that came from the SeaWinds instrument aboard NASA's QuikScat satellite. These data have been utilized in ocean data assimilation models, increasing NASA's knowledge of the processes by which ocean circulation affects climate, including the processes by which the Pacific Ocean transitions from an El Niño to a La Niña state.

The exchange of material and energy between Earth's troposphere and stratosphere has an important impact on Earth's climate. In FY 2002, satellite and theoretical studies carried out by NASA have improved humankind's knowledge of the processes by which water is transported from the troposphere into the stratosphere and the role that high-altitude cirrus clouds can play in this process.

Although Earth science is a global science, and global-scale changes are of great scientific interest, what may be most strongly perceived by individuals, governments, and industry are changes at much smaller spatial scales, especially local and regional scales. Similarly, although changes in the mean state of Earth are important and of interest, changes in extreme events (such as droughts, floods, and fires) may be of greater impact because of the role they play in the sustainability of ecosystems, communities, and economic sectors. NASA has made particular advances in precipitation studies and coastal studies in FY 2002.

Until recently, surprisingly little has been known about the extent of precipitation over much of Earth's surface, especially tropical regions over Earth's major oceans. However, the precipitation in these regions has major impacts on several elements of the Earth system, including atmospheric circulation and oceanic conditions. In FY 2002, data from several years of operation of the

Tropical Rainfall Measuring Mission (TRMM) satellite were available, and as a result, uncertainty about the global rainfall distribution on the tropics has been reduced by a factor of two, and NASA's knowledge of the variation in precipitation from year to year has been dramatically enhanced. Further, through data assimilation techniques that include TRMM precipitation data and QuikScat ocean surface wind data, short-term prediction models that account for the track, intensity, and precipitation of tropical cyclones have been improved.

The coastal regions of the world are becoming ever more populated and, therefore, more vulnerable to negative environmental impacts, especially those associated with flooding from severe storm events. NASA satellite observations are playing an increasing role in documenting the natural and human-induced changes taking place along coastal regions and in coral reefs. Data from Landsat, SeaWiFS, and NASA's EO-1 technology satellite are all being used to map coral reef areas. Data from these satellites, especially SeaWiFS and EO-1, are being used to provide information on turbid coastal waters, especially the documentation of the amount of suspended sediments. These observations are playing an increasing role in studies of local water pollution. NASA's altimetry observations over the last decade have monitored sea level rise and its distribution globally.

The greatest benefit to society from NASA's Earth Science Enterprise rests in the improved predictive capability that comes from the synthesis of knowledge of Earth system variability, natural and human-induced forcings, and Earth system processes, together with the use of modeling tools and computational systems that enable environmental prediction. NASA's unique contribution to the Nation's efforts center on the use of new kinds of environmental data, modeling approaches, and data-assimilation systems for improving modeling capability. As new capability is developed, it is NASA's goal to transition this capability to operational agencies within the Government, most notably (but not exclusively) the National Oceanic and Atmospheric Administration (NOAA). Particular areas of accomplishment for NASA in FY 2002 in the area of environmental prediction include weather forecasting, seasonal climate prediction, and long-term climate prediction.

Data from NASA's TRMM and QuikScat satellites are now being regularly used in weather prediction by NOAA and other national meteorological agencies. Reductions in the uncertainty of hurricane-track forecasts have been demonstrated through the use of these data and can lead to reductions in the size of the region for which evacuation orders may be issued in advance of the predicted landfall of a storm. The reduction in societal impact (including cost) of such reduced evacuation areas associated with the improvement in forecasts is significant.

In order to accelerate and expand the application of NASA's Earth science results, data, and technology to practical problems that confront the U.S. and Earth, the Applications Program developed an Applications Strategy: 2002–2012. This Strategy defined the conceptual approach and strategic direction for the Program. A cornerstone program planning accomplishment was the identification of 12 national applications with agency partners such as NOAA, FEMA, and USDA, which provide focus for the program implementation.

A major achievement in expanding the capability of scientific Earth observation has been the success of the Earth Observing-1 (EO-1) in meeting its objectives of flight validating breakthrough technologies applicable to Landsat follow-on missions. Specifically, EO-1 has validated the use of multispectral imaging capability to address traditional Landsat user communities, hyperspectral imaging capability to address the Landsat research-oriented community with backward compatibility, a calibration test bed to improve absolute radiometric accuracy, and atmospheric correction to compensate for intervening atmosphere.

Laser diodes are critical to the development of future Earth science laser-based instruments for global measurement of ozone, water vapor, winds, carbon dioxide, altimetry, and trace gas constituents. During FY 2002, a first-ever demonstration of a specialized laser system was achieved. This accomplishment is a key to enabling the development of an eye-safe Differential Absorption Lidar system.

The Biological and Physical Research Enterprise (BPRE) seeks to exploit the rich opportunities of the microgravity environment and space flight for fundamental research and commercial development, and to develop efficient and effective technologies and methods for protecting human health in space. BPRE continued to implement its ground and flight research programs at seven NASA Centers and the Jet Propulsion Laboratory, as well as through the participation of 15 Commercial Space Centers (CSC), a National Space Biomedical Research Institute, and a National Center for Microgravity Research on Fluids and Combustion. BPRE also relied upon an extensive external community of academic, commercial, and Government scientists and engineers for the implementation of its programs. Ground-based research precedes flight research and employs such NASA equipment as drop towers, centrifuges, and bed-rest facilities. The flight research programs used the full spectrum of platforms, including free-flying satellites, the Space Shuttle, and now the ISS.

During FY 2002, three experiment racks, two “arctic freezers,” and the Microgravity Science Glovebox were added to the research facilities. In addition, 48 research and technology development experiments were conducted. The BPRE research portfolio (42 of these experiments) consisted of 11 human life sciences, 24 physical sciences, and 7 space product development experiments. In all, it was a safe and highly productive year.

BPRE achievements included successful research on a method to reduce the risk of kidney stones in flight, successful tests of a drug to reduce the light-headedness and inability to stand that can affect space travelers returning to gravity, and suggestive new findings on the spinal cord and how reflexes change in space. Taken together, these and approximately 20 other ongoing investigations continue to expand our understanding of many physiological changes associated with space flight, the risks of space flight, and the best methods for controlling these changes and risks. NASA researchers used historical data to identify cataract risks from space radiation and developed a statistical concept for defining the uncertainties in space-radiation cancer risks, a concept that will allow for new research approaches to risk assessment and mitigation to be evaluated.

Also in FY 2002, BPRE achieved several milestones in support of a radiation protection plan for improved astronaut health and safety. Under the auspices of the ISS Multi-lateral Medical Operations Panel (MMOP), the international partners agreed to mission termination dose limits. The National Council on Radiation Protection and Measurements has issued new recommendations on dose limits that are being incorporated into the NASA medical requirements for astronauts.

During this past year, NASA increased the pace of ISS research to include research in fluid physics, combustion science, materials science, and biotechnology. Each ISS research investigation exploited the space environment to explore questions that could not be explored on Earth. For example, researchers continued to be excited by results from experiments on colloids in space. Colloids are mixtures of very small particles suspended in a liquid; paint and toothpaste are both usually made of colloids. Physicists studying colloids in space continued to explore the processes by which particles in colloids arrange themselves into regular patterns (crystal lattices). NASA researchers hoped that colloid experiments in space will provide the critical information necessary for using colloids to make new materials on Earth, establishing the new field of colloid engineering. These processes are thought to be particularly important for developing three-dimensional photonic materials, optical switches, and components for future computers. Researchers report that they have been able to observe significant phenomena that have never been observed on Earth.

One of the first materials science experiments on the ISS—the Solidification Using a Baffle in Sealed Ampoules (SUBSA)—was delivered by STS-111 for mission UF2 (May 2002) and deorbited on STS-113 in November 2002. SUBSA was conducted during Expedition Five inside the Microgravity Science Glovebox. The Glovebox is the first dedicated facility delivered to the Station for physical science research in microgravity, and this experiment is the first one operated inside the Glovebox. The goals of this experiment are to identify what causes the motion in melts processed inside space laboratories and to reduce the magnitude of the melt motion so that it does not interfere with semiconductor production.

Early in 2002, NASA successfully demonstrated its Avian Development Facility on Space Shuttle flight STS-108. The Avian Development Facility is designed to incubate 36 quail eggs in flight. Eighteen of the eggs are exposed to microgravity (very low levels of gravitational forces), and 18 are spun in a centrifuge to simulate gravity. Researchers can use the developing quail embryos as models for exploring the effects of the space environment on development. The initial flight of the facility was focused on examining the growth and development of the balance system in the inner ear, as well as on the development of the skeleton.

NASA also chartered the Research Maximization and Prioritization (ReMaP) Task Force to help identify research priorities for BPRE. The task force provided an interim report in July 2002 and presented its final report to the NASA Advisory Council in September. ReMaP evaluated research productivity and priorities for the entire scientific, technological, and commercial portfolio of BPRE. The findings and recommendations in the ReMaP report provide a framework for prioritizing a productive research program for BPRE and for the ISS. The report identifies two overarching programmatic goals. The first involves research enabling human exploration of space; the second involves basic research of intrinsic scientific interest.

In FY 2002, the CSC consortia attracted commercial funding in cash and in kind by a factor of 2.7 as they received from NASA. Thirty-five new industrial partners were reported, easily surpassing the goal of 10. The companies identified are active in a variety of fields including technology development, human interest proteins, paper products, education, and computer systems. Two products were brought to market in FY 2002: the Space Rose fragrance product discovered on STS-95 by the Wisconsin Center for Space Automation and Robotics (WCSAR) as an ingredient in “Impulse Body Spray” and the variant “Moon Grass” marketed by Lever Faberge (part of Unilever), launched in January 2002 in the United Kingdom. Meanwhile, Flow Simulation Services, a Solidification Design Center affiliate of CSC in Albuquerque, NM, began marketing software that will enable improved process design for particulate molding processes. The software ARENA-FLOW is initially being marketed to the metal casting manufacturing industry, but future applications are being pursued in food and pharmaceutical production, aerosol drug delivery, and other biotech applications.

BPRE outreach programs continued to involve students and educators in space research opportunities in both formal and informal learning environments. During the past year, five National Education Conferences, with a total attendance of over 70,000 teachers, featured BPRE-sponsored workshops and demonstrations. Additionally, BPRE was a full participant in each Conference’s “One NASA” exhibit. Displays illustrated current research through demonstrations of hands-on activities connecting space research to classroom curricula. Numerous educational publications were distributed.

NASA’s Office of External Relations continued its international activities, expanding cooperation with NASA’s partners through new agreements, discussions in multilateral fora, and support for ongoing missions. NASA concluded over 60 cooperative and reimbursable international agreements for projects across all of NASA’s Strategic Enterprises. These agreements included ground-based research, aircraft campaigns, and satellite missions in the fields of space and Earth science. Significant international agreements signed during this fiscal year included a Memorandum of Understanding between NASA and the Norwegian Space Center, signed November 14, 2001, for a variety of cooperative space activities, including sounding rocket activity, space science, Earth science, and satellite data acquisition and tracking. Another key agreement, signed July 5, 2002, established arrangements for NASA and the Institute for Space and Astronautical Sciences of Japan to conduct balloon-borne experiments with a superconducting magnet spectrometer to search for antinuclei and measure antiprotons and other components of cosmic rays. In addition, NASA and the European Space Agency (ESA) extended the existing Memoranda of Understanding for the HST and for the Ulysses mission.

NASA participated in numerous international meetings designed to review ongoing cooperation or foster new cooperation. These included the Committee on Earth Observation Satellites (CEOS) annual plenary meeting and meetings of the United Nations Committee on Peaceful Uses of Outer Space and its subcommittees. Throughout the year, NASA engaged in discussions with current and potential future partners at the senior management level, hosting visitors from around the world and visiting foreign space officials.

DEPARTMENT OF DEFENSE

DOD

During FY 2002, 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 among 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 2002, the NPOESS Integrated Program Office (IPO) awarded the Shared System Performance Responsibility contract to Northrop Grumman Space Technology (formerly TRW), and the program moved into the Key Decision Point-C (KDP-C) Acquisition & Operations phase. 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 2002. NPP is planned for an FY 2007 launch.

DOD, NASA, NOAA, and other Federal agencies continued to make good progress in FY 2002 on implementing activities for the Space Weather Architecture Transition Plan. DOD continued to participate in the NASA initiative Living with a Star, a systems approach to studies of Sun-Earth connections.

The Global Positioning System (GPS) constellation consists of a total of 28 satellites providing unprecedented levels of accuracy in support of national security, worldwide transportation safety, and scientific and commercial interests. In 2002, 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. Flexible power will enable the warfighter to adjust power levels between the new military code (M-code) and the current military signal (PY Code). Flex power will give warfighters the flexibility to change power requirements as mission operations dictate while providing significant additional antijam capability. In 2002, the Air Force continued concept exploration of GPS III, the next generation of GPS systems.

Of the 15 U.S. ELV launches in FY 2002, 4 were DOD-managed missions. The Evolved Expendable Launch Vehicle (EELV) program had a successful first launch for Atlas V on August 21, 2002. Other significant launches included classified payloads for the National Reconnaissance Office (NRO) on a Titan IV in early October and an Atlas II in late October 2001, as well as a Titan IV Milstar launch in January and a NOAA-M Titan 2 launch in late June 2002.

The NASA/U.S. Air Force (USAF) Reusable Launch Vehicle Development 120 Day Study, out-briefed in February 2002, was chartered by the Secretary of the Air Force and the NASA Administrator to investigate requirements and concepts for a new generation of Reusable Launch Vehicles to meet our national needs. This effort addressed concepts of operation, operational requirements, and technical requirements from both the NASA and Air Force perspectives. The study set the stage for cooperation between the two organizations on upcoming efforts such as the Operationally Responsive Spacelift Analysis of Alternatives.

Construction began in June 2002 on a backup Space Based Infrared System (SBIRS) operational ground station at Schriever Air Force Base (AFB), CO. The first Highly Elliptical Orbit (HEO) payload completed integration in 2002 and was on track for delivery in summer 2003; the first Geostationary Orbit (GEO) satellite is planned for delivery in March 2006, with a planned launch in October 2006. The Attack and Launch Early Reporting to Theater (ALERT) missile warning mission was assumed by the SBIRS Mission Control Station at Buckley AFB, CO, and ALERT was deactivated on September 25, 2002, after operational acceptance of the Interim Mission Control Station Backup. The facility was turned over to the Missile Defense Agency for use in the Ballistic Missile Defense System test bed.

The DOD Space Test Program (STP) continued to actively foster existing and new partnerships between DOD and NASA. The $223.5-million Coriolis satellite mission is a technical risk-reduction experiment for NPOESS. It was acquired under NASA's Rapid Satellite Acquisition process.

STP had three successful Shuttle/ISS missions during 2002, with a total of five experiments flown. In December 2001, STS-108 hosted the Ram Burn Observation (RAMBO) Experiment and Shuttle Ionospheric Modification with

Pulsed Localized Exhaust (SIMPLEX) experiment. These experiments flew again on STS-110 in April 2002. RAMBO used an operational satellite to view Shuttle engine firings to optimize band selection for SBIRS and improve the fidelity of DOD plume models. SIMPLEX observed ionospheric disturbances created by Shuttle engine burns via ground radar sites and supported plume technology, plume signature, and space weather modeling. In June 2002, RAMBO was again successful on STS-111 with a total of four Shuttle engine burns viewed. In 2002, STP actively explored how it could cooperate with NASA in building experiment pallets called EXPRESS for the ISS. Funding limitations prevented any concrete agreements from being reached, and discussions will continue in 2003.

In late FY 2002, STP was working with DOD, NASA, the commercial sector, and the Federal Communications Commission to obtain a 1-year radio frequency license extension for the Picosat experiment. Picosat was launched in September 2001, as part of NASA's Kodiak Star mission, from the Kodiak Island Launch Complex on an Athena booster.

Federal Aviation Administration

FAA

During FY 2002, the Federal Aviation Administration (FAA) continued its critical mission to ensure a safe, secure, efficient, and environmentally friendly civil air navigation and commercial space transportation system. The year, however, saw some significant changes in the FAA's research and development (R&D) program. In the wake of the tragic events of September 11, 2001, the focus of aviation security R&D was dramatically readjusted to meet the challenges of the new environment, and responsibility for aviation security R&D moved to the newly created Transportation Security Administration within the Department of Transportation.

To accomplish its efficiency goal, FAA researchers have worked on developing new technologies and procedures to reduce system delays, improve performance in bad weather, provide air-traffic services to a wider range of aircraft, apply satellite-based navigation and positioning technology, and increase system flexibility and adaptability.

A recent estimate by the FAA identified weather as causing 69 percent of flight delays and approximately 30 percent of accidents. On March 27, 2002, the FAA reached a milestone in ensuring the safety of the flying public: the Current Icing Potential (CIP) weather-safety product became fully operational at the National Weather Service Aviation Weather Center in Kansas City, MO. This product, which generates around-the-clock support, provides information on current in-flight icing conditions and is used for planning flights, determining route changes, and selecting altitudes. The CIP, developed by the National Center for Atmospheric Research in Boulder, CO, with funding from the FAA's Aviation Weather Research Program, is derived from radar and satellite data, surface observations, numerical models, and pilot reports. Users can access CIP information on the Internet via the Aviation Digital Data Service (ADDS) Web site. Using the ADDS Flight Path Tool, the user can select a flight route and view a cross-section display that allows selection of flight altitudes that minimize the possibility of encountering icing en route. CIP provides the user with information on icing "potential" (likelihood of icing) and is updated on an hourly basis.

The FAA also completed the development and implementation of a newly improved version of the Rapid Update Cycle (RUC) numerical weather model. The RUC20, with its 20-kilometer resolution, provides improved aviation and surface weather forecasts. It features increased horizontal resolution and 50 vertical levels. This version improves the overall accuracy of weather data being fed into aviation-weather applications. The smaller grid spacing used by the RUC20 provides better resolution of variations in terrain elevation, land-water boundaries, and other land-surface discontinuities. This type of detail leads to improved forecasts of regional and local precipitation and surface wind phenomena important for aviation operations. The RUC20 assimilates satellite cloud data to improve its cloud, icing, and precipitation forecasts. It also handles convective and nonconvective clouds more effectively. The enhancements in the RUC20 for aviation operations will result in more realistic frontal structures, including areas of potentially hazardous turbulence and icing, and more accurate forecasts of surface winds, temperature, and precipitation. RUC forecasts of jet-level winds and temperature, critical for U.S. flight routing and air-traffic management, are also improved with the RUC20. The RUC20 produces new analyses and short-range forecasts on an hourly basis. The RUC20, developed by researchers from the National Oceanic and Atmospheric Administration's Forecast Systems Laboratory, with funding from the FAA's Aviation Weather Research Program, is operated by the National Weather Services' National Center for Environmental Prediction.

The FAA's Free Flight Program encompasses two Phases. Between 1998 and 2002, the Free Flight Phase (FFP) 1 program deployed a number of tools, such as User Request Evaluation Tool (URET), Traffic Management Advisor (TMA), and Surface Movement Advisor, products of the R&D program. FFP2 began in FY 2000 as a vehicle for further deployment and enhancement of URET, TMA, and Collaborative Decision Making. FFP2 also has a mandate to pursue research into new automation tools. During 2002, the FFP2 research program had several successes.

- Direct-To, developed by NASA Ames Research Center, is a decision-support tool for the radar controller (R-side) that will provide advisories for traffic conflicts and direct routes. It includes an interactive trial planning function that allows the controller to quickly visualize, evaluate, and enter route and altitude changes. In FY 2002, the FAA and NASA conducted operational evaluations of Direct-To in the FAA Technical Center's Integration and Interoperability Facility with the FAA's Air Traffic Conflict Probe Team and the Air Traffic Display System Replacement (DSR) Evolution Team to further refine the FAA's operational concept.
- Problem Analysis, Resolution and Ranking (PARR), developed by the MITRE Center for Advanced Aviation System Development, is an extension of the FFP 1 URET. The Initial PARR Assisted Resolution Tool (ART) will provide the radar associate controller (D-side) with a set of tools to support the development of strategic resolutions to URET-predicted aircraft-to-aircraft and aircraft-to-airspace problems. In FY 2002, the FAA conducted controller-in-the-loop simulations of initial PARR/ART to further refine the operational concept of use for ART.
- Traffic Management Advisor-Multi-Center (TMA-MC) is an extension of the FFP 1 Traffic Management Advisor tool to a multifacility environment. The purpose of TMA-MC is to assist traffic-management coordinators in planning and managing streams of traffic into selected airspace, as well as into selected Terminal Radar Approach Control (TRACON) facilities that receive traffic from two or more en route centers. The FAA and NASA Ames Research Center jointly managed the research and development of TMA-MC, which is focused on the Northeast corridor, with the goal of improving the arrival flows into Philadelphia International Airport, as well as identifying the requirements for TMA-MC at the New York airports.
- During Fiscal Year 2002, a TMA-MC test bed was established in the FAA Technical Center's Free Flight Technology Integration Laboratory (FFTIL). Functional demonstrations and simulations were conducted both at NASA Ames Research Center and in the FFTIL test bed. In addition, in preparation for the TMA-MC field evaluation planned for Fiscal Year 2003, researchers established data feeds from Boston, Cleveland, New York, and Washington Air Route Traffic Control Centers to laboratories at both

NASA Ames Research Center and the FFTIL for continued development and testing of the TMA-MC prototype. The FAA also conducted the first Host Computer System/TMA-MC National Airspace System noninterference demonstration in the FFTIL.

- In 2002, researchers successfully prototyped and evaluated the Slot Credit Substitution (SCS) tool in conjunction with participating airlines. SCS allows airlines greater flexibility in swapping aircraft between "slots" that have been allocated to them in the ground-delay program.

The adverse environmental byproducts of aviation—primarily noise and emissions—are major constraints on the growth of aviation. Public concerns about the environmental effects of aircraft and airport operations, as well as increasingly strict requirements embodied in laws and regulations, can severely constrain the ability of the aviation system to meet the Nation's need for mobility, increased trade/market access, and sustained economic growth. The FAA's environment and energy program seeks to develop superior decision-support tools and ensure that response strategies protect both the environment and aviation's economic health. On June 20, 2002, the FAA and NASA signed a new Memorandum of Agreement (MOA) to leverage each other's aircraft noise-reduction technology investments. This MOA aims to form the basis upon which the FAA and NASA will build programs to achieve the joint long-term national goal of containing objectionable aircraft noise within airport and compatible land-use boundaries. In August 2002, the FAA executed a new interagency agreement with NASA in the amount of $18,161,000 to commit to the tasks outlined in the MOA focusing on advancing the technology readiness level of high-impact technologies.

During FY 2002, the FAA released an enhanced version of the Emissions and Dispersion Modeling System (EDMS). EDMS assesses the air-quality impacts of airport emission sources, particularly aviation sources, which consist of aircraft, auxiliary power units, and ground-support equipment. The Environmental Protection Agency (EPA) accepts this model as a "Preferred Guideline" model, and it is crucial for the FAA to perform the air-quality analyses of aviation emission sources for airport expansion projects. This new version incorporates enhancements resulting from a landmark aircraft plume study conducted by the FAA, in coordination with the Department of Transportation's Volpe National Transportation System Center, the University of Central Florida, and the National

Oceanic and Atmospheric Administration. The study provided the first-ever measurements of aircraft plume rise and spread from aircraft engine exhaust. The results allow a significantly enhanced model of aircraft plume behavior, which enables more prediction of local concentrations of pollutants, and greatly increase the accuracy of current aircraft engine exhaust dispersion modeling.

The FAA also completed a first-time review and analysis of all available data and research findings on particulate matter emissions from aircraft engines. The effort enabled the FAA to develop a first-order approximation methodology to estimate these emissions.

The FAA's aircraft safety technology R&D program addresses the many hazards that face all aircraft, as well as special hazards endemic to select portions of the civil aircraft fleet.

Bonded composite doublers offer airline maintenance facilities a cost-effective way to extend the lives of aircraft safely. Instead of riveting multiple steel or aluminum plates to repair an aircraft, it is now possible to bond a single boron-epoxy composite doubler to the damaged structure. During the FY 2002, researchers at the FAA's Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) completed an experimental project in which they installed composite repair doublers on inservice commercial aircraft. The project validated a family of generic composite patches used to repair various types of damage to metallic structures caused by dents, dings, lightning strikes, corrosion, and certain cracks in nonpressurized areas. Researchers also identified necessary guidance data needed to ensure the continued airworthiness of composite doublers.

In conducting this program, the AANC focused its attention only on the DC-10/MD-11 aircraft and worked collaboratively with FedEx, Boeing, and Textron Specialty Materials. This project built upon research conducted with Delta Airlines to validate the use of a composite reinforcement on an L-1011 door-frame corner. Future users of this technology are all of the airlines and maintenance depots that currently apply metallic repairs. Industry interest in using composite doubler repair has grown considerably since the results from this study have shown that the finished doublers are lighter in weight, corrosion-resistant, stronger, and faster to install than a typical riveted aluminum plate repair.

At the request of the FAA's Seattle Aircraft Certification Office, investigators from the AANC recently completed an experiment to asses the reliability of a sliding probe eddy-current procedure for its effectiveness in finding second- and third-layer cracks in certain Boeing 737 lap splice joints. Lap splice joints are an area on the fuselage of an aircraft where two sheets of aircraft skin overlap and are riveted together. The findings will be taken into consideration in the development of revised and new lap splice inspections.

One of the current activities of the Engine Titanium Consortium is the development of improved ultrasonic inspection capability for nickel alloys used in jet engines. The Consortium is an FAA-funded group consisting of General Electric Aircraft Engines, Honeywell, Iowa State University, and Pratt & Whitney. As a result of this effort, researchers have demonstrated a significant improvement in inspection sensitivity. Billets of both Waspaloy and Inconel 718 were inspected. These are the primary nickel alloys used in critical rotating jet-engine components. The program goal was to develop a fourfold improvement in inspection sensitivity over conventional practice for billets up to 10 inches in diameter. The researchers substantially exceeded this goal.

In FY 2002, the FAA continued its Operational Loads Monitoring Program, which includes data collection for both flight and landing loads on civil transports. During the year, the FAA Operational Loads Monitoring team provided specialized data and analysis for operational loads to the Aviation Rulemaking Advisory Committee, which is developing recommendations for the certification criteria for the A-380 airplane. Agency researchers also merged sink-speed data at touchdown (collected during video landing-parameter surveys at the New York John F. Kennedy International, Honolulu International, and Heathrow International airports) into a single database and presented the data to the Advisory Committee so that it could assess whether or not to increase the limit load design sink speed of 25.475 above the stated 10-feet-per-second level for the new generation of super heavy widebody airplanes.

Ice accretions, which disrupt the normal, smooth airflow over the wing, can seriously affect the aerodynamic efficiency of an aircraft wing. The severity of these aerodynamic effects (loss of lift, increase in drag) depends not only on the ice accretion, but also on the aerodynamic characteristics of the wing cross section (airfoil). Recent accidents and incidents in icing conditions have underscored the need for a systematic study of the sensitivity of different airfoil types to ice accretion and of the most critical ice shape locations for different types of airfoils. In response to these and related concerns, the FAA has sponsored a long-term research investigation at the University of Illinois at Urbana-Champaign. The program includes aerodynamic testing in the university's wind tunnel and in NASA's low-pressure turbulence tunnel at the Langley Research Center in Hampton, VA, as well as extensive computational fluid dynamics investigations. An important conclusion of the investigation is that the severity of the aerodynamic consequence of the ice is strongly dependent on the geometry of the airfoil as reflected in its pressure distribution and lifting characteristics.

Because the possibilities for expanding existing airports or building new ones is limited, FAA researchers are developing and evaluating new technologies that will result in new safety standards, criteria, and guidelines for those who use, design, construct, operate, and maintain this Nation's airfields. As part of this effort, in FY 2002, the FAA began a research effort to investigate operational problems resulting from the installation of in-pavement Runway Guard Lights (RGLs) at entrances to the runways at Chicago O'Hare International Airport. Specifically, pilots exiting the runways at locations where flashing yellow RGLs were located reported seeing considerable reflected light from the recessed fixtures, to the extent that several pilots halted short and informed air traffic controllers that they were concerned about possibly entering a construction area. Researchers determined that changing the flash pattern of the system, thus eliminating the random flashing appearance created from the rear side of the installation, would be the most beneficial solution. As a result of the evaluation, it was determined that the United States should change its specification for the system and standardize the inset runway guard light configuration as a transverse array of simultaneously flashing yellow lights in place of the current configuration.

The FAA requires that human factors be systematically integrated at each critical step in the design, testing, and acquisition of new technology introduced into the national aviation system. Through research in areas such as selection, training, workload, and communication, the agency is identifying the most effective procedures to be used in combination with new technology applications and a more capable workforce to make the global air transportation system of the future safer and more efficient.

FAA researchers and National Air Traffic Controllers Association (NATCA) representatives conducted a beta test of JANUS, a technique for analyzing causal human factors in operational errors. As a part of this process, the FAA and NATCA signed a national Memorandum of Understanding for the beta test and validation processes. Researchers trained in the use of the JANUS taxonomy collected data from 79 operational errors at towers, TRACONs, and Air Route Traffic Control Centers (ARTCCs). Additionally, support was provided to the Runway Safety Program during review of the runway incursion at Linate Airport in Milan, Italy. Researchers used air traffic control (ATC) voice transcripts and other available information to identify and classify potential human and contributing factors using the JANUS technique. The FAA completed a draft version of JANUS for ground operations, and data from existing FAA databases are currently being used to assess the sufficiency of the available human factors information.

The FAA, working with the Department of Transportation's Volpe National Transportation Systems Center, developed a prototype CD-ROM training tool for tower controllers. This interactive CD is based on the highly successful booklet "Runway Safety: It's Everybody's Business." The tool contains "learn-by-doing" modules on memory, communications, attention and perception, teamwork, and fatigue. It also contains information on the limitations of short-term memory and the effects of distractions, the effects of expectation and selective attention on information processing, common errors in controller-pilot communications and how to avoid them, effective teamwork strategies that can help mitigate the effects of individual errors, and techniques for avoiding and managing the effects of fatigue.

In FY 2002, the FAA finalized reports for the congressionally directed shift work and fatigue studies. The Civil Aerospace Medical Institute published and distributed to 20,000 FAA controllers a pamphlet describing the results of the survey and a multimedia CD containing instructions and hints on how to cope with shift work and fatigue. The agency also published three Office of Aviation Medicine technical reports on shift work and fatigue. Researchers made presentations of data from survey, field, and laboratory studies to the Annual Scientific Meeting of the Aerospace Medical Association and the Annual Convention of the American Psychological Association. To view these technical reports online, go to *http://www.cami.jccbi.gov/AAM-400A/Abstracts/2002/FULL%20TEXT/0208.pdf* and *http://www.cami.jccbi.gov/AAM-400A/Abstracts/2002/FULL%20TEXT/0213.pdf*.

FAA researchers and certification specialists began testing a new computerized decision-support tool to help agency certification specialists and aircraft designers ensure that aircraft flight-deck technologies are user-friendly. This decision aid has been designed to assist certification and design personnel in identifying, assessing, and resolving potential design-induced human performance errors that could contribute to aviation incidents and accidents. In addition to enhancing the speed, accuracy, and repeatability with which certification engineers can access relevant regulatory and human factors information to make their decisions, this tool was designed to help designers identify possible design changes to alleviate human performance issues and help researchers identify gaps in current human factors knowledge. This PC-based software has been designed with three major databases addressing regulatory information, flight-deck components, and human factors considerations. In the current version, the information in the databases focuses on flight-deck displays. In the next version, which will be completed in 2003, the databases will be expanded to address flight controls.

The FAA and aviation community are developing surface map displays that will provide real-time information regarding traffic positions on the airport tarmac. Human factors researchers completed a draft report entitled *Human Factors Considerations in the Design of Surface Map Displays*. This document captures all the human factors issues relevant to the design and development of surface map applications and will support Aircraft Certification in their review and evaluation of surface map displays. The report was used as a source of material for human factors guidance in the development of the RTCA SC-181 draft revision of the *Minimum Operational Performance Standards for the Depiction of Navigational Information on Electronic Maps* (DO-257).

Electronic flight bags (EFB) are quickly becoming multifunction devices supporting an array of applications beyond those of a traditional flight bag, from electronic messaging to displaying current weather. In order to help FAA evaluators, system designers, manufacturers, and users understand the human factors considerations that may be associated with EFBs, *Human Factors Consideration in the Design and Evaluation of EFBs*, *Version 2.0*, was developed at the Volpe NTSC. This publication supports FAA EFB Advisory Circular (AC 120-76) and covers human factors system considerations and four EFB functions: electronic documents, electronic checklists, flight performance calculations, and electronic charts.

The *Human Factors Design Guide for Acquisition of Commercial Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems* is a comprehensive compilation of human factors standards, principles, and guidelines integral to the procurement, design, development, and testing of FAA systems, facilities, and equipment. The FAA is updating this important human factors reference tool. Soon to be released as a design "standard," the guide will provide a single, easy-to-use source of human factors design criteria oriented to the needs of the FAA mission and systems. The new document, called the Human Factors Design Standard, revises and expands upon the previously published material. It broadens the focus to include both air traffic and airway facilities systems and has been modified into a set of standards instead of a set of guidelines, providing a common source of FAA-specific design requirements. Chapter 5: Automation Guidelines is now online at *http://www.tc.faa.gov/ act-500/hfl/index.html.*

The 2002 *Access to Egress Study* was the largest cabin-evacuation study ever conducted by the FAA. A total of 2,544 people participated in various group trials to determine passageway configuration, hatch disposal location, and aircraft evacuation through a Type III exit (over the wing). Findings indicated that hatch disposal location slowed egress in some access aisle width configurations but not in others. Waist size, gender, and age all affected individual exit time. The findings are consistent with prior research showing that passageway configuration has only minimal effects on emergency egress as long as ergonomic minimums involving hatch removal are respected. In contrast, differences in the physical characteristics and level of knowledge of individual participants produced large differences in emergency evacuation performance. The results of this research can be found online at *http://www.cami.jccbi.gov/AAM-400A/Abstracts/2002/FULL%20TEXT/0216_low.pdf*.

The FAA's cabin safety researchers completed an Evacuation Slide Study research program to determine the most favorable methods for the evacuation of infants using inflatable emergency evacuation slides and the Type III (overwing) exit. Researchers conducted simulated emergency evacuations from the Civil Aerospace Medical Institute Aircraft Evacuation Facility using a Type I exit fitted with a Boeing 737 evacuation slide. Agency researchers analyzed the results with respect to speed of egress relative to the effects of the carrying and boarding positions. They also analyzed participant responses to a questionnaire regarding comfort and safety. For speed of egress, the study demonstrated that jumping onto the slide facilitated faster egress times than sitting to board the slide. Results also suggested that appropriate carrying and boarding positions for small children would be those most comfortable for the parent and those providing support for the child's head and neck. In some trials, the researchers instructed the participants on how to carry the dummy or to pass the dummy to another participant who had already exited. Results confirmed the expectation that passing an infant to another participant would produce slower egress than carrying the infant. The results also suggested that the appropriate carrying position would depend on the size of the infant. These research results will support cabin evacuation training and procedures development for improved infant evacuation.

The FAA's Office of the Associate Administrator for Commercial Space Transportation (AST) licenses and regulates U.S. commercial space launch activity, ensures public health and safety and the safety of property, and protects national security and foreign policy interests of the United States. AST also licenses operation of non-Federal launch and reentry sites and facilitates and promotes commercial space launches by the private sector.

During Fiscal Year 2002, there were eight commercial launches that were licensed by AST. Six orbital launches included the first Atlas V launch vehicle built by Lockheed Martin with services provided by International Launch Services. The remaining orbital launches were two additional Atlas launches, two Boeing Delta II launches, and one Sea Launch Zenit 3SL launch from a Pacific Ocean launch platform. Two Orion-Terrier suborbital launches by Astrotech took place from Australia. AST also issued a license for the first launch of Boeing's Delta IV launch vehicle. AST issued an advisory circular, *Licensing Test Flight Reusable Launch Vehicle Missions*, and a Supplemental Notice of Proposed Rulemaking on *Licensing and Safety Requirements for Launch*. The Air Force and the FAA released a draft Memorandum of Understanding for *Resolving Requests for Relief from Common Launch Safety Requirements*.

A report requested by Congress, the *Liability Risk-Sharing Regime for U.S. Commercial Space Transportation*, was delivered to Congress and released to the public. The report concluded that the current liability risk-sharing regime is adequate, appropriate, and effective for the U.S. launch industry. Other reports released by AST include *FAA and Industry Guide to RLV Operations and Safety*

Approval; *2002 U.S. Commercial Space Transportation Developments and Concepts*; *Vehicles, Technologies, and Spaceports*; and the *2002 Commercial Space Transportation Forecasts*. The forecasts, prepared by the FAA and its Commercial Space Transportation Advisory Committee, projected an average worldwide demand of 20.5 launches per year to geosynchronous orbit and 6.3 launches per year to non-geosynchronous orbits between 2002 and 2010. AST also hosted its fifth annual commercial space transportation forecast conference. Reports and other documents can be found on the FAA/AST Web site at *http://ast.faa.gov*.

DEPARTMENT OF COMMERCE

DOC

In FY 2002, 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.

A Department-wide activity of note was participation in the Space Policy Coordinating Committee (PCC), established by the National Security Council. The Office of Space Commercialization (OSC), the National Oceanic and Atmospheric Administration (NOAA), and the International Trade Administration (ITA) assumed active roles in interagency space matters under the Space PCC. Commerce has two Space PCC representatives: ITA Assistant Secretary for Trade Development Linda M. Conlin and NOAA's National Environmental Satellite, Data, and Information Service Assistant Administrator Gregory W. Withee. President George Walker Bush's National Security Policy Directive 15, signed in June 2002, initiated a review by the Space PCC of all U.S. space policies. Staff representatives from OSC, ITA, and NOAA participated in both the remote-sensing and space-transportation working groups, which were tasked to revise relevant U.S. Government policy. In these efforts, the bureaus worked closely to emphasize and articulate the key contributions of commercial interests to U.S. national and economic security. In further support of this effort, ITA arranged briefings to U.S. industry by the National Security Council to gain industry support for the new policies.

NOAA reported space-related activities across its organization in FY 2002. In the area of geostationary satellites, two Geostationary Operational Environmental Satellites (GOES)—GOES-8 or GOES-East, stationed at longitude 75° W (launched in April 1994), and GOES-10 or GOES-West, stationed at longitude 135° W (launched in April 1997)—continued to provide the kind of continuous monitoring necessary for intensive data analysis during severe weather conditions such as hurricanes, tropical storms and depressions, tornados, and floods. These satellites transmit full-disc views of the majority of the Western Hemisphere that provide a constant vigil for the atmospheric "triggers" for severe weather conditions. When such conditions develop, the components of GOES satellites are able to monitor storm development and track storms' movements. In addition to satellite operations, NOAA continued to provide space-weather monitoring and forecasts to protect spacecraft and power grids. NOAA's newest environmental satellite, GOES-12, launched last year and currently being stored in orbit, has successfully completed testing and is ready to replace one of the country's older weather satellites when needed.

NOAA's National Environmental Satellite, Data and Information Service (NESDIS) made preparations to strengthen Pacific geostationary satellite coverage by preparing to use GOES-9 when failure occurs in the aging Japanese Geostationary Meteorological Satellite (GMS)-5. Launched in 1995, GMS-5 is past its useful life and is encountering imaging problems and fuel shortages. GOES-9, also launched in 1995 and currently in storage mode, does not meet U.S. weather-forecasting requirements but does have sounding and limited imaging capabilities, which will supply data comparable to that of GMS-5. In preparation for this operation, the Japan Meteorological Agency is providing upgrades to an antenna at NOAA's Fairbanks Command and Data Acquisition Station and related operations costs. These efforts have led to a subsequent agreement that provides continuity of satellite services not only for Japan, but also for U.S. civilian and military assets and U.S. territories in the western Pacific. The agreement with Japan contains a provision for Japan to back up U.S. satellite coverage in case of an unexpected U.S. failure and will lead to a mutual backup agreement in the future.

Special satellite coverage was also provided for the firefighting community, land managers, and air-quality-monitoring personnel during the extremely serious outbreak of wildfires in the Western United States this year. Efforts included switching channels on the Advanced Very High Resolution Radiometer (AVHRR) to get better daytime infrared (IR) data for the Western United States and integrating detections from GOES AVHRR and Moderate Resolution

Imaging Spectroradiometer (MODIS) automated algorithms to provide a twice-daily product and a new Geographic Information System (GIS) Internet site.

NOAA played a critical role in handling data from the Defense Meteorological Satellite Program (DMSP), a Department of Defense (DOD) program run by the Air Force Space and Missile Systems Center (SMC). The Air Force Weather Agency (AFWA) sent DMSP data to NOAA's National Geophysical Data Center's Solar Terrestrial Physics Division (NGDC/STP) to be archived. The data from the DMSP satellites were received and used at operational centers continuously. Each DMSP satellite had a 101-minute, Sun-synchronous, near-polar orbit at an altitude of 830 kilometers above Earth's surface. The DMSP visible and infrared sensors collect images across a 3,000-kilometer swath, providing global coverage twice a day. The combination of day/night and dawn/dusk satellites allows monitoring of global information such as the movement of clouds every 6 hours. The microwave imager (MI) and sounders cover one-half the width of the visible and infrared swath. These instruments cover polar regions at least twice per day and the equatorial region once per day. The space environment sensors record along-track plasma densities, velocities, composition, and drifts. Currently, data from four satellites (three day/night, one dawn/dusk) are added to the archive each day. Satellites now record a similar view of actual events for scientists to study. The DMSP has a unique capability to detect low levels of visible near-infrared radiance (VNIR) at night. With these data, it is possible to detect clouds illuminated by moonlight, plus light from cities, towns, industrial sites, gas flares, and ephemeral events such as fires and lightning-illuminated clouds.

In April 2002, The GOES-12 Solar X-ray Imager (SXI) met all of its NOAA and U.S. Air Force (USAF) requirements and was ready to enter operation. This accomplishment created significant enthusiasm in the scientific and space communities because solar flares are readily located in SXI images. NOAA's Space Environment Center (SEC), which is part of NOAA's Office of Oceanic and Atmospheric Research, has developed software to support the automated location of bright regions; this capability, in conjunction with data from the GOES full-disk integrated X-Ray Sensor (XRS), provides flare location. The GOES-12 SXI takes one image per minute of the outer atmosphere, or corona, of the Sun. Over 100,000 pictures were downloaded during the postlaunch test period as part of the telemetry stream to NOAA's SEC in Boulder, CO. Other SEC achievements included ongoing support of satellite requirement workshops, as well as support for various solar models including Solar2000, the Chen Interplanetary Magnetic Field (IMF) Prediction Model, the Wang-Sheely Model, the Time Empirical Ionospheric Correction Model, and the Relativistic Electron Forecast Model, in addition to the ongoing provision of Space Weather Alerts.

Complementing the geostationary satellites, NOAA operated two polar-orbiting satellites known as Advanced Television Infrared Observation Satellites, constantly circling Earth in an almost north-south orbit, passing close to both poles. One satellite crosses the equator at 7:30 a.m. Eastern time, the other at 1:40 p.m. Eastern time. Operating as a pair, these satellites ensure that the data for any region on Earth are no more than 6 hours old. Together, they make nearly polar orbits 14.1 times daily.

NOAA-M, NOAA's polar-orbiting environmental satellite, was successfully launched on June 24, 2002. NOAA-M has a new orbit that provides improved product capabilities; it also has new solid-state recorders that allow for improved product capabilities. Renamed NOAA-17 upon reaching Earth orbit, the satellite is performing functions critical to virtually all of NOAA's missions, such as weather, climate, oceans, fisheries, and ecosystem monitoring. NOAA-17 sent its first images of Earth from space 2 days after launch.

NOAA's NESDIS also evaluated and awarded a potential $4.5 billion contract to TRW for the National Polar-Orbiting Environmental Satellite System (NPOESS), which will have a first launch in 2009. The contract is for the Acquisition and Operations phases and will combine the Nation's military and civilian environmental satellite programs into a single, NOAA-led national system that will significantly improve weather forecasting and climate prediction. This is the largest NOAA (and Department of Commerce) contract award to date.

NOAA's NESDIS initiated an agreement with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) on access to data from EUMETSAT's Meteosat Second Generation (MSG). Under this discussion, NOAA's NESDIS and its U.S. affiliates will have access to the full set of MSG image data, subject to negotiated terms on use and redistribution of the data. Signature of the agreement is expected in early 2003. MSG-1 was launched successfully in August 2002, representing a significant advancement in geostationary Earth-observing capabilities.

NOAA's NESDIS and EUMETSAT continued this collaboration under the Initial Joint Polar System agreement, as well as their cooperation as partners in the NPOESS. NOAA participated in the development of an operational altimetry program between the U.S. and Europe, which led to letters of intent among Centre Nationale d'Etudes Spatiale (CNES), EUMETSAT, NASA, and NOAA for pursuit of Jason-2/Ocean Surface Topography Mission (OSTM) collaboration. Jason-2/OSTM, when launched, will represent the transition of ocean altimetry from research to operations.

NOAA's National Ocean Service (NOS) continued to use the Global Positioning System (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. As part of these efforts, NOAA's NOS is investigating the use of Light Detection and Ranging (LIDAR) technology for the NOAA shoreline-mapping program. Accurate elevation data referenced to the ellipsoid are collected with LIDAR at or below Mean Lower Low Water (MLLW) and is transformed via the NOAA's NOS VDatum transformation tool to a desired tidal elevation. This process has the potential to eliminate black and white infrared film collection at the MLLW tidal stage. Historically, the MLLW tidal datum line was very difficult to capture. LIDAR technology increases data collection windows and automates tidal datum-line construction.

Along these lines, NOAA's NOS persisted in its work on advancing centimeter-level positioning accuracy of GPS through its national Continuously Operating Reference Stations (CORS) program. It added 109 new stations to the national CORS network during FY 2002. At the end of the fiscal year, the network contained 338 sites. NOAA's NOS completed upgrading the sampling rate of all nationwide differential GPS from 30 seconds to 5 seconds to better serve those involved in Geographical Information Systems (GIS) development and/or kinematic applications. As part of further efforts to better serve those in the GPS and GIS communities, NOAA's NOS hosted a CORS Industry Forum in April 2002. 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. NOAA's NOS and the Federal Aviation Administration (FAA) Technical Center in Atlantic City, NJ, undertook a joint effort to establish a T1 Internet connection to download GPS data from approximately 50 sites contained in the Wide Area

Augmentation System/National Satellite Test Bednetwork. Last year, four Wide Area Augmentation System sites with 1-second data became part of the CORS network. NOAA's NOS plans to bring 30 more sites into the network. In cooperation with NOAA's National Geographic Data Committee, NOAA's NOS has also established an alternate collection site for CORS data to ensure continued operations.

Last year, NOAA's NOS developed the On-line Positioning User Service (OPUS) as a means to provide GPS users with facilitated access to the National Spatial Reference System. OPUS allows users to submit their GPS data files to NOAA's NOS, where the data will be processed to determine position. Each submitted file is processed with respect to three CORS sites; results are e-mailed back to users within a few minutes. The first full year of operations has been very successful. User feedback has been overwhelmingly positive, and OPUS submissions are now averaging about 3,000 per month. Several improvements and new features are currently under development for OPUS.

NOAA's NESDIS also supported improved Search and Rescue Satellite-Aided Tracking (SARSAT) response capabilities in the expanded Central American network by collaborating with the U.S. Air Force to establish points of contact in Central America to receive search and rescue distress alerts from NOAA satellites. The new contacts, established in Panama, Ecuador, and Honduras (on behalf of Belize, Guatemala, El Salvador, Nicaragua, and Costa Rica) will improve search and rescue operations in that region. By the conclusion of FY 2002, the international COSPAS (a Russian acronym meaning Space System for Search of Vessels in Distress) SARSAT program had led to approximately 14,000 rescues worldwide.

A number of key milestones in NOAA's efforts to promote the commercial remote-sensing industry occurred in FY 2002. NOAA, in consultation with its interagency partners, approved one new license, two foreign agreements, and two amendments. In May 2002, the Secretary established the Advisory Committee for Commercial Remote Sensing. The Committee will advise the Secretary of Commerce, through the Under Secretary of Commerce for Oceans and Atmosphere, on a broad range of issues including operational monitoring, compliance and enforcement, the licensing of more advanced systems, and industry internationalization. The Committee held its first meeting in September 2002.

NOAA, OSC, and ITA's Office of Aerospace continued to represent commercial interests as part of the Remote Sensing Interagency Working Group. Led by the Department of State, the group 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. The group held consultations on remote-sensing satellite cooperation with several countries including Canada and France.

As a key partner in the NASA Synthetic Vision System Program, NOAA's NOS continued to provide essential data and information to be incorporated into this system. NASA is working with industry to create 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.

NOAA's NOS also provided data it collects and maintains within the Aeronautical Survey Program. Additionally, it continued to derive specialized data to support the Synthetic Vision System Program. These data include obstruction data, runway positional information, digital terrain models, and orthorectified imagery. NOAA's NOS has collaborated with the FAA Aviation Systems Standards, the University of Florida Geomatics Department, and Optech, Inc., to test the feasibility of using an Optech 33-kHz Airborne Laser Terrain Mapper for FAA programs (Aviation Systems Standards-Flight Check/National Aeronautical Charting Office-Flight Edit) and NOAA's NOS Aeronautical Survey Program.

The Safe Flight 21 program, which is led by the FAA, also remained an active priority for NOAA's NOS. 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. The role of NOAA's NOS is to provide accurate runway and taxiway data cross-referenced with the National Spatial Reference System. 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.

In the area of international cooperation and activities, NOAA also assisted in negotiating inputs into the World Summit on Sustainable Development (WSSD) Implementation Plan to recognize the value of Earth observations and their applications to sustainable development. NOAA assisted in development of a WSSD-recognized Type II partnership, Earth Observation Education and Training, under a CEOS lead, to facilitate education and training in satellite-based Earth-observation techniques, data analysis, interpretation, use, and application—as an outcome of the WSSD. NOAA assisted in the development of a U.S.-proposed Geographic Information for Sustainable Development partnership. NOAA Administrator Conrad Lautenbacher participated in key WSSD events. NOAA's NESDIS continued its active participation with CEOS and the Integrated Global Observing Strategy (IGOS) while preparing to assume the Chairmanship of CEOS and the Co-Chairmanship of IGOS in November 2002.

NOAA participated in the Array for Real-time Geostrophic Oceanography Ocean Profiling Network, an international effort using sophisticated space and in situ systems to collect and share information on the temperature, currents, and salinity of the world's oceans. This information will be used to better predict the influence of events such as El Niño and La Niña on our seasonal climate. Since weather and climate are linked to the ocean, data from the floating observing systems will increase our knowledge of long-term temperatures as well as help us to better prepare for major climate events—such as hurricanes and El Niño—that affect human safety, food production, water management, and transportation. Each float is programmed to sink a mile into the ocean, drifting at that depth for about 10 days, then slowly rise, measuring temperature and salinity through the layers as it makes its way to the surface. At the surface, data is transmitted to a communications satellite, and the probe begins another cycle. Each float is designed to last 4 to 5 years.

In providing support to Afghanistan humanitarian relief efforts and assistance in military response, NOAA's NESDIS expanded access to climate products, converting several offline products to online access such as the Afghanistan Climate Web Page and CD-ROM. NESDIS assisted in reestablishing the Afghanistan Climate Service by providing paper copies of unclassified

Afghanistan weather records and weather summaries to the World Meteorological Organization.

The DOC also engaged in a variety of non-NOAA aerospace activities. The Technology Administration 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 Department of Commerce on space-related issues, coordinating positions with and disseminating information to various bureaus with separate space-related responsibilities and authorities, including NIST, NOAA, the ITA, the National Telecommunications and Information Administration (NTIA), and the Bureau of Industry and Security, formerly the Bureau of Export Administration.

In October 2001, OSC partnered with George Washington University's Space Policy Institute to hold a workshop entitled "Space Economic Data: Classification, Collection, Access, and Use." Held at DOC headquarters in Washington, DC, the workshop assembled representatives of industry, Government, and academia to discuss the current state of space economic data and options for potential improvement. The DOC Assistant Secretary for Technology Policy delivered welcoming remarks, followed by an introductory issue overview by a senior representative of the White House Office of Science and Technology Policy (OSTP). Federal agencies providing presentations included DOC (Bureau of Economic Analysis), the FAA (Office of Commercial Space Transportation), and the Department of the Interior (U.S. Geological Survey). Private-sector organizations offering presentations included the Brookings Institution, the RAND Corporation, Eurospace, and companies involved in research and investment. The event generated considerable comment and analysis regarding options for improving space economic data collection and dissemination.

In November 2001, OSC collaborated with the Space Transportation Association and the Space Enterprise Council (administered by the U.S. Chamber of Commerce), to hold a second innovative workshop entitled "Market Opportunities in Space: The Near-Term Roadmap." Held at the Washington, DC, headquarters of the U.S. Chamber of Commerce, this workshop brought together representatives from a variety of public- and private-sector organizations and was designed to examine near-term options for private investment and entrepreneurial initiative in space commerce. Market opportunities included biotechnology, pharmaceuticals, materials processing, power generation, media, advertising, sponsorship, cargo delivery, and passenger travel. Following a welcome by the U.S. Chamber of Commerce Executive Vice President/Chief Operating Officer, DOC Under Secretary for Technology Phillip J. Bond provided introductory remarks. The Under Secretary highlighted DOC's goal of promoting U.S. space industry growth, concentrating on both emerging and established markets. U.S. Government presenters included representatives from the U.S. Senate Committee on Commerce, Science, and Transportation; the White House OSTP; and DOC (ITA). The composition of presenter panels also reflected OSC's commitment to invite viewpoints from the investment community, space and nonspace companies, and entrepreneurial as well as established firms. The event stimulated new dialogue about the involvement of nonspace organizations and companies in commercial space activities and generated considerable media coverage.

During the remainder of FY 2002, the DOC prepared reports concerning space economic data and space market opportunities, drawing both on the autumn 2001 workshops and additional research, with the expectation of publication early in FY 2003. As a follow-on project to the space market opportunities workshop, OSC also commissioned the Aerospace Corporation, a highly regarded engineering and consulting group, to prepare the first-ever overview of commercial suborbital vehicle development programs and potential markets.

Following up on the efforts of the Interagency Working Group on the Future Use and Management of the U.S. Space Launch Bases and Ranges, led by the White House, OSC collaborated with the USAF and the FAA Office of the Associate Administrator for Commercial Space Transportation to ensure full consideration of the needs of commercial users of the two major Federal space launch facilities. This project resulted in the signing of an interagency MOA in February 2002, which was subsequently implemented, with FAA's Commercial Space Transportation Advisory Committee playing a key role.

OSC assisted the FAA Office of the Associate Administrator for Commercial Space Transportation with the preparation of its report to Congress evaluating the U.S. liability risk-sharing regime for commercial space transportation. As required by the Commercial Space Transportation Competitiveness Act of 2000, OSC represented industry interests by providing its views and recommendations for the report, which was published in April 2002.

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 the GPS radio spectrum from encroachment by ultrawideband 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 board, to engage in international and domestic outreach missions to promote GPS as a global standard, and to participate in the GPS modernization program.

As part of the Department of State's ongoing negotiations with the European Union regarding the compatibility and interoperability of GPS and the Galileo satellite navigation system, 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 Department of State to affirm the two nations' mutual commitment to promote and use GPS as an international standard for satellite navigation and timing.

In FY 2002, NIST performed a broad range of measurements and standards-related research, technology transfer, and industry support in the areas of aeronautics and space. In support of the aerospace industry and with the sponsorship of the FAA, the Transportation Security Administration, and the Boeing Company at the Naval Surface Warfare Center, NIST has been developing efficient techniques and methodologies for measuring aircraft radiation shielding. Shielding reduces interference between aircraft navigation systems and other radiation sources like external radiation and onboard laptops and mobile phones. Aircraft hull shielding determines the test level needed to ensure safe operation for internal electronics, but shielding data are costly to obtain and often difficult to interpret. NIST developed new measurement techniques to enable fast, reliable in situ measurements in production facilities and aircraft hangars that are typically heavily cluttered, as demonstrated by successful measurements of a Boeing 737-800 aircraft by NIST scientists at the Boeing manufacturing plant in Reston, WA. These techniques eliminate the need to place an aircraft in an unobstructed area or special facility for shielding tests, thus reducing hull shielding test costs and allowing simpler, less expensive internal electronics testing.

NIST initiated work with the Microwave Instrument Technology Branch of NASA GSFC on problems of calibration and validation of microwave radiometers for remote sensing. In FY 2002, NIST staff helped perform tests at GSFC on the Conical Scan Millimeter-wave Imaging Radiometer and identified several suggested improvements. A long-term focus of the joint effort will be to develop a compilation of standard terms and recommended measurement practices for microwave remote sensing, particularly for calibration and validation of microwave radiometers. An initial Web site *(http://www.boulder.nist.gov/stdterms)* was developed and brought online as an international forum for the standardization of radiometry terminology.

NTIA and NIST completed a joint effort to use time-domain measurements to characterize ultrawideband (UWB) emissions of commercially available UWB devices for simulated interference studies. This work could be helpful to the Transportation Security Administration and the FAA in reducing potential interference between UWB broadcast signals and global positioning systems.

With funding from NASA, NIST continued to collaborate with GSFC to develop cryogenic transition-edge-sensor microcalorimeter x-ray detectors for use by the future Constellation-X mission. NIST developed new surface micromachining microelectromechanical (MEMS) fabrication techniques and developed an 8x8 array of microcalorimeters. NIST continued to develop new prototype arrays using both alternative surface-MEMS structures and bulk-MEMS structures to address issues of robustness when arrays are thermally cycled. In addition, NIST demonstrated a superconducting multiplexer system for readout of these detectors and for a separate millimeter and submillimeter imaging effort.

NIST continued to provide radiometric calibration support for the NASA Earth Observing System (EOS) program to ensure the accuracy of the sensors used in global remote sensing. NIST-calibrated radiometers were deployed to EOS users' sites to assess the accuracy of radiation sources used to calibrate EOS satellite sensors. NIST also provided the radiometric calibration of the Marine Optical Buoy for NOAA, which furnishes accurate data necessary to calibrate and validate satellite ocean color measuring instruments such as SeaWiFS and MODIS. NIST has a multiyear effort to improve calibration techniques for radiometers used for remote sensing. These new developments should provide greater measurement accuracy in satellite applications such as locating resource position and measuring Earth's temperature, the wind speed over the ocean, and sea salinity. In further calibration work, NIST's synchrotron ultraviolet radiation facility 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, as well as the NASA Solar Radiation and Climate Experiment.

In 2002, NIST deployed a transportable Thermal-infrared Transfer Radiometer (TXR) it developed to calibrate ship-based radiometers, which in turn validate satellite measurements of sea-surface temperature. The TXR was to perform measurements of the radiance of two calibration targets used for the NOAA GOES Imagers and to measure the radiance of blackbody sources used to calibrate a space-flight instrument currently flown for the Department of Energy. The TXR was developed to perform onsite calibrations of critical remote-sensing instruments, which establish the traceability of measurements performed by the remote-sensing community to NIST's highly accurate and validated radiometric scales.

NIST partnered with the Jet Propulsion Laboratory (JPL) on the Condensate Laboratory Aboard the Space Station (CLASS) project to develop measurement instruments involving Bose-Einstein Condensates (BECs) that will achieve their full potential in a microgravity environment. NIST demonstrated the wave-coherence of a BEC and demonstrated a temporal interferometer exploiting this coherence. NIST's expertise in Bose-Einstein condensation was recognized in 2001 by the Nobel Prize in Physics. Additional NIST efforts related to microgravity included work supported by the NASA Microgravity Research Program and conducted in collaboration with researchers at the University of Alabama in Birmingham to study the interaction of fluid flow with crystal growth. NIST also 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.

With NASA funding, NIST continued to collaborate with JPL, the University of Colorado, and the Harvard-Smithsonian Center for Astrophysics on the development of an atomic clock system for the International Space Station. The key advance in 2002 was the movement from general concept development to actual design of all the various components for the system in anticipation of the preliminary design review. The experiment was designed to test certain aspects of relativity theory and demonstrate the viability of operating a primary frequency standard in space.

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 SI unit of length, mass, and time, as well as their derived units (force, acceleration, sound pressure, and ultrasonic power). As one small example, NIST provided calibration services in 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 also provided standards and calibrations for antennas used with a variety of satellites, spacecraft, and radar systems. In addition, NIST performed calibrations of length standards for U.S. aerospace companies to ensure that the dimensions of their manufactured parts conformed to design specifications.

NASA and NIST collaborated on a project exploring the technical challenges to efficient low-temperature, high-magnetic-field technology. Investigations into the behaviors of nanocomposite materials helped researchers to evaluate their potential use in future satellite launches for magnetic refrigeration. NIST also worked with the NASA Glenn Research Center to broaden the use of advanced ceramics by aerospace designers. NIST 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 integrated a miniature pulse tube cryocooler into the Get Away Special canister provided by NASA for the December 2001 flight aboard the Space Shuttle. It performed flawlessly and achieved its designed low temperature of 90 kelvin. This miniature pulse tube cryocooler is designed for cooling infrared sensors in future space applications. NIST, with support from Kirtland Air Force Base, helped develop microscale heat exchangers for use in compact cryocoolers that would be used for cooling infrared detectors on satellites. For this program, NIST completed the development of a test microscale heat exchanger, which was found to be 97.5 percent effective. NIST also continued to provide technical guidance to Northrop Grumman and Lockheed Martin in their research and development of cryocoolers for the Spaced Based InfraRed System in low-Earth orbit. Such satellites can track incoming missiles and would become one component of the National Missile Defense System. In addition, NIST participated on a panel to guide NASA in the development of cryocoolers to achieve 6 kelvin for use in future space programs, including the Next Generation Space Telescope to replace the Hubble Space Telescope in about 2010.

In partnership with the Applied Physics Laboratory at the Johns Hopkins University, NIST invented a new technology known as parallel cantilever biaxial micropositioning. This technology supports very accurate beam steering used in deep space communications to and from a variety of spacecraft.

The NIST Manufacturing Extension Partnership (MEP) helped hundreds of U.S. aerospace parts and systems manufacturers increase sales and productivity and reduce costs by adopting lean manufacturing methods and other competitive processes. One example is Sonic Machine & Tool, Inc., a 35-employee machine shop in Tempe, AZ, that manufactures aerospace parts for large clients in the aerospace industry. The Arizona MEP helped Sonic implement lean manufacturing practices in its new facility. These practices generated about $1 million in additional annual sales and created 15 new jobs at the company. The Colorado MEP helped Ball Aerospace and Technologies Corporation, a 115-employee company in Westminster, CO, that designs and manufactures complete spacecraft and space systems, cryogenic subsystems, and communication and antenna systems, to adopt lean manufacturing processes to become a supplier to Boeing. The Colorado MEP assisted with the implementation of those practices, and Ball Aerospace and Technologies found that they increased production by 33 percent, reduced a 7-day product cycle to a 2-day cycle, minimized inventories, and increased antenna production from 45 to 60 units a day, while simultaneously improving quality.

Through a cost-sharing agreement with the NIST Advanced Technology Program, Acellent Technologies, Inc., started developing the foundation of a revolutionary breakthrough technology in the field of structural health monitoring with its integrated family of SMART technology products—SMART Layers, SMART Suitcase and Diagnostic/Application Software. NASA Marshall Space Flight Center and Oak Ridge National Laboratory are key partners in this research, which will benefit new and aging aircraft in the areas of improving public safety, reducing life-cycle costs, improving maintenance scheduling, and substantially reducing costs for analysis and evaluation. In another such agreement, NIST awarded GSE, Inc., an ATP award to develop a new diesel engine design that will tolerate the low cetane rating and physical properties of JP5, JP8, and Jet-A-fuel. When commercialized, the engine could be made in a wide range of sizes for civilian and military aviation.

The ITA's Office of Aerospace conducted a number of aeronautical activities in FY 2002. The Office of Aerospace contributed significantly to the research activities and development of recommendations by the Commission on the Future of the United States Aerospace Industry in FY 2002. Congress established the Commission to study issues associated with the future of the industry in the global context, particularly in relation to national security. An Office of Aerospace staff member served as co-leader of the study team responsible for global market and trade issues. In that capacity, he led the collection of data and testimony on related topics, interviewed public- and private-sector officials, organized fact-finding trips to Asia and Europe, and prepared draft analyses and recommendations for consideration by the Commissioners. All five public meetings in FY 2002 were hosted in the Commerce Department Auditorium, and the Deputy Secretary and two Deputy Assistant Secretaries from Commerce testified before the Commission. Other DOC bureaus, including the Bureau of Industry and Security and the Technology Administration assisted the Commission via the Office of Aerospace on an as-needed basis.

The Office of Aerospace continued to play a critical role in the U.S. Government team seeking resolution to aircraft noise- and emissions-related disputes between the United States and the European Union (EU). The primary dispute centered on the EU regulation that restricted the registration and operation in the EU of aircraft modified with noise-suppression technology, including aircraft engine "hushkits" and replacement engines. The Office of Aerospace and other agency representatives participated in bilateral discussions with EU officials under the mediation of the International Civil Aviation Organization (ICAO) Council President to press for the withdrawal of the regulation and European implementation of aircraft noise-related policy guidelines endorsed by the ICAO. Through extensive technical discussions, the U.S. Government team persuaded European officials to remove the most objectionable elements of new European aircraft noise legislation adopted in March 2002 to replace the EU "hushkit" regulation. Accordingly, the United States agreed to withdraw its complaint in ICAO about the hushkit regulation against 14 of the 15 EU member states. However, the U.S. Government continued negotiations with Belgium regarding the repeal of a Belgian decree adopted in April 2002 that perpetuates discriminatory aspects of the EU hushkit regulation. The U.S. Government also initiated negotiations with French officials about new restrictions at French airports that would have a significant impact on U.S.-based airlines and cargo carriers. The U.S. Government continued to monitor the adoption of national aircraft noise- and emissions-related regulations in other European countries.

Following successful efforts in 2000 and 2001 to have the Czech Government approve a 1-year tariff waiver for imports of large civil aircraft, helicopters, and certain spare parts, the Office of Aerospace again worked closely with other U.S. agencies for the renewal of the tariff waiver through December 31, 2003. The U.S. Department of State, 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. The Office of Aerospace is encouraging as many countries as possible to agree to sign the WTO Agreement on Trade in Civil Aircraft as part of their WTO access process.

The Office of Aerospace continued to monitor and address European government loans to Airbus for the development of the A380 super jumbo jet. In January, a U.S. interagency team, led by USTR and the DOC, held consultations with the EU in Brussels. U.S. officials expressed concern about government loans and stated that they are a subsidy unless they are provided on a commercial basis and 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 up to 33 percent of total aircraft development costs. During the consultations, the EU provided some, but not all, information about the loans as required in the 1992 Agreement.

The Office of Aerospace and the Civil Aviation Administration of the People's Republic of China Department of Planning successfully carried out the 2002 Aviation and Airport Subgroup Work Plan under the U.S.-China Joint Commission on Commerce and Trade. Delegations of Chinese from various disciplines in the aviation community participated in a number of training programs and conferences sponsored by the FAA or hosted by industry associations such as the American Association of Airport Executives (AAAE), the National Business Aviation Association, and the General Aviation Manufacturers Association. The United States hosted an Aerospace Product Literature Center and represented 14 U.S. companies at the China Air Show 2002, November 4–7, in Zhuhai, China. The Office of Aerospace's events have fostered an increasingly stronger relationship between U.S. and Chinese aerospace industries.

Office of Aerospace staff participated in U.S. Government negotiations with EU officials to press for the removal of provisions in draft legislation establishing the European Aviation Safety Agency (EASA) in FY 2002, which would link aircraft safety to international trade considerations. Senior DOC officials also raised these concerns during bilateral meetings with European Commission officials. Due in part to U.S. Government intervention, the legislation adopted in June 2002 establishing EASA to regulate civil aircraft safety in the EU and other European states did not include the objectionable provisions. The Office of Aerospace continued to monitor progress in the establishment of the agency to avoid any disruption in transatlantic trade or discrimination against U.S. interests.

In FY 2002, the Office of Aerospace continued to assist the U.S. aerospace industry's competition in the global marketplace through several international trade promotion and marketing activities. The Office of Aerospace sponsored Aerospace Product Literature Centers at major international exhibitions and air shows in the People's Republic of China, the United Arab Emirates, and the United Kingdom. More than 2,000 trade leads were generated through this program. The Office of Aerospace worked closely with the overseas posts to maximize the exposure of small- and medium-sized U.S. companies to the export market at these events.

In August 2002, the Office of Aerospace organized and managed an aerospace executive trade mission to Hanoi and Ho Chi Minh City, Vietnam. More than 20 U.S. business representatives participated in the mission, which featured high-level meetings with Vietnamese Government and industry aerospace officials. In October, the Office of Aerospace organized and managed an airport trade mission to Johannesburg and Durban, South Africa. U.S. business representatives visited numerous airports and met with high-level South African Government and industry officials. Both trade missions arranged one-to-one meetings for each of the participants, and several participants identified local representatives, agents, or distributors, or negotiated sales contracts during the mission.

Along with the AAAE, the Office of Aerospace cosponsored the 8th Annual Eastern European Airport and Infrastructure Conference and Trade Show in Salzburg, Austria. This event attracted more than 150 U.S. airport businessmen and 30 foreign delegations. This continuing program is designed to promote the export of aviation- and airport-related U.S. products and services by providing direct contacts and meaningful dialog between aviation-related companies and key international aviation and airport officials. The Office of Aerospace and AAAE also cosponsored a similar event in Bangkok, Thailand, demonstrating a variety of U.S. airport products and services to the Asian market.

The Office of Aerospace supported the visit of the Under Secretary of International Trade, Grant Aldonas, to the Farnborough Air Show, arranging meetings with Government and industry officials in a setting that fosters cooperation. The Farnborough Air Show was the largest international aerospace trade event for 2002; it attracted about 1,200 exhibiting companies and 130,000 trade visitors.

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

The Office of Aerospace coordinated the official signing ceremony for the sale of four Boeing 777 aircraft worth $680 million to Vietnam Airlines. With Secretary of Commerce Donald L. Evans overseeing the event, the signing of this historic contract marked the first major commercial transaction between the United States and Vietnam since the approval of the historic U.S.-Vietnam Bilateral Trade Agreement.

In September 2002, the Department of Commerce's Bureau of Industry and Security and the Department of State's Office of Defense Trade Controls published concurrent notices in the *Federal Register* revising the export licensing jurisdiction and requirements for space-qualified and related items that are designed, manufactured, and tested to meet the special requirements for use in satellites or high-altitude flight systems. These notices were designed to clarify confusion resulting from the 1999 transfer of satellites and "related items" from the Department of Commerce's Commerce Control List to the Department of State's U.S. Munitions List.

DEPARTMENT OF THE INTERIOR

DOI

In the area of satellite operations, the Department of the Interior's (DOI) U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) continued their partnership to manage the Landsat 5 and 7 satellites; the USGS has full responsibility for Landsat mission operations *(http://landsat7.usgs.gov)*. Landsat 7, launched in 1999, has collected over 300,000 scenes for the U.S. archive, as well as nearly 280,000 scenes for the network of international ground stations. Landsat 5, launched in 1984, is nearing its 100,000th orbit and is operating far beyond its design life. The Landsat ground station at the USGS Earth Resources Observation Systems (EROS) Data Center is the primary U.S. receiving station for Landsat 7 and the only North American ground station for Landsat 5 data.

The USGS and NASA continued a joint two-step procurement strategy for the Landsat Data Continuity Mission (LDCM) under which the private sector will provide data to the U.S. Government that ensures continuity with the Landsat 7 mission. The LDCM will be a commercially developed, built, launched, operated, and owned system that will deliver multispectral digital image data for global coverage of Earth's land masses on a seasonal basis through a data purchase arrangement *(http://ldcm.usgs.gov)*. Contracts were awarded to DigitalGlobe and Resource 21 in March 2002 to develop a mission concept for a complete LDCM system. The request for proposals to implement the program is being developed with substantial input from the contractors' first phase results. The winning contractor for the implementation phase will deliver data to the U.S. Government over a 5-year period starting in 2007, with an option for a 5-year extension.

A new NASA-USGS partnership for the Earth Observing-1 (EO-1) Extended Mission was established in November 2001. NASA operates the flight segment and the polar receiving stations, and the USGS EROS Data Center now performs image data capture, data processing, product generation, and distribution of Hyperion and Advanced Land Imager data (*http://eo1.usgs.gov*). Hyperion is the world's only civil spaceborne hyperspectral sensor. The EO-1 Extended Mission is an outgrowth of a highly successful 1-year NASA technology demonstration mission that confirmed the ability of several new technologies to lower the cost and increase the performance of future Earth science missions. The EO-1 Extended Mission has collected over 5,000 paired Hyperion and Advanced Land Imager scenes so far.

In the area of planetary exploration, USGS scientists continued to assist in data analysis for the NASA Mars Global Surveyor and Mars Odyssey missions as part of the science team mapping global subsurface ice deposits and mineral species on Mars. They are making important scientific and cartographic contributions to the site selection for two future Mars Excursion Rovers. These multicamera rovers will be about the size and weight of a riding lawn mover, as opposed to Mars Pathfinder's Sojourner rover, which was about the size of a microwave oven. USGS investigators also continued their work with the Cassini spacecraft; they are responsible for the orbital imaging of Saturn and the descent to and surface imaging of its moon Titan, should the probe survive.

In FY 2002, the Land Processes Distributed Active Archive Center at the USGS EROS Data Center (*http://edcdaac.usgs.gov*) produced and distributed over 1.7 million satellite image products from the MODerate resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instruments on NASA's Terra satellite, with a data volume of over 168 terabytes. USGS installed a direct reception and processing system for rapid turnaround of MODIS data. Improvements in data reception and processing now permit users to receive MODIS data for the United States from an FTP server just 4 hours after imaging occurs. The data provide daily coverage of the United States at low spatial resolution (250 to –1,000 kilometers) and in 36 spectral bands, facilitating data applications for emergency response, wildland fire mitigation, and field data-collection activities.

The USGS is cooperating with NASA, the National Imagery and Mapping Agency (NIMA), and the Jet Propulsion Laboratory (JPL) to archive and distribute digital elevation model (DEM) data from the Shuttle Radar Topography Mission (SRTM). The USGS offered initial data for the United States at 30-meter and 90-meter resolution to the public on a Web-based, seamless server in September (*http://srtm.usgs.gov*). Over the next 2 years, NIMA will process data for the USGS to distribute at 90-meter resolution covering Earth's land areas between latitude 60° N and 56° S on a continent-by-continent basis.

The USGS EROS Data Center now archives and provides public access to a second series of high-resolution intelligence satellite photographs declassified through Executive Order 12951 (*http://earthexplorer.usgs.gov*). The photography includes 19,000 frames acquired by the KH-7 surveillance system from 1963 to 1967 and 29,000 frames acquired by the KH-9 mapping system from 1973 to 1980. The photography (black-and-white, color, and some color-infrared and stereo coverage) was added to the more than 800,000 previously declassified intelligence photographs that were taken between 1959 and 1972. These newly released photographs extend the record of land surface changes at least a decade before the advent of the Landsat satellite program and are useful for historical and environmental research.

The USGS is developing *The National Map*, a seamless, Web-enabled set of current public-domain geographic base information that serves as a foundation for integrating, sharing, and using other geospatial data easily and consistently. As part of *The National Map*, USGS scientists are creating a layer of the best available, current, geometrically registered Landsat 7 data for the entire United States. The data can be used to provide reference information for Web browsers and map applications at a scale of 1:100,000 or smaller. The first installment of scenes for the conterminous United States was complete and ready for public access at the end of FY 2002. The Landsat database, which is made using three of the eight Landsat 7 spectral bands, will be kept current with data no more than 1 year old. Over time, the archive will provide a valuable historical reference to determine landscape baseline conditions and to measure change.

Users enthusiastically endorsed the utility of the new USGS Global Visualization (GloVis) Web-based image browser (*http://glovis.usgs.gov*). GloVis allows a user to browse the entire USGS archive of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data. GloVis users select a region and specify filter criteria such as dates and maximum cloud cover; then they can view dozens to hundreds of images of that region.

During FY 2002, the Bureau of Indian Affairs (BIA) used high-resolution satellite remote sensing and global positioning systems (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 data, digital raster graphics, and high-resolution IKONOS satellite data 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. In addition, they developed inundation maps for input to Emergency Action Plans for seven dams during the reporting period.

The BIA used commercial GPS receivers to collect data for 2,276 ditch miles and 20,483 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 photographs and satellite data were also key components in the mapping process in both the irrigation and Safety of Dams projects.

The Bureau of Land Management (BLM) used a wide variety of remote-sensing technologies in FY 2002 to inventory and monitor public lands in support of rangeland health issues; fire detection, behavior, and management; wildlife habitat evaluation; refinement of soil survey techniques; hazardous materials inventory; and energy and mineral leasing activities.

The BLM and the Department of Agriculture's Natural Resources Conservation Service have completed soil surveys for almost half of a 445,000-acre area of BLM land in the Mojave Desert, CA. As part of the project, BLM scientists developed a new Landsat TM band ratio image-processing technique for making preliminary soil survey delineations prior to field mapping; aerial photography has traditionally been used for this task.

In FY 2002, the BLM cooperated with the USGS to complete digital orthophotoquad (DOQ) coverage of all BLM lands. The BLM is making DOQ data for Utah and NAPP color-infrared aerial photography of Wyoming available to the public over the Internet. BLM field office specialists and managers were trained to use DOQs and other digital cartographic data to map off-highway vehicle routes to support BLM Resource Management Plans. BLM resource specialists were also trained to use color-infrared aerial photographs to assess riparian areas; they applied the tool over the entire Anvik River drainage based on BLM criteria for proper functioning condition.

The BLM investigated the use of airborne hyperspectral data and Light Detection And Ranging (LIDAR) surveys to assess fire fuels and map invasive weeds in Cascade-Siskiyou National Monument in Oregon, as well as in two study areas near the Snowstorm Mountains in Nevada. The data also provide a high-resolution spatial and spectral database to support resource management plans.

The BLM used interferometric synthetic aperture radar (InSAR) and Landsat TM data, as well as 1:40,000-scale color-infrared aerial photographs, to evaluate the long-term effects of ice roads that were built in the Arctic 25 years ago for oil exploration and drilling. Remote sensing and field investigations revealed little current evidence of these old roads, suggesting that the environmental impacts are almost fully healed.

The California Central Valley Project Improvement Act Biological Opinion requires that data on wildlife habitat change be used in water-related negotiations between Irrigation Districts and the U.S. Fish and Wildlife Service. Bureau of Reclamation (BOR) image analysts continued to examine such areas of change using multitemporal Landsat TM data for the Central Valley acquired in 1993 and 2000. They updated and improved 1993 databases of land use/land cover through this process. They also updated year 2000 information for approximately 60 percent of Federal water district areas within the Central Valley Project Improvement Act area.

BOR analysts used Landsat TM, Indian Remote Sensing Satellite multispectral and panchromatic data, and USGS DOQs to map irrigated land and/or agricultural crops in the Colorado River Basin, the Sevier Basin in Utah, the Klamath River Basin in Oregon, and the Central Valley of California. Water managers use irrigation status and crop type data with crop water use coefficients and locally varying climate data to calculate water use for agriculture. Landsat TM data and field verification were used to map riparian communities in the Lower Colorado River Basin to estimate water use by natural vegetation.

The National Park Service (NPS) used data from the Landsat, French Systeme Probatoire d'Observation de la Terre, and IKONOS satellites, along with conventional aerial photographs and digital orthophotographs, to map and monitor land cover, vegetation, cultural features, and other specific features in many national parks. LIDAR data were used to monitor coastal change at several park units, including Assateague Island and Cape Cod. High-resolution IKONOS data were used to monitor land-use change at several units in the Midwest. The NPS Pacific Island Network partnered with other Federal and State agencies to acquire Landsat and IKONOS data for applications such as mapping, change detection, and long-term resource monitoring. Approximately 400 GPS receivers were used for mapping and navigation to support a variety of NPS resource management and park maintenance applications. National park units used land-cover data from the interagency Multi-Resolution Land Characteristics Program for temporal ecosystem and change-detection studies and to provide context for analysis of higher spatial resolution imagery.

DOI scientists and resource specialists continue to use Precision Lightweight GPS Receivers (PLGR) to access the Department of Defense Navstar GPS Precise Positioning Service, primarily at the field-office level in wildland areas that are out of reach of traditional differential GPS service. The DOI currently operates approximately 1,250 PLGRs, as well as a variety of other types of commercial GPS units. DOI bureaus are replacing some PLGR units, where appropriate, with alternative commercial systems.

The USGS, the U.S. Environmental Protection Agency (EPA), and NASA are collaborating to use Landsat data from five dates (1972, 1980, 1986, 1992, and 2000) and other data to study changes in land use and land cover over the past 30 years for the conterminous United States. They assessed the rates, causes, and consequences of change in each of the 84 ecoregions covering the conterminous United States. Results from eight eastern ecoregions spanning the Atlantic coastal zone through Appalachia show that the characteristics of change vary significantly from ecoregion to ecoregion. Rates of land-cover change are highest in forested plains, predominantly due to an expanding timber industry. Piedmont regions exhibit substantial urbanization, but the spatial extent of change is lower than those estimated for the plains. Appalachian regions show the lowest rates of land-cover change, though pockets (such as the southern Blue Ridge) are urbanizing.

Vegetation scientists from USGS, the University of Alaska-Fairbanks, Russia, Norway, Greenland, Iceland, Denmark, and Canada produced the first true vegetation map of the entire arctic biome north of the treeline that had sufficient detail for global modeling efforts. The map was produced at a final scale of 1:7,500,000 using spatial data analysis, manual image interpretation, and digital image classification and modeling of NOAA Advanced Very High Resolution Radiometer (AVHRR) satellite data and derived Normalized Difference Vegetation Index (NDVI), a standardization measure of vegetation "greenness," data.

The BLM and the USGS are continuing the Southwest ReGap project that uses multitemporal Landsat ETM+ data to map vegetation for five Southwestern States—Arizona, Colorado, Nevada, New Mexico, and Utah. BLM scientists partnered with the Colorado Division of Wildlife to classify vegetation using Landsat TM data by watershed for approximately 75 percent of the State of Colorado.

USGS scientists used AVHRR data and AVHRR-derived NDVI data to extend a database of 10 different measures of vegetation growth for the State of Alaska to cover the period from 1991 to 2000. These data are used for a variety of land-management and resource-monitoring activities in Alaska, such as predicting the annual survival rate of caribou calves, based on summertime (June 21) NDVI values, and examining the relationships between climate gradients, interannual weather patterns, NDVI, biomass, and plant phenology. All data are available from the Alaska Geospatial Data Clearinghouse at *http://agdc.usgs.gov*. In a similar activity, USGS scientists cooperated with the National Drought Mitigation Center at the University of Nebraska-Lincoln to use AVHRR data to create a Phenological Metrics Database of the conterminous United States for 1989 to the present.

The USGS completed a land-cover/land-use database to document the temporal and spatial extent of urbanization for part of Anchorage, AK. Land-use and land-cover information was obtained by interpreting aerial photographs from 1973, 1985, and 1988–90, as well as 2000 IKONOS high-resolution satellite data. The database is being used for environmental analyses of water quality, urban growth, impervious cover, and loss of wildlife habitat.

BLM specialists analyzed AVHRR data to show the probability of increase of cheatgrass, a widely occurring invasive plant species in the Great Basin, including portions of Nevada, Utah, Idaho, California and Oregon. This information helps demonstrate the role of cheatgrass increase in relation to areas altered by fire. The U.S. Forest Service and the BLM also used the cheatgrass data to refine Fire Frequency Condition Classes in western rangeland ecosystems. BLM used historical and current aerial photographs to identify change over time in canopy cover and extent of pinyon-juniper communities in western Utah to support fire fuels management.

In FY 2002, the 8-day repeat capability of Landsats 5 and 7 was used to monitor major wildfires in the Western United States, including the Rodeo-Chedeski fire (the largest fire in Arizona history), the Biscuit fire in Oregon, and the Haman fire in Colorado, and also to aid in postfire damage assessment. USGS analysts assisted the BIA Burned Area Emergency Rehabilitation Team and the White Mountain Apache Tribe to prepare Landsat and IKONOS high-resolution satellite image products to support mitigation efforts on the Fort Apache Indian Reservation following the Rodeo-Chedeski fire. The products included Landsat image mosaics from October 1999 (prefire), June 21, 2002 (during the height of the fire), and July 7, 2002 (at approximate time of containment); IKONOS images; and burn-severity maps made from July 7, 2002, Landsat data.

The NPS continued to work with the USGS and the BOR to map vegetation and wildland fire fuels while obtaining uniform baseline data on the composition and distribution of vegetation types for 270 U.S. national park units. The pace of mapping continued to increase in FY 2002. The NPS Fire Program also worked with USGS scientists to produce fire history and burn-severity maps for a variety of park units.

At the request of the EPA, the USGS engaged in a rapid-response project with NASA and JPL to assess environmental impacts of the September 11, 2001, attack on the World Trade Center (WTC) in New York City *http://pubs.usgs.gov/of/2001/ofr-01-0429/*). Work began immediately following the attack and continued into FY 2002. JPL scientists acquired data over the WTC from the aircraft-based hyperspectral Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) beginning on September 16, 2001. The data were processed overnight; the next day, USGS and JPL scientists determined the locations and temperatures of hot spots in the WTC debris pile and sent information to the White House. The high temperatures and extent of the fires were a concern because of possible adverse chemical reactions in various materials in the debris. Based on this information, firefighters changed their strategy on September 18 in response to the fire extent and the recognition that temperatures exceeded 800 °F, with some over 1,300 °F. USGS scientists collected field samples around the WTC site between September 17 and 19. USGS scientists analyzed these samples and prepared preliminary maps of materials from the AVIRIS data, including the presence of asbestos, and delivered results to WTC emergency response teams on September 27. Although only trace levels of chrysotile asbestos have been detected in the dust and airfall samples studied to date, the presence of up to 20 percent by volume of chrysotile in material coating the steel beams in the WTC debris, along with the extent of potential areas indicated in the AVIRIS mineral maps, indicates that asbestos can be found in localized concentrations. The study also found that the WTC dust was quite alkaline, having a potential of hydrogen (pH) as high as 11.8, which is a probable reason for the burning and stinging sensations experienced by people in the WTC area.

The USGS collaborated with the National Cancer Institute and Colorado State University to identify populations exposed to elevated nitrates in drinking water in the Platte River Valley (Colorado and Nebraska), who may be at risk for methemoglobinemia, a blood disease that affects infants and also causes increased risk of certain cancers and adverse reproductive outcomes in adults. Human health scientists have been hampered in their study of the relationship between agricultural chemical exposure and health outcomes by the lack of information on historical environmental exposure to agricultural chemicals for rural populations in particular. USGS scientists used historical Landsat data to map land-cover types associated with high nitrate concentrations (such as cattle feedlots and corn crops). They combined these maps with other geospatial data to estimate nitrate exposure levels for populations using private wells. Results will be used to evaluate cancer incidence in relation to estimated nitrate exposure through drinking water.

Scientists from the USGS, the University of California-Davis, the Valley Fever Center for Excellence (Department of Veteran Affairs), and the University of Arizona used Landsat and other data to produce a map of Organ Pipe Cactus National Monument in Arizona depicting soils that are favorable hosts for the soil-borne pathogen that causes valley fever. The disease is an important public health issue in the arid Southwestern United States because of rapid population growth, increasing numbers of individuals with suppressed immune systems, and the continued stationing of military personnel in the region. This map will help land managers mitigate the effects of valley fever by locating new public-use facilities in areas where the occurrence of the soil pathogen may be low.

Wind-induced dust coming from sources in the Southwestern United States is not a major contributor to global dust flux, but it has important negative local and regional effects on air quality, human health and safety, and ecosystem dynamics. Since 1999, USGS scientists have used NOAA Geostationary Operational Environmental Satellite (GOES) satellite data and a ground-based automated digital camera to detect, monitor, and analyze the location, size, frequency, duration, and transport patterns of large dust storms in the central Mojave Desert (*http://TerraWeb.wr.usgs.gov/projects/RSDust/*). USGS scientists detected and monitored the arrival of two very large dust plumes in Las Vegas, NV, on April 15, 2002. Large, rapid increases in levels of PM10 (a measure of particulate matter less than 10 micrometers in size) occurred in the area when these plumes arrived. Besides showing that the very unhealthy air quality on that day was a direct result of regional (not local) dust sources, USGS scientists also computed the amount of airborne dust in the greater Las Vegas valley to be approximately 1.2 million tons.

USGS scientists used radar data from European Remote Sensing satellites (ERS) and InSAR techniques to map ground deformation caused by magma accumulation in Earth's crust, strain along earthquake faults, groundwater changes, and other processes that are common near active volcanoes. They found evidence for magmatic inflation at several Alaskan volcanoes. They used InSAR data to image the spatial extent and volume of lava flows at Okmok volcano in Alaska by constructing precise DEMs that represent volcano topography before and after the 1997 eruption. Comparable high-resolution DEMs are not easily obtainable from conventional sources such as optical photogrammetry or LIDAR sensing.

The USGS, JPL, the Scripps Orbit and Permanent Array Center, and the Southern California Earthquake Center unveiled the Southern California Integrated GPS Network (SCIGN), the largest continuous GPS network in the Western Hemisphere. The Keck Foundation, NASA, the NSF, the USGS, and several local counties and agencies provided funding. The SCIGN is a new type of earthquake monitoring network; rather than recording ground-shaking like other networks, SCIGN uses GPS to track the slow motion of Earth's plates and to detect small movements of Earth's surface through 250 stations in one of the world's most seismically active and highly populated areas. This network supports earthquake hazard assessments that help motivate people to prepare for earthquakes.

USGS scientists combined InSAR data from ERS satellites with SCIGN GPS data to measure, more accurately than ever before, the tectonic squeezing across Los Angeles that is responsible for earthquakes like the 1987 M-6 Whittier Narrows and M-6.7 Northridge shocks. They discovered that large regions of metropolitan Los Angeles are rising and falling by up to 11 centimeters (4.3 inches) every year, and that a large portion of the city of Santa Ana is sinking at a rate of 20 millimeters (0.79 inch) per year. The satellite data show that the ground surface of the 40-kilometer (25-mile)-long Santa Ana basin drops during the summer due to widespread pumping, and then rises in the winter due to regional groundwater recharge. Scientists also discovered three distinct subsidence regions due to groundwater pumping in the Coachella Valley—in the cities of Palm Desert, Indian Wells, and La Quinta. InSAR data were also used to identify the location of faults that restrict groundwater flow and map the margins of the groundwater aquifers.

In FY 2002, USGS scientists continued a successful partnership with NASA and local governments to produce high-resolution topographic data for the Puget Lowland of Washington State. The consortium more than doubled the existing coverage of dense multiple-return LIDAR data, reaching a total coverage of 10,000 square kilometers, or more than half of the Puget Lowland area. Using these data, the consortium discovered three new young fault scarps beneath the forest cover and confirmed that surface-rupturing earthquakes have occurred on each fault. Scientists also used the data to make geologic and geomorphic maps, investigate landslide hazards, describe beach processes, understand the effects and mechanisms of continental glaciation, and study forest ecosystems.

A tornado struck La Plata, MD, in April 2002. Local emergency response teams used Landsat, ASTER, and EO-1 data to measure the extent of the tornado track and make a preliminary damage assessment.

Office of Surface Mining Reclamation and Enforcement (OSMRE) specialists continued to use IKONOS 1-meter-resolution, pan-sharpened multispectral stereo satellite data to monitor five active western coal mines on a quarterly basis for regulatory purposes, including reviewing coal mining permits, making topographic measurements, and ensuring that mine operators comply with regulations. OSMRE specialists orthorectified the data with high-accuracy GPS ground control and generated digital elevation model products from the IKONOS stereo pairs on a photogrammetric workstation. They monitor over 500 square kilometers' worth of surface coal mines quarterly.

OSMRE specialists also evaluated the utility of IKONOS data for regulatory enforcement in a 500-square-kilometer area of the Appalachian region. The OSMRE Technical Innovation and Professional Services Program trained 12 State and Federal employees to generate orthoimagery and topographic data by photogrammetric processing of aerial and satellite imagery; it also deployed 12 photogrammetric workstations in five States for stereo viewing and processing of imagery. OSMRE analysts used aerial photography at a scale of 1:24,000 to 1:2,400 covering 800 square kilometers in Appalachian and western regions for topographic mapping at active mine sites.

In FY 2002, the OSMRE expanded the use of GPS for surface mine reclamation verification, technical assistance projects, and Abandoned Mine Land (AML) reclamation designs. Mine inspectors employed GPS, in tandem with mobile tablet computers, to verify large western surface mine jurisdictional boundaries, and to field-verify locations of mine features such as hydrologic structures, surface depressions, and reclaimed topography. AML specialists and contractors used GPS receivers to locate and inventory abandoned mine features nationwide and to map subsidence complaints and acid mine drainage discharges.

BLM researchers are applying data from hyperspectral sensors to locate coal bed methane gas seeps and are applying data from thermal-infrared sensors to locate actively burning coal seams. It is important for the BLM to locate these features for public safety and to ensure the efficient use of public resources.

USGS scientists mapped salt crusts in Death Valley, CA, using AVIRIS data and a new least-squares spectral band-fitting software algorithm. They identified eight different saline minerals, including three borates that have not been previously reported in Death Valley. Borates and other saline minerals provide a basis for making remote chemical measurements of desert groundwater systems. Such data aid in understanding how saline minerals indirectly reflect groundwater compositions and processes, and they will facilitate studies on how desert groundwater systems change through time in response to climatic and other variables.

USGS scientists completed an initial evaluation of ASTER data of the Cuprite, NV, mining district for geologic mapping and mineral resource investigations. Research concluded that data from the nine ASTER sensor bands in the visible and near-infrared wavelength regions can be used to map minerals typically associated with mineral deposits more completely and efficiently than using conventional field-mapping methods alone. Additional rock-composition information was obtained of the Mountain Pass, CA, area from analysis of spectral emittance data recorded in the five thermal-infrared ASTER bands. These positive results led to successful ASTER applications in Morocco and Mexico, where USGS scientists worked with their counterparts from the Moroccan and Mexican Geological Surveys. Post-field-mapping evaluations in these countries indicated that the ASTER rock-composition image maps provided accurate primary information.

The USGS released the newest of the 11-volume *Satellite Image Atlas of Glaciers of the World* series. This major work on the glaciers of North America reviews historical and ongoing changes in the glaciers of Canada, the United States, and Mexico, primarily using data from Landsats 1, 2, and 3. Long-term monitoring of glacier fluctuations can provide an important indicator of changes in regional and global climates. The volume was a collaborative effort among the USGS, the National Park Service, U.S. and Canadian universities, the Geological Survey of Canada, and the United Kingdom International Glaciological Society.

USGS scientists developed a methodology to use Landsat 7 data in conjunction with USGS mass balance measurements at South Cascade Glacier, WA, to estimate the annual storage or release of water by glaciers and perennial snowfields in the North Cascade Mountains. The method uses satellite data from late summer to determine the spatial distribution of snow and ice. This information is analyzed with other spatial data to determine the vertical distribution of snow and ice within a drainage basin, which is then combined with the measured mass balance, as a function of elevation, to estimate the glacial storage or release.

The USGS and the BLM used Landsat 7 data for the Bering Glacier ecosystem in Alaska to map the retreat of the glacier terminus as it undergoes large-scale calving into Vitus Lake, to determine the surface-flow velocities of the glacier, and to map the reestablishment of terrestrial vegetation after the glacier's surge of 1993–95. Scientists also used these data to monitor the level of Berg Lake and the integrity of the ice dam that forms the southern shore of the lake in order to assess the potential hazard presented by an outburst flood.

The worldwide decline of coral reefs due to natural forces and human activities is of great concern because reefs protect coastlines from erosion, provide shelter and food for economically valuable fisheries species, and bring recreational dollars to local economies. USGS scientists developed remote-sensing techniques to map and monitor sea floor habitat and to monitor both the shallow (1- to 5-meter) and deeper (5- to 40-meter) reefs off the Hawaiian Island of Molokai (*http://Terraweb.wr.usgs.gov/projects/CoralReefs/*). During FY 2002, they used Scanning Hydrographic Operational Airborne Lidar Survey bathymetry to map potential coral habitats. They also used shipborne dual-frequency acoustics to investigate the mapping of sea floor cover types in deeper waters. Finally, they used high-resolution 1:20,000-scale aerial photographs and Landsat TM data to detect and map suspended sediment deposited on reefs by on-land runoff after a large storm. This analysis helped to determine how such sedimentation affects algae growth and the general health of reefs.

The Minerals Management Service (MMS) continued to support satellite altimetry research by University of Colorado scientists for applications such as improving estimates of sea surface height and ocean currents, particularly for the large Loop Current eddies in the Gulf of Mexico. Accurate measurement of ocean currents is important for monitoring offshore oil and gas operations and for estimating oil-spill trajectories. In FY 2002, data from the Navy GEOSAT Follow-On and Jason-1 altimetry satellite missions were added to ongoing analysis of data from the TOPEX/Poseidon and ERS-2 satellites. MMS specialists continued to collect GPS data to help delineate offshore boundaries in the U.S. Virgin Islands in support of Territorial Submerged Lands jurisdictions.

In FY 2002, USGS scientists regularly used GPS and thermal-imaging technologies to support scientific research conducted in the Great Lakes basin. GPS surveys provided precise geographic coordinates of wetland plant-sampling transects along the U.S. shore of Lake Ontario, supporting binational wetland research in the International Joint Commission's reevaluation of the water-level regulation plan for Lake Ontario. All collection sites within the Finger Lakes region and tributaries to Lake Ontario in upstate New York were geo-referenced with GPS in studies characterizing the fish community structure, biodiversity, and ecosystem health.

USGS scientists collaborated with University of Minnesota researchers to use GPS to track sea lampreys in northern Lake Huron via telemetry and relate their daily movements to a river plume that was also being monitored. The study assessed how adult sea lampreys use a newly discovered migratory pheromone excreted by larval sea lampreys to select streams for spawning. This research may provide a new cost-effective, environmentally safe method for controlling the exotic sea lamprey that annually causes millions of dollars' worth of damage to the Great Lakes fishery.

Since 1975, the USGS has chaired the Civil Applications Committee (CAC), which is chartered under the signatures of the National Security Advisor to the President, the Director of Central Intelligence, and the Director of the Office of Management and Budget to facilitate the use of classified National Systems data for applications central to civil agency missions, such as mapping, charting, and geodesy; environmental monitoring, studies, and analyses; resource management; homeland security; natural hazards; and emergency response applications. The CAC Executive Steering Group was established in FY 2002 under the Chairmanship of the Deputy Secretary of the Interior to provide a forum for senior administration officials in the civil, defense, and intelligence communities to discuss and resolve key national policy issues that impact civil community access to and exploitation of data from National Systems.

During FY 2002, the CAC interacted with several individuals and organizations on important national issues, including the following: the National Security Space Architect, to identify civil requirements related to concepts for future remote-sensing systems; the Federal Law Enforcement Working Group, to consult on law-enforcement applications of remote sensing; and the Office of

Homeland Security, on the use of National Systems data to support the homeland security activities of civil agencies.

The Global Fiducials Library is an archive of National Systems data covering environmentally sensitive locations worldwide to meet near-term mission goals and perform long-term monitoring of natural and anthropogenic processes and critical indicators associated with causes or effects of environmental change. The Global Fiducials Library, which became operational in 1998, continues to expand based on recommendations for additional sites from CAC members.

Federal Communications Commission

FCC

All Federal Communications Commission (FCC) accomplishments during FY 2002 were related to communications and Earth-observation satellites. The FCC formulates and regulates the rules to facilitate the U.S. domestic satellite industry; it also authorizes licenses for all stations and satellite launches. Internationally, the FCC coordinates satellite placement with other countries. FCC's specific accomplishments for FY 2002 are outlined below.

The FCC authorized a number of communication satellite launches. On October 26, 2001, the FCC granted authority to launch and operate a Direct Broadcast Satellite, DirecTV-4S, and the satellite was successfully launched on November 27, 2001. On January 16, 2002, the FCC granted EchoStar Satellite Corporation authority to launch and operate a new spot beam Direct Broadcast Satellite, EchoStar 7; it was successfully launched on February 21, 2002. Also, FCC granted EchoStar Satellite Corporation authority to launch and operate a new spot beam Direct Broadcast Satellite, EchoStar 8, on June 20, 2002; it was successfully launched on August 22, 2002. The FCC Authorized PanAmSat to launch and operate its Galaxy III-C satellite using the C/KU band on May 30, 2002, and the satellite was successfully launched on June 15, 2002. On April 15, 2002, the FCC authorized Loral Cyberstar, Inc., to incorporate two additional Ku-band beams into the design of its Orion F2 geostationary satellite.

The FCC granted a number of Special Temporary Authorizations for satellite networks. On October 18, 2001, the FCC granted permission to Intelsat to deploy the Intelsat 602 satellite temporarily from longitude 62° E to longitude

64° E. On May 29, 2002, the FCC granted the authorization to PanAmSat to conduct inorbit testing of Galaxy III-C. On May 31, 2002, the FCC authorized PanAmSat to use the downlink beam on PAS-5 for commercial purposes; it had previously been used to monitor the satellite's Asian beams. On October 15, 2001, the FCC authorized PanAmSat to move the PAS-6 satellite from longitude 68.5° E to longitude 72° E; the satellite operates in a traditional Ku band. The FCC authorized PanAmSat to move Galaxy III-R from longitude 95° W to longitude 95.15° W on August 30, 2002, so that Galaxy III-C could assume its orbit location at longitude 95° W. Also, on September 16, 2002, the FCC granted a Special Temporary Authorization for PanAmSat to move the PAS-9 satellite from longitude 58° W to longitude 45.15° W.

On October 9, 2002, the FCC granted authorizations to 70 Mobile Earth Terminals to provide aeronautical, land mobile, and maritime services in the upper and lower L-bands via Inmarsat satellites. The FCC granted these authorizations to Comcast Corporation doing business as Comcast Mobile Communications; Comcast General Corporation; Stratos Mobile Networks (USA) LLC; Comcast Corporation; Marinesat Communications Network, Inc., doing business as Stratos Communications; Honeywell, Inc.; Deere & Company; Sita Information Computing Canada, Inc.; and IDB Mobile Communications, Inc.

During FY 2002, the FCC was also active in international satellite coordination. In the first quarter of FY 2002, the FCC reached Operator-to-Operator Coordination Arrangements with the Canadian, Brazilian, and Dutch satellite operators for 18 U.S. satellite systems. The FCC reached Administration-to-Administration Coordination Agreements with Canadian, Japanese, Russian, and U.S. Government satellite operators for 64 U.S. satellite systems.

In the second quarter of FY 2002, the FCC reached Operator-to-Operator Coordination Arrangements with the Brazilian and Indian satellite operators for four U.S. satellite systems. The FCC reached Administration-to-Administration Coordination Agreements with Brazilian satellite operators for four U.S. satellite systems.

In the third quarter of FY 2002, the FCC reached Operator-to-Operator Coordination Arrangements with the Canadian, Indian, and Chinese satellite operators for eight U.S. satellite systems. The FCC reached Administration-to-

Administration Coordination Agreements with the Chinese, Japanese, Swedish, Malaysian, Spanish, Saudi Arabian, Laotian, Dutch, Russian, Australian, Luxembourg, Brazilian, and French administrations for 201 U.S. satellite systems.

In the fourth quarter of FY 2002, the FCC reached Operator-to-Operator Coordination Arrangements with the Australian satellite operators for 90 U.S. satellite systems. The FCC reached Administration-to-Administration Coordination Agreements with the Brazilian and Australian administrations for 16 U.S. satellite systems.

Department of Agriculture

USDA

In FY 2002, U.S. Department of Agriculture (USDA) agencies used remote sensing to accomplish numerous operational and research activities. Several agencies applied these data, including the Foreign Agricultural Service (FAS), Forest Service (FS), National Agricultural Statistics Service (NASS), and Natural Resources Conservation Service (NRCS). Following are brief summaries from these four agencies, describing how remote sensing was used to accomplish various departmental goals and objectives.

The FAS Production Estimates and Crop Assessment Division was the focal point within USDA for assessing the global agricultural production outlook and conditions that affect world food security; it also served as the USDA Imagery Archive. The FAS satellite remote-sensing program remained a critical element in the Department's analysis of global agricultural production and crop conditions, providing timely, accurate, and unbiased estimates of global area, yield, and production. Satellite-derived early warning of unusual crop conditions and production enabled more rapid and precise determinations of global supply conditions. FAS exploited many global imagery datasets, including global Advanced Very High Resolution Radiometer (AVHRR) Local Area Coverage (LAC), High Resolution Picture Transmission (HRPT), and Global Area Coverage (GAC) from the National Oceanic and Atmospheric Administration. The ability to exploit 10-day global composites from the spot-vegetation sensor was added this year. FAS had standing orders for Landsats 5 and 7 imagery acquiring 8- to 16-day coverage for selected path/rows. All operational imagery was delivered within 12 days of acquisition. Due to budget constraints, use of Space Imaging IKONOS and

DigitalGlobe QuickBird satellites was extremely limited. In addition, FAS and NASA entered into a project to monitor global lake and reservoir height variations. One goal of this project was to use radar altimeters to provide information on global water supply. Information on the FAS remote-sensing program can be found on the Internet at *http://www.fas.usda.gov/pecad*.

During FY 2002, the FS Remote Sensing Application Center (RSAC) processed Moderate-Resolution Imaging Spectroradiometer (MODIS) data to produce active fire maps for the entire United States twice daily. The maps provided the interagency fire community with a synoptic view of the wildfire situation that aided with the strategic allocation of firefighting resources and assets throughout the country, as well as provided information for the general public. This service has been provided on a daily basis since July 4, 2001. This is a collaborative effort with NASA Goddard Space Flight Center (GSFC), the University of Maryland, and the Forest Service Missoula Fire Sciences Laboratory.

RSAC acquired MODIS imagery of the Western United States from a receiving station located at the RSAC facility in Salt Lake City, UT. Imagery of the Eastern United States was acquired by GSFC. RSAC used a fire-detection algorithm developed by the University of Maryland to identify active fire locations. These locations were overlaid on a cartographic base map that showed State boundaries, topography, major cities, and interstates. The maps were then posted on the Internet (*http://www.fs.fed.us/eng/rsac/fire_maps.html*), where they were accessible to national fire managers and the general public. During the 2002 fire season, the RSAC Active Fire Map Web site averaged 3,000 visitors per day and distributed approximately 3.5 gigabytes of maps daily. The peak usage occurred on June 21, 2002, when over 25,000 visitors accessed the Web site.

During FY 2002, FS, through its RSAC, continued to work with NASA Ames Research Center (ARC) and GSFC on a number of fire-related technologies. ARC work included advanced sensor design and image processing from airborne platforms, as well as unpiloted aerial vehicle development and mission profiling for tactical wildland fire mapping. At the request of FS, ARC provided emergency airborne thermal imagery over fires in southwestern Oregon and northern California during July and August 2002. This request came at a time when requests for airborne thermal imaging exceeded the capabilities of FS airborne assets. GSFC work involved preliminary designs of both air-to-ground and air-to-satellite communications systems designed to enable rapid transmission of FS airborne thermal-image products to incident command personnel. Various equipment alternatives were examined, and a final design was being formulated with the goal of conducting operational trials during the upcoming 2003 fire season.

The NASS mission was to provide timely, accurate, and useful statistics in service to U.S. agriculture. These statistics cover virtually every facet of U.S. agriculture, from production and supply of food and fiber to prices paid and received by farmers and ranchers, as well as the Census of Agriculture every 5 years. Remote-sensing data and techniques are valuable tools used to improve the accuracy of some NASS statistics. Remote-sensing data, including both satellite and aerial, combine with area sampling frame designs to form the backbone of our most important early-season survey conducted to provide a first look at planted acreage for the season. NASS used remote-sensing data to construct and sample area frames for statistical surveys, estimate crop area, and create crop-specific land-cover data layers for the Geographic Information System (GIS). In FY 2002, NASS used Landsat imagery, digital orthophoto quadrangles, and other remotely sensed inputs for 19 States to select the yearly sample. In addition, NASS used these materials in these States to select a supplemental area sample to measure the completeness of the list used for the 2002 Census of Agriculture. The remote-sensing acreage estimation project analyzed Landsat data from the 2001 crop season in Arkansas, Illinois, Indiana, Iowa, Mississippi, the Missouri boot heel, eastern Nebraska, New Mexico, and North Dakota to produce crop-acreage estimates for major crops at State and county levels, as well as a crop-specific categorization in the form of a digital mosaic of Thematic Mapper (TM) scenes distributed to users on a CD-ROM. For the 2002 crop season, NASS headquarters and several NASS field offices continued partnership agreements with State organizations to decentralize the Landsat processing and analysis tasks and expanded their efforts into a pilot area in central Wisconsin. Data for 2002 acreage-estimation analyses were collected in Arkansas, Illinois, Indiana, Iowa, Mississippi, Missouri, Nebraska, New Mexico, North Dakota, and Wisconsin. NASS, in conjunction with the Agricultural Research Service, continued research on data from the MODIS sensor on the TERRA satellite for use as an additional input for setting yield estimates and as a possible replacement for AVHRR data in generating vegetation-condition images. Specific pilots were conducted in McLean County, IL, and Cass County, ND.

During FY 2002, NRCS was the primary Federal agency working with private landowners to help them protect their natural resources. Much of the land-management business conducted by NRCS required the use of geospatial technologies and remote-sensing products. NRCS has used aerial-photography products for over 50 years in conducting agency programs and business. Today, NRCS has completely transitioned to the exclusive use of digital-imagery products.

All aerial-photography and derivative digital-orthoimagery products used by NRCS were acquired from commercial sources. NRCS was an original member of both the National Aerial Photography Program (NAPP) and the National Digital Orthophoto Program (NDOP). Most of the imagery used was acquired through cost-share partnerships with NAPP and NDOP member agencies at the Federal and State levels. The NDOP reached a milestone in FY 2002 when it completed, for the first time ever, full 1-meter ground sample distance (GSD) orthoimagery coverage of all private lands in the Nation. Only a small percent of Federal lands remained incomplete. In FY 2002, NRCS began to partner with State agencies in the development of higher resolution orthoimagery (1- to 2-foot GSD) over areas originally done at 1-meter GSD. NRCS delivered all imagery and other geospatial data to county field offices over the Internet on the USDA Resource Data Gateway. It was important to NRCS that all imagery acquired by the agency resided in the public domain. This permits NRCS to distribute data and imagery internally and externally without costly and restrictive use licenses.

In FY 2002, 1-meter orthoimagery was used extensively nationwide for conducting soil surveys as part of the National Cooperative Soil Survey program. Soil scientists used digital orthoimagery as the base for mapping and digitizing soil surveys. Approximately 45 percent of the Nation's detailed soil surveys had been converted to a nationally consistent digital geospatial format. Also in FY 2002, NRCS completed the installation of the Department's enterprise GIS in all 2,600 county field offices. Natural-resource planners at county field offices routinely used digital orthoimagery with the USDA's GIS to delineate farm tracts, wetlands, and crop fields in support of conservation programs. Land features such as farmsteads, gullies, oil wells, ponds, and strip mines were easily located on the orthoimagery.

The orthoimagery backdrop was a valuable land-planning tool when digital soils, hydrography, land parcels, and other geospatial data were superimposed onto the orthoimage base map.

NRCS continued to contract for high-resolution aerial photography (ground resolving distance of less than 1 foot) to collect data for the annual continuous National Resources Inventory (NRI) program. NRI required high-resolution imagery over confidential statistical sampling sites. NRCS purchased NRI imagery for approximately 50,000 sites nationwide. Six aerial firms acquired the natural color imagery within short photo periods during the growing season. The USDA Aerial Photography Field Office of the Farm Service Agency (FSA) contracted for the imagery. The FSA office had responsibility for contracting aerial photography in the USDA.

NRCS increased its use of satellite imagery by accessing the Landsat imagery acquired by FAS. FAS brokered a contract with a satellite provider that permits FAS to reproduce the data for other USDA agencies to use. With commercial off-the-shelf remote-sensing and GIS software becoming so commonplace on personal workstations, more resource planners within NRCS had the ability to use satellite and other digital imagery on a daily basis.

In FY 2002, NRCS purchased about 700 Nationwide Differential GPS receivers through a USDA GPS contract. Over 1,700 GPS receivers were used in everyday applications by soil scientists, engineers, and resource-planning specialists at the county level. NRCS partnered with FSA to complete a nationwide GPS training effort for each member of NRCS State and field office staff.

NRCS was well represented on Federal mapping, remote-sensing, GPS, and geodata committees. Much time and many resources were devoted to support the work of the Federal Geographic Data Committee, NAPP, NDOP, and the Interagency GPS Executive Board.

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, multiyear, 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 larger by a factor of 15 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 (ISI), under development by Townes at the University of California, 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 USAF 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 kilometers 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 Global Navigation Satellite System (GLONASS) satellite.

DEPARTMENT OF STATE

DOS

The Department of State (DOS) conducted successful negotiations with the Japanese Government to resolve policy issues related to the 1969 U.S.-Japan Space Agreement and current U.S. export control practices that had been impeding Japan's ability to obtain U.S. technology and hardware to support its space launch vehicle development programs. As a result of these negotiations, the U.S. aerospace industry will now be in a significantly better position to market its space launch technology and hardware successfully in Japan.

The DOS presented a draft framework agreement between the United States and the European Community on satellite navigation systems in October 2000; this agreement has led to three negotiation sessions and two technical working groups with the European Community. In September 2002, the European Commission recommended that Galileo use the same frequencies for its Public Regulated Service as GPS uses for the future military service, M-code. This overlay raises serious national security concerns for the United States and would impact NATO operational capability. The Department has led multiple bilateral discussions with the European Commission and European Union member countries in an attempt to reverse this M-code overlay plan.

The DOS provided funding for a series of four regional Global Navigation Satellite Systems (GNSS) Workshops and one Plenary Session. These workshops were held under the auspices of the United Nations and the United States. The workshops were held in Kuala Lumpur, Malaysia, for the Asia Pacific regions; Vienna, Austria, for the Eastern European region; Santiago, Chile, for the Latin American region; and Lusaka, Zambia, for Africa. A summary plenary conference was held in Vienna, Austria. The workshops were highly successful in bringing together regional experts and decisionmakers to advance awareness and support for the use of GNSS applications for sustained growth, transportation safety, and environmental management.

In addition to the GNSS workshops, the Department gained approval for FY 2002 funding for GPS international outreach efforts from the Interagency GPS Executive Board Secretariat. As a result, a GPS exhibit and support team carried the U.S. message to such venues as the International Civil Aviation Organization General Assembly in Montreal, Canada; the Working Party 8D of the International Telecommunication Union in Geneva, Switzerland; the Commission on Inter-American Telecommunications (CITEL) in Mexico City, Mexico; IV Space Conference of the Americas in Cartagena, Colombia; the GNSS 2002 Workshop in Copenhagen, Denmark; the Asia-Pacific Telecommunications Workshop in Bangkok, Thailand; the Farnborough air show in Farnborough, England; and the United Nations/U.S. workshops mentioned above. This exhibit greatly contributed to providing an accurate picture of GPS policy capabilities and modernization plans.

The Department of State led U.S. Government participation in the United Nations Committee on the Peaceful Uses of Outer Space. The Committee was formed in 1958 and is the only standing body of the United Nations to consider international cooperation in the exploration of outer space. The Committee has been responsible for the elaboration and adoption by consensus of five multilateral treaties governing space activities and three sets of nonbinding principles concerning the use of nuclear power sources in outer space, sharing the benefits of space exploration and remote sensing of Earth from space. These treaties form the basis for international law in the use and exploration of outer space. Over the past year, important work was undertaken by the Committee in areas such as global navigation satellite systems, meteorology, astronomy and astrophysics, space transportation, human space flight, planetary exploration, addressing the problem of orbital space debris, and environmental monitoring. The Committee also considered legal issues related to international liability and responsibility of launching states, international financial security interests in space equipment, and the equitable access to geostationary orbit.

The DOS implemented a number of international initiatives that harness space-based technologies in support of U.S. foreign policy goals relating to oceans, the environment, science, and technology. Many of these initiatives entail applying geospatial technologies (such as satellite remote sensing, geographic information, Global Positioning System, and online Web-mapping) to issues related to the international environment, natural resources, and science and technology cooperation. The Geographic Information for Sustainable Development initiative was featured by the U.S. delegation to the World Summit on Sustainable Development in Johannesburg, Republic of South Africa, in September 2002. The initiative is an international public-private partnership in applying geographic information technologies to help decisionmakers address a range of sustainable development problems including food, security, sustainable agriculture, natural resource (including forests and water) management, disaster mitigation, and poverty alleviation. In addition, the DOS supported other applications and projects of satellite remote sensing and geographic information in the Amazon Basin, Afghanistan, Thailand, India, and other countries around the world.

The DOS hosted a consultation of the 16 international partners participating in the International Space Station (ISS) program in July. The Partners discussed the progress to date on the ISS and the way forward for completion of the project.

DEPARTMENT OF ENERGY

DOE

The Department of Energy (DOE) continued to support NASA's space exploration program by maintaining the infrastructure for producing radioisotope power sources and heater units, as well as developing new, advanced power systems covering a range of power levels required to meet more stringent power systems requirements for future missions. DOE initiated the preparation of the Final Safety Analysis Report to support the launch approval process for the use of heater units on the Mars 2003 missions. DOE competitively procured a systems contractor to develop and demonstrate a Stirling power system, a high-efficiency dynamic system for providing electrical power for potential use on such future missions as the Mars Science Laboratory in 2009. DOE also initiated the procurement of a systems contractor to develop a multimission Radioisotope Thermoelectric Generator (RTG) suitable for providing electrical power on the surface of Mars and in the vacuum of deep space. Finally, DOE worked to produce an RTG to provide 285 watts of electrical power for potential use on a mission to Pluto and the Kuiper Belt, scheduled for launch in 2006.

DOE worked to close out the Cape Canaveral Dense Nonaqueous Phase Liquid project. At the end of the fiscal year, all the field work was done, and the final reports were under review. The technologies tested are under consideration for use at several other sites at Cape Canaveral and Patrick Air Force Base. The follow-on work entails the development of guidance documents on the use of source removal technologies. These will be interagency documents developed with the regulatory community. DOE has also been working with NASA on cost-modeling issues as well. The ability to estimate cleanup costs for environmental contamination cuts across all agencies, so DOE is working with NASA and DOD. DOE has begun an effort to develop better monitoring methods and systems with

NASA for long-term stewardship of areas that have been remediated. Both agencies are concerned with the residual contamination and the impacts on adjacent sites, and they are discussing better and cheaper methods to watch the areas for the long term (in excess of 25 years).

In FY 2002, DOE's Office of Science cooperated with NASA in a wide variety of activities, such as exploring the experimental techniques of fundamental physics for use in outer space, using the science and technology plasma science to devise new propulsion systems, undertaking joint efforts to understand atmospheric and environmental phenomena, and building a working partnership in advanced computing research. The agencies carried out these activities under an MOU signed by NASA Administrator Daniel Goldin and DOE Secretary James Watkins in 1992.

Through an Implementing Arrangement with NASA signed in 1995, the Office of Science continued in 2002 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 2002 was used to analyze data acquired during a 10-day Space Shuttle flight in 1998 and to plan for an upcoming Shuttle flight to the International Space Station in 2003.

DOE's Office of Science and NASA's Office of Space Science (OSS) have worked together since FY 2000 to build the Large Area Telescope (LAT), the primary instrument for NASA's Gamma-ray Large Area Space Telescope mission, currently scheduled for launch in 2006. An Implementing Arrangement was signed in early 2002 for cooperation on the LAT project, which has continued in FY 2002. 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 overall management of the LAT project, the data acquisition system, the tracker detector, software development, and assembly and integration of the complete instrument. Researchers funded by DOE's Office of Science at the University of California, Santa Cruz, are building the tracker detector. In conjunction with NASA and international partners, DOE provided funding in FY 2002 for R&D, design, and fabrication of the telescope.

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 (BNL). The AGS is the only accelerator in the United States capable of providing heavy ion beams at energies useful for space radiobiology. Since fall 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, the Booster Applications Facility, is under construction at the RHIC complex. This new user facility, scheduled for completion in 2003, is designed to continue NASA's radiation biology studies more effectively, specifically to serve as a radiation simulation facility for human space exploration. The Office of Science and NASA continued working together to expand the range of technical resources available for experimentation and the analysis of experimental results at BNL.

Astrophysicists supported (in part) by the DOE Office of High Energy and Nuclear Physics use the National Energy Research Scientific-computing Center (NERSC), funded by the DOE Office of Advanced Scientific Computing Research, to perform computer simulations and analysis of data. In 2002, this effort produced the first three-dimensional simulation of an exploding supernova, the first observation of asymmetric supernova explosions (using data collected by the HST), and the first computer model of the spiraling merger of two black holes.

Researchers at several DOE labs receive NASA support for their work. This support includes an "early career" grant and astrophysics theory grant for an astrophysicist working on supernova modeling in NERSC at Lawrence Berkeley National Laboratory (LBNL), as well as support for the cosmology and astrophysics group at LBNL, which continued working in several areas of cosmic microwave background research and technology development. NASA funds also supported some members of the astrophysics theory group at Fermilab. In FY 2001 and

FY 2002, LBNL received funds from NASA under the Work For Others program toward the development of charge coupled devices, which are used for optical imaging in telescopes. Also in FY 2002, LBNL received NASA funds for scientific analysis using data from the HST. These funds are based on the number of HST orbits a researcher has been awarded.

Transfer of knowledge to NASA and NASA's use of research capabilities developed in the Fusion Energy Sciences program by the Office of Science continued in FY 2002 in a number of NASA-funded research activities with the potential to revolutionize interplanetary space travel through the use of plasma and fusion propulsion. The research activities were part of NASA's Advanced Space Transportation Program (ASTP), NASA's activity in Revolutionary Aerospace System Concepts (RASC), and NASA's newly launched Nuclear System Initiative (NSI).

Researchers at DOE's Princeton Plasma Physics Laboratory (PPPL) were funded by NASA to participate in a study led by NASA Glenn Research Center on the potential of the spherical torus as an advanced form of fusion rocket with propulsive power in excess of 8 gigawatts (GW). The spherical torus is being investigated by DOE's Office of Science for magnetized fusion energy applications at PPPL, and NASA is using PPPL facilities to perform some experiments pertinent to space applications.

Researchers at DOE's Los Alamos National Laboratory (LANL) were funded by NASA to participate in research, led by NASA Marshall Space Flight Center, that is investigating the feasibility of developing a very compact, lightweight fusion rocket based upon magnetized target fusion and with a power capacity of about 1 GW. (DOE's Office of Science continued investigating magnetized target fusion for fusion energy applications.) Three-dimensional hydrodynamics computer codes and two-dimensional magnetohydrodynamic computer codes, developed by LANL, were used by NASA in this research. Fusion experts at the University of Wisconsin, funded by NASA, participated in the RASC Group's system study of the magnetized target fusion concept, led by NASA Langley Research Center, for use in human missions to the outer planets. The University of Wisconsin is a major research center funded by the Office of Science for fusion energy applications.

The two fusion rocket concepts based upon the spherical torus and the magnetized target fusion have the potential of reducing traveling times to the planets by more than a factor of ten.

PPPL researchers also worked on a high-power Hall thruster, a form of electric thruster, in FY 2002. The high-power Hall thruster has potential performance levels that are relevant to NASA's NSI to send advanced science missions to the outer planets.

DOE's Oak Ridge National Laboratory, PPPL, and NASA Johnson Space Center continued to collaborate in FY 2002 on the development of an advanced plasma rocket technology called the Variable Specific Impulse Magnetoplasma Rocket, which could cut in half the time required to reach Mars. The technology is potentially a precursor to fusion rockets based upon the magnetic mirror fusion approach previously investigated in the Office of Science's magnetic fusion program. A key to the technology is the capability to vary the plasma exhaust to maintain optimal propulsive efficiency.

PPPL worked on several other basic science projects for NASA in 2002. These projects focused on magnetic reconnection and other work on ionospheric and space-related plasma physics topics. The Magnetic Reconnection Experiment (MRX) investigated the coupling between microscale reconnection layers and global-forcing and plasma-topology evolution. The MRX team won the 2001 American Physical Society Division of Plasma Physics award for excellence in plasma research. The project to study the equilibrium magnetic field and current of Earth's magnetosphere studies realistic, three-dimensional structures of Earth's magnetic field; plasma currents; and plasma pressure, all in equilibrium, by solving the force balance equation. One project was developing a model to describe magnetosphere/ionosphere coupling; another project was studying the onset mechanism of substorms that occur in the near-Earth plasma sheet region.

The Office of Science and NASA worked together to calculate the daily primary productivity of terrestrial ecosystems at diverse sites in North and Central America. In FY 2002, the AmeriFlux Program of the Office of Science provided real-time meteorological and solar radiation data for these calculations, and NASA provided data on gross primary productivity and leaf area. This joint work made possible continental-scale estimates of seasonal and geographic patterns of productivity. The AmeriFlux program produced unique ground-based measurements of net ecosystem production from 16 locations across the United States. These results provided an independent calibration of NASA's productivity calculations based on data derived from remote sensing.

The NASA Aqua Satellite was launched in May 2002. One of the instruments on board is the Atmospheric Infrared Sounder (AIRS). The NASA AIRS Instrument Team requires profiles of atmospheric thermodynamic variables in order to validate the performance of the AIRS instrument. These data were provided by balloon launches from three Office of Science Atmospheric Radiation Measurement (ARM) sites—Barrow, AK; Lamont, OK; and the Republic of Nauru—all equipped for advanced radiosonde operations. Data from these soundings and from other ARM instruments are being used for development and testing of AIRS water vapor retrievals.

The ARM program participated in the NASA Cirrus Regional Study of Tropical Anvils and Cirrus Layers Florida Area Cirrus Experiment (CRYSTAL-FACE) field campaign. CRYSTAL-FACE was a complex airborne and spaceborne science campaign exploring how cirrus clouds affect climate change. Results from the project will also help create better weather forecasting models. In July 2002, researchers supported by NASA and other agencies used six aircraft equipped with state-of-the-art instruments to measure characteristics of clouds and their influence on Earth temperatures in the Florida region. Satellites and ground-based instruments played an important role in the experiment. ARM provided the ground-based measurements that complemented the multiple airborne measurements. Expected results are improved remote-sensing algorithms for estimating the properties of cirrus clouds and a better understanding of the impact of cirrus clouds on the energy budget.

The Office of Science and NASA continued a close collaboration on the development and implementation of climate models. Both agencies support a variety of activities associated with the Community Climate System Model. The NASA Earth-System Modeling Framework project is coordinated with the Office of Science Scientific Discovery Through Advanced Scientific Computing effort in climate modeling to develop software frameworks and implement efficient software engineering practices for complex climate and Earth system models. DOE researchers at ORNL and LANL are working with NASA staff at Goddard Space Flight Center and Ames Research Center to evaluate and utilize next-generation high-end computers for climate modeling.

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 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 cause radiation risks. In FY 2001, NASA and DOE developed an MOA to better coordinate their common interests. This close collaboration between NASA and DOE enhances progress in understanding and predicting the effects and health risks resulting from low doses of radiation. DOE and NASA also issued joint Requests for Applications in FY 2002 and 2003 for research that addresses both DOE and NASA needs to understand the human health effects and risks of exposures to low doses of radiation.

In the computing area, the Office of Science and NASA continued their collaboration on "Grids," a way to connect geographically dispersed computer systems so that they can work together to solve science and engineering problems. Two Office of Science laboratories, the Lawrence Berkeley National Laboratory and the Argonne National Laboratory, set up experimental Grids with NASA 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 form the central information service for Grids. 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.

In FY 2002, DOE initiated a new activity on programming models for scalable parallel computing in which NASA researchers are participating. This project focuses on research, development, and deployment of software technology to support effective parallel programming models for tera-scale computing and beyond. Developing applications for tera-scale systems is difficult; typical applications achieve only a small fraction of peak performance. Advances in programming models will shorten application development time by making parallel algorithms easier to express and will improve application efficiency by matching the programming model more closely with the underlying systems.

Many of the NASA-funded activities listed above entered the Department of Energy through the Work For Others program. This program allows non-DOE sponsors access to the Office of Science laboratories' unique and specialized facilities and expertise. Other areas supported by NASA through this program include research in the space radiation environment and its implications for human presence in space, aerogel-based materials, combustion under microgravity conditions, the biological impact of solar and galactic cosmic radiation exposure on astronaut health, and the genetic and epigenetic effects produced by high-energy heavy ions.

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, MA, to form the Harvard-Smithsonian Center for Astrophysics. Here, more than 300 scientists engage in a broad program of research in astronomy, astrophysics, and science education. The Smithsonian National Air and Space Museum in Washington, DC, also contributed to national aerospace goals through its research and education activities.

SAO continues to control the science and flight operations of the Chandra X-Ray Observatory from a control center in Cambridge, MA. The Chandra X-Ray Observatory is one of NASA's "great observatories" and, since its launch in 1999, has made many significant discoveries about the high-energy universe. In FY 2002, Chandra released its spectacular view of the center of the Milky Way galaxy, which revealed hundreds of white dwarf stars, neutron stars, and black holes bathed in an incandescent fog of multimillion-degree gas. Also in FY 2002, a movie created from a series of Chandra and HST images made a big splash by showing how matter is propelled nearly to the speed of light by the Crab pulsar, a rapidly rotating neutron star the size of Manhattan.

Using the HST, a team including SAO scientists discovered the atmosphere of a planet orbiting another star in FY 2002. This accomplishment was possible because the planet passes directly in front of its host star, causing some of the star's light to be absorbed by the planet's atmosphere. Such studies open the future possibility of detecting Earth-sized worlds with atmospheres capable of supporting life. Also in FY 2002, SAO astronomers using ground-based observations found signatures of a planet forming in the dusty disk surrounding the nearby star Vega. They also developed a model indicating that the periodic extreme dimming of Mira and similar variable stars occurs because a chemical found in sunscreen forms in the star's atmosphere. Peering from a South Pole telescope into the heart of the Milky Way, they found evidence that our galaxy will undergo a dramatic burst of star formation in about 300 million years.

Solar scientists at SAO continued to study the electrically charged atoms (ions) that the Sun expels into the solar system. These ions occur in a steady, high-speed wind and in sudden bursts called coronal mass ejections. New observations from SAO's UltraViolet Coronagraph Spectrometer aboard the Solar and Heliospheric Observatory (SOHO) spacecraft allowed scientists 1) to probe physical processes in the explosive coronal mass ejections that can have a strong impact on Earth's local space environment and 2) to observe, for the first time, the properties of the sources of the high-speed solar wind as these sources re-form during the reversal of the Sun's magnetic polarity. These measurements are coordinated with other SOHO instruments, with the extreme ultraviolet images from the Transition Region and Coronal Explorer satellite, and with hard x-ray images from the Ramaty High Energy Solar Spectroscopic Imager satellite. In FY 2002, the Solar Physics group completed a Phase A definition study for the Advanced Spectroscopic and Coronagraphic Explorer (ASCE), an Explorer-class satellite designed to further investigate discoveries made by SOHO. ASCE is among four projects chosen for Phase A studies from 35 proposals.

Construction of SAO's Submillimeter Array (SMA) on Mauna Kea, HI, being done in collaboration with the Academia Sinica of the Institute of Astronomy and Astrophysics in Taiwan, continued to make good progress. Scientists at the SMA achieved phase closure at a frequency of 690 gigahertz. This achievement demonstrated the imaging capability of the Array at that frequency, which is the highest ever used to obtain high-resolution radio interferometric imaging. In FY 2002, the SMA observed a number of astrophysically interesting targets and made unique measurements of them, including the Egg Nebula (a protoplanetary nebula formed of gas ejected from a dying star) and the black hole at the center of the Milky Way galaxy. When completed, the eight antennas of the SMA will function together to provide a resolution at submillimeter wavelengths equal to the visible-light resolution of the HST.

The Science Education Department (SED) at the Center for Astrophysics completed the 3-year design and construction of a new 5,000-square-foot museum exhibit entitled “Cosmic Questions: Our Place in Space and Time.” This traveling exhibition, which focuses on the theme that the story of the universe is the story of us, opened in the Boston Museum of Science in September 2002. “Cosmic Questions” was designed to engage the public and school audiences in high-quality content exploration. The exhibition was seen by 110,000 in its first 7 weeks. Total attendance over the 5-year lifetime of the exhibit is expected to be 3 to 4 million visitors. Both the exhibition and the accompanying planetarium show “Journey to the Edge of Space and Time” are rated “highly engaging” by visitors.

SED activities included the MicroObservatory Program, a curriculum of investigations using online telescopes, which provides authentic inquiry for students and high-quality professional development for pre- and inservice teachers. Using the MicroObservatory telescopes and the *From the Ground UP!* curriculum, students can plan observations, take data, and share their results with other schools. To date, the online telescope network and accompanying activities have been used by 15,000 students in 30 States. In FY 2002, students took more than 30,000 images, and the program Web site reported approximately 400,000 unique visitors.

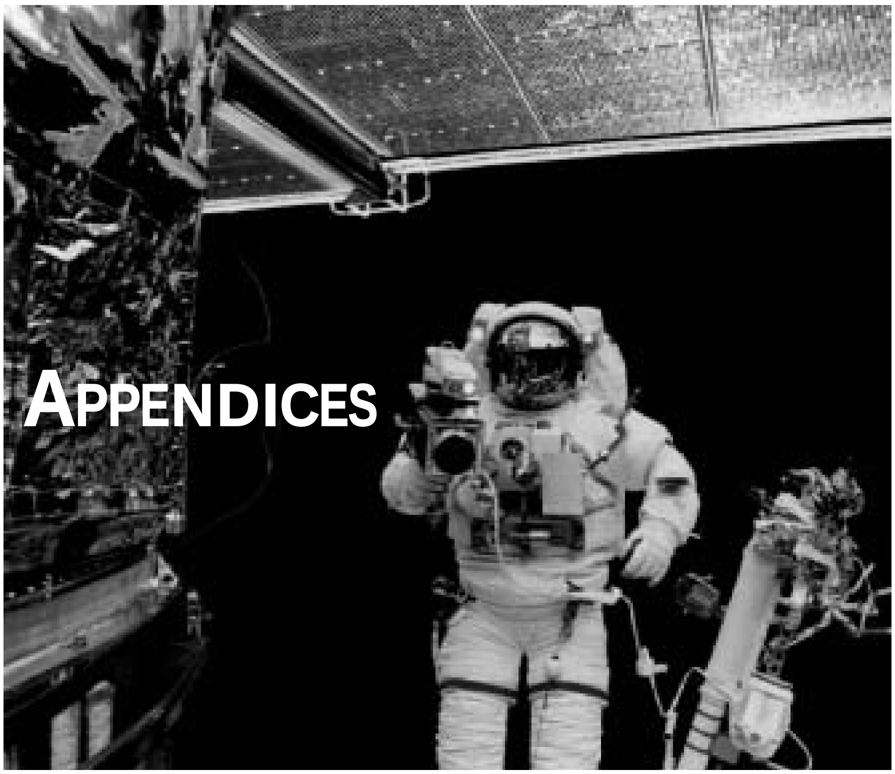
SED’s Science Media Group produced several television workshops and documentaries, ranging from a 30-minute special on science and sports to an eight-part workshop for elementary teachers that examines the science of energy. Work also began on new projects, including the three-part, 24-episode *Essential Science for Teachers* workshop series. Additionally, the Science Media Group 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 75,650 schools and 42 million households.

SAO continued to offer its popular Observatory Night lectures and telescope observing to the public on a monthly basis. In the spring of 2002, SAO held six special events to observe a rare planetary alignment, offering visitors the opportunity to see every planet in the solar system on a single night. SAO also continued to offer Children’s Night programs aimed at younger audiences and Sci-fi Movie Nights to explore the theme “Everything I learned about science, I learned at the movies.”

Staff members in the Center for Earth & Planetary Studies (CEPS) at the National Air and Space Museum continued to participate on the science teams of several spacecraft missions in FY 2002. Dr. John Grant is a Co-Investigator for the HiRISE High Resolution Imager on the 2005 Mars Reconnaissance Orbiter, and he was selected to be a Participating Scientist on the 2003 Mars Exploration Rover missions. Dr. Bruce Campbell is a member of the science team for the Shallow Subsurface Sounding Radar on the 2005 Mars Reconnaissance Orbiter, and he is the Principal Investigator (PI) on a proposal submitted to the Mars Scouts program for a mission to orbit a Synthetic Aperture Radar system at Mars in 2007. Dr. Thomas Watters is a science team member on the imaging team for MESSENGER, a funded mission to orbit Mercury in 2009. CEPS staff were further involved in planetary mission planning through co-chairing the Mars Landing Site Steering Group and working on numerous NASA evaluation groups for various programs.

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

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. CEPS 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 Museum galleries.


APPENDICES

APPENDIX A-1

U.S. Government Spacecraft Record

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

Calendar Year	Earth Orbit[a] Success	Earth Orbit[a] Failure	Earth Escape[a] Success	Earth Escape[a] Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2
1962	55	12	4	1
1963	62	11	0	0
1964	69	8	4	0
1965	93	7	4	1
1966	94	12	7	1 [b]
1967	78	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1
1972	33	2	8	0
1973	23	2	3	0
1974	27	2	1	0
1975	30	4	4	0
1976	33	0	1	0
1977	27	2	2	0
1978	34	2	7	0
1979	18	0	0	0
1980	16	4	0	0
1981	20	1	0	0
1982	21	0	0	0
1983	31	0	0	0
1984	35	3	0	0
1985	37	1	0	0
1986	11	4	0	0
1987	9	1	0	0
1988	16	1	0	0
1989	24	0	2	0
1990	40	0	1	0
1991	32 [c]	0	0	0
1992	26 [c]	0	1	0
1993	28 [c]	1	1	0
1994	31 [c]	1	1	0
1995	24 [c, d]	2	1	0
1996	30	1	3	0
1997	22 [e]	0	1	0
1998	23	0	2	0
1999	35	4	2	0
2000	31 [f]	0	0	0
2001	23	0	3	0
2002 *(through September 30, 2002)*	*14*	*0*	*0*	*1* [b]
TOTAL	1,520	153	97	16

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	25	31				1			8	1	
2002 (through September 30, 2002)	*14*	*15*			*2*	*2*			*11*	*1*	*1*
TOTAL	1,254	2,680	10	8	56	67	1	1	149	13	4

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, 2001–September 30, 2002

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Oct. 5, 2001 USA 161 2001-44A Titan 4B	Military communications satellite	Orbital parameters unknown	
Oct. 11, 2001 USA 162 2001-46A Atlas 2AS-Centaur	Military communications satellite	Geosynchronous	
Oct. 18, 2001 Quickbird 2 2001-47A *Delta 2	Commercial imaging satellite	464 km 460 km 93.8 min 97.2°	
Dec. 5, 2001 STS-108/Endeavour 2001-54A Space Shuttle	ISS assembly	377 km 353 km 92 min 51.6°	
Dec. 7, 2001 Jason 1 2001-55A Delta 2	Oceanographic satellite	1,340 km 1,328 km 112 min 66°	U.S.- French effort to supplement TOPEX/Poseidon mission
Dec. 7, 2001 TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics) 2001-55B Delta 2	Scientific satellite	628 km 627 km 97.3 min 74.1°	Study of ionosphere
Dec. 16, 2001 Starshine 2 2001-54B Space Shuttle	Educational microsatellite	389 km 361 km 92.1 min 51.6°	Built with participation of 25,000 students in 26 countries. Launched from Space Shuttle
Jan. 16, 2002 US 164 2002-1A Titan 4B	Military communications satellite	Geosynchronous	Part of Milstar 2 fleet
Feb. 5, 2002 HESSI (High Energy Solar Spectroscopic Imager) 2002-4A Pegasus XL	Scientific satellite	607 km 579 km 96.5 min 38°	Solar Flare Observatory

*UN Committee on Space Research.

APPENDIX B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2001–September 30, 2002

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Feb. 11, 2002 Iridium 90-91, 94-96 2002-5A-5E *Delta 2	Communications satellite	Circular 660 km altitude 98 min 86.6°	5 additions to fleet of 73 Iridium sats. for global phone links
Feb. 21, 2002 Echostar 7 2002-6A *Atlas 3B	Communications satellite	Geosynchronous	Direct to home video and data
March 1, 2002 STS-109/Columbia 2002-10A Space Shuttle	Hubble Space Telescope servicing mission #4.	578 km 486 km 95.3 min 28.5°	
March 8, 2002 TDRS 9 2002-11A Atlas 2A	Communications satellite	Intended geosynchronous 35,805 km 3,523 km 697 min 21.4°	
April 8, 2002 STS-110/Atlantis 2002-18A Space Shuttle	ISS assembly	225 km 155 km 88.3 min 51.6°	Installation of the S0 (S-Zero) Truss.
May 4, 2002 Aqua (previously EOS PM-1) 2002-22A Delta 2	Scientific satellite	686 km 673 km 98.4 min 98.2°	Study of global water cycle
June 5, 2002 STS-111/Endeavour 2002-28A Space Shuttle	ISS crew and supplies	387 km 349 km 91.9 min 51.6°	
June 15, 2002 Galaxy 3C 2002-30A *Zenit 3SL/Sea Launch	Communications satellite	Geosynchronous	Internet and video for subscribers
June 24, 2002 NOAA 17 2002-32A Titan 2	Weather satellite	823 km 807 km 101.2 min 98.8°	

APPENDIX B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2001–September 30, 2002

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
July 3, 2002 CONTOUR (Comet Nucleus Tour) 2002-34A Delta 2	Scientific spacecraft	394 km 377 km 92.3 min 51.6°	Presumed lost after reaching Earth orbit. Intended to analyze composition of comets.
Aug. 21, 2002 Hot Bird 6 2002-38A *Atlas 5/Centaur	Communications satellite	Geosynchronous	Maiden flight of Atlas 5.
Sept.18, 2002 Hispasat 1D 2002-44A *Atlas 2AS/Centaur	Communications satellite	Geosynchronous	Spanish satellite providing Internet, video, and data.

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

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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 h.
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 h.
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 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. “Buzz” Aldrin, Jr.	3:22:35	Longest EVA to date (Aldrin, 5 h.).
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–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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. "Buzz" 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, including welding and Earth and celestial observation.
Soyuz 7	Oct. 12, 1969	A. V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4:22:41	
Soyuz 8	Oct. 13, 1969	Vladimir A. Shatalov Aleksey S. Yeliseyev	4:22:50	
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	10:4:36	Second human lunar landing explored surface of Moon and retrieved parts of Surveyor 3 spacecraft, which landed in Ocean of Storms on Apr. 19, 1967.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	5:22:55	Mission aborted; explosion in service module. Ship circled Moon, with crew using 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 in-flight EVA of 38 min, 12 s 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–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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; 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.
Soyuz 18A (Anomaly)	Apr. 5, 1975	Vasiliy G. Lazarev Oleg G. Makarov	0:0:20	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr I. Klimuk Vitaliy I. Sevastyanov	62:23:20	Docked with Salyut 4 and occupied station.
Soyuz 19	July 15, 1975	Aleksey A. Leonov Valery N. Kubasov	5:22:31	Target for Apollo in docking and joint experiments of ASTP mission.
Apollo	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	9:1:28	Docked with Soyuz 19 in joint (ASTP) experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris V. Volynov Vitaliy M. Zholobov	48:1:32	Docked with Salyut 5 and occupied station.
Soyuz 22	Sep. 15, 1976	Valery F. Bykovskiy Vladimir V. Aksenov	7:21:54	Earth resources study with multispectral camera system.
Soyuz 23	Oct. 14, 1976	Vyacheslav D. Zudov Valery I. Rozhdestvenskiy	2:0:6	Failed to dock with Salyut 5.
Soyuz 24	Feb. 7, 1977	Viktor V. Gorbatko Yury N. Glazkov	17:17:23	Docked with Salyut 5 and occupied station.
Soyuz 25	Oct. 9, 1977	Vladimir V. Kovalenok Valery V. Ryumin	2:0:46	Failed to achieve hard dock with Salyut 6 station.
Soyuz 26	Dec. 10, 1977	Yury V. Romanenko Georgiy M. Grechko	37:10:6	Docked with Salyut 6. Crew returned in Soyuz 27; crew duration 96 d, 10 h.
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 d, 22 h, 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 d, 14 h, 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 d, 20 h, 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 d, 36 min.
Soyuz 33	Apr. 10, 1979	Georgi I. Ivanov	1:23:1	Failed to achieve docking with Salyut 6 station. Ivanov was first Bulgarian cosmonaut to orbit.
Soyuz 34	June 6, 1979	(unmanned at launch)	7:18:17	Docked with Salyut 6, later served as ferry for Soyuz 32 crew while Soyuz 32 returned without a crew.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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 d, 20 h, 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 d, 20 h, 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 d, 20 h, 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 d. 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 crewmembers. 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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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 female 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 crewmembers, one of whom was West German; Merbold was first non-U.S. astronaut to fly in U.S. space program.
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 d. 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 EVA by a woman.
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 crewmembers, including first flight of two U.S. women and one Canadian (Garneau).

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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.

Appendix C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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 Wubbo J. Ockels	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 record of 326 days for long-distance stay in space.
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 on 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 June 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 Sep. 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 Sergei 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-d mission on Dec. 21. Crew of Krikalev, Volkov, and Valery Polyakov returned Apr. 27, 1989, in Soyuz TM-7.

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(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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	5:1:0	Thirtieth STS flight. Dedicated DOD mission.
Soyuz TM-8	Sep. 5, 1989	Aleksandr Viktorenko Aleksandr Serebrov	166:6:46	Docked with Mir space station. Crew of Viktorenko and Serebrov returned in Soyuz TM-8 on 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	10:21:0	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. See listing for Soyuz TM-11.

Appendix C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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	175:1:52	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 aboard 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).

APPENDIX C

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U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TM-13	Oct. 2, 1991	Aleksandr Volkov Toktar Aubakirov Franz Viehboeck	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	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	145:15:11	First piloted CIS space mission. Docked with Mir space station on Mar. 19. The TM-13 capsule with Flade, Aleksandr Volkov, and Sergei Krikalev returned to Earth on Mar. 25. Krikalev had been in space 313 d. 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	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.

APPENDIX C

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U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Space Shuttle Atlantis (STS-46)	July 31, 1992	Loren J. Shriver Andrew M. Allen Claude Nicollier Marsha S. Ivins Jeffrey A. Hoffman Franklin R. Chang-Díaz Franco Malerba	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 10 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 Hans W. Schlegel	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, which had been in orbit since Aug. 1992.

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(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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 test bed 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 M. Rhea Seddon	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 to the Hubble Space Telescope.
Soyuz TM-18	Jan. 8, 1994	Viktor Afanasyev Yuri Usachev Valery Polyakov	182:0:27	Docked with Mir space station on 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	8:7:9	Sixtieth STS flight. Carried the Wake Shield Facility to generate new semiconductor 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 Earth and on 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 on July 3. Both Malenchenko and Musabayev returned to Earth with the Soyuz TM-19 spacecraft, landing in Kazakhstan on Nov. 4 with Ulf Merbold of Germany, who went up aboard Soyuz TM-20 on Oct. 3, 1994. Merbold gathered biological samples on the effects of weightlessness on the human body in the first of two ESA missions to Mir to prepare for the International Space Station.

U.S. and Russian Human Space Flights
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Spacecraft	Launch Date	Crew	Flight Time (d:h: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	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	*	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 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	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 the International Space Station. (Shuttle flew close by 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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TM-21	Mar. 14, 1995	Vladimir Dezhurov Gennadi Strekalov Norman Thagard	*	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 100th 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	*	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 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 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).

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Space Shuttle Columbia (STS-75)	Feb. 22, 1996	Andrew M. Allen Scott J. Horowitz Jeffrey A. Hoffman Maurizio Cheli Claude Nicollier Franklin R. Chang-Díaz Umberto Guidoni	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	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 Robert B. Thirsk	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 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.

* 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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TM-25	Feb. 10, 1997	Vasily Tsibliev Aleksandr Lazutkin Reinhold Ewald	*	Soyuz TM-24 returned to Earth on Mar. 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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h: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 Feb. 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 and 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 Chiaki Mukai 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	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 Ivan Bella	*	Soyuz mission to Mir.

* 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.

APPENDIX C

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U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Space Shuttle Discovery (STS-96)	May 27, 1999	Kent V. Rominger Rick D. Husband Daniel T. Barry Valery I. Tokarev Ellen Ochoa Julie Payette 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 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	Third Hubble Space Telescope servicing mission.
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)	Sep. 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 the Shuttle program's history. ISS assembly mission.
Soyuz TM-31	Oct. 31, 2000	William Shepherd Yuri Gidzenko Sergei Krikalev	140	Launch of first resident crew (Expedition One) to the ISS.
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.

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
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)	Mar. 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 Two crew to the ISS and returned the Expedition One crew to Earth.
Space Shuttle Endeavour (STS-100)	Apr. 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	Apr. 28, 2001	Talgat A. Musabaev Yuri M. Baturin Dennis Tito	7:22:4	Launch of the first “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 Two crew to Earth.
Soyuz TM-33	Oct. 21, 2001	Victor M. Afanasyez Konstantin M. Kozeev Claudie Haigneré	9:18:58	Launch of the second “taxi” flight to the ISS, bringing a “fresh” Soyuz crew return vehicle for the ISS crew. Crew returned 8 d later on older Soyuz TM-32.
Space Shuttle Endeavour (STS-108)	Dec. 5, 2001	Dominic L. Gorie Mark E. Kelly Linda M. Godwin Daniel M. Tani Yuri I. Onufrienko (up) Carl E. Walz (up) Daniel W. Bursch (up) Frank L. Culbertson (down) Mikhail Turin (down) Vladimir N. Dezhurov (down)	11:19:36	Delivered Expedition Four crew to the ISS. Returned Expedition Three crew to Earth.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–June 30, 2002

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Space Shuttle Columbia (STS-109)	Mar. 1, 2002	Scott D. Altman Duane G. Carey John M. Grunsfeld Nancy J. Currie James H. Newman Richard M. Linnehan Michael J. Massimino	10:22:11	Fourth Hubble Space Telescope servicing mission.
Space Shuttle Atlantis (STS-110)	Apr. 8, 2002	Michael J. Bloomfield Stephen N. Frick Jerry L. Ross Steven L. Smith Ellen Ochoa Lee M.E. Morin Rex J. Walheim	10:19:43	Thirteenth ISS flight. Installation of the S0 (S-Zero) Truss. Jerry Ross became the first human to fly in space seven times.
Soyuz TM-34	Apr. 25, 2002	Yuri Gidzenko Roberto Vittori Mark Shuttleworth	9:21:25	Launch of the third “taxi” flight to the ISS, bringing a “fresh” Soyuz crew return vehicle for the ISS crew. Crew returned 8 d later on older Soyuz TM-33. This mission also carried the second commercial space tourist, Mark Shuttleworth.
Space Shuttle Endeavour (STS-111)	June 5, 2002	Kenneth Cockrell Paul Lockhart Franklin Chang-Diaz Philippe Perrin Valeri Korzun (up) Peggy Whitson (up) Sergei Treschev (up) Yuri Onufriyenko (down) Carl E. Walz (down) Daniel W. Bursch (down)	13:20:35	Delivered Expedition Five crew to ISS. Returned Expedition Four 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

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[b, c]	Max. Dia. x Height (m)	Max. Payload (kg)[d]: 185-km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[e]	First Launch[f]
Pegasus				6.71x15.5[h]	380	—	210	1990
	1. Orion 50S	Solid	484.9	1.28x8.88	280[e]			
	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				2.44x29.70	5,089	1,842[i]	3,175	1990,
					3,890[e]			Delta-7925
	1. RS-270/A	LOX/RP-1	1,043.0 (SL)	3.05x38.1				[1960, Delta]
	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]	—	910[k]	1968, Atlas F
					1,860[e, k]			[1958,
	1. Atlas: MA-3	LOX/RP-1	1,739.5 (SL)	3.05x21.3				Atlas LV-3A]
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:	LOX/LH_2	73.4/engine	3.05x9.14				
	RL10A-3-3A (2)							
Atlas II				4.2x47.5	6,580	2,810	4,300	1991, II [1966,
					5,510[e]			Atlas Centaur]
	1. Atlas: MA-5A	LOX/RP-1	2,110.0 (SL)	3.05x24.9				
	2. Centaur II:	LOX/LH_2	73.4/engine	3.05x10.05				
	RL10A-3-3A (2)							
Atlas IIA				4.2x47.5	6,828	3,062	4,750	1992, Atlas
					6,170[e]			IIA [1966,
	1. Atlas: MA-5A	LOX/RP-1	2,110.0 (SL)	3.05x24.9				Atlas Centaur]
	2. Centaur II:	LOX/LH_2	92.53/engine	3.05x10.05				
	RL10A-4 (2)							
Atlas IIAS				4.2x47.5	8,640	3,606	5,800	1993, IIAS
					7,300[e]			[1966,
	1. Atlas: MA-5A	LOX/RP-1	2,110.0 (SL)	3.05x24.9				Atlas Centaur]
	Castor IVA (4)[j]	Solid	433.6 (SL)	1.01x11.16				
	2. Centaur II:	LOX/LH_2	92.53/engine	3.05x10.05				
	RL10A-4 (2)							

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]
Athena								
1.	Athena	Solid	1450	2.36x19.8	520	245		1995
Titan II				3.05x42.9	1,905[e]	—	—	1988, Titan II SLV [1964, Titan II Gemini]
1.	LR-87-AJ-5 (2)	N204/A-50	1,045.0	3.05x21.5				
2.	LR-91-AJ-5	N204/A-50	440.0	3.05x12.2				
Titan III				3.05x47.3	14,515	5,000[l]	—	1989, Titan III [1964, Titan IIIA]
0.	Titan III SRM (2)	Solid	6,210.0	3.11x27.6				
1.	LR87-AJ-11 (2)	N204/A-50	1,214.5	3.05x24.0				
2.	LR91-AJ-11	N204/A-50	462.8	3.05x10.0				
Titan IV				3.05x62.2	17,700	6,350[m]	—	1989, Titan IV
0.	Titan IV SRM (2) (7 segments)	Solid	7,000.0	3.11x34.1	14,110[e]			
1.	LR87-AJ-11 (2)	N204/A-50	1,214.5	3.05x26.4				
2.	LR91-AJ-11	N204/A-50	462.8	3.05x10.0				
Titan IV				4.3x62.2	—	5,760[a]	—	1994, Titan IV Centaur
0.	Titan IV SRM (2) (7 segments)	Solid	7,000.0	3.11x34.1				
1.	LR87-AJ-11 (2)	N204/A-50	1,214.5/engine	3.05x26.4				
2.	LR91-AJ-11(1)	N204/A-50	462.5	3.05x10.0				
3.	Centaur: RL-10A-3-3A	LOX/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, *Columbia*
1.	SRB: Shuttle SRB (2)	Solid	11,790.0 (SL)	3.70x45.46				
2.	Orbiter/ET: SSME (3)	LOX/LH_2	1,668.7 (SL)	8.41x47.00 (ET) 23.79x37.24[h] (orbiter)				
3.	Orbiter/OMS: OMS engines (2)	N_20_4/MMH	26.7	23.79x37.24[h]				
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				

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 wingspan.

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, as well as oxidizer from the External Tank. The boosters stage first, with SSMEs 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	USDA	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	43	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		21,768
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	1,056	164	575	60	44	207	6	26,518
2001	14,230	13,304	14,326	1,062	145	577	60	36	232	12	28,692
2002	14,868	13,871	15,740	1,180	166	644	64	28	266	12	30,791

* 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 the latter 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 2002 DOLLARS
(adjusted for inflation)

FY	Inflation Factors	NASA Total	NASA Space[b]	DOD	Other[c]	DOE[d]	DOC	DOI	USDA	NSF[a]	DOT	Total Space
1959	5.0822	1,682	1,326	2,490	173	173						3,990
1960	5.0009	2,620	2,310	2,806	215	215				0		5,331
1961	4.9444	4,766	4,579	4,025	336	336						8,939
1962	4.8761	8,899	8,762	6,329	970	722	249					16,062
1963	4.8223	17,712	17,486	7,475	1,239	1,032	207					26,200
1964	4.7594	24,273	23,873	7,610	1,014	999	14					32,497
1965	4.7041	24,696	24,170	7,404	1,134	1,077	56					32,708
1966	4.6226	23,922	23,413	7,808	989	864	125					32,210
1967	4.5250	22,471	21,856	7,530	964	833	131					30,349
1968	4.3853	20,115	19,427	8,429	764	636	123	0.9	4			28,620
1969	4.2326	16,892	16,177	8,520	721	499	85	0.8	4	132		25,418
1970	4.0492	15,168	14,363	6,795	571	417	32	4	4	113		21,728
1971	3.8389	12,711	11,904	5,804	622	365	104	8	4	142		18,330
1972	3.6554	12,088	11,226	5,143	488	201	113	22	7	144		16,857
1973	3.4920	11,894	10,801	5,668	515	189	140	35	7	144		16,983
1974	3.3436	10,155	9,225	5,905	528	140	201	30	10	147		15,658
1975	3.1213	10,079	9,099	5,905	492	94	200	25	6	168		15,496
1976	2.8283	10,040	9,121	5,609	476	65	204	28	11	168		15,206
TQ*	2.6418	2,462	2,243	1,215	114	13	58	8	3	32		3,572
1977	2.5608	9,777	8,809	6,177	496	56	233	26	15	165		15,481
1978	2.4572	9,976	8,902	6,728	555	84	253	25	20	174		16,186
1979	2.2996	10,569	9,267	6,982	570	136	225	23	18	168		16,819
1980	2.1270	11,145	9,954	8,185	492	85	198	26	30	153		18,631
1981	1.9534	10,779	9,751	9,431	458	80	170	23	31	153		19,640
1982	1.7807	10,762	9,844	11,893	557	109	258	21	27	142		22,294
1983	1.6642	11,441	10,531	15,009	544	65	296	8	33	142		26,084
1984	1.5941	11,889	10,932	16,252	629	54	376	5	30	164		27,813
1985	1.5374	11,643	10,646	19,629	897	52	650	3	23	169		31,173
1986	1.4882	11,619	10,663	21,023	709	52	460	3	34	160		32,395
1987	1.4532	15,874	14,255	23,669	677	70	404	12	28	163	1	38,600
1988	1.4143	12,817	11,770	25,004	1,048	341	498	20	25	163	1	37,822
1989	1.3695	15,022	13,828	24,523	767	133	412	23	29	166	4	39,118
1990	1.3188	16,253	15,114	20,595	667	104	320	41	33	163	5	36,375
1991	1.2710	17,814	16,582	18,024	981	319	319	37	33	268	5	35,587
1992	1.2234	17,515	16,147	18,379	976	273	400	42	35	221	5	35,502
1993	1.1922	17,060	15,575	16,817	871	197	386	39	30	214	5	33,263
1994	1.1644	16,965	15,163	15,330	736	86	363	36	36	209	6	31,229
1995	1.1397	15,790	14,296	12,131	865	68	401	35	36	317	7	27,292
1996	1.1156	15,489	14,022	12,845	923	51	527	40	41	257	7	27,790
1997	1.0937	14,994	13,624	12,826	863	38	490	46	43	240	7	27,313
1998	1.0728	14,641	13,218	13,258	901	110	467	46	42	229	6	27,377
1999	1.0578	14,443	13,180	13,967	1,039	111	608	62	39	212	6	28,185
2000	1.0442	14,202	13,074	13,513	1,102	171	600	63	46	216	6	27,690
2001	1.0231	14,559	13,611	14,657	1,087	148	590	61	37	237	12	29,355
2002	1	14,868	13,871	15,740	1,180	166	644	64	28	266	12	30,791

Appendix E-2

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority				Budget Outlays	
	2001 actual	2002 actual	2003 est.	2004 est.	2001 actual	2002 actual
NASA	13,304	13,871	14,244	14,484	13,197	13,449
Defense	14,326	15,740	18,448	20,392	13,046	14,906
Energy	145	166	184	191	143	167
Commerce	577	644	647	866	520	228
Interior	60	64	63	60	54	63
Agriculture	36	28	39	42	36	28
Transportation	12	12	12	13	12	12
NSF	232	266	317	335	213	244

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	
	2001 actual	2002 actual	2003 est.	2004 est.	2001 actual	2002 actual
NASA[a]	926	997	1,069	959	867	956
Defense[b]	6,149	6,995	9,604	10,508	6,297	6,655
Transportation[c]	2,792	2,949	2,963	3,008	2,571	2,799

a. Research, development, construction of facilities, and program management.
b. Research, development, testing, and evaluation of aircraft and related equipment.
c. Federal Aviation Administration: research, facilities, engineering, and development.

SOURCE: Office of Management and Budget

Glossary and Acronyms

A

AAAE	American Association of Airport Executives
AANC	Airworthiness Assurance Nondestructive Inspection Validation Center
ACS	Advanced Camera for Surveys
ACTS	Advanced Communications Technology Satellite
ADDS	Aviation Digital Data Service
ADEOS	Advanced Earth Observing Satellite
ADS-B	Automated Dependent Surveillance-Broadcast
AEAP	Atmospheric Effects of Aviation Project
AEOS	Advanced Electro-Optical System
AFB	Air Force Base
AFWA	Air Force Weather Agency
AGATE	Advanced General Aviation Technology Experiment
AGS	Alternating Gradient Synchrotron
AIRS	Atmospheric Infrared Sounder
ALERT	Attack and Launch Early Reporting to Theater
AML	Abandoned Mine Land
AMOS	Air Force Maui Optical Site
AMS	Alpha Magnetic Spectrometer
ARC	Ames Research Center
ARM	Atmospheric Radiation Measurement
ARS	Agricultural Research Service (USDA)
ARTCC	Air Route Traffic Control Centers
ASCE	Advanced Spectroscopic and Coronagraphic Explorer
AST	Advanced Subsonic Technology (Program); Associate Administrator for Commercial Space Transportation (FAA)
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTP	Apollo-Soyuz Test Project; Advanced Space Transportation Program
ATC	Assurance Technology Center
ATLAS	Atmospheric Laboratory for Applications and Science
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
AVOSS	Advanced Vortex Sensing System
AXAF	Advanced X-ray Astrophysics Facility (former name of Chandra X-Ray Observatory)

B

BEC	Bose-Einstein Condensates
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.
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory
BOR	Bureau of Reclamation

BPRE	Biological and Physical Research Enterprise
BXA	Bureau of Export Administration (DOC)

C

CAC	Civil Applications Committee
CAU	Cockpit Avionics Upgrade
CEOS	Committee on Earth Observation Satellites
CEPS	Center for Earth & Planetary Studies
CIP	Current Icing Potential
CIS	Commonwealth of Independent States
CITEL	Commission on Inter-American Telecommunications
CLASS	Condensate Laboratory Aboard the Space Station
CME	Coronal mass ejections
CNES	Centre National d'Etudes Spatiales (France)
CO	Carbon monoxide
CONTOUR	Comet Nucleus Tour
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
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers Florida Area Cirrus Experiment
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
DDU	Device Driver Unit
DEM	Digital elevation model
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
DOQ	Digital Orthophotoquad
DOS	Department of State
DOT	Department of Transportation
DSN	Deep Space Network

DSP	Defense Support Program
DSR	Display System Replacement

E

EASA	European Aviation Safety Agency
EDMS	Emissions and Dispersion Modeling System
EELV	Evolved Expendable Launch Vehicle (program)
EFB	Electronic flight bags
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.
ELV	Expendable Launch Vehicle
EO	Earth Observing
EO-1	Earth Observing-1
EOS	Earth Observing System—a series of satellites, part of NASA's Earth Science Enterprise, designed for launch at the end of the 1990s to gather data on global change.
EPA	Environmental Protection Agency
EPIC	Environmental Photographic Interpretation Center (EPA)
E/PO	Education and Public Outreach
ERAST	Environmental Research Aircraft and Sensor Technology (project)
EROS	Earth Resources Observation Systems (USGS)
ERS	European Remote Sensing satellite
ESA	European Space Agency
ESE	Earth Science Enterprise
ET	External Tank
ETM+	Enhanced Thematic Mapper Plus (Landsat instrument)
EU	European Union
EUMETSAT	Exploitation of Meteorological Satellites
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)
FAST	Fast Auroral Snapshot Explorer
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FFP	Free Flight Phase
FFTIL	FAA Technical Center's Free Flight Technology Integration Laboratory
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 with 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 with 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.
FS	Forest Service
FSA	Farm Service Agency (USDA)
FSS	Fixed Satellite Service
FTP	File Transfer Protocol
FUSE	Far Ultraviolet Spectroscopic Explorer
FWS	(U.S.) Fish and Wildlife Service (DOI)
FY	Fiscal Year

G

GAC	Global Area Coverage
Gamma rays	The shortest of electromagnetic radiations, emitted by some radioactive substances.
GDIN	Global Disaster Information Network
Geostationary	Traveling around Earth's equator at an altitude of at least 35,000 kilometers and at a speed matching that of Earth's rotation, thereby maintaining a constant relation to points on Earth.
Geosynchronous	Geostationary
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System
GloVis	USGS Global Visualization
GMS	Geostationary Meteorological Satellite
GNSS	Global Navigation Satellite Systems
GOES	Geostationary Operational Environmental Satellite
GOIN	Global Observation Information Network
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GSD	Ground Sample Distance
GSFC	Goddard Space Flight Center

H

Heliosphere	The region of the Sun's influence, including the Sun and the interplanetary medium.
HEO	Highly Elliptical Orbit
HESSI	High-Energy Solar Spectroscopic Imager
HiRISE	High Resolution Imaging Science Experiment
HRPT	High Resolution Picture Transmission
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 distinguish specific features or phenomena on the body being observed (such as Earth).

I

ICAO	International Civil Aviation Organization
ICM	Interim Control Module
IGEB	International GPS Executive Board
IGOS	Integrated Global Observing Strategy
IGS	International GPS Service for Geodynamics
ILS	International Launch Services
IMF	Interplanetary magnetic field
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 replaces multiple black boxes with shared common equipment and generic software.
INTELSAT	International Telecommunications Satellite (organization)
Interferometry	The production and measurement of interference from two or more coherent wave trains emitted from the same source.
Internet	An international computer network that began about 1970 as the NSF Net; very slowly, it became a collection of more than 40,000 independently managed computer networks worldwide that have adopted common protocols to permit the exchange of electronic information.
Ionosphere	That region of Earth's atmosphere so named because of the presence of ionized atoms in layers that reflect radio waves and shortwave transmissions.
IPO	Integrated Program Office
IR	Infrared
ISI	Infrared Stellar Interferometer
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)
JSC	Johnson Space Center

K

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

L

LAC	Local Area Coverage
Landsat	Land (remote sensing) Satellite—a series of satellites designed to collect information about Earth's natural resources.
LANL	Los Alamos National Laboratory
Laser	Light amplification by stimulated 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.
LAT	Large Area Telescope
LBNL	Lawrence Berkeley National Laboratory
LDEF	Long-Duration Exposure Facility
LDCM	Landsat Data Continuity Mission
LEE	Low Energy Electrons
LEO	Low-Earth Orbit—100 to 350 nautical miles above Earth
LH_2	Liquid Hydrogen
LIDAR	Light Detection and Ranging
LOX	Liquid Oxygen
LSDM	Landsat Data Continuity Mission
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 ^{0}F of 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.
MAP	Microwave Anisotropy Probe
MCC-H	Mission Control Center–Houston
MCC-M	Mission Control Center–Moscow
MCO	Mars Climate Orbiter
MEMS	Microelectromechanical
MHz	Megahertz
MI	Microwave imager
MilSatCom	Military Satellite Communications
MISR	Multiangle Imaging Spectroradiometer
MLLW	Mean Lower Low Water
MMH	Monomethyl Hydrazine
MMOP	Multi-lateral Medical Operations Panel
MMS	Minerals Management Service (DOI)
MMU	Modular Memory Unit
MOA	Memorandum of Agreement
MODIS	MODerate resolution Imaging Spectroradiometer

MOU	Memorandum of Understanding
MPL	Mars Polar Lander
MPLM	Multipurpose Logistics Module
MRX	Magnetic Reconnection Experiment
MSFC	Marshall Space Flight Center
MSG	Meteosat Second Generation

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)
NATCA	National Air Traffic Controllers Association
NATO	North Atlantic Treaty Organization
NAWQA	National Water Quality Assessment
NCAP	National Civil Applications Program (USGS)
NDGPS	Nationwide Differential GPS
NDOP	National Digital Orthophoto Program
NDVI	Normalized Difference Vegetation Index
NEAR	Near Earth Asteroid Rendezvous
NERSC	National Energy Research Scientific-computing Center
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
NEXT	NASA's Exploration Team
NGDC/STP	National Geophysics Data Center's Solar Terrestrial Physics Division
NGS	National Geodetic Survey
NGSO	Nongeostationary Orbit
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
NIMA	National Imagery and Mapping Agency
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
NOS	National Ocean Service
NOx	Nitrous Oxide
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)
NRI	National Resources Inventory
NRO	National Reconnaissance Office (DOD)

NSC	National Security Council
NSF	National Science Foundation
NSI	Nuclear System Initiative
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
OPUS	On-Line Positioning User Service
Order of magnitude	An amount equal to 10 times a given value; thus, if some quantity were 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)
OSTM	Ocean Surface Topography Mission
OSTP	Office of Science and Technology Policy (White House)

P

PAMS-STU	Passive Aerodynamically Stabilized Magnetically Damped Satellite-Satellite Test Unit
PARCS	Primary Atomic Reference Clock in Space
PARR	Problem Analysis, Resolution and Ranking
Pathfinder	A program that focuses on 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
PCC	Space Policy Coordinating Committee
PEACESAT	Pan-Pacific Education and Communications Experiment by Satellite
PECAD	Production Estimates and Crop Assessment Division (FAS)
pH	Potential of hydrogen
Photo-grammetry	The science or art of obtaining reliable measurements by means of photography.
PI	Principal Investigator
PLGR	Precision Lightweight GPS Receiver
PMA	Pressurized Mating Adapter
POES	Polar-orbiting Operational Environmental Satellite (program)
PPPL	Princeton Plasma Physics Laboratory

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

R&D	Research and Development
RADARSAT	Canadian Radar Satellite
RAMBO	Ram Burn Observation Experiment
Ramjet	A jet engine with no mechanical compressor, consisting of spe cially 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.
RASC	Revolutionary Aerospace System Concepts
ReMaP	Research Maximization and Prioritization
RFID	Radio Frequency Identification
RGL	Runway Guard Lights
RHESSI	Reuven Ramaty High-Energy Solar Spectroscopic Imager
RHIC	Relativistic Heavy Ion Collider
RLV	Reusable Launch Vehicle
RPA	Remotely Piloted Aircraft
RSA	Russian Space Agency (Rosaviakosmos)
RSAC	Remote Sensing Application Center
RSML	Remote Sensing and Modeling Laboratory (ARS)
RTG	Radioisotope Thermoelectric Generator
RUC	Rapid Update Cycle

S

SAGE	Stratospheric Aerosol and Gas Experiment
SAMRSS	Shafter Airborne Multispectral Remote Sensing System
SAO	Smithsonian Astrophysical Observatory
SAR	Synthetic Aperture Radar
SARSAT	Search and Rescue Satellite-Aided Tracking
SBIRS	Space Based Infrared System
SBS	Satellite Business Systems
SCIGN	Southern California Integrated GPS Network

Scramjet	Supersonic-combustion ramjet
SCS	Slot Credit Substitution
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SEC	Space Environment Center
SI	Le Système International d'Unités (International System of Units)
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Localized Exhaust
SLAC	Stanford Linear Accelerator Center
SLEP	Service Life Extension Program
SLS	Spacelab Life Sciences
SMA	Safety and Mission Assurance; Submillimeter Array
SMC	Air Force Space and Missile Systems Center
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
SRTM	Shuttle Radar Topography Mission
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
STP	Space Test Program
STS	Space Transportation System
SUBSA	Solidification Using a Baffle in Sealed Ampoules
SWAS	Submillimeter Wave Astronomy Satellite
SXI	Solar X-ray Imager

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
THREADS	Technology for Human and Robotic Exploration and Development of Space
TIMED	Thermoshere, Ionosphere, Mesosphere Energetics and Dynamics
TM	Landsat Thematic Mapper
TMA-MC	Traffic Management Advisor-Multi-Center
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
TXR	Thermal-infrared Transfer Radiometer

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
USAF	U.S. Air Force
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
USTR	U.S. Trade Representative
USWCL	U.S. Water Conservation Laboratory (ARS)
UWB	Ultrawideband

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
VNIR	Visible near-infrared radiance

W

WAAS	Wide Area Augmentation System
WCSAR	Wisconsin Center for Space Automation and Robotics
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
WSC	White Sands Complex
WSDDM	Weather Support to Deicing Decision Making
WSF	Wake Shield Facility
WSSD	World Summit on Sustainable Development
WTC	World Trade Center
WTO	World Trade Organization

X-Y-Z

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

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