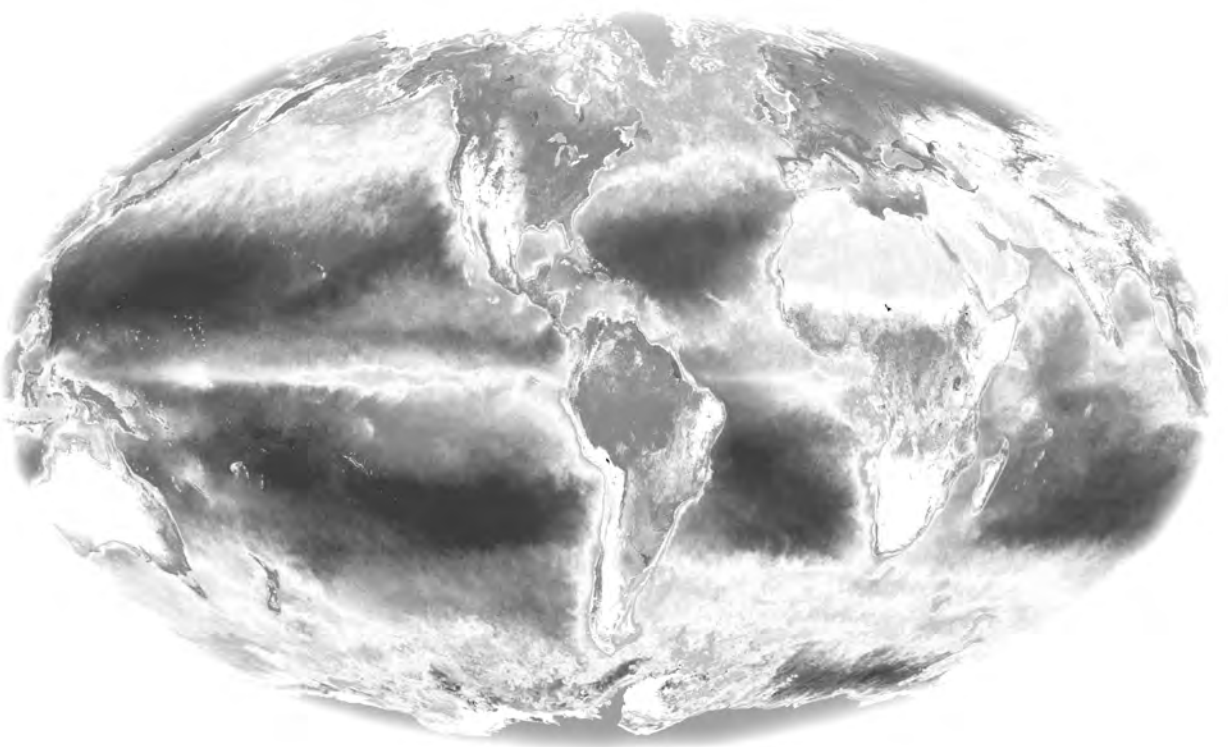
Aeronautics and Space Report of the President



Fiscal Year 2004 Activities

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, 2003, through September 30, 2004.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

Office of Safety and Mission Assurance

NASA continued to implement the recommendations of the Columbia Accident Investigation Board (CAIB) and to evaluate and strengthen NASA's safety and mission assurance (SMA) capabilities. The NASA Engineering and Safety Center (NESC) is now operational. With a core cadre of experts and matrixed support from around the Agency, the NESC is working on critical assessments of several NASA programs including the Space Shuttle Return to Flight and the International Space Station (ISS). NASA also continues to emphasize leadership responsibility and accountability for the safety of programs and operations. NASA put into place several initiatives to create and sustain an environment where leaders and employees understand the importance of reporting safety concerns and consider the safety implications of their day-to-day work and the programs they develop. NASA's results for the first year of the President's January 2004 Safety, Health, and Return to Employment (SHARE) initiative for Federal agencies show that safety is valued at NASA. NASA achieved its assigned rate-reduction goal of 3 percent per year in lost-time injuries.

In the policy area, NASA revised its procedures for mishap reporting, investigating, and recordkeeping (including CAIB lessons learned where appropriate). The Agency established SMA requirements for risk classification for NASA payloads and probabilistic risk assessment. SMA experts provided critical assurance planning and analysis for space operations, science programs, and new efforts sup-

porting the Vision for Space Exploration. NASA developed and implemented enhanced programmatic, institutional, facility, and operational safety review and assessment processes based on CAIB recommendations and an Agency imperative to move toward a more rigorous and precisely defined "compliance with requirements philosophy" that emphasizes the need to collect and evaluate objective, quality evidence to demonstrate compliance. The Agency rechartered the Aerospace Safety Advisory Panel (ASAP) to be consistent with the original intent of Congress in enacting the statute establishing the panel in 1967. The ASAP charter is to focus on NASA's safety and quality systems, including industrial and systems safety, risk management and trend analysis, and the management of these activities. The revised charter also enables more timely feedback to NASA by requiring quarterly rather than annual reports and by requiring the panel to perform special assessments with immediate feedback to NASA.

Exploration Systems Mission Directorate

After the January 14, 2004, announcement of the new Vision for Space Exploration, then-NASA Administrator Sean O'Keefe announced a strategic realignment of NASA's organizational structure. The following day, a new Office of Exploration Systems was formed to focus on carrying out that vision.

In August of 2004, the Agency responded to the President's Commission on the Implementation of the U.S. Space Exploration Policy, also known as the Aldridge Commission, by forming a robust Exploration Systems Mission Directorate (ESMD) from the Office of Exploration Systems and the Office of Biological and Physical Research.

The Crew Exploration Vehicle (CEV) was the cornerstone for ESMD activities in 2004, as the CEV will be the first ferry that transports explorers from point to point in space. The CEV Request for Proposal process was successfully initiated with a target award date of August 2005. Through the Concept Exploration and Refinement Broad Agency Announcement process, ESMD selected 11 contractors ranging from traditional aerospace primes to more nontraditional entrepreneurial firms. The teams met frequently with NASA to work on building the necessary elements of ESMD's requirements and acquisition strategy. Their first task was to derive a set of requirements for the CEV and then to review them

against requirements documentation that NASA had generated. ESMD also focused on analyzing alternatives from crew and cargo launch systems.

In addition, ESMD created research and technology themes to address new technology needs as the exploration mission progresses. These themes included a broad, general technology research area, as well as focused development activities in human and nuclear systems.

The general ESMD Research and Technology theme released an external proposal announcement in 2004 that generated intense interest among U.S. industry, academic communities, and international organizations. More than 3,700 Notice of Intent letters were originally received, resulting in 498 full proposals being developed by hundreds of the most innovative firms and the finest universities in the United States. It also resulted in first-of-a-kind proposals from eight international organizations—providing access for NASA into advanced space technology outside the United States. These projects included work in key areas of propulsion, electronics, and structures.

The Human Systems Research and Technology theme, comprised mostly of the former Biological and Physical Research Enterprise, conducted internal relevancy reviews to realign its activities to support human exploration. A critical part of the reviews involved redefining the role of the ISS to support the human exploration initiative. Human Systems completed an exhaustive assessment of alternatives to determine the quality and quantity of scientific research that needs to be done in the coming years to support the mission.

The Prometheus Nuclear Systems Research and Technology theme forged a strategic alliance with the Department of Energy, Office of Naval Reactors, in order to capitalize on their previous successes with commercial nuclear technology development. The Prometheus theme competitively awarded the Prometheus-1 Spacecraft Design and Integration contract, in addition to selecting several additional teams to conduct advanced nuclear electric propulsion technology research. Prometheus was intended to provide a sustainable enabling capability in the form of power and propulsion systems for a wide range of exploration pursuits, from lunar reconnaissance to robotic explorers and pathfinder technologies for astronaut expeditions.

In 2004, ESMD awarded over 400 Small Business Innovative Proposals in support of the new exploration program. ESMD also explored novel relations with international partners by allowing all companies to compete for our awards and by

conducting an international space exploration workshop to identify and discuss the areas in which international collaboration holds promise. ESMD also worked to develop education programming that enhances its research and technology development through undergraduate, graduate, and postdoctorate levels with direct contributions to ESMD research. Finally, ESMD initiated planning for and implementation of NASA's new program of prize contests called Centennial Challenges. The goal of Centennial Challenges is to build prize competitions that attract strong fields of competing teams in exploration-based theme areas.

Through relevancy reviews and realignment of investment portfolios, ESMD began building a focused program for space exploration. ESMD also instituted a competitive process to award new work to the NASA Field Centers and industry. As part of this process, core competency and skills database reviews across the Agency were begun to ensure that critical facilities, technologies, and Government skill sets are not lost. The competitions within NASA through internal calls for proposals have encouraged cooperation among Field Centers.

ESMD funded 118 new research and technology projects to develop and mature advanced technologies required for the exploration mission. Of those, 48 were selected to be internal NASA-led projects, involving more than 100 NASA personnel, and 70 were selected to be industry- or university-led projects. Fifteen universities and 55 industrial partners, including 2 foreign companies, will lead the 70 external projects selected. More than 700 NASA Field Center personnel will support these new technology projects, and more will have the opportunity as future announcements are released in the coming year.

Space Operations Mission Directorate

The first step in the Vision for Space Exploration is returning the Space Shuttle to flight and focusing on the mission for which it is uniquely qualified—completing the assembly of the ISS. Throughout FY 2004, NASA made significant progress toward meeting this goal. NASA is on track to fulfill all safety and processing milestones for the Space Shuttle Discovery and its Return to Flight mission, STS-114, in 2005.

The final report of the CAIB identified a number of systemic cultural, organizational, managerial, and technical issues within the Space Shuttle Program (SSP) and throughout NASA that contributed to the Columbia accident on

February 1, 2003. The Board identified 15 "Return to Flight" and 14 "Continuing to Fly" recommendations designed to address these issues. NASA's Return to Flight effort is guided by these recommendations, as well as by "raising the bar" actions identified by the SSP. NASA continues to embrace the Board's report, to accept its findings, and to comply with all of its recommendations.

NASA's *Implementation Plan for Space Shuttle Return to Flight and Beyond* outlines the path that NASA is taking to respond to the Board's recommendations and safely return the Shuttle to flight. The *Implementation Plan* is updated periodically to reflect NASA's continuing progress and to provide detailed cost estimates of the Return to Flight process. The seventh update to the *Implementation Plan* was released on August 27, 2004.

The Return to Flight effort has focused on the technical, organizational, and procedural issues that led to the Columbia accident. This year, SSP officials increased their understanding of the debris environment and the material characteristics of the orbiter and its thermal-protection system. As a result, NASA has targeted critical areas for orbiter hardening prior to Return to Flight. The Space Shuttle's External Tank was modified significantly to reduce the potential for debris generation below the point that could be dangerous to the orbiter during ascent.

To facilitate on-orbit inspections of areas of the Shuttle that are not visible when using just the Shuttle Remote Manipulator System, NASA is installing a newly developed Orbiter Boom Sensor System to inspect critical areas of the Shuttle's exterior. NASA also is developing repair techniques and materials for the Shuttle's thermal-protection system, and the Agency made significant progress in developing hardware and procedures for repairing tile and reinforced carbon-carbon on orbit. New cabling and wiring have been installed to support 66 acceleration and impact sensors and 22 temperature sensors on each orbiter wing. These new sensors will warn mission managers if the Space Shuttle is hit by the kind of debris that led to the Columbia accident. NASA employees and contractors have made more than 100 major maintenance modifications and upgrades to the Space Shuttle and its supporting systems.

The Space Shuttle and International Space Station programs also made progress in planning for a Contingency Shuttle Crew Support capability to sustain a Shuttle crew on the Station if a rescue mission is ever needed. Access to the

resources of the Station gives Space Shuttle mission managers an additional option should damage to the orbiter make a crewed reentry unsafe.

The Return to Flight Task Group, cochaired by former astronauts LTG Thomas Stafford (USAF, Ret.) and COL Richard Covey (USAF, Ret.), was formed to advise the NASA Administrator on the SSP's Return to Flight effort. The task group is chartered to perform an independent assessment of NASA's actions to implement the CAIB's 15 Return to Flight recommendations as they relate to the safety and the operational readiness for STS-114. The task group also will review NASA's "raising the bar" initiative for Contingency Shuttle Crew Support. As of the end of FY 2004, the task group had conditionally closed five of these activities. NASA ended FY 2004 on track to fully closing out all Return to Flight requirements in time to support the launch of STS-114 in 2005.

Severe hurricanes forced the temporary shutdown of several Space Shuttle processing facilities in FY 2004. Some facilities in Florida and Louisiana received minor damage. However, no injuries to NASA personnel were reported, and no flight hardware was damaged thanks to the effective implementation of NASA hurricane preparedness plans. Nevertheless, these disruptions did have an effect on Space Shuttle processing flows that were supporting a March 2005 launch opportunity. The full impact of these disruptions was still being assessed at the end of FY 2004.

Despite these setbacks, by the end of FY 2004 the SSP moved from modifying the orbiter to preparing it for its next flight. Major flight hardware needed to support STS-114 arrived at the Kennedy Space Center (KSC). Preparations were underway to begin stacking the two Solid Rocket Boosters in the Vehicle Assembly Building. The STS-114 modified External Tank was scheduled for delivery from the Michoud Assembly Facility in Louisiana to KSC in late calendar year 2004.

NASA mission requirements now call for a second Space Shuttle to be ready to mount a rescue mission within 30 to 45 days if an orbiter is disabled during a mission and unable to make a safe crewed return. Space Shuttle Atlantis will serve as the rescue vehicle for STS-114. If STS-114 proceeds normally, Atlantis will then continue processing for the second Return to Flight mission, STS-121. Processing of Atlantis for these missions continued in 2004. Meanwhile, Space Shuttle Endeavour was being cycled through its scheduled Orbiter Major Down Periods.

Finally, NASA began planning for the retirement of the existing Space Shuttle system after completion of the ISS and the transition of the Space Shuttle

legacy to future exploration missions. In 2004, the Space Shuttle Service Life Extension Program, which had previously been the venue for planning Space Shuttle upgrades, was reorganized into the Integrated Space Operations Summit. Experts from Government, industry, and academia were asked to serve on panels that would prepare recommendations to the senior NASA leadership in the areas of Space Shuttle mission execution, transition, industrial capability support, and lessons learned. For the first time, an ISS panel was created to deal with space transportation requirements to and from the orbiting facility in the post-Space Shuttle era. The first summit was held in March 2005. Future summits will work to further refine the Space Shuttle retirement and transition plan to ensure post-Space Shuttle requirements for the ISS are adequately addressed and these activities are tightly integrated with the rest of NASA's exploration agenda.

In FY 2004, overall ISS systems performance surpassed expectations in light of the grounding of the Space Shuttle fleet. Our Russian partners are supporting crew and cargo transportation to the ISS until the Shuttle is available again in 2005. In FY 2004, automated Russian Progress vehicles resupplied the two-person Station crew three times, and Russian Soyuz vehicles transported two crews safely to and from the Station. This level of cooperation has enabled a continuous crew presence on the ISS.

FY 2004 on the Station began with a crew exchange. The Expedition 8 crew, U.S. Commander Michael Foale and Russian Flight Engineer Alexander Kaleri, replaced Expedition 7 on board the Station on October 20, 2003. Foale and Kaleri conducted one two-person extravehicular activity (EVA) safely and successfully without a crewmember inside the Station.

The Expedition 8 crew returned to Earth in April 2004, replaced by Expedition 9, Russian Commander Gennady Padalka and NASA Flight Engineer Mike Fincke, who arrived at the Station on April 21, 2004. Fincke and Padalka performed four EVAs while at the Station. Expedition 9 returned to Earth on October 23, 2004, eastern daylight time (e.d.t.).

The smaller crew size and transport capabilities of the Russian Progress and Soyuz spacecraft, which have been used heavily since the grounding of the Space Shuttle in February 2003, have limited the planned science activities. However, NASA maximized the research opportunities available through replanning and rescheduling science activities. Through the end of FY 2004, approximately 2,031

hours of combined crew time have been dedicated to research, and approximately 78 investigations have been initiated or completed.

The announcement of the Vision for Space Exploration on January 14, 2004, refocused research on the ISS to prepare for eventual missions to the Moon and Mars. While a two-person crew limits the amount of dedicated science performed on the Station, everything that happens on board prepares us for the day when we leave low-Earth orbit. Every maintenance issue, every experiment performed, and every EVA is a learning experience for both the crew on orbit and the crew on the ground.

One of the most important areas of research on the Station is how humans react during long-duration space flights. During their stay on board, crewmembers serve as test subjects for human life sciences experiments crucial to learning how to keep people healthy, safe, and productive in environments with different gravity levels. One experiment required crewmembers to wear special pairs of Lycra cycling tights fitted with sensors that measure how much weight and stress astronauts' legs and feet endure on a typical day in space. Since the human body is designed to function in Earth's gravity, placing weight and some amounts of stress on limbs helps maintain muscle strength and bone density. This experiment will provide a better understanding of the bone and muscle mass loss experienced by astronauts in near weightlessness. This research also will help researchers understand and treat the effects of osteoporosis and other illnesses and injuries that attack limb strength on Earth.

Station crews also observe and photograph natural and manmade changes on Earth. Crew photographs document both changes in Earth's surface over time and more fleeting events, like storms, floods, fires, and volcanic eruptions. In August and September, the Expedition 9 crew, using a handheld digital camera mounted to the outside of the ISS, captured still images and video of Hurricanes Bonnie, Charley, Frances, and others as they swept out of the Atlantic and onto the Eastern U.S. seaboard.

The Station is a safe, reliable, and well-managed on-orbit research facility. Station crews conduct basic and applied research in biology, physics, chemistry, ecology, medicine, manufacturing, and the long-term effects of space flight on humans. Commercial experiments also have been conducted on bone-loss treatments, plant growth, pharmaceutical production, and petroleum refining.

The International Partnership has met the challenge of continuing ISS operations while the Space Shuttle is grounded. The partners have met frequently at the technical and management levels to coordinate efforts to maintain our common goal of keeping the ISS crewed. The partnership is prepared to resume assembly as soon as the Space Shuttle returns to flight.

Through a Multilateral Program Partner Team reporting directly to the Multilateral Coordination Board, the International Partners are evaluating options for the Station on-orbit configuration. This team principally has explored options related to accommodating a crew greater than three and the associated advanced life support systems, habitability elements, and rescue vehicles necessary to meet utilization mission requirements for an increased crew size.

Space agency leaders from the United States, Russia, Japan, Europe, and Canada met at the European Space Agency Technical Centre in Noordwijk, the Netherlands, on July 23, 2004, to discuss ISS cooperation activities. At this meeting, the International Partner Heads of Agency unanimously endorsed the Multilateral Coordination Board's recommended configuration, which includes all the International Partner elements, as well as the Centrifuge Accommodation Module, Node 3, and the U.S. regenerative Environmental Control and Life Support System. Additional Multilateral Coordination Board and Heads of Agency meetings are planned for early 2005 to approve a final technical configuration and review the status of implementation plans and agreements.

The ISS is supporting Return to Flight efforts by providing the Shuttle crew with the ability to inspect the Shuttle orbiter once it is docked to the Station. The Station also can serve as a "safe haven" for the Shuttle crew in the event that the orbiter is unable to return to Earth.

Reliable connectivity for the ISS and SSP has been the focus of Space Communications activities in FY 2004. Space Communications also led the development of a communications and navigation architecture in conjunction with the Vision for Space Exploration.

NASA continued to develop and validate requirements for the Tracking and Data Relay Satellite System (TDRSS) Continuation Program in conjunction with the development of a Transformational Communications Architecture (TCA) program. The TCA is an initiative led by the Department of Defense to provide an integrated national space communications architecture. TDRSS is a

constellation of geosynchronous communications satellites and ground support facilities that is used by the Space Shuttle, the ISS, the Hubble Space Telescope (HST), and other low-Earth orbiting spacecraft. When first launched, these satellites were the largest, most sophisticated communications satellites ever built. In 2004, a set of three replenishment spacecraft (TDRS 8, 9, and 10) completed operational checkout and are now ready for deployment. These satellites replicate all of the services of TDRS 1–7, as well as provide Ka-band service and enhanced multiple access capability.

An Agencywide Space Communication Architecture Working Group (SCAWG) was established to address future NASA mission communication needs. The SCAWG is developing 5-year "snapshots" of the space communication architecture that must evolve from the present Deep Space Network, Space Network, and Ground Network in order to provide the necessary communication capabilities to support the NASA exploration and science programs. A key consideration in the SCAWG's work is to project technology maturity in order to determine when it can be introduced into the architecture to enhance capabilities.

After a very successful World Radiocommunication Conference (WRC) in 2003, NASA began in 2004 to coordinate positions with other relevant U.S. Government agencies for the WRC in 2007. NASA also significantly contributed to the development of the recently released National Positioning, Navigation, and Timing policy and the President's National Spectrum Policy Directive aimed at reforming national spectrum management. Senior NASA spectrum management personnel remain actively involved in implementing this Presidential initiative to bring the United States spectrum management activities into the 21st century.

In August 2002, NASA determined that it would not exercise the 5-year option under the Consolidated Space Operations Contract (CSOC), which expired on December 31, 2003. Solicitations for seven successor contracts at five Centers (Kennedy Space Center, Marshall Space Flight Center, Goddard Space Flight Center, Johnson Space Center, and the Jet Propulsion Laboratory) were successfully completed, and transitions from the CSOC to these successor contracts went smoothly. These contracts deal with Agency space communication activities, such as the Space Network and the Deep Space Network.

The Space Operations Mission Directorate's Launch Services Program successfully managed four expendable launch vehicle flights in FY 2004. The Gravity

Probe B (GP-B) and Aura missions launched from Vandenberg Air Force Base in California. The mission of GP-B is to test two extraordinary, unverified predictions of Albert Einstein's general theory of relativity. Aura is analyzing Earth's ozone, air quality, and climate. The MESSENGER and SWIFT spacecraft were launched from Cape Canaveral Air Force Base in Florida. MESSENGER began its journey to the planet Mercury, and SWIFT began documenting the origins and nature of gamma-ray bursts. Private industry provided all launch services procured for NASA's civilian missions.

Science Mission Directorate

Calendar year 2004 started out with NASA's Stardust mission receiving a close flyby of a comet on January 2. Images and other data of the ancient object revealed a much stranger world than previously believed. Stardust, which was launched in 1999, flew 236 kilometers (about 147 miles) from comet Wild 2. The flyby yielded the most detailed, high-resolution comet images ever taken, revealing a rigid surface dotted with towering pinnacles, plunging craters, steep cliffs, and dozens of jets spewing material into space. After collecting samples of the comet, the Stardust spacecraft began its journey back to Earth with its payload of thousands of captured particles. By January 2006, when it returns to Earth with a soft landing in the Utah desert, Stardust will have flown a total of 5.2 billion kilometers (3.2 billion miles).

A NASA study found that changes in Arctic temperatures and sea ice cover observed in 2004 were remarkable compared to past years. The Arctic warming study appeared in the American Meteorological Society's *Journal of Climate*. It showed that (compared to the 1980s) most of the Arctic warmed significantly over the last decade, with the biggest temperature increases occurring over North America. The Arctic changed in ways that were unobservable until the advent of satellite remote sensing.

In addition to using data from passive satellites, scientists used NASA's ICESat satellite in 2004 to understand how the Arctic region is changing. ICESat uses a laser technology called lidar to measure the thickness and extent of sea ice from space. Data from lidar improved scientific understanding of changing ice extent and how it contributes to changes in sea level and ocean circulation, which

in turn affect climate and agriculture worldwide, habitats for sea life, and accessibility of Arctic shipping lanes.

The GP-B spacecraft successfully launched on April 20, 2004, from Vandenberg Air Force Base, CA. GP-B orbited 400 miles above Earth while completing the initialization and orbit calibration phase of its mission. On August 27, 2004, the spacecraft began science data collection testing two predictions of Albert Einstein's general theory of relativity.

NASA-supported biologists developed a modeling approach that used satellite data and specimen locality data from museum collections to predict the geographic distribution of 11 known chameleon species in Madagascar. The model also helped lead to the discovery of seven new chameleon species. This project showed that combining NASA satellite and museum data could help identify places to survey for new species of life as well as areas in need of conservation. The study appeared in the December 2003 issue of the journal *Nature*.

Space science flourished in 2004. The combined abilities of three of NASA's great observatories, the HST, Spitzer Space Telescope (SST), and Chandra X-ray Observatory (CXO), allowed scientists to analyze infrared radiation, visible light, and x rays. Our team of great observatories continued to work toward the unraveling of the 400-year-old supernova mystery.

On December 9, two of these great observatories, the SST and HST, provided astronomers an unprecedented look at dusty planetary debris around stars the size of our Sun. SST discovered dusty discs around mature, Sun-like stars known to have planets. Hubble captured the most detailed image ever observed of a brighter disc circling a much younger Sun-like star. The findings provided "snapshots" of the process by which our own solar system evolved, from its dusty and chaotic beginnings to its more settled present-day state. CXO continued to work toward unlocking one of the biggest mysteries in physics, dark energy. Astronomers detected and probed dark energy by applying a powerful new method that uses images of galaxy clusters made by CXO. The results trace the transition of the expansion of the universe from a decelerating to an accelerating phase several billion years ago. CXO is studying 26 clusters of galaxies at distances between 1 and 8 billion light years. These data span the time when the universe slowed from its original expansion before speeding up again. CXO results suggest the dark energy

density does not change quickly with time and may even be constant, consistent with the "cosmological constant" concept first introduced by Albert Einstein.

A new NASA study found that emissions of soot, or black carbon, alter the way sunlight reflects off snow. A computer simulation indicated that soot may be responsible for as much as 25 percent of observed global warming over the past century. Soot on snow absorbs more of the Sun's energy and heat than icy, white backgrounds, which reflect the Sun's rays. With global warming, many snow- and ice-covered areas have begun to melt. As can be seen when glaciers and ice sheets melt, they tend to get dirtier as the soot becomes even more concentrated. Soot thereby adds to the warming effect as ice melts, making icy surfaces darker and absorbing more solar energy. Soot is generated from traffic, industrial pollution, outdoor fires, and household burning of coal and other fuels. It is the product of incomplete combustion. The soot particles absorb sunlight very effectively, just as wearing a black shirt outdoors absorbs more solar energy and keeps you warmer than a white shirt does.

NASA successfully landed two mobile geology labs on the surface of Mars on January 3 and January 24—a feat unparalleled in history. NASA's Spirit and Opportunity rovers drew tremendous worldwide interest in 2004 when they landed on the red planet. Within weeks, Opportunity discovered evidence that its landing site had been the location for a standing body of water sometime in the distant past, raising the possibility that the necessary ingredients for life may have existed on Mars at one time. In April, both rovers successfully completed their primary 3-month missions and went into bonus overtime work. On April 8, NASA approved an extended mission, up to 5 months, for these twin rovers. This extension provided for seven new goals, more than doubling exploration for less than 2 percent of additional investment. During the summer, Spirit completed a 3-kilometer (2-mile) trek southeast to the Columbia Hills. Opportunity descended into Endurance Crater, where it found layer upon layer of rocks bearing evidence that they had once been drenched in water. Spirit and Opportunity remained in good health well past their intended operational lifespan.

Our twin rovers did not operate alone in 2004. About 85 percent of the images and other data from Spirit and Opportunity reached Earth via communications relay by the Mars Odyssey orbiter. Mars Odyssey began working overtime

on August 25 after completing a prime mission that discovered vast supplies of frozen water, ran a safety check for future astronauts, and mapped the surface textures and minerals all over Mars. The orbiter helped to analyze potential landing sites for the rovers.

Public interest in the rovers' exploits was seen in front-page headlines around the world. Such interest made the NASA Web portal the most visited Web site in the world during the week of the landings.

NASA scientists found that circulation in the northern North Atlantic Ocean weakened considerably in the late 1990s, based on the satellite record of this system. The slowing of this ocean current is an indication of dramatic changes in the North Atlantic Ocean climate. This subpolar system moves water in a counterclockwise pattern from Ireland to Labrador, carrying warm water to northern Europe and moderating that area's climate. The satellite record is too short to determine whether this trend is part of a natural cycle or the result of factors related to global warming. Satellite data made it possible to view the current over the entire North Atlantic basin. A new satellite called the Ocean Surface Topography Mission is in development at NASA. It will use active satellite sensors to gather the information needed to quantify how Earth's ocean circulation is changing and to gauge the consequences of changing circulation patterns for life on Earth.

After a 7-year, 2-billion-mile (3.5-billion-kilometer) journey, Cassini-Huygens became the first spacecraft ever to go into orbit around the ringed planet on July 1, 2004. The joint NASA, European Space Agency, and Italian Space Agency Cassini-Huygens mission made a grand entry with a 96-minute engine burn and dramatic crossing of the rings. Dozens of stunning ring images showed hundreds of ringlets, waves, and ripples. Cassini found that the planet is roiled by storms, detected lighting, discovered a new radiation belt, found four new moons and a new ring around Saturn, and, for the first time, mapped the composition and temperature of the rings. On October 26, Cassini flew by the moon Titan at a distance of 745 miles (1,200 kilometers), the closest any spacecraft has ever come to the largest moon of Saturn. Titan is a prime target of the Cassini-Huygens mission because it is the only moon in our solar system with an atmosphere.

NASA's Aura satellite successfully launched into orbit on July 15, 2004, on a Delta II 7920 rocket from Vandenberg Air Force Base, CA. Aura uses cutting-edge Earth science technologies to provide global-scale information about Earth's atmospheric composition. Such information is crucial to protecting the air we breathe. Aura will survey the atmosphere from the surface of Earth through the upper atmosphere, where the ozone layer protects life on Earth. Aura's observations will allow scientists to understand how atmospheric composition affects and responds to Earth's changing climate. The observations, moreover, will provide better information on the extent to which Earth's protective ozone layer is recovering and will reveal the processes that connect local and global air quality. The Aura mission is a collaboration with the Netherlands, the United Kingdom, and Finland.

August 2004 marked NASA's first trip to Mercury in 30 years with the predawn launch of the MESSENGER spacecraft from Cape Canaveral Air Force Station, FL. MESSENGER is conducting an in-depth study of the Sun's closest neighbor, the least explored of the terrestrial "rocky" planets that also include Venus, Earth, and Mars. MESSENGER will provide the closest look ever at the innermost planet. Its voyage includes three flybys of Mercury in 2008 and 2009, and a yearlong orbit of the planet starting in March 2011.

Water covers approximately 70 percent of our world's surface, yet only 0.5 percent of Earth's water is available fresh water that can help meet the growing demands of society. Most of this fresh water resides in ground-water reservoirs that are hard to measure. In 2004, the Gravity Recovery And Climate Experiment (GRACE) science team reported that GRACE was demonstrating the first-ever capability to weigh Earth's fresh water from space. The GRACE satellites measure changes in Earth's gravitation field that signal shifts in the movement of water on Earth. GRACE consists of a pair of satellites that were launched in 2002. The mission was tasked with improving the gravity field by at least a factor of 10 and measuring monthly gravity fields. Last year, GRACE reported a global gravity field 50 to 100 times more accurate than previously available.

In a dramatic ending that marks a beginning in scientific research, on September 8, 2004, the Genesis solar sample return mission made a hard landing on a desert in Utah when its parachute failed to open. The return capsule suffered damage, but managed to preserve a significant portion of the precious samples of the Sun it had brought back from space. The Genesis mission was launched in

August 2001 on a journey to capture samples from the Sun. The Genesis scientists are encouraged they will be able to achieve the most important portions of their science objectives, which should tell us about the conditions that existed at the birth of the Sun and the planets over 5 billion years ago.

The Spitzer Space Telescope, launched on August 24, 2003, pierced through cosmic dust to reveal hidden objects, including a family of newborn stars whose birth was triggered by the death of another star; a dying star surrounded by a mysterious donut-shaped ring; and a cannibalistic galaxy with a strange parallelogram-shaped meal at its core. The telescope also peered deep into the dustiest regions of space and spotted cold and dusty planet-forming discs, which are the "planetary construction zones" around stars. One of the discs was discovered to harbor what may be the youngest planet ever detected. SST also identified one of the farthest galaxies ever seen and was able to measure its age and mass for the first time. The SST also joined forces this year with HST and CXO to study a supernova and distant black holes.

NASA and the Environmental Protection Agency (EPA) are working together to improve air quality forecasts that are used to issue public air quality notifications. The two agencies are relating NASA satellite measurements of aerosol optical depth and cloud optical thickness with EPA ground measurements. NASA provided the EPA with a near-real-time data-fusion product that served as a prototype during the pollution aerosol season in the fall of 2003. This prototype involved NASA aerosol and cloud data, National Oceanic and Atmospheric Administration (NOAA) wind speeds and fire locations, and EPA ground data. The prototype served air quality forecasters who used the 3-day visualizations of the data-fusion products to assess transport of aerosols into their region and then developed the air quality forecasts they issued to the public (e.g., severe air quality notifications).

An Earth Science-funded infrared-imaging technology was selected to detect flaws in the leading edges of the Shuttle wings. Originally created under the Earth Science Laser Risk Reduction Program as a way to diagnose problems in diode laser arrays for use in Earth observing satellites, this technology was adopted by the Leading Edge Infrared Camera Team to help inspect the Shuttle panels for tiny cracks, mechanical stresses, and other defects. The new infrared imaging capability will greatly increase NASA's ability to discover irregularities by sensing heat absorbed by the panels and by measuring rates of cooling.

On January 10, scientists made two discoveries at black holes' edges with the European Space Agency's XMM-Newton satellite. Scientists detected streams of gas that appear to be surfing on a wave of space as the gas falls toward the black hole, providing compelling evidence for an exotic prediction of Einstein's theory of general relativity—how a spinning black hole can drag the fabric of space around with it, creating a choppy sea of space that distorts all that passes through it on a descent into the black hole. The other discovery involves a super massive black hole in a galaxy more than 170 million light years away. Scientists clocked three separate clumps of hot iron gas whipping around the black hole at 20,000 miles per second, which is more than 10 percent of light speed. This marked the first time scientists could trace individual blobs of shredded matter on a complete journey around such a black hole. The United States was involved with two instruments. These science results complemented all the other black hole findings and stand as an excellent example of international collaboration.

NASA's Science Education and Public Outreach (EPO) program continues to be one of the largest programs in astronomy, Earth, and space science education. Our commitment to education places a special emphasis on precollege education, higher education, diversity, and increasing the general public's understanding and appreciation of science and technology. We now have more than 5,000 EPO events annually; an online directory of hundreds of educational resources, traveling museum exhibitions, and planetarium shows appearing in venues across the country; and a presence in every State. For the first time, NASA supported a summer science camp for blind students in grades seven through nine at the Goddard Space Flight Center in collaboration with the newly established Research and Training Institute of the National Federation of the Blind. A new book, entitled *Touch the Sun*, allows blind and visually impaired students to experience images of the Sun and solar activity by feeling transparent, raised textures bonded to the pictures. A new Uninhabited Aerial Vehicles (UAVs) Resource Center, underway at the Georgia Institute of Technology, prepares students for employment with the UAV industry. Students gain knowledge of and experience with environmental science applications of UAVs and engage in experimental design, sensor integration, and field deployment activities. The Global Learning and Observations to Benefit the Environment (GLOBE) program, known for its national and international partnerships in bringing students, teachers, and scien-

tists together to gather important Earth science data, was the winner of the 2004 Goldman Sachs Foundation Prize for Excellence in International Education in the Media and Technology category. The prizewinners exemplify how international knowledge and skills are no longer a luxury for high-achieving or affluent students, but a necessity for all. The Earth Explorers Institutes, in collaboration with the National Park Service, the Girl Scouts, and communities of amateur/citizen scientists, are expanding NASA's support to the informal education community. The Earth Observatory Web site (*http://www.earthobservatory.nasa.gov*) had yet another banner year in publishing many feature stories (178) and reference articles (60) in FY 2004. In addition to the captioned images that appear daily, the site also hosts 22-plus gigabytes of data each day. Created from the interdisciplinary Earth, solar, planetary, and space science missions and observatories that we develop and the ever-inspiring research and exploration we undertake, these investments are inspiring a new generation of explorers.

Aeronautics Research Mission Directorate

In FY 2004, the Aeronautics Research Mission Directorate, formerly the Aerospace Technology Enterprise, accomplished many major successes, primarily in revolutionary new capabilities and technologies, air transportation efficiency, aviation safety, environmental protection, and space access.

One especially noteworthy event was that NASA broke an important aviation barrier with the NASA X-43A airplane using a scramjet engine to fly seven times the speed of sound, setting a new world speed record for air-breathing aircraft. This scramjet technology is expected eventually to provide the most efficient path from ground to space and be of benefit to military and civilian commercial use. (In FY 2005, the X-43A broke its own record when it flew at 10 times the speed of sound.)

"What I really need is a pair of spectacles to see through the fog," declared Charles A. Lindbergh during his historic solo flight across the Atlantic in 1927. Almost eight decades and a host of technological advances later, NASA and its Government, industry, and university partners have developed the equivalent of Lindbergh's fog-penetrating spectacles. Test flights on a small aircraft demonstrated that NASA has brought "tunnel in the sky" Synthetic Vision Systems to an impressive level of functionality. The pursuit of this system is part of NASA's Aviation Safety and Security program intended to cut fatal accident rates by 80

percent over 10 years. This accomplishment has presented the possibility of eliminating low-visibility-induced accidents. This new system increases pilot situational awareness and reduces errors and workload by giving pilots "enhanced vision"-sensor-based information about terrain and humanmade features when visibility is obscured. The Synthetic Vision Systems create an artificial, computer-generated view based on a detailed terrain database. Although the pilot may not be able to see the ground through the fog, a computer screen presents the landing site accurately based on map and terrain information.

Eventually, every frequent traveler experiences sitting on a jet as it waits in line to take off or as it circles an airport waiting for permission from the tower to land. It is the inevitable result of too many jets vying for too little runway space. NASA, in collaboration with the Federal Aviation Administration (FAA), completed operational tests and a cost-benefit assessment for a Surface Management System computer program that will assist air traffic controllers and air carriers in managing the movement of aircraft on the airport runway, thereby improving runway capacity, efficiency, and flexibility. This program provides near-term predictions of runway delays and forecasts of total daily demand for a runway to support strategic surface planning. This capability also allows air traffic controllers, pilots, and airline officials to collaborate, plan, and make decisions based on shared information. Once in use at airports, this system will help move flights easily and safely from heavily used runways to runways that are free of congestion, preventing backups on the ground and in the air and speeding passengers to their destinations.

Restricted airspace exists throughout the United States. Civilian aircraft often accidentally fly into this space. More rarely, aircraft deliberately breach these protected areas. The FAA is responsible for monitoring all flights within the United States, and NASA is helping with that job. NASA demonstrated the prototype of a computer program designed to detect aircraft that deviate from their flight plans. The Fort Worth, TX, and Washington, DC, air traffic control centers evaluated the Rogue Evaluation And Coordination Tool, using a live traffic feed over 8 hours, to demonstrate the ability to detect aircraft that are deviating from their expected flightpaths and predict entry into restricted airspace. Tools like this will enhance public safety by mitigating the potential for catastrophic harm that could result from a rogue aircraft.

In support of a safer and more efficient air transportation system, NASA has developed and demonstrated technology that may one day enable unrestricted supersonic flight (faster than 750 miles per hour at sea level) over land and improve supersonic flight performance and safety. When aircraft fly faster than the speed of sound, a shock wave is formed, and a loud sonic boom is heard on the ground. Although sonic booms last less than a second, they can be disruptive and annoying to people and animals and can even cause damage to buildings. Identifying and maturing technologies to reduce sonic booms is a major hurdle to unrestricted supersonic flight. NASA and the Defense Advanced Research Projects Agency conducted the Shaped Sonic Boom Experiment to test the theory that altering the contours of a supersonic aircraft would shape the shock wave and its accompanying sonic boom, greatly reducing how loud the sonic boom sounds on the ground. Flight-test data gathered from supporting aircraft and ground sensors proved NASA's theory and paved the way toward improving and extending supersonic flight.

In a related study, NASA completed testing on a new type of inlet (a component that regulates airflow into aircraft engines for speed and lift capability) for supersonic propulsion systems. The Supersonic Parametric Inlet tests helped refine the inlet's performance through adjustments to the inlet geometry. Unlike typical inlets for supersonic cruise that rely on a mix of external and internal air compression, this inlet accomplishes all of the supersonic compression outside the engine. The tests showed that the inlet's performance was comparable to typical inlets with the added benefit of lower weight and the elimination of "unstart," a recurring safety problem in propulsion systems with mixed compression inlets. NASA also designed and manufactured full-scale engine components using alternative composite materials that will be tested for improved material integrity.

The air transportation system is integral to economic growth, national security, and enhanced quality of life, but negatively impacts the environment. NASA has developed technologies that reduce the negative environmental impacts of aviation operations by reducing aircraft carbon dioxide greenhouse emissions through the development of clean-burning engines and new energy sources like solar-electric fuel cells. NASA's research into lighter weight vehicles and components will reduce fuel consumption. NASA also is pursuing innovative vehicle concepts, such as blended-wing bodies and vaneless, counter-rotating turboma-

chinery that show potential for reducing noise and the emissions that contribute to smog and global warming. Some of these include the following:

- New tools that will enable researchers to identify and model aircraft noise sources and find ways to reduce this noise to acceptable, community-friendly levels. As part of this effort, NASA has explored low-noise propulsion systems, advanced vehicle concepts, advanced materials, and innovative noise-shielding techniques that keep objectionable noise within airport boundaries. NASA partnerships with the aerospace industry and other Government agencies are identifying the key technologies needed to increase engine and airframe efficiency and to speed the transfer of environmentally friendly technologies to the marketplace and to local airports.
- Validation of an initial set of noise-reduction concepts for airframes and engines by testing components in wind tunnel and engine rig experiments. The concept tests verified the potential for significant noise reduction with minimal loss of performance. Researchers also performed acoustic and aerodynamic performance tests on a new swept- and tapered-wing concept in aircraft approach flow conditions. Low-noise modifications to the high-lift devices on the wings reduced noise while maintaining wing performance.
- Successful testing of modifications to aircraft fan and nozzle designs and validation of the noise reduction predicted for those concepts. The test results validated noise-reduction projections that, combined with benefits from other noise-reduction techniques, resulted in a 5-decibel reduction relative to the baseline. The total suite of technologies, including those developed in previous programs, is projected to reduce aircraft noise sufficiently to meet NASA's 10-year goal of reducing perceived noise from aircraft by one-half.
- Production of preliminary designs for full-annular combustors (those that mix fuel with air for combustion) that exhibit the low nitrous-oxide emission characteristics that were demonstrated previously in combustor sector tests. These full-annular combustor designs include considerations for commercial service and are compatible with existing and future engine families. They also meet requirements for flight safety, component life, affordability, and maintainability at levels appropriate for product viability.

- Design of a two-stage compressor rig with 50 percent higher stage loading than the currently flying engine compressor. NASA also modified an existing facility to collect flow measurement data using state-of-the-art instrumentation. Researchers completed fabrication of the compressor rig hardware and began the assembly and instrumentation process.

NASA worked closely with other Government agencies and industry to modernize equipment, software, and procedures for significant improvements in air traffic management both in the air and on the ground. The Agency has developed and tested new vehicle concepts and technologies to reduce aircraft weight, improve aerodynamic performance, and increase speed. NASA has helped to maximize airport capacity in all types of weather, expand throughput at the Nation's small airports, effectively manage high-density traffic flows, and design aircraft that can operate on short runways. As part of this effort to improve airport flow and traffic management, NASA has developed technologies to enable high-bandwidth, highly reliable, secure networks with global connectivity, ensuring safe and secure links between aircraft and the ground. Additionally, NASA's new models and simulations are helping researchers understand the human operator, improving safety and performance throughout the complex air transportation system.

NASA developed, tested, and, in some cases, transferred to the FAA for deployment advanced air transportation technologies decision-support tools. These products will enable improvements in National Airspace System (NAS) throughput, user flexibility, predictability, and overall system efficiency while maintaining safety. The results were so promising that the Radio Technical Commission for Aeronautics (a Federal advisory committee to the FAA on policy, program, and regulatory decisions) selected NASA's Surface Management System and Multi-Center Traffic Management Advisor decision-support tools to become part of the FAA Free Flight Phase 2 Program, a program to create modernized computer hardware and software tools to help air traffic controllers and airlines.

NASA successfully completed two versions of the Airspace Concept Evaluation System simulation system designed to measure the effects of a new airspace concept on the National Airspace System. By modeling key features of a concept (or competing concepts), the system explores the interactions between participants and factors in the NAS and decides which new concept is best. Development of the third version of the system is on schedule. The latest version

features a higher fidelity terminal model, supports international flights, and has improved support for Advanced Airspace Concept modeling. In addition, NASA employees completed site visits to Cleveland's Air Route Traffic Control Center and Northwest Airlines' System Operations Control Center to collect field data and awarded a contract to support development of a preliminary operational concept description. NASA also completed the development of the following air traffic tools:

- Direct-To (D2)—Developed principally to help monitor and manage the FAA's Free Flight plan, it was provided to the FAA under its new organization.
- Airspace Concepts Evaluation System—The core of a new modeling toolbox under development by NASA, this provides a flexible NAS simulation and modeling environment that can asses the impact of new NAS tools, concepts, and architectures, including those that represent a significant departure from the existing NAS operational paradigm.

The combined year 2015 potential economic benefit from various air traffic control tools developed by NASA will be $3.5 billion, per the FAA's traffic forecast. Under a more conservative estimate that assumes the air traffic levels are constrained to levels that keep delays tolerable, the benefit would be $2.3 billion.

NASA developed prototypes of risk-analysis tools to integrate capabilities for archiving, searching, visualizing, and investigating hazards. The Risk Tool Suite for Advanced Design aids users in considering a wide range of risk types (e.g., hardware, software, programmatic, organizational). The suite helps designers determine a number of optimal portfolios of project risks, costs, and mitigations, which they can analyze and use to guide them in choosing the best technology solutions. The Mishap and Anomaly Information System provides the capability to evaluate historical mishap and anomaly data for patterns, trends, and associated risks, then integrates this capability with the Risk Tool Suite to better use historical data to enhance early-phase design.

Through the fusion of accident investigation methodology with collaborative information-sharing technology, the Investigation Organizer tool was used for multiple investigations, most recently by the CAIB. In addition, the National Transportation Safety Board and other Federal agencies began evaluating this tool for their use. An industry partnership initiated its commercialization. This project was canceled.

NASA has developed many other safety- and security-related technologies for aviation. Some of these include the following:

- Assessment of Vehicle Vulnerability decision-support tool including attack scenarios, risk evaluation of scenarios including likelihood of a consequence, mapping of technologies to scenarios, risk ranking of preventive and mitigating measures for FAR Part 121 (large passenger/cargo turbo jets) and 135 (regional jets) aircraft, and methodology and approach for airspace and airport vulnerability assessment.
- Safety Analysis for Distributed Systems, a tool used to improve automation such as autopilots system design for aeronautics technology. This was successfully demonstrated by analyzing the autoland system of the Boeing 777.
- Several prototype disk and engine containment materials that, when implemented, will dramatically reduce fan blade component failures, which currently account for about 15 percent of all fatal accidents resulting from propulsion system malfunctions.
- Aircraft Condition Analysis and Management System prototype on NASA's Boeing 757 flying lab and on a Gulfstream G5 with successful results in detecting and identifying a variety of faults and failures with no false alarms. This makes flying safer and less expensive.
- Validation of improvements to the Lewis Ice ice-accretion computational tool that is extensively used for design and certification of aircraft while making the process more robust and efficient. Improvements include the physical modeling of ice growth, expanded validation of thermal algorithms, new routines for multielement airfoil prediction analysis, and expanded operational capability.
- Provision of improved system-wide risk assessment for flight operations by merging existing Flight Operational Quality Assurance databases. The databases contained different types of data that, when combined, provide greatly increased analysis and incident reporting capabilities in plain-language descriptions.
- New risk-analysis techniques based on industry input of nearly 1,400 incident reports between 1998 and 2002. The new techniques helped identify procedural errors and their outcomes and provided new methods for characterizing procedural errors and identifying appropriate intervention strategies.

- The first single, national system concept with interagency coordination for protected area surveillance. This conceptually combined existing systems into a single system providing easy coordination of the work and was the basis for briefing members of the Interagency Homeland Air Security section of the Joint Theater Air and Missile Defense Organization and preparing for a multiagency review via the Homeland Air Security Coordination Center Work Group.

NASA entered into an agreement with the FAA on a portfolio of technologies and associated performance metrics, which will allow operation of uncrewed aerial vehicles in the national airspace at flight level 400 or 40,000 feet (above where most planes fly).

NASA took a leadership role in the Joint Planning and Development Office (JPDO), an organization established in 2004. The office includes NASA; the Departments of Transportation, Commerce, Defense, and Homeland Security (DHS); the FAA; the Office of Science and Technology Policy; and other public and private-sector experts. JPDO began to formulate a "National Plan" to transform the Nation's air transportation system to meet the needs of the year 2025 while providing substantial near-term benefits. The plan is a roadmap for the Next-Generation Air Transportation System. It has six overarching goals: 1) promote economic growth and create jobs; 2) expand system flexibility and deliver capacity to meet future demands; 3) tailor services to customer needs; 4) ensure national defense readiness; 5) promote aviation safety and environmental stewardship; and 6) retain and enhance U.S. leadership and economic competitiveness in global aviation.

DEPARTMENT OF DEFENSE

DOD

During FY 2004, the Department of Defense (DOD) engaged in a wide variety of aerospace activities. These activities focused on continuing space-based missile-warning systems, preparing for the next-generation Global Positioning System (GPS) constellation, further developing new military communication systems, and partnering with NASA and the Department of Commerce (DOC) on the new National Polar-orbiting Operational Environmental Satellite System (NPOESS). The Air Force also had continued success with the Evolved Expendable Launch Vehicle (EELV) program while preparing to retire both the Atlas and Titan legacy launch vehicles.

The Defense Support Program launched its 22nd satellite on the last Air Force Titan IV in February 2004, continuing over 30 years of space-based missile warning. The first advanced Space-Based Infrared System (SBIRS) payload, the Highly Elliptical Orbit-1, was delivered to its host satellite for integration. The SBIRS Mission Control Station stood up its operational initial SBIRS missile defense capability providing critical warning data to the Ballistic Missile Defense System.

The GPS Joint Program Office (JPO) launched satellites IIR-10 (December 2003), IIR-11 (March 2004), and IIR-12 (June 2004). Contract options with Boeing were exercised to procure IIF satellites 4–6 and long-lead parts for IIF satellites 7–9. Per the direction of the Under Secretary of the Air Force, the Modernized User Equipment (MUE) acquisition strategy to procure M-Code-capable user equipment was modified to include the course acquisition signal and the precise military signal. This was done to maximize MUE utility during the transition period between the launch of the first M-Code-capable satellite and the

achievement of a full operational capability. A GPS/Galileo Agreement was signed in June 2004 that will provide a mechanism for future cooperation on issues like compatibility between the two systems and will ensure protection for the M-Code signal. Consultations also were conducted with Japan and Russia to maximize cooperation and increase support for GPS.

The operational DOD Military Satellite Communications constellations—Defense Satellite Communications System, Global Broadcast Service, and MILSTAR—continued to support U.S. and allied operations in Afghanistan, Iraq, and throughout the world. The DOD completed the Transformational Communications Study, producing the first version of the Transformational Communications Architecture (TCA), a Governmentwide, joint communications concept aimed at providing dynamic, end-to-end accessibility and coverage for global communications requirements across the civil, Federal, and intelligence communities. Programs forming the foundation of the TCA include the Wideband Gapfiller Satellite system, the Advanced Extremely High Frequency satellites, the Mobile User Objective System, and the Transformational Satellite Communications constellation, all of which passed crucial development milestones during 2004.

The NPOESS—a tri-agency program involving DOD, DOC, and NASA that converges DOD's polar-orbiting weather satellite programs with those of DOC's National Oceanic and Atmospheric Administration (NOAA)—continued to progress. In FY 2004, NPOESS, in partnership with NASA, established a fiber-optic connection with the Norwegian island of Svalbard to be used as the mission data downlink site for the NPOESS Preparatory Project (NPP).

The Air Force achieved success with several legacy launch vehicle systems in FY 2004. Titan IVB had one successful launch in 2004 with launch vehicle B39 launching the DSP-22 satellite on February 14, 2004. Delta II successfully launched three GPS IIR satellites in orbit during December, March, and June 2004. Atlas IIAS launched on August 31, 2004, placing an NROL satellite in orbit. Closeout activities are nearing completion for the Atlas heritage launch vehicle program in FY 2005, with the final Atlas III launch scheduled for February 2005. Titan closeout activities begin in earnest following the final two launches of Launch Vehicles B26 and B30, scheduled for the first half of 2005. Titan closeout will end 50 years of Titan launch operations serving the national space interests of the United States.

For the newest Air Force launch vehicles, the major FY 2004 accomplishment for the EELV program was preparation for the Delta IV Heavy Lift Vehicle Demonstration launch. This launch will provide a wealth of engineering data and accomplish significant test objectives, such as activating and launching from the heavy version of the Delta IV launch pad, flying three common booster cores as a single vehicle, separating the two strap-on common booster cores from the center booster core, flying the first 5-meter-diameter composite payload fairing and separating it from the vehicle, and flying the first 5-meter-diameter cryogenic upper stage through a long-duration, three-burn profile of the RL10B-2 engine. In addition, the Air Force is in the process of revising the acquisition approach for EELV to adjust for decreased commercial launch demand.

Federal Aviation Administration

FAA

Every day, the aviation community faces challenges that range from ensuring the health and safety of passengers and crew to protecting the environment, increasing capacity and efficiency, and creating an aviation system that is performance based and human centered. As the Federal Aviation Administration's (FAA) approximately 38,000 controllers and maintenance specialists work around the clock to keep the system operating safely, they retain the confidence that FAA researchers are working in the background to develop next-generation technologies and procedures that will help them keep the system safe and efficient. FAA researchers had another successful year in FY 2004, working to advance scientific knowledge to ensure the safety of the flying public and to enhance capacity in the national aviation system.

The FAA's Aircraft Certification Job Aid, a computerized decision-support tool, helps aircraft certification personnel ensure aircraft flight deck technologies are user friendly and safe. With FAA funding, Research Integrations, Inc., is developing the job aid that focuses on air transport category aircraft.

In 2004, researchers added an advanced search function to allow keyword searches of all Part 25 regulatory and guidance information, as well as all summaries of human factors information addressing the design of flight deck displays, controls, and systems. This greatly enhanced the speed with which certification personnel can access the extensive human factors information found in this decision-support tool. Researchers also reviewed FAA regulatory information and other human factors literature for human factors systems-related information to update the databases. They developed a hierarchy of human factors considerations

pertinent to the design and certification of flight deck systems and expanded the three databases to address systems-related human factors.

In 2004, the FAA issued Advisory Circular 120-76A to create a streamlined field approval process for electronic flight bags (EFBs). Although the advisory circular addressed human factors considerations, it did not specify a procedure for conducting a human factors evaluation. To aid FAA aircraft certification specialists in conducting structured and comprehensive EFB usability evaluations in the field, aviation human factors experts evaluated vendor-supplied flight bags. Researchers discovered that the language used in the assessment tools is especially important for evaluating EFB usability. The tools need to be understood by many types of users who may or may not have a human factors background. Results from several evaluations yielded tools and procedures that show great promise for evaluating EFBs. Some manufacturers tested these tools and began to consider how to fit them into existing design and development processes.

The Human Factors Workbench provides FAA employees, system developers, those working in human factors research, and other associated individuals easy access to human factors information that supports aviation-related activities. It presents a compendium of essential information in an easily accessible framework on the Internet. This information is categorized under four human factors components: 1) process descriptions; 2) more than 100 human factors tools; 3) Human Factors Awareness Course/Tool; and 4) more than 1,200 publications, studies, and other papers with embedded search tools. To access the Human Factors Workbench online, please visit *http://www.hf.faa.gov/Portal/default.aspx*.

The FAA currently has no means to measure quantitatively what improvement in air traffic controller visibility can be gained by changing the tower height and location on the airport surface. Because tower height and location strongly affect construction costs as well as airport safety, it is critical that the FAA develop a reliable means to determine optimal tower location prior to construction. In FY 2004, a team of researchers from the FAA, the U.S. Army Research Laboratory, and the University of Nevada—Reno conducted tests to quantify what improvements could be gained by increasing the height of the air traffic control tower at Deer Valley Airport in Phoenix, AZ, from 110 feet to 130 or 150 feet. This and other investigations of tower siting procedures revealed that additional visibility analyses and criteria, such as those for observer line of sight

and object obscuration, could enhance the objectivity of tower construction decisions. Many factors determine tower height and location, and visibility analyses provide additional quantitative data to assist in acquisition and construction decisions. Research results will be used in future tower construction projects, enhancing safety and protecting the Nation's airport investments.

Last year, with the assistance of several industry partners, the FAA developed and tested an onboard inert gas generation system with air separation modules that use aircraft bleed air to generate nitrogen-enriched air at varying flow and purity (oxygen concentration). In FY 2004, during a commercial transport airplane flight cycle, researchers performed a series of ground and flight tests designed to prove the effectiveness of a simplified inerting concept. They mounted the FAA-developed system in the cargo bay of an Airbus 320 that the manufacturer operates specifically for R&D testing and inerted the center-wing fuel tank. Then they used special instruments to analyze the system performance and its related inerting capability. The FAA's onboard oxygen analysis system continuously measured the oxygen concentration in the fuel tank during the test flights. The results of the tests proved the validity of the simplified inerting system concept.

The extreme damage tolerance and high strength-to-weight ratio of composites motivate designers to expand the role of glass and graphite fiber reinforced composites in aircraft structures, most notably in principal structural elements. The use of these composites necessitates the development of nondestructive inspection methods designed for these new composite structures. FAA researchers at the Airworthiness Assurance Nondestructive Inspection Validation Center, located at Sandia National Laboratory, began developing better ways to inspect composite structures. In FY 2004, researchers completed an experiment assessing the performance of both conventional and advanced nondestructive inspection techniques to detect various flaws within typical aircraft honeycomb panels. Researchers inspected a series of composite honeycomb specimens with statistically relevant flaw profiles using both tap test equipment and more sophisticated techniques introduced to automate and improve composite nondestructive inspection. (Tap testing uses an audible change in acoustic response to locate flaws, voids, disbonds, and delaminations in adhesively bonded composite aircraft parts.) The researchers then took these specimens to a number of airline maintenance shops and third-party repair facilities for inspection by actual inspectors. From the

collected data, the researchers established a baseline of current inspection techniques, determined a wide array of nondestructive inspection methods, and identified limitations and optimum applications for specific inspection methods.

The University of Dayton Research Institute, funded by the FAA, completed the collection and analysis of flight loads data from 11,066 flights of Boeing 747-400 airplanes operated in commercial service overseas. The data, consisting of 95,883 flight hours, included typical inservice flight and ground loads data—such as accelerations, air and ground speeds, altitudes, flight duration and distance, gross weights, speed brake and spoiler cycles, thrust reverser usage, and gust velocities. The 747-400 is the first heavy wide-body model added to the FAA's operational loads monitoring research program. The International Aviation Rulemaking Advisory Committee has used these results extensively in their efforts to harmonize the rulemaking process for Airbus's new 380 airplanes. This research also will be used to provide the technical data to substantiate selected loads-related Federal Aviation Regulations.

The En Route Descent Advisor (EDA) is an advanced decision-support tool intended to help en route controllers to handle traffic operating within transition airspace. EDA builds on NASA's Center-TRACON Automation System (CTAS). In FY 2004, the FAA and NASA conducted a full evaluation of the prototype EDA system. FAA operational air traffic control personnel participated in the evaluation, providing system design reviews and recommendations periodically during the year. This successful evaluation marked the completion of a major development milestone.

The runway status light (RWSL) system is an array of red lights that can be deployed at taxiway entrances to warn pilots and vehicle operators that a runway is unsafe to enter. During the year, the FAA made progress in assembling an operational, evaluation-ready RWSL system at Dallas/Ft. Worth International Airport. Working closely with Lincoln Laboratory and Sensis Corporation, the FAA developed key system improvements to address technical issues identified during initial field testing, completed construction and installation of Siemens' airfield lighting equipment for the RWSL system, and conducted a successful field retest at the airport.

The Weather Support to Decision Making (WSDM) system, funded by the FAA, provides deicing decision-makers and airport plowing crews with up-to-the-minute information on potentially hazardous freezing precipitation. It uses data

from Doppler radars, surface weather stations, and snow gauges located near the airport to measure accurately the amount of water in the snowfall. In FY 2004, researchers increased the 2-hour WSDM precipitation forecast to 4 hours, allowing users longer lead times for more effective strategic decisions and enhancing efficiency as well as safety.

The FAA upgraded the Emissions and Dispersion Modeling System (EDMS) to permit assessment of the quantity of ground emissions that can be preventable by specific actions. EDMS calculates emissions from airport sources and models the air quality at an airport. The EDMS enhancements enable computation of on-road and off-road vehicle emission factors. The new version also includes more accurate techniques for computing total hydrocarbon and volatile organic hydrocarbon emissions. These enhancements supported airport applications for FAA program funding and emissions-reduction credits from the EPA.

In collaboration with NASA, the FAA initiated a long-term, strategic effort to develop analytical tools to address the relationships between noise and emissions, and between different types of emissions. Current analytical tools focus on noise or emissions; however, noise and emissions are interdependent phenomena. In FY 2004, at the request of the FAA, the Transportation Research Board of the National Research Council completed a study to assess the proposed aviation environmental design tool (AEDT) that will allow integrated assessment of noise and emissions impact at the local and global levels. The TRB assembled a committee to analyze the AEDT requirements and conducted a workshop in early 2004. The FAA and NASA used the comments from the workshop to refine the conceptual foundation of AEDT and formulate a comprehensive work plan.

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

During FY 2004, the FAA issued the world's first suborbital reusable launch vehicle mission license to Scaled Composites for SpaceShipOne. It also granted a second such launch license to XCOR Aerospace. In addition, it issued its fifth

FAA launch site operator license to East Kern Airport District for suborbital launches at Mojave Airport in California, making it the first inland licensed launch site.

There were 13 commercial space launches in FY 2004, including 4 suborbital launches of SpaceShipOne, the first privately built crewed spacecraft to travel into space. The FAA awarded the first-ever commercial astronaut wings to pilot Mike Melvill of Scaled Composites on June 21, 2004, after SpaceShipOne successfully reached an altitude of just over 100 kilometers (62 miles).

Orbital space launches for FY 2004 included three launches of Atlas II vehicles and two launches of Atlas III vehicles provided by International Launch Services; three launches by Sea Launch, a multinational company that provides the Zenit 3SL launch vehicle; and one launch of a Taurus XL, built by Orbital Sciences Corporation. The Atlas II series of vehicles finished service in FY 2004 with a perfect record of 63 straight successful launches. Lockheed Martin manufactures Atlas vehicles in Colorado.

The Office of Commercial Space Transportation released a number of important regulatory documents during FY 2004, including *Draft Guidelines for Licensed Suborbital RLV Operations with Flight Crew*, *Commercial RLV Operations and Maintenance Preliminary Guidelines*, *Draft FAA Guidelines on Probability of Failure Analysis for New Expendable Launch Vehicles*, and an FAA definition of a Suborbital Rocket Launch that was published in the *Federal Register*.

In addition, the FAA hosted workshops for the launch industry on launch site applications and on refinements to maximum probable loss methodology. The National Transportation Safety Board, Air Force, and FAA signed an agreement regarding investigations of space launch accidents from Federal ranges. The FAA established an agreement with the 30th Space Wing for Launch Safety Support at Vandenberg Air Force Base and signed a memorandum of understanding with SpaceTec promoting aerospace technology education.

The FAA also created three new technical training courses on launch trajectory analysis, system safety and risk assessment, and interpretation of lightning launch weather rules. Three research initiatives commenced in FY 2004: creation of a simplified debris survivability analysis, verification methods for critical reusable launch vehicle (RLV) structures, and identification of communications frequencies that are less susceptible to radio frequency blackout during RLV reentry.

The FAA released several informative research reports of interest to the space industry, the U.S. Government, and the public, including *The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2002 Results and Outlook for 2010*; the *2004 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports* report; a summary of AST R&D accomplishments; and the *2004 Commercial Space Transportation Forecasts*. The forecasts, prepared by the FAA and its Commercial Space Transportation Advisory Committee, projected an average worldwide demand of 18.3 launches per year to geosynchronous orbits and 5.1 launches per year to nongeosynchronous orbits between 2004 and 2013.

Information about the Office of Commercial Space Transportation, reports, and other documents can be found at *http://ast.faa.gov*. For additional information about the FAA's R&D program, please see *http://research.faa.gov*.

DEPARTMENT OF COMMERCE

DOC

In FY 2004, the Department of Commerce (DOC) engaged in a wide variety of activities that furthered U.S. interests in aeronautics and space, including national policy development, satellite operations, technology development, international cooperation, and trade promotion.

At the departmental level, DOC continued its active role on the National Security Council's Space Policy Coordinating Committee (Space PCC), with direct participation from the Deputy Secretary of Commerce and staff from the National Oceanic and Atmospheric Administration (NOAA), the International Trade Administration (ITA), the Office of Space Commercialization (OSC), and the National Telecommunications and Information Administration (NTIA). Among the Space PCC's accomplishments was the release of the President's Vision for Space Exploration in January 2004 and the development of new national policies on space-based positioning, navigation, and timing and space transportation in early FY 2005. During the development of these policies, ITA arranged briefings to U.S. industry to ensure commercial interests were adequately addressed.

In April 2004, NOAA Administrator Conrad C. Lautenbacher convened with ministers from over 35 countries for the second Earth Observation Summit in Tokyo, Japan. During the summit, the ministers endorsed the framework of a 10-year implementation plan for a Global Earth Observation System of Systems (GEOSS). The ad hoc intergovernmental Group on Earth Observations, cochaired by the NOAA Administrator and three other international leaders, subsequently developed the plan for final presentation and endorsement at the third Earth Observation Summit in February 2005. The plan details the establishment of an international, comprehensive, coordinated, and sustained Earth observation

system of systems centered around nine societal benefit areas, including disaster mitigation, human health, energy, climate, water, weather, ecosystems management, agriculture, and biodiversity.

In June 2004, NOAA cosponsored the U.S.-India Conference on Space Science, Applications, and Commerce in Bangalore, India, along with NASA, the State Department, and the American Institute for Aeronautics and Astronautics. The conference was partly an outcome of the Next Steps in Strategic Partnership with India initiative announced by President Bush in January 2004. NOAA's efforts and the conference as a whole represented a major step toward the President's vision of greater cooperation between the United States and India.

In July 2004, DOC sponsored the U.S. Pavilion at the Farnborough International Air Show. Deputy Secretary Kassinger presided over its official opening and met with several exhibitors, senior industry executives, and foreign government officials. ITA also sponsored an Aerospace Products Literature Center at the air show. The event provided hundreds of trade leads for participating companies.

Also at the departmental level, DOC continued to play a key role on the Interagency GPS Executive Board (IGEB), representing the interests of commercial, scientific, and governmental users of GPS technology during meetings of the IGEB and its associated management bodies. DOC continued to host the offices and meetings of the IGEB, providing both personnel and resources. DOC also continued to serve on the U.S. delegation that negotiated with the European Community toward cooperation between GPS and Galileo, Europe's future satellite navigation system. After several years of talks, the United States and Europe signed a landmark accord on this matter in June 2004, paving the way for GPS-Galileo interoperability and fair competition among all commercial providers of satellite navigation goods and services. OSC staff participated in bilateral consultations with Brazil to discuss potential GPS cooperation and helped organize a local workshop on GPS applications that took place at the American Chamber of Commerce in Sao Paulo, Brazil, in September 2004.

DOC participated in the review of Administration policies on aeronautical research and development through the National Science and Technology Council's Aeronautics Science and Technology Subcommittee. ITA staff participated in subcommittee assessments of Federal science and technology priorities, infrastructure, policies, and related activities across relevant Federal agencies.

DOC participated in an interagency initiative to develop an integrated plan for the Next-Generation Air Transportation System. ITA contributed to the formation of the interagency JPDO overseeing this initiative, as well as various technical working groups. NOAA led the interagency team developing a national aviation weather strategy. ITA's Deputy Assistant Secretary for Transportation and Machinery participated in a joint Government-industry initiative to identify aerospace workforce and education concerns and to create a coordinated Government-industry workforce action plan. ITA also contributed to the Administration's review of the U.S. export control regime.

DOC continued to represent commercial remote sensing interests within the Remote Sensing Interagency Working Group (RSIWG). RSIWG is charged with coordinating policy for the export of remote sensing satellite systems and negotiating government-to-government agreements covering the safeguarding of those systems' technology. During FY 2004, the group held consultations with several countries on remote sensing satellite cooperation, including Turkey, Canada, United Arab Emirates, and France.

Within NOAA, space-related activities occurred across the entire organization. During the first quarter of FY 2004, NOAA continued to chair both the international Committee on Earth Observation Satellites (CEOS) and the Integrated Global Observing Strategy (IGOS). In November 2003, NOAA hosted the 17th CEOS Plenary in Colorado Springs, CO, where over 100 participants, representing 19 CEOS member space agencies and 17 associated organizations, met to address a range of satellite coordination issues including data utilization and capacity building. NOAA also led the implementation of CEOS's work in response to the Johannesburg Plan of Implementation from the World Summit on Sustainable Development through the planning of a capacity-building workshop focused on the needs of satellite data users in Africa. As chair of IGOS, NOAA took the lead in bringing together the major in situ and space-based systems to coordinate the identification of user requirements for coastal areas and facilitated the creation of a coastal plan to be implemented in FY 2005.

During FY 2004, NOAA continued its leadership role in the International Charter for Space and Major Disasters, serving as both the Executive Secretariat and a rotating Emergency On-Call Officer. The International Charter aims at pro-

viding a unified system of space data acquisition and delivery to those affected by natural or humanmade disasters.

NOAA's two Geostationary Operational Environmental Satellites (GOES), GOES-East and GOES-West, continued to monitor the Western Hemisphere for severe weather "triggers" in the atmosphere and to provide the kind of continuous data necessary for intensive analysis during hurricanes, tropical storms and depressions, tornadoes, floods, and other severe weather conditions. In addition to the two operational satellites, NOAA positioned a spare satellite, GOES-11, over the center of the United States to replace one of the operational satellites if necessary. During the 2004 Atlantic hurricane season, the GOES satellites provided a continuous flow of imagery that contributed significantly to the development of storm forecasts. These forecasts helped minimize loss of life in the United States as the country was impacted by three tropical storms and six hurricanes, including Hurricanes Charley, Ivan, and Jeanne. NOAA also continued to provide space weather monitoring and forecasts to protect spacecraft and power grids.

Under an agreement with the Japan Meteorological Agency (JMA), NOAA continued to support GOES operations in the Western Pacific. Since April 2003, GOES-9 satellite imagery has been utilized by Japan to replace the data formerly received from their aging GMS-5 satellite. GOES-9 support ensures the continuity of geostationary satellite services to support severe weather forecasting for Japan, U.S. assets and territories in the Western Pacific, and other regional allies. JMA continued to fund related GOES-9 operations costs.

NOAA's Polar-orbiting Operational Environmental Satellites (POES) continued to provide an uninterrupted flow of global environmental information in support of weather, oceanic, and space environmental modeling, tropical storm analysis and forecasting, local weather forecasting, ecosystem monitoring, and climate monitoring.

The NPOESS program made significant progress toward the development of the next generation of polar-orbiting environmental satellites. The program successfully developed a new high-speed data interface chip, the first of its kind for spaceborne application, that will allow NPOESS to rapidly transmit large volumes of data. NOAA and NASA made significant progress on the NPP, a test and proof-of-concept satellite that will validate performance of three major NPOESS

instruments, the complete command and control system, and the data processing/distribution system. The Navy successfully demonstrated wind speed and direction retrievals from the Coriolis/WindSat sensor launched in 2003 as a risk mitigator for NPOESS. The year 2004 also saw the successful completion of the Build 1.3 Ground System software, NPP Compatibility Test, operational test with the Svalbard communications station, and the delivery of a number of sensor engineering development units.

In September 2004, NOAA and Lockheed Martin signed a contract modification to rebuild and launch the NOAA-N Prime satellite by December 2007. The decision to rebuild NOAA-N Prime substantially reduced the risk of a coverage gap in the polar satellite system prior to the launch of the first NPOESS satellite into an afternoon orbit.

NOAA and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) supported the exchange and integration of instruments for the upcoming U.S. POES and the EUMETSAT Metop polar satellite missions, continuing a 20-year tradition of cooperation in this area. The exchange of instruments and satellite instrument data will enable each partner to improve weather forecasts and mitigate the impact of natural disasters.

NOAA continued to participate in the exchange of geostationary and polar-orbiting satellite data between the United States and India under the auspices of the Memorandum of Understanding (MOU) for Scientific Cooperation in the Areas of Earth and Atmospheric Sciences involving NOAA, NASA, and India's Department of Space and Department of Science and Technology.

During FY 2004, NOAA developed new satellite products to enhance the Nation's ability to predict weather, monitor climate change, observe ocean conditions, and detect natural hazards. NOAA enhanced the accuracy and coverage of a product that measures rainfall based on satellite imagery. NOAA completed work on a product to analyze the size and temperature of wildfires seen by satellites and increased the coverage of this product to include South America, where thousands of wildfires are visible every day. NOAA also developed a product that will greatly increase the detection of ice drifts, a significant hazard to marine commerce and transportation. NOAA enhanced weather forecast models by introducing new satellite-based wind measurements and made additional weather analysis products available based on high-frequency observations from weather satellites.

NOAA experienced record levels of public demand for its satellite imagery in 2004 as four hurricanes struck the State of Florida. NOAA's Web servers logged a record number of hits and distributed unprecedented amounts of data to the public. On September 15, 2004, as Hurricane Ivan was about to make landfall on the U.S. Gulf Coast, one NOAA site served a 24-hour total of 2.52 terabytes of data and reported a weekly access count of 230 million users.

The need to monitor fire and smoke activity across national borders led NOAA to enter into a new phase of development and prototype operations. The American Fellows Program awarded two fellowships to distinguished Mexican Weather Service personnel who worked with NOAA satellite analysts in detecting wildfires and smoke utilizing weather satellite data over Mexico. The ability to detect wildfires in Mexico and Central America is critical for tracking the large plumes of smoke that emanate from the region during the spring and that can drift to the United States causing air quality and health problems.

During FY 2004, NOAA's Search and Rescue Satellite-Aided Tracking (SARSAT) program contributed to the rescue of 248 mariners, aviators, and land-based users by relaying distress signals from emergency beacons to search and rescue services via satellite. NOAA participated in a U.S./United Nations (U.N.) workshop on satellite search and rescue for Latin America and Caribbean nations, part of the U.N.'s efforts to bring space technology to developing countries. NOAA began providing the Ship Security Alerting System (SSAS), a new capability that helps protect mariners from terrorism and piracy by providing a discrete means to transmit security alerts to a dedicated response center via the SARSAT system. NOAA was instrumental in the development of the technical standard for SSAS beacons. During 2004, NOAA recorded the first rescue as a result of the personal locator beacons introduced in 2003. NOAA's efforts to expand the SARSAT user base included an effort to revise international standards for emergency beacons so that new technology could be introduced to lower their cost.

Supporting the above operations, NOAA provided a suite of services including data rescue, information technology, and scientific data stewardship. Under data rescue, for instance, the University of Wisconsin completed the transfer of 120 terabytes of GOES satellite data from over 10,000 tapes to modern media, which are to be transferred to the NOAA archives. NOAA also completed the overall design of top-level architecture for its Comprehensive Large-Array

Data Stewardship System, including requirements, interface control, concept of operations, and management plans and procedures.

FY 2004 was successful for the Joint Center for Satellite Data Assimilation, in which NOAA, NASA, the Navy, and the Air Force cooperated to accelerate the use of satellite observations in numerical weather and climate prediction. New models of the surface properties of ice and snow enabled observations from satellite microwave sensors to be applied to improve weather prediction at high latitudes. The program demonstrated additional forecasting gains for the polar regions by assimilating winds inferred from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instruments and improved weather-prediction capability over the entire globe through optimal use of data from NASA's Atmospheric Infrared Sounder (AIRS).

NOAA and NASA made progress toward the creation of an improved ozone vertical profile data set from the Solar Backscatter UltraViolet instruments (SBUV and SBUV/2), developing a new retrieval algorithm with a consistent intercalibration for the SBUV(/2) instruments flown on NIMBUS-7, NOAA-9, NOAA-11, and NOAA-16. The 2004 ozone climatology derived from SBUV revealed that the Antarctic ozone hole was of average size and depth relative to the previous 10 years, as expected.

NOAA implemented improvements to a GOES multispectral image product for aircraft icing detection that resulted in higher detection rates. The product also included information on cloud top heights, allowing estimation of the maximum height of icing conditions. The GOES icing product algorithm was transferred to the Air Force for testing in its Mark-IVB satellite processing system. NOAA implemented a new capability to model winds in the polar regions using observations from the Terra and Aqua satellites into its satellite-based winds processing suite. NOAA developed an integrated GOES sounder product system that will provide the National Weather Service with full-resolution products for use in numerical weather prediction and the Advanced Weather Interactive Processing System, as required by forecasters in the field. This new integrated system will replace the current operational systems.

NOAA began to study global climate change using the long-time series of retrospective satellite data now available. Using historic data from the Microwave Sounding Unit (MSU) and the Advanced Very High Resolution Radiometer

(AVHRR), NOAA's preliminary studies revealed a modest long-term increase in Earth's atmospheric temperature of 0.17°C per decade.

NOAA began producing a weekly green vegetation fraction product from AVHRR observations. Satellite-derived surface products such as snow cover, sea-surface temperature, surface albedo, and green vegetation fraction have proved to be very important to accurate weather predictions of near-surface temperature and humidity.

In FY 2004, for the first time in its over 25-year history, the World Magnetic Model (WMM) was both developed and distributed by NOAA. The WMM is the standard navigation magnetic field model used by NOAA, FAA, DOD, the U.K. Department of Defence, NATO, and the World Meteorological Organisation. In developing the WMM, NOAA incorporated data from the Danish Ørsted and German Champ magnetic satellites, as well as magnetic observatory data from over 200 stations in more than 80 countries, to create an accurate model of Earth's main magnetic field and its current rate of change.

In the area of GPS data services, NOAA updated the systems that enable the Continuously Operating Reference Stations (CORS) West parallel processing site in Boulder, CO, to collect and deliver Coast Guard, FAA, and CORS National Internet data. The upgrades expedited CORS data access for NOAA's Forecast Systems Laboratory in Boulder as well as NOAA's Space Environment Center, which uses the data to compute the total electron content for the conterminous United States.

Outside NOAA, the National Institute of Standards and Technology (NIST) was highly active in FY 2004, performing a broad range of aeronautics and space-related measurements, technology development, and industry support. NIST supported NASA's MESSENGER mission to Mercury by helping calibrate a gamma-ray detector intended to map that planet's gamma-ray emission spectra. Analysis of the data will help determine the composition of Mercury's crust and shed light on the evolution of that planet and the solar system. Calibration of the detector could not be performed using conventional methods, so the project scientists turned to the unique beam facilities of the NIST Center for Neutron Research. The work performed will allow MESSENGER to yield a relatively accurate compositional map of Mercury and will likely set a new standard for spaceborne gamma-ray spectrometers.

NIST continued to provide computational support to NASA to aid in the interpretation of x-ray data obtained from the Near Earth Asteroid Rendezvous (NEAR) Shoemaker spacecraft, which landed on an asteroid in 2001. Successful code modifications achieved on this project were also applied to other space missions involving x-ray spectrometer data, including Japan's Hayabusa, NASA's MESSENGER, and Europe's and Japan's BepiColumbo.

With NASA funding, NIST continued to conduct ground-based experiments to investigate the development of new spaceborne atomic clocks based on optical rather than microwave transitions. Using optical transitions could potentially improve atomic clock performance by a thousandfold while dramatically reducing size, weight, and power consumption. Highly accurate clocks in space would be used to study gravitational waves and relativity, enhance space-based astronomical observations, and improve navigation and communication. With funding from DOD's Defense Advanced Research Projects Agency (DARPA), NIST demonstrated a prototype chip-scale atomic clock using all optical excitation and detection, with the potential for atomically precise timekeeping (10^{-11} frequency stability at 1 hour) in a small package (1 cubic centimeter total) with minimal power consumption (30 mW, compared to dozens of watts for "standard" atomic clocks). While the chip-scale atomic clock is not intended to be as accurate or stable as larger optical frequency standards, its exceptionally small size and low power consumption make it potentially ideal for many space applications involving navigation and communications.

NIST worked with NASA to understand and characterize surface barrier detectors to be used in the Space Environment Monitor on the GOES-P satellite. NIST shared its expertise in the performance characteristics, failure modes, and safe handling procedures for these detectors, and tested the performance of a small number of sample detectors in a specialized testing apparatus. As a result of this interaction, NASA was able to generate purchase specifications and testing protocols ensuring that they would receive functional and robust detectors for use on the GOES-P weather satellite.

With NASA funding, NIST helped collaborators at the Harvard-Smithsonian Center for Astrophysics develop and deploy a new cryogenic transition-edge-sensor microcalorimeter x-ray detector with characteristics that are significantly improved over previous such instruments. NIST detector arrays

demonstrated energy resolving power (the key performance characteristic) that doubled the previous world record. NIST continued developing a superconducting multiplexer system for readout that would be used both for these x-ray detectors and for a separate millimeter and submillimeter imaging effort. NIST successfully demonstrated multiplexing of signals from a small x-ray microcalorimeter array with no loss of sensor performance. NIST also demonstrated a new higher performance multiplexer scheme that should enable the construction of much larger imaging arrays. The new instrument was deployed at the NIST Electron Beam Ion Trap facility, one of the few places in the world capable of simulating hot astrophysical plasma emission under well-controlled conditions. The NIST-Harvard team initiated spectroscopic studies that will guide the interpretation of data from NASA's CXO and will pave the way for the future launch of Constellation-X.

NIST received funding from NASA to work on new concepts to achieve electrical cooling of cryogenic detectors. Electrical cooling can greatly simplify spacecraft design by replacing large, heavy mechanical coolers with simpler, lower weight electronic systems. Using standard microelectronic processes, NIST fabricated large-area coolers that demonstrated cooling from 260 mK to 115 mK with cooling power 100 to 1,000 times greater than previous demonstrations. NIST also created devices combining both x-ray microcalorimeters and electrical refrigerators on a single chip. These achievements were highlighted on the covers of *Physics Today* and *Applied Physics Letters*.

NIST collaborated with NASA in the measurement of laboratory far-infrared and infrared collision-induced absorption spectra of water vapor. The spectra provided critical data for the modeling of the radiative balance and transmittance of the atmosphere to aid the interpretation of satellite measurements of atmospheric and surface properties, such as sea-surface temperature, by the EOS and other space, atmospheric, and ground-based sensors.

NIST continued work with NASA, NOAA, and DOD to address problems of calibration and validation of microwave radiometers used for remote sensing. In FY 2004, measurement-based methods were developed to evaluate two significant components of the uncertainty in microwave remote sensing radiometry: uncertainties due to detector nonlinearity and to calibration target proximity. In addition, NIST continued work on an online compilation of standard terminology

and recommended measurement practices for microwave remote sensing, particularly for calibration and validation of microwave radiometers.

NIST performed a detailed optical characterization of the Marine Optical Buoy (MOBY), stationed off the coast of Hawaii, to improve the accuracy of satellite ocean-color measurements used in the estimation of ocean carbon levels. NIST developed a novel laser instrument to demonstrate that stray light within the MOBY instrumentation was causing data discrepancies. Applying a correction algorithm to remove the stray light effects reduced satellite measurements of global chlorophyll-a concentrations and associated ocean carbon levels by 15 to 20 percent, leading to a 6-percent total adjustment in the data.

NIST developed a novel optical radiation standard based on light-emitting diodes (LEDs) for the characterization and calibration of remote sensing instruments used by NASA and NOAA. An integrating sphere instrumented with LEDs allowed the laboratory reproduction of the color of natural optical radiation sources such as the ocean under solar illumination, providing a new tool to characterize space, ground, and ocean sensors prior to deployment. The light source was developed as an alternative to expensive laser-based systems.

NIST worked with NASA to develop new methods to measure aspheric optics for space astronomy. This collaboration built on prior joint developments by NIST and NASA for calibration of reference optical flats.

NIST's Synchrotron Ultraviolet Radiation Facility (SURF III) served as a source of soft x rays and vacuum ultraviolet light to calibrate mirrors, detectors, and spectrometers used in NASA spacecraft that study solar flares and astronomical bodies, such as the Extreme Ultraviolet Variability Experiment, part of NASA's Solar Dynamics Observatory mission. SURF III also continued to provide the calibration standard for experimental determination of atomic radiation intensities required for interpretation of HST data.

NIST developed methods to improve the calibration of the European Space Agency's Space Telescope Imaging Spectrograph (STIS) on the HST, thereby increasing the scientific value of STIS archival data. This involved wavelength calibration of the platinum/chromium-neon (Pt/Cr-Ne) hollow cathode lamps used on board the HST. NIST also conducted a series of accelerated aging tests to determine the likely lifespan of the lamps used on the HST and future space observatories. When the NASA Anomaly Review Board convened to investigate

intermittent failures of the Pt/Cr-Ne lamps on the HST, the data acquired by NIST in its laboratory studies of these lamps proved critical.

With NASA support, NIST continued to produce and compile atomic spectroscopic data needed by space astronomers. With the recent launch of NASA space observatories for the vacuum ultraviolet, x-ray, and infrared spectral regions, NIST atomic data activities focused on these areas of the electromagnetic spectrum, compiling critical data on the spectra of iron (Fe I and Fe II) and others of high cosmic abundance.

With NASA funding, NIST released three new online databases: Atomic Spectra Database (Version 3.0-beta); Handbook of Basic Atomic Spectroscopic Data; and Spectral Data for the CXO. The databases are intended to facilitate the interpretation of observations carried out with NASA space observatories, including the HST, the CXO, the Far Ultraviolet Spectroscopic Explorer, and the Spitzer Infrared Observatory.

NIST released the final report from the Satellite Instrument Calibration for Measuring Global Climate Change workshop, held in November 2002 and jointly organized by NIST, the NPOESS Integrated Program Office, NOAA, and NASA. The workshop addressed the measurement challenges and instrument calibration needs for the accurate space-based measurement of global climate change variables such as atmospheric temperature and solar irradiance.

NIST calibrated heat-flux sensors for the Arnold Engineering and Development Center to allow accurate measurements in wind tunnel tests critical to the Space Shuttle and other programs. NIST successfully developed a procedure to extend the range of the sensor calibration to encompass the high heat-flux levels typically experienced in these tests.

NIST continued efforts to improve upon the acoustic emission technique for the nondestructive evaluation and inspection of aircraft and spacecraft structures. Advances were achieved through the use of increased, high-sensitivity bandwidth. This effort supports NASA's general nondestructive evaluation (NDE) program with overall goals to improve sensitivity, reduce uncertainty, and ensure reliable use of NDE in the field.

NIST, with sponsorship from FAA/TSA and Boeing, continued its development of new techniques for measuring the electromagnetic shielding of aircraft, which, among other things, reduces interference to avionics from external radia-

tion and onboard laptops and cell phones. The new time-domain techniques developed by NIST are much faster and more efficient than conventional methods. Following up on tests performed in 2002 and 2003, NIST tested an FAA aircraft in 2004 and released the data into the public domain to further discussion of shielding standards within the aerospace community.

NIST upgraded the Low Background Infrared (LBIR) facility to provide more accurate infrared measurements and standards for the development and implementation of the U.S. National Missile Defense (NMD) System. The LBIR facility uses specialized radiometric test chambers and radiometers to disseminate the NIST infrared radiance scale to DOD and contractor sites by providing onsite calibration of blackbodies or offsite calibration of test chambers. These calibrations help ensure the infrared sensors mounted on interceptor missiles can reliably discriminate between target and decoy. Facility upgrades included improvements in the cryogenic system to allow operation down to 15 K and the addition of a low-noise absolute cryogenic radiometer. Together, these improvements have led to a tenfold reduction in measurement uncertainty for onsite blackbody calibrations.

NIST deployed a transfer standard radiometer to assist the Exo-atmospheric Kill Vehicle program of the Missile Defense Agency. It evaluates the performance of test chambers used to calibrate the sensors on the interceptor. The radiometer was sent to test chambers at Boeing, Raytheon, and the Air Force to tie measurements performed at these sites to the NIST High Accuracy Cryogenic Radiometer, the national standard for optical power.

NIST continued to provide the tools, methodologies, standards, and measurement services needed by aerospace parts manufacturers and assemblers to maintain their accurate and traceable use of the International System of Units (SI) units of length, mass, and time, as well as their derived units (force, acceleration, sound pressure, and ultrasonic power). For example, NIST performed calibrations of length standards for U.S. aerospace companies to ensure that the dimensions of their manufactured parts conformed to design specifications. In the area of force metrology, NIST calibrated load cells for United Space Alliance/Pacific Scientific in preparation for the Space Shuttle's return to flight. The calibrated load cells are used to measure tensile loading of the separation bolt housings on the solid rocket boosters, to size the bolt fracture area, and to perform 100-percent proof load testing of the final assemblies before shipment to KSC.

NIST's Manufacturing Extension Program (MEP) continued to help U.S. aerospace companies improve their productivity, reduce costs, and expand their business by providing ISO 9000-quality lean management systems and professional development opportunities to complement existing technical expertise and resources. For example, the Alabama Technology Network at the University of Alabama in Huntsville (an MEP affiliate) helped Griffon Aerospace obtain a contract to redesign tooling and build a prototype composite satellite panel for NASA. The successful completion of this project led to the team submitting a proposal to build the test and flight hardware, which upon award could bring nearly $500,000 of new business to Griffon Aerospace.

Working in partnership with the Boeing Company and a number of small Boeing suppliers, NIST's MEP developed a National Supplier Training Program to improve the productivity and competitiveness of Boeing's U.S.-based supply chain. Decentralized by design, the program connects regional Boeing representatives and local MEP Center Directors to create training and implementation programs customized to the circumstances of individual States, including California, Missouri, Illinois, Ohio, Washington, and Alabama. The MEPs provide quality affordable training and development services to suppliers of all tiers as identified by Boeing. Boeing, in conjunction with the MEP, works to garner State and Federals funds to reduce the cost of training to suppliers.

DOC's ITA continued to play an important role in promoting U.S. aerospace trade interests as the industry faced mounting competition from abroad. ITA provided advocacy to support U.S. companies in international aerospace competitions, including commercial sales for aircraft, helicopters, airport construction, communications and remote sensing satellites, commercial space projects, and air traffic management projects.

ITA supported efforts aimed at ending unfair government subsidies to Airbus, which have helped its market expand at the expense of U.S. interests. In early 2004, ITA proposed a strategy for addressing aircraft subsidies in the context of U.S. trade policy and aircraft trade agreements. Subsequently, with the Office of the U.S. Trade Representative coordinating the Administration's action on aircraft subsidies, ITA provided technical support and policy recommendations aimed at ending subsidies to Airbus.

ITA continued to seek avenues for cooperation with European governments on aerospace issues of mutual interest. Deputy Secretary Ted Kassinger discussed possible aerospace cooperation with his European counterparts at the Farnborough International Air Show, and Deputy Assistant Secretary for Transportation and Machinery Joseph Bogosian continued cooperation discussions with his counterparts from Germany, France, and the United Kingdom.

In January 2004, ITA and the American Association of Airport Executives cosponsored an Airport and Infrastructure Conference and Trade Show in San Jose, Costa Rica. The event attracted more than 125 U.S. airport businesspeople and 30 foreign delegations and demonstrated a variety of U.S. airport products and services to the Latin American market. This continuing program is designed to promote the export of U.S. aviation and airport-related products and services by providing direct contacts and meaningful dialog between U.S. companies and key international aviation/airport officials.

In February 2004, ITA cosponsored the "Space at the Crossroads" conference along with several industry associations including the Space Foundation and the Satellite Industry Association. The event, which addressed the balance between commercial and military space, drew an international audience of approximately 250 participants and included speakers from the DOD, DOC, DHS, NASA, industry, and foreign governments.

ITA and the Civil Aviation Administration of China (CAAC) successfully carried out several activities under the 2004 Aviation and Airport Subgroup Work Plan, part of the U.S.-China Joint Commission on Commerce and Trade (JCCT). ITA worked in conjunction with the Trade Development Agency, American Association of Airport Executives, and CAAC to organize the U.S.-China Aviation Symposium in Beijing, April 2004. The event focused on expanding airport and air traffic control prospects across China. Following the symposium, DOC worked with the FAA to hold a 2-day Airport Operation and Financing Seminar for Chinese airport executives. ITA was instrumental in strengthening ties with CAAC's Airports Division with respect to the DOC's trade goals in China and in leading positive discussions on proposed 2005 JCCT activities surrounding trade policy and promotion.

ITA organized a U.S. industry roundtable to discuss the impact of standards and regulations on U.S. aerospace competitiveness. The discussion and subsequent

consultations with individual companies contributed to Secretary Evans's May 2004 report to the President, entitled *Standards and Competitiveness—Coordinating for Results: Removing Standards-Related Trade Barriers Through Effective Collaboration*.

In 2004, ITA collaborated with the American Chamber of Commerce in Russia and the Russian Federal Space Agency (RSA) to organize the annual meeting of the Russian-American Commercial Aerospace Working Group during the Farnborough International Air Show in July 2004. The Working Group was established under the umbrella of the Russian-American Business Dialogue to foster and facilitate aerospace trade and investment. The meeting addressed aerospace trade restrictions in Russia, areas of cooperation, and consolidation within the Russian industry. Specifically, Russian officials discussed a concept to merge the Russian aerospace industry into a single, competitive, commercial entity. Also discussed was the level of Russian cooperation and involvement in the Boeing 7E7 program.

ITA played an instrumental role in expediting U.S. ratification of the Cape Town Convention. The Cape Town Convention—officially the Convention on International Interests in Mobile Equipment and the Protocol to the Convention on International Interests in Mobile Equipment on Matters Specific to Aircraft Equipment—is a treaty designed to facilitate asset-based financing and leasing by reducing risks to the seller, lender, and/or lessor. The United States signed the convention in May 2003 and ratified it in October 2004.

During FY 2004, DOC's Bureau of Industry and Security (BIS) approved a total of 24 license applications valued at $78.4 million for the export of equipment to support the ISS. In addition, BIS approved over 400 technology and hardware export licenses that directly supported the aerospace industry.

Department of the Interior

DOI

In response to the President's 2003 U.S. Commercial Remote Sensing Space Policy, the U.S. Geological Survey (USGS) led an interagency team of more than 20 Government agencies that identified their collective requirements for commercial remote sensing products. The resulting report summarized these agencies' short-term remote sensing data requirements. The USGS also awarded contracts to three commercial providers of high-resolution satellite remote sensing data in 2004 and made significant progress in developing a computer infrastructure to archive and disseminate these data. Existing agency infrastructure was leveraged to accelerate development of this infrastructure (*http://crsp.usgs.gov/*).The USGS continued to operate, collect, archive, and distribute data from the Landsat 5 and 7 missions, collecting over 130,000 Landsat scenes in 2004 and increasing the number of scenes collected over Earth's land masses in the U.S. archive to over 1,700,000.

The USGS released a new product for Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data captured after the Scan Line Corrector (SLC) anomaly that occurred in May 2003. This new product uses Landsat 7 data collected before the anomaly to fill the missing areas due to the nonfunctional SLC. This product will increase the utility of the Landsat 7 data affected by the anomaly (*http://landsat.usgs.gov/*).

The USGS and NASA continued the Earth Observing-1 (EO-1) Extended Mission in 2004. The mission continued to collect and distribute EO-1 Advanced Land Imager (ALI) multispectral and Hyperion hyperspectral products in response to acquisition and archive requests placed by the public and Federal customers. Over 30,000 scenes of EO-1 data have been archived by the USGS National Center for Earth Resources Observation and Science and made available in a

number of products and formats, including a new geometrically corrected ALI product (*http://eo1.usgs.gov/*).

In FY 2004, the USGS Seamless Data Distribution System (*http://seamless.usgs.gov/*) added a substantial number of products for free distribution. The system allows customers to define their area of interest and obtain seamless coverage for elevation, orthoimagery, land cover, and transportation data. Up to 1.6 gigabytes of data can be downloaded at no cost to the user; larger requests are referred to an e-commerce capability so that the USGS can recover the costs of handling and distributing data on media. Additions to the server in FY 2004 included National Elevation Dataset (NED) 1/9-arc-second data over a limited area and increased coverage of 1/3-arc-second data. Three products from the 2001 National Land Cover Dataset (NLCD) became available for limited areas. The orthoimagery category offering increased through the addition of a Landsat 7 satellite mosaic, NASA MODIS satellite data, Bureau of Land Management (BLM) 0.5-meter data over northern New Mexico, and State of New Jersey 1-foot-resolution color-infrared aerial imagery. The USGS also began providing seamless access to its national coverage of 1-meter-resolution orthoimagery by offering data over Washington, DC, and Tampa, FL.

The USGS continued to support the AmericaView Consortium, a nationwide collaboration of State organizations that fosters remote sensing education, research, and geospatial applications. Through this partnership, the USGS successfully operated and maintained a direct broadcast capability for NASA MODIS data in 2004. The MODIS data are available for download by 130 registered users within 3 hours of data acquisition by the satellite (*http://edc.usgs.gov/modisdata/*). In addition, algorithms were implemented for derived products such as time-composited products, vegetative indices, and conterminous U.S. mosaics. A rolling 7-day Normalized Difference Vegetative Index (NDVI) product for the conterminous United States is processed nightly and sent to the USGS Seamless Server where it is available as a layer for *The National Map* (*http://nationalmap.gov/*). Five new States—California, Hawaii, Kentucky, Louisiana, and North Dakota—were accepted into the AmericaView Consortium in 2004, bringing the membership to 20 States.

USGS scientists took a step toward the evolution of the National Atlas of the United States of America by including larger scale data and better resolution

imagery, in accord with the National Atlas's role as "the small-scale implementation of *The National Map*." They assembled, clipped, masked, and delivered a Landsat mosaic and shaded relief map of the conterminous United States to the National Atlas. Elevation data were extracted from the NED. The Landsat data came from the dataset used to produce the 1992 NLCD. USGS staff assembled data mosaics and combined the imagery with shaded relief at 200-meter resolution. Future work will bring additional data sets, such as land cover and greenness data, into the National Atlas as well as develop 100-meter versions of elevation and Landsat data mosaics. Incorporating such data into the National Atlas makes them viewable by the public in the National Atlas mapmaker (*http://www.nationalatlas.gov/natlas/Natlasstart.asp*) and makes them available for download for use in geographic information systems (GIS) applications.

During responses to emergencies, difficult-to-access, incompatible, and out-of-date base geospatial data hamper and degrade communications among organizations that respond to emergencies, thus endangering lives and property. To help ensure that Federal responders and support personnel have quick and easy access to the same detailed and current data as local first responders, the USGS is working with State and local governments and other Federal agencies to integrate data for America's urban areas into *The National Map* to support a variety of public safety programs. Initial USGS efforts have focused on developing and integrating detailed and accurate imagery for America's 133 largest urban areas. Interest in these data has grown over the last 3 years, with coverage of data sets of these urban areas increasing from 20 percent in FY 2002 to 63 percent in FY 2004. Local governments and the USGS received the resulting data, and USGS forwarded copies to Federal agencies to support homeland security and other public safety efforts. In FY 2004, Federal agencies and other public safety and security organizations used these data to plan public security measures for activities such as President Reagan's funeral, the national political party conventions, and the Presidential debates. USGS makes the data available for viewing, downloading, and ordering online from *The National Map*.

Exploration and extraction of new mineral and oil resources in Alaska are important national and local priorities. This especially is true for the North Slope where oil reserves are yet to be fully developed. However, USGS topographic maps for the State in general, and for the National Petroleum Reserve-Alaska (NPR-A)

specifically, are more than 40 years old and do not meet National Map Accuracy Standards. In addition, no aerial photography is available to meet current needs for detailed orthoimagery. Development of these data is further hindered by the lack of high-resolution, current digital elevation data required for production of orthoimagery and detailed analysis of the land surface in the State. The development of a new generation of orthoimagery and elevation data for the NPR-A represents a new era in the production of orthoimagery and high-resolution elevation data for Alaska. USGS anticipates that the products generated for NPR-A will set the standard for all of Alaska's next generation of digital cartographic map products.

In FY 2004, USGS contracted for 2- to 5-meter elevation data and orthoimagery for NPR-A and other development corridors on the North Slope. USGS provided overall coordination among other Federal, State, and nongovernmental organizations for input and agreements for reimbursable funding to assist in data acquisition and production. Activities included 1) delivery of new orthoimagery for about one-third of NPR-A; 2) a data and needs assessment conducted by USGS and the BLM, and 3) the award of contracts for collecting data using radar techniques for the production of elevation data.

USGS geologists also used Landsat Thematic Mapper (TM) and Interferometric Synthetic Aperture Radar (IFSAR) data to produce a digital elevation model (DEM), surficial sediment classification map, and shaded relief and surficial sediment map for the northeastern part of the NPR-A. The classification and DEM maps have helped to define lake, eolian, fluvial, and deltaic depositional systems and surficial geologic units. The BLM will use the maps to manage the habitats of critical species and to assist in future petroleum exploration and development in NPR-A.

For the NED, the nationally consistent, integrated elevation coverage for *The National Map*, USGS has made available data at 1/3-arc-second (10-meter) post spacing for approximately one-third of the contiguous 48 States. For the first time, elevation data from very-high-resolution LIght Detection And Ranging (LIDAR) data sources were incorporated into the NED at 1/9-arc-second (3-meter) post spacing for the Puget Sound area and at 1/3-arc-second (10-meter) post spacing for eastern North Carolina.

In February 2000, the Shuttle Radar Topography Mission (SRTM) successfully collected IFSAR data for over 80 percent of the landmass of Earth between

60° north and 56° south latitudes. NASA and the National Geospatial-Intelligence Agency (NGA) cosponsored the mission, from which digital elevation data were derived. All of the "Research" grade data (for which initial processing was performed by the Jet Propulsion Laboratory) were delivered to the USGS and are available to customers through an FTP server. In addition, NGA processed the "Finished" data and performed quality assurance checks and several additional finishing steps: final editing, verification, and conformance to National Map Accuracy Standards. These data are available from USGS on the Internet at *http://edc.usgs.gov/products/elevation/srtmbil.html*.

The USGS is responsible for preserving, making available, and distributing aerial and satellite data in the National Satellite Land Remote Sensing Data Archive (*http://edc.usgs.gov/archive/nslrsda/index.html*) to a worldwide community of Federal and scientific users. The archive consists of over 107,000 rolls of aerial and satellite imagery containing more than 13 million frames. It also includes a digital inventory of over 3 million scenes, totaling nearly 500 terabytes. The USGS is a world leader in archiving remotely sensed land data and in providing those data to users quickly, affordably, and in the most accessible format.

Since the early 1970s, the USGS has offered a variety of photographic products (both prints and film) of images in its historical film archive; however, over the last few years, customer demand for these types of products has declined. Therefore, with production expenses continuing to increase and the user community transitioning to digital data and products, the USGS discontinued offering photographic products from the historical film archive on September 3, 2004, and began to offer a new digitized product on October 1, 2004. The response to this transition was favorable.

The USGS participates in the calibration and validation of satellite data to ensure that products derived from such data are of high quality. USGS also is responsible for characterizing and calibrating the Nation's aerial mapping sensors. To meet these responsibilities, the USGS provides system characterization and product validation in the laboratory and in the field for both satellite and aerial sensors (*http://edclxs22.cr.usgs.gov/crs/index.php*). A cooperative agreement between the USGS and South Dakota State University (SDSU) provided an opportunity to use the unique skills of SDSU scientists to develop and operate a calibration system for the Landsat Multispectral Scanner (MSS) and TM data. Because of this agreement,

the Landsat user community will benefit from the improved radiometric and geometric calibrations of more than 30 years of Landsat data.

Since 2000, the USGS has been working with NASA, NGA, industry, and academia to validate and characterize commercial remote sensing satellite data products through the Joint Agency Commercial Imagery Evaluation (JACIE) team. The results of these tests, designed and documented by the JACIE team, ensure that the data meet the specialized needs of a range of Government applications. Test results have proven to be highly useful to satellite vendors who use the results of these assessments to improve their products and services. Presentations at the fourth annual High Spatial Resolution Commercial Imagery Workshop in 2004 featured the results from analyses of satellite data from Space Imaging, DigitalGlobe, and ORBIMAGE.

The Bureau of Reclamation continued to use Landsat TM data, Indian Remote Sensing (IRS) satellite data, and USGS digital orthophoto quarterquads (DOQQ) to map agricultural crops in southeastern California, southwestern Arizona, and the Central Valley of California. Water managers used crop maps to verify crop-fallowing agreements, and they combined crop maps with crop water-use coefficients and locally varying climate data to calculate agricultural consumptive water use. Water managers estimated water use by riparian vegetation along the Lower Colorado River in a similar fashion, using riparian vegetation maps generated from Landsat TM data and high-resolution digital aerial imagery.

Reclamation specialists used Landsat TM data to map areas of land cover change in California's Central Valley. This information is used during water-related negotiations with irrigation districts and with the U.S. Fish and Wildlife Service (USFWS), as required by the California Central Valley Project Improvement Act Biological Opinion. These data also will be incorporated into the statewide change-detection project being coordinated by the U.S. Forest Service (USFS) and the California Department of Forestry.

Reclamation analysts continued to refine computer algorithms that use NEXRAD weather radar data to calculate precipitation accumulation estimates that are input to decision-support systems that guide water releases from reservoirs and water deliveries to irrigated crops. Reclamation analysts routinely used GPS throughout the Bureau for a variety of applications, including locating field-sampling sites of all kinds (e.g., for studies of vegetation, soils, geology, and ground

water), surveying of construction sites, and developing geospatial databases of irrigation infrastructure.

To meet Federal Clean Water Act standards, individual States must identify, monitor, and control pollutants that impact water quality. During 2004, the USGS collaborated with the South Dakota Department of Environment and Natural Resources and the East Dakota Water Development District to develop crop-specific maps using Landsat data for South Dakota water quality initiatives. Nearly 100 Landsat images were required to develop crop maps for 2000 and 2001 for the State of South Dakota. These maps and other geospatial data were used to model the relationship between pollutants, such as fertilizers and pesticides, and water quality. Spatial information on crop types is essential to determine where specific agricultural chemicals are applied across the landscape. An advanced object-oriented, knowledge-based approach was developed to automate much of the processing, considerably reducing the time and costs of this effort.

The BLM uses an array of remote sensing technologies to inventory, monitor, and address concerns about urban growth, resource conditions, and energy and mineral resource extraction on public lands. During FY 2004, GPS and GIS supplemented data from multispectral and hyperspectral sensors and aerial cameras to support management activities associated with wildlife habitat, wilderness, recreation, rangeland, timber, fire, minerals, and hazardous materials. These projects subsequently supported on-the-ground resource management and decisionmaking activities.

In FY 2004, the BLM completed its partnership with the Colorado Division of Wildlife to classify vegetation (by watershed), using Landsat TM data for the State of Colorado, and to make the final dataset available to the public. The BLM continued its partnership with the Wyoming Game and Fish Department to collect field data for use in vegetation classification mapping with Landsat TM data. A collaborative effort between the BLM and the National Park Service (NPS), USDA Natural Resources Conservation Service (NRCS), USFS, and Utah State University resulted in the development of value-added band ratio products derived from Landsat data for predictive soil mapping. The BLM also used Landsat TM data to map lynx habitat and to identify areas in Wyoming rangelands dominated by cheatgrass, an invasive plant species.

The BLM worked with the NRCS to collect site-specific LIDAR data over the Dull Knife/North Fork Powder River area in Wyoming for use in evaluations

of stream floodplains. The National Wildlife Federation worked with the BLM to collect LIDAR data over study areas in Colorado to test its ability to identify Mexican Spotted Owl habitat. Investigators used data with a postprocessing spacing of 2 to 3 meters to extract terrain and forest structural information in the upland steep canyons dominated by old-growth mixed conifer forest where this endangered species occurs in its most northern range. Working with NASA Stennis Space Center (SSC), the BLM facilitated a large purchase of high-resolution QuickBird satellite data of Glenallen, AK, for work with off-highway vehicles (OHVs) and Resource Management Plan recommendations.

The BLM continued to use DOQQs to monitor the health of rangelands and riparian areas, plan field travel, and evaluate proposed land exchanges. The Bureau formed partnerships to acquire new data to update the DOQQ dataset. The BLM also used the 2001 National Aerial Photography Program and new aerial photography for specific projects, such as the following:

- Assessed the proper functioning condition of riparian wetland areas in Wyoming and, in conjunction with the organization Ducks Unlimited, on the George River drainage in Alaska.
- Cooperated with USFWS and the Corps of Engineers to create DOQQs of the north Oregon coast for use in wetlands inventory.
- Produced large-scale topographic maps and orthophotos to aid in the characterization and reclamation of abandoned mine lands in Nevada.
- Created topographic maps for interpretive and recreational facilities such as archeological and historical sites in Fort McKinney and Castle Gardens, WY, and recreation facilities at Four Dances, MT, and Yuma, AZ.
- Created route inventories—including OHV trails—for use in resource management planning in Nevada.
- Provided technical support and conducted training sessions for BLM resource specialists on "Using Aerial Photography to Assess Proper Functioning Condition of Riparian Wetland Areas."

The BLM conducted the following evaluation projects and methodologies in 2004:

- Investigated and developed a three-dimensional remote sensing-based visualization application for use in predictive soils mapping and jointly worked with the NRCS on predictive soils modeling.

- Developed enhanced processing techniques to collect OHV routes, using remotely sensed data, and presented those techniques in an OHV training course.
- Acquired 0.5-meter orthoimagery from a large-format digital aerial camera to support on-the-ground land-management issues such as timber sales near Roseburg, OR.
- Refined close-range photogrammetric techniques used in microtopographic digital terrain data collection. A hybrid methodology was developed that combines traditional photogrammetric techniques with recent advances in digital cameras and three-dimensional measuring and modeling software. This methodology is used by the BLM to collect detailed (1-centimeter resolution or better) digital terrain data of small (1- to 5-meter) areas used to monitor paleontological and archeological sites.
- Evaluated the feasibility of using the USGS Seamless Server for public access to BLM natural-color DOQQs of Farmington, NM, and for serving the data to the public.
- Developed and refined a Spatial Data Engine interface for a pilot Intranet site that provides access to the BLM's Aerial Photography Archive.
- Maintained, updated, and completed data migration and storage for the BLM-wide Satellite Imagery Archive.

USGS scientists provided a prime example of how digital elevation data derived from the SRTM mission over Mount St. Helens, WA, can show dramatic changes in Earth's topographic form. Prior to 1980, Mount St. Helens had a shape roughly similar to other Cascade peaks—a tall, bold, irregular conic form that rose to 2,950 meters (9,680 feet). The explosive eruption of May 18, 1980, caused the upper 400 meters (1,310 feet) of the mountain to collapse, slide, and spread northward, covering much of the adjacent terrain, leaving a crater atop the greatly shortened mountain.

Eruptions subsided in 1986, but renewed volcanic activity here and at other Cascade volcanoes was anticipated. USGS and NASA scientists documented topographic changes resulting from the 2004 eruptions of Mount St. Helens using LIDAR data acquired after these eruptions occurred. When processed using GPS reference points, the LIDAR data are used to produce an accurate high-resolution DEM of the mountain, ensuring that elevation changes could be safely monitored

in relation to the surrounding area. USGS and NASA scientists have compared subsequent LIDAR acquisitions to the USGS base data to quantify volumetric changes associated with dome growth inside the crater. Both the LIDAR dataset and GPS network proved to be important baseline measurements in analyzing surface-elevation changes within the crater. For the first time, scientists were able to visualize and quantify crater-elevation changes with greater accuracy and safety, enhancing hazard monitoring and mitigation of the volcanic unrest.

As part of ongoing research to study the consequences of land cover change on surface weather and climate variability, the USGS and Colorado State University (CSU) used regional climate modeling with historical land cover change data sets to investigate the potential link between land use change and damaging radiation freeze events in South Florida. Agricultural production in former wetlands areas now includes extensive cultivation of winter season vegetable, citrus, and sugar cane crops, but, in spite of this shift southward, crops are still prone to damaging winter "radiation freezes" which occur on calm, clear nights with nocturnal cooling. The USGS measured land cover change in South Florida over the past 100 years by comparing reconstructed pre-1900 natural vegetation versus current land use derived from Landsat data acquired in the early 1990s. CSU's model indicated that the conversion of natural wetlands to agriculture may increase the incidence and severity of damaging freezes in South Florida. This research demonstrated the importance of coupled models to quantify the potential effects of land cover change. Furthermore, this joint USGS and CSU research demonstrated the utility of the Landsat-derived NLCD as an important resource for regional modeling studies.

The USGS Western Earth Surface Processes Team applied image-enhancement technologies to new LIDAR and high-resolution, color-infrared aerial photography for earthquake fault investigations and to study landscape evolution processes (including landsliding, wildfire impacts, erosion, and climate change). LIDAR applications were also used in conjunction with other remotely sensed data to study wildlife and vegetation habitats, soil characteristics, water infiltration, and surface erosion processes in the desert Southwest, with preliminary focus on fragile ecosystems in the western Mojave Desert (*http://deserts.wr.usgs.gov/*). LIDAR data of portions of northern California have been extremely useful in locating the offset of alluvial fans by earthquake faults and in rugged forested ter-

rain. LIDAR investigations were conducted in the Napa Valley wine-growing region and along the northern San Andreas Fault system north of the San Francisco Bay Area. The team used GPS location data and aerial photographs for nearly all its project activities, including geologic mapping, hazard assessment, geophysical data collection for gravity and magnetic surveys, landslide motion assessment, and field orientation and mapping. GPS data are used to reconcile aerial photography with ground-based investigation and in the construction of geologic maps.

The evaluation of changes in land cover resources over an extended study period is critical to developing ecosystem management plans that use historic and current data to support wise resource use. For example, USGS scientists used Landsat data to assess land cover change over an extended study on Navajo/Hopi Indian Reservations lands in northern Arizona. Landsat TM data from 1984 (the earliest valid TM data), 1993 (a very wet year), and 2002 (a drought year) were analyzed and compared to give a visual indication of land cover changes during the last 18 years. Pre-1977 MSS data provided a benchmark of part of the landscape where grazing previously occurred but no longer does.

USGS scientists used MODIS Enhanced Vegetation Index (EVI) data to map perennial vegetation cover in the Mojave Desert ecosystem of eastern California and western Nevada. Models were developed and applied to the MODIS-EVI data and data from more than 1,300 ground sites to construct maps estimating the percentage of perennial vegetation cover. This study represents a proof-of-concept for applying MODIS-EVI and field observations to estimate perennial cover throughout the Mojave Desert. These maps are an important enhancement to vegetation-distribution mapping that can be used to inform several ongoing scientific investigations and management efforts related to the vulnerability and recoverability of desert landscapes.

The U.S. Department of Housing and Urban Development (HUD) and the USGS have cooperated to create Internet-enabled geospatial databases in order to help communities along the United States-Mexican border address issues related to *colonias* (United States) or *colonias marginales* (Mexico) that lack adequate infrastructure of housing. One of the initial study areas is the city of Douglas, AZ, and its sister city, Agua Prieta, Sonora. Because of its location on the border, this area is especially well suited to international manufacturing and commerce, which has

led to an uncontrolled spread of *colonias*. USGS scientists used imagery collected between 1973 and 2000 and infrastructure information to delineate *colonia* boundaries and to conduct a land use change analysis focused on urbanization in the cities. They developed geospatial databases describing the area's infrastructure and land use and established a framework for sharing information through Internet-based GIS decision-support systems, making planning tools and data available to the public as well as participating agencies. In addition, a local youth organization was trained using GPS receivers to identify and describe important resources in the community, and this information was incorporated into the geospatial database.

USGS scientists and partners from the Desert Research Institute completed their fourth year of work in the Lake Tahoe Basin analyzing historical changes in land use and land cover. They digitized archived aerial photographs and acquired recent high-resolution Ikonos satellite data and used these sources to derive land cover, impervious-surface, road, and stream network geospatial data sets for 1940, 1969, 1987, and 2002. They analyzed these data sets using a digital change-detection process to determine the amounts, rates, and trends of change to the Lake Tahoe Basin landscape since the onset of urbanization. The most significant changes during the 62-year study period appear to be an increase in urban lands and corresponding decrease in natural-cover classes; variable increase and decrease in forest stand density; conversion of shrublands, grasslands, and wetlands to forest; and tree mortality.

The USFWS used remotely sensed data and GPS technology in several programs. FY 2004 activities focused mainly on the creation and verification of vegetation and wetlands data. In the Midwest, USFWS analysts mapped the vegetation of Swan Lake National Wildlife Refuge (NWR), MO, using visual interpretation of IRS satellite data, and the vegetation of Mingo NWR, MO, using visual interpretation of 1:15,000-scale, color-infrared aerial photographs. Accuracy assessment sites for data collection were selected for both maps using random sampling routines.

USFWS specialists worked to improve methods to prepare vegetation and habitat data layers for refuges in the Pacific Northwest. They examined existing successful programs and made minor changes to how remotely sensed data are collected, analyzed, stored, and accessed for use in refuge planning and management. Objectives include more consistent and extensive use of remote sensing to define

habitat-based management goals and objectives for refuges and to map and monitor invasive plant species.

Land-surface heterogeneity can affect how well land cover is identified at different scales. As new sensor systems produce progressively higher forms of resolution, land-surface heterogeneity increases due to a complex interaction between the biological (vegetation types and conditions) and physical (topographic) influences across the land surface. USGS scientists completed a study that evaluated the utility of merging high-resolution (2.5-meter) airborne radar data with coarser resolution (30-meter) Landsat 7 ETM+ data for producing high-resolution land cover maps over tundra areas of Alaska. Results indicated that merging of the multispectral Landsat data with the higher resolution radar data did not increase the information content (i.e., detail of the land cover classification), but actually decreased the information extracted. However, the process did increase the visual qualities of the Landsat data if a visual analysis of the area was desired.

USGS scientists completed a land cover, change-detection analysis around the Cordillera Azul National Park in Peru based on Landsat TM and ETM+ data collected at intervals between 1989 and 2002, with a goal to quantify and analyze patterns of forest clearing, land conversion, and other disturbances. Results showed a slow but steady increase in disturbances prior to 1999 and a rapid and increasing conversion rate after that time. The highest concentrations of clearings have spread upward from the western border of the study area on the Huallaga River. Most disturbances took place in the buffer zone around the National Park, not within it, but the data show dense clearings are occurring closer to the park border each year. Park managers in Peru used an Internet-based map service that was created to streamline the delivery and access of all geospatial data sets used in this study.

USGS scientists implemented a cooperative project with West Africa's Regional AGRHYMET Program to identify land use and land cover trends within ecological regions in 15 countries covering most of West Africa. The effort combines the use of historical and current satellite image data, existing published studies, supporting ground and aerial information on biophysical resources, and socioeconomic data. The USGS provided complete coverage of Corona declassified satellite photography (1965), Landsat MSS (1972), Landsat TM (1985), and Landsat ETM+ (2000) data recording land resource conditions of most of the

countries of West Africa. Teams of West African scientists from government agencies in each country conducted the time-series analysis, with technical support from AGRHYMET and the USGS. Some ecoregions exhibited stability and land use permanency, while others showed dramatic change as agriculture expands into areas of natural vegetation. The most troublesome finding was the continued decline of dense forest. Some countries (e.g., Togo and Benin) have lost nearly all of their dense forest cover. Others (e.g., Guinea and Ghana) still have large tracts of forest, but these are coming under great pressure from logging and agriculture.

Staff from the USFWS National Wetlands Inventory (NWI) and the South Florida Water Management District coordinated efforts using GPS-guided helicopters and rectified DOQQs to conduct field verification of wetland cover types to update NWI wetland maps in South Florida. Check sites were identified on aerial photographs and their location coordinates stored in a GPS unit. Azimuth headings generated by the GPS unit guided the helicopter pilot to each plot location, where one team member viewed the image displayed on the laptop to verify the check site location and other members recorded video and still images of the plot and annotated vegetation by species and estimated percent cover. All information, including video, was linked to the appropriate plot and stored in a geodatabase format.

The USFWS used 1:40,000-scale aerial photographs to update NWI maps and digital data in priority areas in Massachusetts, New York, New Jersey, Maryland, Delaware, and Virginia. For some areas, USFWS staff enhanced the NWI digital data record by adding descriptors for landscape position, landform, water flow path, and water body type, and the data were used to prepare watershed-based wetland characterizations (e.g., for New York City's water supply watersheds). These characterizations included a summary of wetland types and a preliminary assessment of wetland functions based on correlations between wetland characteristics in the NWI database and wetland functions. This technique was used in the Nanticoke River watershed in Maryland where USFWS specialists prepared characterizations and assessed the condition of "natural habitat" throughout the watershed. They developed "remotely sensed natural habitat integrity indices" to describe and monitor the status of natural habitat throughout the watershed and in key locations such as stream corridors and wetland buffers. Integrity indices also reflected major human-induced impacts such as stream channelization, dams, wet-

land alterations, and habitat fragmentation caused by road development (*http://wetlands.fws.gov/Pubs_Reports/EcologicalIndicatorsTiner.pdf*).

Bureau of Reclamation analysts used hyperspectral data to map surface chlorophyll-a concentrations on two Reclamation reservoirs. EO-1 Hyperion hyperspectral data were used for Flaming Gorge Reservoir, WY/UT, and AVIRIS hyperspectral data (from aircraft) were used for Owyhee Reservoir, OR. Chlorophyll-a prediction models for both reservoirs were effective, explaining more than 97 percent of the variability present in the data sets. This represents a significant improvement over chlorophyll-a prediction results obtained from models that used broader-band multispectral data.

The Minerals Management Service (MMS) continued to support research by University of Colorado scientists on applications of satellite altimetry to improve 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 2004, data from the Navy GEOSAT Follow-On, Jason-1, TOPEX/Poseidon, and ERS-2 altimetry satellite missions were used in ongoing analysis of data from the Gulf of Mexico field observational studies. In addition, MMS specialists concluded surveys using GPS data to help delineate offshore boundaries in parts of Massachusetts and Alaska in support of Territorial Submerged Lands jurisdictions.

The U.S. Coral Reef Task Force identified land-based pollution as one of six priority threats on which to focus efforts to protect coral reefs. The task force commissioned regional partnerships to plan Local Action Strategies (LAS) to reduce or eliminate threats to coral reefs. Land-based pollution threats were identified for action in the LAS for Hawaii, American Samoa, Northern Mariana Islands, Guam, and other former territories in Micronesia. Hawaii's LAS partners (including USFWS, NPS, USGS, NRCS, EPA, NOAA, Hawaii natural resource, health, and coastal zone management agencies, and local nongovernmental organizations including The Nature Conservancy) developed a strategy based on traditional native Hawaiian natural resource management systems that encompass the whole ecosystem from the high-island ridges to the near-shore reef.

In FY 2004, USGS initiated a "Ridge to Reef" study that monitored and provided research support for LAS-identified priority restoration sites on the Hawaiian

Islands of Molokai, Kauai, and Maui. USGS scientists began assembling a network of stream gauges and sediment-monitoring devices in critical watersheds to monitor seasonal and interannual variability in turbidity on the sediment-impacted back reef along the south shore of Molokai, where the longest of the fringing coral reefs in the Hawaiian Islands is strongly affected by land-based sedimentation.

The Global Land Ice Measurements from Space (GLIMS) program is an international consortium of 25 nations dedicated to satellite imaging and tracking of the status and changes of the world's glaciers (*http://www.glims.org*), primarily using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data. In 2004, USGS scientists developed tools for automated mapping of glacier lakes and ice and made available to the global GLIMS community an assortment of tools needed to make their analysis work easier and more comprehensive, uniform, and accurate. USGS also contributed to the systematic mapping of glaciers and glacier lakes in Alaska and of hazardous glacier lakes in Peru. USGS also mapped glaciers in Afghanistan as part of a U.S. Agency for International Development (USAID)-funded project to rebuild that country. USGS provides the central coordination of GLIMS, with funding support from NASA. Other American GLIMS activities include construction and management of the GLIMS glacier database (University of Colorado), monitoring of glaciers in the Arctic and Antarctic (University of Maine) and Afghanistan and Pakistan (University of Nebraska at Omaha). Foreign participants funded GLIMS regional centers to monitor glaciers on every continent except Australia.

USGS and BLM used Landsat-7 data to monitor the rapid wastage of the Bering Glacier, AK, and the resulting establishment of new ecosystems. Bering Glacier is retreating rapidly and thinning as it accelerates its retreat from an advanced position that resulted from a major glacial surge that occurred between 1993 and 1995. Satellite observations and ground-based data were combined to determine the surface-flow velocities and calving rates of the glacier and to monitor the expansion of Vitus and Berg Lakes, two large lakes whose boundaries include the glacier terminus.

USGS scientists used National Systems data to monitor glaciers in Alaska, Washington, and Montana. Mountain glaciers are ideal subjects for these systems because they are remote, have an appropriate space scale, and require infrequent but repetitive observations. The observations were used to establish a baseline of

regional glacial conditions that will be used to determine recent and future glacier fluctuations. In addition, techniques have been developed to generate derived products that provide critical glacial parameters, including DEMs, equilibrium line altitudes, and ablation rates. These products were incorporated into a glacial runoff model of the South Cascade Glacier, WA, where they proved to be a valuable source of otherwise unavailable data.

USGS scientists, in cooperation with the French Space Agency (CNES), improved a dynamic algorithm to measure snow depth from passive microwave observations acquired by the Special Sensor Microwave Imager (SSMI) on a Defense Meteorological Satellite. The algorithm was used to develop a snow-depth climatology for Siberia. NASA, CNES, and USGS scientists examined the numerous factors that influence satellite passive microwave observations of snow packs. These factors included snow depth, air temperature, terrain type, land cover, and proximity to large bodies of water.

Afghanistan is trying to reconstruct its economy and commerce after 30 years of war and civil strife. As a result of the conflicts, no geoscience activities have been performed there in the past 30 years. To encourage foreign investment in developing Afghanistan's natural resources, the USGS is cooperating with USAID to develop assessments for oil and gas, coal, precious metals and gems, economic minerals, and water resources, as well as geologic hazards. The largest scale existing geologic maps that cover the entire country were completed in the 1970s at 1:250,000 scale using aerial photographs and field work before the advent of multispectral satellite data. USGS scientists used Landsat ETM+ data that were acquired between 2000 and 2001 to prepare 2º x 1º multispectral mosaics of the country at 14.25-meter resolution and controlled to 50-meter horizontal accuracy. Reinterpreting and remapping the geology and tectonics of Afghanistan with these Landsat and ASTER data revealed a wealth of geologic information that was not included on the old maps.

Working in cooperation with USAID, USGS geologists completed regional hydrothermal alteration mapping for mineral resources in parts of Iran, Pakistan, and Afghanistan using ASTER data. Hydrothermal alteration is typically associated with ores such as copper, gold, silver, and molybdenum. Over 70 ASTER scenes (1 scene covers 3,600 square kilometers) were calibrated using EO-1 Hyperion and MODIS data in order to improve the accuracy of the alteration maps. Alteration data were converted into a form that is suitable for GIS analysis.

The USGS used satellite and LIDAR data to compile geologic maps and to evaluate fault locations and geologic hazards potentials in Oregon and Washington. LIDAR visualization was used to cut through dense forest canopy in both urban and wildness terrain to reveal detail not attainable by other means. Examples of how LIDAR data were used can be seen on the Puget Sound LIDAR Consortium Web site at *http://duff.geology.washington.edu/data/raster/lidar/*.

The USGS Astrogeology Team cooperated with NASA on a variety of planetary exploration programs. The team has been heavily involved in the Mars Exploration Rover (MER) mission since its inception. The Spirit and Opportunity rovers landed on Mars in January 2004 and made many important discoveries that have greatly advanced Mars science. USGS efforts were focused on the rover cameras. USGS scientists hold several key roles in the program, including serving as Payload Element Lead (PEL), commanding the navigation and hazard avoidance cameras on both rovers; as one of the Science Operations Working Group Chairs, leading the development of consensus on each day's plan for rover operations; as MER participating scientist, serving as lead for planning and analysis of photometric observations of the Martian surface; and as downlink lead and Deputy PEL for the multispectral panoramic stereo cameras (Pancams).

The USGS has been directly supporting the testing and calibration of the High-Resolution Imaging Science Experiment (HiRISE) camera destined for Mars aboard the 2005 Mars Reconnaissance Orbiter (MRO). This camera will provide the highest resolution images of Mars from orbit (≈30 centimeters/pixel) and will be used for certifying future robotic and human landing sites, as well as supporting Mars science. The development of the camera proved more complex than anticipated, requiring significant effort in testing of the camera before it could be delivered to the spacecraft. The USGS team continued to support MRO testing and analysis of HiRISE calibration data. The USGS also was responsible for a major fraction of the development of the HiRISE processing and analysis software.

The NASA-funded USGS Robotic Lunar Observatory (ROLO) project continued to support remote sensing satellite instrument teams for on-orbit radiometric calibration using the Moon. The ROLO is dedicated to studying one of the remaining unknowns of the Moon: "What is its precise brightness?" ROLO provided comparisons of its lunar irradiance model to the lunar observations acquired monthly by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite and

also additional SeaWiFS observations taken to coincide with lunar views acquired by MODIS through its space-view port. The SeaWiFS comparisons demonstrated the capability of this technique for instrument response trending with precision approaching 0.1 percent per year. Lunar images acquired by ASTER during the Deep Space Maneuver of April 14, 2003, were analyzed by ROLO personnel to determine instrument response characteristics. Other instruments receiving ROLO lunar calibration support included MODIS, MISR, EO-1 Hyperion, and the NPP VIIRS.

USGS researchers also analyzed Thermal Infrared Imaging System (THEMIS) data from the NASA Mars Odyssey mission to study the polar caps and other ice deposits on Mars. THEMIS images of the Mars South Polar Residual Cap revealed the existence of regions of exposed water ice and soil. Further, high-resolution topographic data for these layered ice/soil deposits derived from THEMIS data suggested that ice/soil layers at the South Pole of Mars are relatively thin and flat-lying, and their presence at the surface varies with seasons on Mars.

USGS scientists participated as science team members on the NASA Cassini-Huygens mission to Saturn and its moon Titan in 2004. Although Titan is unlike any other moon or planet in our solar system, its atmosphere in many ways resembles the chemical composition of Earth as it was before life began. It is hoped that the Cassini-Huygens mission will help answer many of the major fundamental questions about conditions on Earth and in the solar system before life as we know it began. The USGS will be intensively involved in the analysis of Huygens data, in particular, by mapping the surface with the probe images and comparing the results with observations returned by the Cassini "mother ship."

Since 1975, the USGS has chaired the Civil Applications Committee (CAC), chartered under the signatures of the National Security Advisor to the President, the Director of Central Intelligence, the Director of the Office of Management and Budget, and the Secretary of the Interior to facilitate the use of National Systems data for applications central to civil agency missions, such as mapping, charting, and geodesy; environmental monitoring, studies, and analyses; and resource management, homeland security, natural hazards, and emergency response applications.

To represent civil community interests and advocate for civil requirements for access to National Systems data and related technologies, the committee par-

ticipated on a regular basis in 2004 with the National Security Space Office (NSSO, formerly the National Security Space Architect) to represent civil requirements related to future space remote sensing architectures; with Federal Law Enforcement to provide advice and consultation on issues related to law-enforcement applications of remote sensing; with the Department of Homeland Security (DHS) to explore how civil agencies will use National Systems data in support of homeland security activities; and with the USNORTHCOM Interagency Directorate to explore how the civil community can facilitate USNORTHCOM access to and application of domestic imagery and geospatial data for homeland defense activities. The committee also worked with the National Air and Space Intelligence Center (NASIC) to identify key issues involved in adapting advanced data exploitation tools to civil agency missions such as early identification of emergency service needs and emergency response management.

FEDERAL COMMUNICATIONS COMMISSION

FCC

The Federal Communications Commission (FCC) formulates rules to facilitate the provision of commercial satellite services in the United States. It also issues licenses for launch and operation of all nongovernmental U.S. satellites. Internationally, the FCC coordinates satellite radio-frequency usage with other countries. The FCC's accomplishments for FY 2004 related primarily to commercial communications and Earth observation satellites, as outlined below.

The FCC completed two major rule-making proceedings in FY 2004. In one proceeding, the FCC reduced the amount of the bonds satellite licensees must post, after receiving a license, to $3 million for each satellite in geostationary orbit and $5 million for each constellation of nongeostationary-orbit satellites. In another proceeding, the FCC adopted a comprehensive set of rules concerning mitigation of orbital debris by FCC licensees. These new rules require applicants for FCC licenses to disclose debris mitigation plans so that those plans can be analyzed prior to authorization. The new rules also simplified the licensing process by eliminating the need for separate authorizations for certain types of spacecraft operations, provided that those operations are consistent with requirements designed to mitigate debris and avoid radiofrequency interference.

In FY 2004, the FCC authorized a number of commercial communication satellite launches and operations. On November 21, 2003, the FCC authorized Rainbow DBS Company to launch and operate four satellites, one at the longitude 62° west orbit location, one at the longitude 71° west orbit location, one at the longitude 119° west orbit location, and one at the longitude 129° west orbit location. On December 8, 2004, the FCC authorized Echostar Satellite LLC to launch

and operate a satellite at the longitude 123° west orbit location. On January 7, 2004, the FCC authorized Rainbow DBS Company to launch and operate a satellite at the longitude 77° west orbit location. On January 30, 2004, the FCC authorized Pegasus Development Corporation to launch and operate a satellite at the longitude 87° west orbit location. On March 8, 2004, the FCC authorized Echostar Satellite LLC to launch and operate a satellite at the longitude 97° west orbit location. On April 28, 2004, the FCC authorized DIRECTV Enterprises LLC to launch and operate the DIRECTV 7S satellite at the longitude 119.2° west orbit location. The satellite was successfully launched on May 4, 2004. On July 13, 2004, the FCC granted SES Americom authority to launch and operate the AMC-23 satellite at the longitude 172° west orbit location. On August 26, 2004, the FCC granted Panamsat Licensee Corporation conditional authority to operate the PAS-9 satellite (operating under the commercial name of PAS-5) until January 2, 2007, at the longitude 26.15° west orbit location in order to provide capacity, needed because of a satellite failure, for the Arabsat satellite system. On September 30, 2004, the FCC authorized Echostar KuX Corporation to launch and operate one satellite at the longitude 109° west orbit location and one at the longitude 121° west orbit location.

The FCC granted a number of Special Temporary Authorizations (STAs) for satellite networks. Many involved routine testing or redeployment of satellites within a multiple-satellite system. Several actions, however, were notable. On October 10, 2003, the FCC granted Intelsat LLC the first of a series of authorizations to operate the Intelsat 602 satellite at the longitude 50.5° east orbit location, pursuant to an understanding between Intelsat and a Thai satellite operator. On November 13, 2003, following the successful launch of the Indian Space Research Organization's INSAT-3E satellite, the FCC granted Intelsat LLC the first of a series of authorizations to relocate the Intelsat 702 satellite from the longitude 55° east orbit location, where it had been providing interim capacity to the Indian Space Research Organization, to the longitude 54.85° east orbit location, and to operate the satellite at the longitude 54.85° east orbit location. On June 23, 2004, the FCC granted DIRECTV, Inc., authority to move the DIRECTV 3 satellite to the longitude 82° west orbit location to provide Canadian satellite operator Telesat Canada with the capacity needed following the development of anomalies in the operations of the Canadian Nimiq 2 satellite. The FCC indicated that the

satellite would subsequently operate at the longitude 82° and 91° west orbit locations pursuant to Canadian authorizations. On August 13, 2004, the FCC granted DIRECTV Enterprises LLC authority to move the DIRECTV 5 satellite to the longitude 72.5° west orbit location. From that location, the satellite would operate pursuant to a Canadian authorization. The FCC also authorized reception of signals from DIRECTV 5 in the United States in order to provide increased capacity for delivery of signals to U.S. consumers.

Throughout FY 2004, the FCC continued to issue STAs and other authorizations for the Iridium system to operate its "Big LEO" MSS satellites in the 1620.10- to 1621.35-megahertz band. The additional authorized spectrum was to support the satellite communications needs of U.S. and Coalition Forces in the Middle East.

The FCC added a number of non-U.S.-licensed space stations to the Commission's permitted space station list to allow these space stations to provide domestic and international satellite service in the United States, to U.S. Earth stations that have routine technical parameters. On October 15, 2003, the FCC added Hispasat S.A.'s satellite, Hispasat-1DB, to its permitted list for certain Ku-band frequencies. On November 24, 2003, the FCC added the Japanese Horizons I communications package (aboard the Galaxy XIII spacecraft) to its permitted list for Ku-band frequencies. On December 23, 2003, the FCC added the Brazilian Estrela do Sol 1 satellite to its permitted list for Ku-band frequencies. On June 18, 2004, the FCC added the Brazilian Amazonas-1 satellite to its permitted list for C- and Ku-band frequencies. On September 28, 2004, the FCC added the Japanese Superbird-C satellite to its permitted list, with certain conditions for specific Ku-band frequencies.

During FY 2004, the FCC also was active in international satellite coordination. In the first quarter of FY 2004, the FCC reached a total of 16 Administration-to-Administration Coordination Agreements for U.S. networks, with Brazil, Germany, Japan, Luxembourg, Russia, the Seychelles, and the United Kingdom. In the second quarter of FY 2004, the FCC reached a total of 116 Administration-to-Administration Coordination Agreements for U.S. networks, with Brazil, Canada, India, Luxembourg, the Netherlands, and Spain. In the third quarter of FY 2004, the FCC reached a total of 21 Administration-to-Administration Coordination Agreements for U.S. networks, with Brazil, Canada,

France, the Netherlands, and the United Kingdom. In the fourth quarter of FY 2004, the FCC reached a total of 21 Administration-to-Administration Coordination Agreements for U.S. networks, with Belarus, Japan, Luxembourg, and the Netherlands.

DEPARTMENT OF AGRICULTURE

USDA

The United States Department of Agriculture (USDA) used remote sensing data and related technologies to support the research and operational activities of several agencies. These agencies included the Cooperative State Research, Education, and Extension Service (CSREES), Economic Research Service (ERS), Farm Service Agency (FSA), Foreign Agricultural Service (FAS), Forest Service (FS), National Agricultural Statistics Service (NASS), Natural Resources Conservation Service (NRCS), and Risk Management Agency (RMA). Although the mission and responsibilities of each agency differed, similar data and technologies were used by these agencies to help accomplish departmental objectives. The CSREES is the extramural research arm of USDA. It primarily provides financial assistance in the form of grants to conduct high-priority agricultural research and education. Many grants awarded by CSREES use NASA data products to solve complex environmentally related problems on topics such as water quality, air quality, and land-use change. A few examples of research supported by CSREES in 2004 include investigating methods of data normalization, integration, and service for the natural resources research community in Arizona; classifying land cover, monitoring vegetation condition, and sensing and analyzing urban ecology in Minnesota; understanding urban wildlife populations in Texas; and incorporating remote sensing data into weather-forecast models in Utah. CSREES funded long-term studies in Mississippi, Kentucky, Alabama, and Wisconsin that used remote sensing and geospatial technologies to develop precision management techniques for various agricultural production strategies and to evaluate land-use practices. CSREES cooperated with the Applications Division of the former Earth

Science Enterprise (now a part of the Science Mission Directorate) at NASA to create geospatial extension programs at land-grant, sea-grant, and space-grant institutions. This outreach program helped to train local and regional technologists to use NASA data products and geospatial technologies more effectively.

ERS used derived remote sensing products, such as the National Land Cover and the Global Land Cover datasets, extensively. ERS used these derived products to quantify domestic and international agricultural efficiency and to track environmental responses to changes in agricultural markets and policies.

Much of the remote sensing activity within USDA involved the use of imagery for program operations, program enforcement, and research purposes. ERS, as part of its annual farm and field-level survey program, began to document the use of remote sensing and GPS technologies by the Department's primary clientele—farmers. Experts expected GPS usage to increase, partly due to the increased reliance on GIS by many domestic program agencies, such as NRCS and FSA, which work closely with farmers. In addition, many land-grant universities and Government agencies conducted research on the use of remote sensing, GPS, and other precision-farming technologies to enhance economic opportunities and reduce the environmental risks associated with agricultural production.

The FSA is the Federal agency charged with administering vital farm programs that ensure a strong and viable agriculture sector in the United States. These programs help America's farmers, ranchers, and other agricultural producers cope with weather, volatile markets, and natural disasters; conserve land and water resources; receive farm credits; and provide humanitarian aid to hungry people in the United States and abroad. Because nearly all programs are related to individual farms and tracts of land, the backbone of effective program delivery is the use of GIS fully integrated with up-to-date imagery and digital land and program data.

In FY 2004, the FSA saw many successes in the areas of remote sensing. FSA was charged with creating and maintaining the Common Land Unit (CLU), a nationally consistent geospatial data set representing farm and field boundaries. Ultimately, the CLU layer will include all farm fields, rangeland, and pastureland in the United States. At the end of 2004, FSA had digitized 74 percent of the Nation's counties.

FSA used the CLU, 1-meter digital imagery, digitized soil surveys, and other data sets to manage farm programs. Landsat imagery archived in the FAS-managed USDA Imagery Archive provided supplemental imagery for compliance and monitoring activities as well as ad hoc program analysis. Nationwide differential GPSs were used by all field offices in conjunction with GIS for day-to-day operations such as field-measurement services, development of boundary descriptions, and collection of point features for buildings and facilities identification.

During the 2004 Conservation Reserve Program (CRP) signup, FSA used GIS with digital imagery, CLU, and digital soils data to facilitate the producer offer process and to reduce costs associated with technical assistance. FSA also used CRP data associated with CLU in a study to determine the effects of that program on bird populations as represented by the USGS Breeding Bird Survey.

The use of imagery linked to CLU and agency program data was invaluable to respond to disaster events in 2004. For example, FSA assisted the Florida State Department of Agriculture in compiling information relating to agriculture losses occurring after Hurricanes Charley, Frances, Jeanne, and Ivan. Hurricane path data from NOAA, satellite imagery from several sources, citrus grove data from multiple State sources and USDA's National Agriculture Statistics Service, and FSA's CLU were used to create loss tiers for damage analysis and follow-on ground truth operations.

In its second year of large-scale operation, FSA's National Agriculture Imagery Program (NAIP) provided cost-effective, consolidated imagery procurement for USDA and other Federal, State, and local partners. Using best-value contracting, NAIP as a dual-product program provided for FSA's yearly digital 2-meter compliance imagery requirements and set the stage for successful cost-share partnerships to update outdated 1-meter base imagery. In 2004, FSA acquired 2-meter imagery to meet farm program compliance requirements in 25 States and partnered with Federal, State, and local entities to acquire 1-meter replacement imagery in 10 more States. FSA acquired imagery through film cameras and increasingly sophisticated large-format digital cameras to provide the best product possible to its field staff and partners. Approximately 30 days after the end of the flight season, NAIP delivered natural-color or color-infrared imagery, in a compressed, county-mosaic format, as an interim product to FSA field offices. This

imagery provided field offices with a timely, easy-to-use product for compliance activities. Full-resolution imagery tiles were available to the agency, partners, and the public approximately 9 to 12 months after acquisition. The FSA Aerial Photography Field Office (APFO) also provided cost-effective contracting services for other USDA agencies for resource and spot aerial photography.

FSA worked in conjunction with the USDA Office of the Chief Information Officer and NRCS to continue development of a Geospatial Data Warehouse (GDW), providing agency users and the public with online access to geospatial data acquired from or developed by the agencies. The GDW supported precepts promoted by Geospatial One Stop.

FSA actively supported remote sensing activities through involvement in Federal remote sensing and geodata coordination committees. The agency devoted time and resources in support of initiatives such as Geospatial One Stop, the Federal Geographic Data Coordination Committee, the National Aerial Photography Program, the National Digital Orthophotography Program, the USDA Remote Sensing Coordination Committee, and others.

The FAS Production Estimates and Crop Assessment Division (PECAD) is the focal point within FAS and USDA for assessing the global agricultural production outlook and conditions that affect world food security and serves as the USDA Imagery Archive. The FAS satellite remote sensing program remained a critical element in USDA's analysis of global agricultural production and crop conditions by providing timely, accurate, and unbiased estimates of global area, yield, and production. Satellite-derived early warning of unusual crop conditions and production enabled more rapid and precise determinations of global supply conditions. FAS exploited many global imagery data sets, including global AVHRR local area coverage, global area coverage, and high-resolution picture transmission data from NOAA. FAS also used 10-day global composites from the SPOT Vegetation sensor. FAS had standing orders for Landsat 5 and 7 imagery, acquiring 8- to 16-day coverage for selected paths and rows. All operational imagery had delivery requirements within 12 days of acquisition. Due to budget constraints, use of Space Imaging IKONOS and DigitalGlobe QuickBird data was extremely limited. In addition, FAS and NASA cooperated on many projects to exploit space technologies, including MODIS Rapid Response and global reservoir monitoring.

Information on the FAS remote sensing program can be found on the Internet at *http://www.fas.usda.gov/pecad*.

In FY 2004, the FS continued to process data from NASA's MODIS sensor, using these data to produce active wildland fire maps for the entire United States three times a day. FS acquired MODIS imagery of the western United States from a receiving station located at the agency's Remote Sensing Applications Center (RSAC) facility in Salt Lake City, UT. Imagery of the eastern United States was acquired by Goddard Space Flight Center (GSFC). MODIS data from Alaska and western Canada were acquired at the receiving station located at the University of Alaska, Fairbanks. 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 interstate highways. These maps were then posted on the Internet (*http://activefiremaps.fs.fed.us*), where they were accessible to national fire managers and the general public.

The Active Fire Mapping Web site was accessed by a large number of users during the 2004 Alaska fire season. The maps provided the interagency fire community with a synoptic view of the wildland fire situation, aiding in the strategic allocation of fire-fighting resources and assets throughout the country. This service has been available on a daily basis since July 4, 2001, and is a collaborative effort with NASA GSFC and the University of Maryland. Several major media entities, including the *Washington Post*, the Cable News Network, the Associated Press, and the *Los Angeles Times*, also use the map and fire-detection data.

The FS also continued to work with both 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 UAV development and mission profiling for tactical wildland fire mapping. GSFC completed development and construction of the RIPComm air-to-ground communications system that will enable rapid transmission of FS airborne thermal-image products to incident command personnel in the coming fire season. The Freewave communications system was utilized for the first time in Alaska during the 2004 fire season and provided the incident commands with current fire imagery in minutes rather than hours. The FS has two planned UAV missions in the spring and

summer of 2005 to demonstrate the capabilities of UAVs in support of wildfire mapping, management, and suppression activities.

The FS continued its collaboration with NASA ARC in the Wildfire Research and Applications Partnership (*http://geo.arc.nasa.gov/sge/WRAP/*) and together formed the interagency Tactical Fire Remote Sensing Advisory Committee (TFRSAC) to speed technology transfer to the wildfire detection, mapping, and suppression arena. The TFRSAC consisted of remote sensing scientists and wildfire-suppression specialists from across the country and around the globe.

The mission of NASS is 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. Every 5 years, NASS also conducts the Census of Agriculture, which provides a comprehensive statistical summary of many aspects of U.S. agriculture. Remote sensing data and techniques are valuable tools used to improve the accuracy of some NASS statistics. Remote sensing data and area sampling frame designs also form the backbone of our most important early season survey, conducted to provide the first look at planted acreage for the season.

During FY 2004, 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 GIS. NASS used Landsat imagery, digital orthophoto quadrangles, and other remotely sensed inputs for all 48 continental States and Puerto Rico to select the yearly area-based samples. In addition, NASS constructed new area-based sampling frames in Indiana, Mississippi, Virginia, and the reservation areas of New Mexico. These frames will be used for the first time in 2005. The remote sensing acreage estimation project analyzed Landsat data from the 2003 crop season in Arkansas, Illinois, Indiana, Iowa, Mississippi, the Missouri boot heel, Nebraska, North Dakota, and Wisconsin to produce crop-acreage estimates for major crops at State and county levels and a crop-specific categorization in the form of a digital mosaic of TM scenes distributed to users on a CD-ROM. For the 2004 crop season, NASS headquarters and several NASS field offices continued partnership agreements with State organizations to decentralize the Landsat processing and analysis. Data for 2004 acreage estimation analysis were

collected in Arkansas, Illinois, Indiana, Iowa, Mississippi, Missouri, Nebraska, North Dakota, and Wisconsin.

NASS forged new remote sensing partnerships during FY 2004, as well as maintained existing partnerships. In cooperation with Towson University, and as a subcontract of the Raytheon-sponsored synergy contract, NASS began to create a crop-specific categorization for the 2002 crop year for a 10-State Mid-Atlantic region. The region included the States of North Carolina, Virginia, West Virginia, Maryland, Pennsylvania, Delaware, New Jersey, New York, Connecticut, and Rhode Island. NASS continued the work it began in 2003 with the Florida Department of Citrus by working with the European Union to evaluate the use of its tree-counting program, OLICOUNT, with high-resolution imagery, such as QuickBird, to remotely count citrus trees. NASS, in conjunction with the Agricultural Research Service (ARS), continued research on data from the MODIS sensor on the Terra and Aqua satellites for use as an additional input for setting small-area yield estimates. NASS conducted a specific pilot for the States of Iowa and North Dakota.

The NRCS is the primary Federal agency working with private landowners to help them protect and conserve their natural resources. Much of the land-management business conducted by NRCS is accomplished using remote sensing, geospatial, and GPS data and technologies. The NRCS primarily uses digital orthoimagery and GIS at county field service centers nationwide.

NRCS purchased all aerial photography and derivative digital orthoimagery products from commercial sources by coordinating and cost sharing, to the maximum extent possible, with other Federal and State agencies. Through this partnership, in FY 2004 the NRCS acquired statewide 1-meter or better resolution orthoimagery for 10 States and partial coverage for Alaska. NRCS acquired most of the orthoimagery by cost sharing with the FSA through NAIP. Participation in NAIP has permitted NRCS to refresh State orthoimagery on a 5-year cyclic schedule.

In response to imagery needs in support of USDA conservation programs, homeland security, natural resource inventories, and nationwide GIS use, NRCS continued to work with the Department of Agriculture and FSA to enhance our GDW and Geospatial Data Gateway. These two initiatives provided agency users and the public with online 24-7 access to geospatial data, including imagery, developed or purchased by FSA and NRCS. All imagery purchased by NRCS resided in

the public domain. This arrangement permitted NRCS to distribute imagery internally and externally without limiting or restricting its usability.

In FY 2004, NRCS used 1-meter orthoimagery nationwide to conduct 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 at either 1:12,000 or 1:24,000 scales. Approximately 70 percent of the Nation's detailed soil surveys are now digitized to a nationally consistent geospatial format.

NRCS continued to contract for high-resolution aerial photography (less than 1-foot ground-resolving distance) as the primary source for collecting natural resource data for the annual National Resources Inventory (NRI) program. The NRI required high-resolution imagery over confidential statistical sampling sites. NRCS purchased NRI imagery for approximately 70,000 sites in the conterminous United States. Six aerial firms flew the natural-color imagery within short photography periods during the growing season. The FSA APFO, which had USDA responsibility for coordinating and contracting aerial photography, administered the contracts. The NRI program also contracted for high-resolution satellite and aerial imagery over Alaska in an effort to begin collecting and providing statistically reliable statewide natural resource data annually in Alaska.

In FY 2004, NRCS reorganized to meet changes in agriculture business practices, technologies, and conservation programs. One organizational change resulted in the establishment of three Remote Sensing Laboratories (RSLs) that are responsible for collecting NRI natural resource data.

Nationwide, NRCS natural resource specialists increased work efficiencies while providing better products through the advanced use of geospatial technologies to carry out daily business. It was now mandatory for field office planners to use GIS to plan and document conservation plans for producers and landowners. GPS also became a standard tool for field office staff.

The NRCS, FAS, and University of Texas Center for Space Research collaborated on a remote sensing project using Landsat and other satellite data to collect data on water resources and invasive plant species in the Rio Grande Basin along the Texas-Mexico border.

The RMA mission is to promote, support, and regulate sound risk management solutions to preserve and strengthen the economic stability of America's agricultural producers. As part of this mission, RMA operates and

manages the Federal Crop Insurance Corporation (FCIC). In FY 2004, RMA used remote sensing data and related technologies to support its program compliance efforts, to assist in new insurance product development, to support existing products, and to aid RMA personnel and outside customers working on agency mission-critical projects.

RMA used remote sensing to combat waste, fraud, and abuse in its programs. In 2004, the Compliance Division, in conjunction with the USDA Office of Inspector General and the Department of Justice, used Landsat 5 and Landsat 7 data to support an investigation of conspiracy and insurance fraud for submitting false claims and statements to the USDA. This investigation resulted in a conviction and the sentencing of a producer to 3 years and 5 months in Federal prison and $448,000 in restitution. A co-conspirator also was convicted. Based upon the success of this investigation in combating waste, fraud, and abuse, RMA provided remote sensing training to a number of its compliance investigators in March 2004. Investigators were trained to acquire Landsat 5 and Landsat 7 imagery from the USDA Imagery Archive, managed by PECAD, and then to make preliminary determinations from the imagery to approve a crop insurance claim or forward it on to a remote sensing expert for further investigation.

RMA had an interagency agreement with the ARS National Soil Tilth Laboratory for the evaluation of the utility of satellite and aircraft remote sensing for crop-loss adjustment. The purpose of this agreement was to study and develop a risk management tool to assess crop damage across fields using remote sensing methods and conventional information. The management tool would help producers make decisions that should reduce the potential risk of crop loss. In addition, the results of this study may be used for producers to receive the most accurate loss-adjustment possible, thus receiving all benefits to which they are entitled.

RMA had a partnership with AIR Worldwide Corporation for the development of AgALERT, a weather-analysis and risk management tool for producers of specialty crops. The purpose of this partnership was to develop a Web-based interactive weather-analysis tool that will assist specialty crop producers to manage their operations and improve management of multiyear risk. This system utilized NOAA GOES satellite imagery.

RMA also had a partnership with AgriLogic Inc. for the development of a Forage and Rangeland Decision Support System (FRDSS). The purpose of this partnership was to develop a Web-based tool that would assist livestock producers in improving price revenue and lowering market risk and would offer easy access to a specialized combination of local environmental information (weather, soil moisture, terrain elevation) and financial-management tools specifically designed for forage and rangeland applications. This system utilized NOAA AVHRR imagery.

National Science Foundation

NSF

The National Science Foundation (NSF) continued to serve as the lead Federal agency for the support of ground-based astronomy and space science. Through the Divisions of Astronomical Sciences, Atmospheric Sciences, and Physics, as well as through the Office of Polar Programs, the NSF sponsored a broad base of observational, theoretical, and laboratory research aimed at understanding the states of matter and physical processes in the universe. Areas of research ranged from the most distant reaches of the universe and the earliest moments of its existence to the nearby stars and planets, including our own planetary system.

The NSF also supported the development of advanced technologies and instrumentation for astronomical sciences and provided core support for optical and radio observatories that maintain state-of-the-art instrumentation and observing capabilities accessible to the community on the basis of scientific merit. The NSF's national astronomical facilities included the National Radio Astronomy Observatory (NRAO), the National Astronomy and Ionosphere Center (NAIC), the National Optical Astronomy Observatory (NOAO), and the National Solar Observatory (NSO). The NSF served as the executive agency for the Gemini Observatory, an international partnership operating optical/infrared telescopes in both the Northern and Southern Hemispheres. The Atacama Large Millimeter Array, an interferometer located near San Pedro de Atacama, Chile, was in the process of being constructed in partnership with Europe, Canada, and Japan. Groundbreaking in Chile took place on November 6, 2003.

The NSF continued a joint activity with the U.S. Air Force Office of Scientific Research (AFOSR) to provide the U.S. astronomical community with

access to state-of-the-art facilities at the Advanced Electro-Optical System telescope on Maui, HI.

The Improved Solar Observing Optical Network (ISOON) telescope at the NSO on Sacramento Peak, NM, a joint Air Force/NSO project, collected data daily and made it available on the Web for the tracking and prediction of solar activity. The NSO Synoptic Optical Long-term Investigations of the Sun Spectral Vector Magnetograph produced full-disk magnetograms and vector magnetograms. Regular vector magnetographs of the full solar disk permit early identification of solar regions that are likely to produce activity in the form of flares and coronal mass ejections.

The first working version of a "one-stop shopping" service for solar data was placed online, giving scientists a much easier way to search for data on specific solar phenomena and to confirm the results of earlier research. Enabled by a collaboration of NASA and NSF's NSO, the Virtual Solar Observatory (VSO) makes it possible to access data from multiple sources using one Web service. At the VSO's core are decades of data and images from the NSO Digital Library (ground-based solar telescopes) and NASA's Solar Data Analysis Center (spacecraft observations).

The NSF's Division of Astronomical Sciences, in collaboration with the Division of Atmospheric Sciences, supported the development of the Advanced Technology Solar Telescope (ATST), the next-generation U.S. ground-based solar telescope designed to resolve fundamental spatial and temporal scales of the basic physical processes governing solar variability and promising to improve our understanding of the physical processes on the Sun that ultimately affect Earth. The ATST, a collaboration of 22 institutions representing a broad segment of the U.S. solar physics community, had previously earned the strong recommendation of the National Research Council of the National Academy of Sciences. The design phase of the ATST project continued in 2004.

The Upper Atmospheric Research Section (UARS) in NSF's Division of Atmospheric Sciences supported a wide variety of research programs in space science. These included the funding of advanced radar systems to study the ionosphere and magnetosphere, ground-based optical equipment to study the aurora and airglow, ground-based solar telescopes, and a wide-ranging portfolio of basic research in space physics. The major UARS-funded activities included the

Upper Atmospheric Facilities (UAF), the National Space Weather Program (NSWP), the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) program, the Geospace Environment Modeling (GEM) program, and the Solar, Heliosphere, and INterplanetary Environment (SHINE) program.

The NSWP is a multiagency Federal program whose goal is to mitigate the adverse effects of space weather on the Nation's technological infrastructure by providing timely, accurate, and reliable space environment observations, specifications, and forecasts. In 2004, scientists submitted proposals to the NSWP for basic research in solar, heliospheric, magnetospheric, ionospheric, and thermospheric physics aimed at meeting these goals. In addition, space physicists implemented and validated computer models at the multiagency Community Coordinated Modeling Center (CCMC) located at GSFC in order to accomplish many of the above objectives. Information about the NSWP can be obtained from the NSWP Strategic Plan and Implementation Plan, available online through the Office of the Federal Coordinator for Meteorology.

Research facilities are a key component of UARS's efforts. The major goal of the UAF program in 2004 continued to be the promotion of basic research on the structure and dynamics of Earth's upper atmosphere. Research efforts utilizing these facilities were linked strongly to the CEDAR and GEM programs.

UARS supported four large incoherent-scatter radar facilities and the Super Dual Auroral Radar Network (SuperDARN) coherent-scatter radar system in 2004. SuperDARN consists of a number of coherent-scatter, high-frequency radars in both the Northern and Southern Hemispheres focused on studies of magnetosphere-ionosphere coupling processes occurring over the poles. In contrast, the four incoherent-scatter radars emphasized global ionospheric and upper atmospheric research. They are located along a longitudinal chain from Greenland to Peru at Millstone Hill Observatory, Sondrestrom Radar Facility, Arecibo Observatory, and Jicamarca Radio Observatory. Most of these incoherent-scatter radar facilities continued to use colocated optical diagnostic instruments for scientific observations in addition to the radars themselves.

A recent addition to the UAF program in UARS was the Advanced Modular Incoherent-Scatter Radar (AMISR), which was under construction in 2004 and is expected to become operational in 2005. AMISR is deployable to any geographic location on the globe for ionospheric research.

The CEDAR, GEM, and SHINE programs continued to constitute broad-based, community-initiated efforts focused on studying solar influences on the space environment surrounding Earth known as "geospace." The goal of these programs continued to be the development of the next generation of researchers to lead this fundamental research for the Nation. These programs encouraged participation by undergraduate and graduate students, who benefited from the interdisciplinary nature of the research and the multifaceted approaches involving theory, numerical simulations, instrument development, data analysis, field measurements, and teamwork. CEDAR, GEM, and SHINE workshops held in 2004 provided forums for investigators to present results, exchange information, and plan future experimental campaigns.

CEDAR's goal continued to be the increased understanding of the behavior of atmospheric regions, from the middle atmosphere upward through the thermosphere and ionosphere into the exosphere, in terms of coupling, energetics, chemistry, and dynamics on regional and global scales. These processes are related to the sources of perturbations that propagate upward from the lower atmosphere, as well as to solar radiation and particle inputs from above. In 2004, CEDAR continued to manage networks of instruments and facilities to address research topics involving global-scale coupling and transport effects between geographic regions and different altitudes. These observations were combined with sophisticated models to test our understanding of atmospheric-coupling processes. A database of CEDAR observations continued to be maintained for community use at the National Center for Atmospheric Research in Boulder, CO.

GEM supported research on the physics of Earth's magnetosphere and, in particular, the coupling of the magnetosphere to Earth's atmosphere and to the solar wind. The primary goal of GEM continued to be understanding how the flow of energy, mass, and momentum in the solar wind couples to Earth's magnetosphere and, in turn, how the magnetosphere is coupled to Earth's atmosphere. In 2004, the GEM program therefore supported basic research on magnetohydrodynamics and plasma physics, and especially on the dynamical and structural properties of geospace, with the purpose of constructing a global Geospace General Circulation Model (GGCM) with predictive capability. The strategy for achieving GEM goals continued to emphasize the undertaking of multiple theoretical and observational campaigns, each focusing on particular aspects of the geospace environment.

SHINE research focused on the connections between eruptive events and magnetic phenomena on the Sun and the corresponding solar wind structures in the inner heliosphere. In 2004, SHINE research focused on those processes by which magnetic fields and particles produced by the Sun permeate interplanetary space and on the mechanisms by which these fields and particles are transported to geospace through the inner heliosphere. SHINE therefore also supported basic research on magnetohydrodynamics and plasma physics. The goal of SHINE research continued to be the enhancement of both our physical understanding and predictive capabilities for solar-driven events in geospace, and SHINE was complementary to, but distinct from, the NSWP and GEM.

DEPARTMENT OF STATE

DOS

The Department of State (DOS) supports U.S. space activities through the negotiation of bilateral and multilateral agreements on scientific and technical cooperation with partner countries and through outreach programs designed to support key U.S. foreign policy objectives, including sustained growth, transportation safety, and sound environmental management.

In FY 2004, DOS led successful negotiations with the European Union on cooperation between the U.S. GPS and Europe's planned Galileo satellite navigation system. The negotiations resulted in an agreement on GPS-Galileo cooperation that was signed by Secretary of State Colin Powell and his European counterparts in Ireland on June 26, 2004. The agreement calls for the Galileo and next-generation GPS satellites to broadcast a common civil signal, which will benefit civil users around the world. It also provides for a nondiscriminatory approach to trade in satellite navigation goods and services and ensures that the Galileo signals will not degrade the ability of the United States and its allies to prevent adversaries from having access to satellite-based positioning information in areas of conflict. During FY 2004, DOS also led Government-level consultations on satellite navigation issues with Japan, India, and Brazil and continued work with the U.N. Office of Outer Space Affairs for the development and exploitation of global navigation satellite system applications.

As part of the President's initiative to strengthen bilateral cooperation with India, the DOS led efforts to organize a pioneering India-U.S. Conference on Space Science, Applications, and Commerce that was held in Bangalore, India, June 21–25, 2004. More than 500 officials, researchers, and business representatives participated in the conference, including representatives from the DOC, NASA,

NOAA, and other U.S. agencies. The American Institute of Aeronautics and Astronautics (AIAA) assisted with conference arrangements, and a number of key U.S. aerospace firms also were involved. The conference reviewed the status of existing Indo-U.S. cooperative projects and explored the future of space cooperation and commercial space activities between the two countries. Participants identified a number of areas with strong potential for enhanced cooperation in civil space activities, supported a vision statement calling on the two governments to continue efforts to facilitate bilateral cooperation, and developed a set of detailed recommendations for expanding civil space cooperation between India and the United States.

Through new outreach activities, DOS continued to harness U.S. leadership in geospatial technologies, including GPS, remote sensing, and Web-based mapping, in support of transportation safety and sustainable development applications. Under DOS leadership and with funding from the Interagency GPS Executive Board, the GPS outreach team developed an exhibit to promote GPS technology and applications that traveled to the India-U.S. Conference on Space Science, Applications, and Commerce. As a followup to the initiative on Geographic Information for Sustainable Development that the United States brought to the Johannesburg World Summit on Sustainable Development, DOS promoted the distribution of global Landsat data sets for environmental and agricultural applications through regional conferences in the developing world.

DOS continued work with the U.N. Office of Outer Space Activities for the development and exploitation of Global Navigation Satellite System (GNSS) applications. DOS provided funding for regional GNSS workshops and experts meetings held under the auspices of the U.N. and the United States. The workshops brought together regional experts and decisionmakers to advance awareness and support for the use of GNSS applications for sustained growth, transportation safety, and environmental management.

Through the coordinated efforts of DOS, NASA, and NSF, the number of countries participating in the U.S.-led GLOBE program was expanded to 107. GLOBE is a hands-on science and education program that involves primary and secondary school students around the world in scientific research on Earth's environment. Two new countries, the Republic of France and Mauritania, joined the program in 2004. The GLOBE program received the

2004 Goldman Sachs Foundation Award for International Education in the category of media and technology.

During FY 2004, DOS again led U.S. Government participation in the U.N. Committee on the Peaceful Uses of Outer Space. The committee undertook significant work in areas such as global navigation satellite systems, the problem of orbital space debris, meteorology, astronomy and astrophysics, space transportation, nuclear power sources in space, planetary exploration, and environmental monitoring. The committee also considered legal issues related to international liability and responsibility of launching nations, international financial security interests in space equipment, and equitable access to the geostationary orbit.

DEPARTMENT OF ENERGY

DOE

In FY 2004, the Department of Energy's (DOE) Office of Science (SC) cooperated with NASA in a wide variety of activities, such as developing experimental techniques of fundamental physics for use in outer space, using plasma science to devise new propulsion systems, engaging in joint efforts to understand atmospheric and environmental phenomena, and entering into a working partnership in advanced computing research. These activities were carried out under an MOU between NASA and DOE signed by NASA Administrator Daniel Goldin and DOE Secretary James Watkins in 1992. NASA and DOE revitalized their joint space nuclear efforts in FY 2004, including new work in the space nuclear technology area and commencement of a space nuclear reactor design and development effort for Prometheus-1, the Jupiter Icy Moons Orbiter mission.

Through an Implementing Arrangement with NASA signed in 1995, the SC continued in 2004 to build the Alpha Magnetic Spectrometer (AMS) for use on the ISS. 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. The DOE built the AMS to 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 lead to a clearer understanding of the actual origin of the universe. DOE provided funding in FY 2004 to support the research group at the Massachusetts Institute of Technology (MIT) that is leading the AMS program.

DOE's SC and NASA's Science Mission Directorate (formerly the Space Science Enterprise) have collaborated since FY 2000 on the Large Area Telescope (LAT), the primary instrument for NASA's Gamma-ray Large Area Space

Telescope mission currently scheduled for launch in August 2007. This device, using the techniques of experimental particle-physics research, is to detect gamma rays emitted by the most energetic objects and phenomena in the universe. The Stanford Linear Accelerator Center, a DOE facility at Stanford University, was responsible for the overall management of the LAT project. DOE provided funding in FY 2004 for the design and fabrication of the telescope, in conjunction with NASA and international partners.

Determining the nature of dark energy, which is causing the acceleration of the expansion of the universe, is a high-priority science objective for both DOE and NASA. The Joint Dark Energy Mission (JDEM) is a plan endorsed by both DOE and NASA for this mission. In the plan, both DOE and NASA will be responsible for the success of the mission. NASA will be in charge of the space mission management. DOE and NASA will jointly select a team to conduct the dark energy science investigation. DOE supported a large portion of R&D activities by the Supernova Acceleration Probe (SNAP) collaboration, led by LBNL, which proposed a space-based dark energy experiment designed to precisely probe the nature of dark energy. SNAP will be one of the proposals for the dark energy science investigation for JDEM. Although neither DOE nor NASA has identified funds for the development of JDEM, both agencies provided R&D funding in FY 2004 toward project planning and mission concepts.

The Office of Nuclear Physics is a separate office in the SC. Previously, High Energy and Nuclear Physics served the Nation as a single Office. Nuclear Physics continued to make available the Alternating Gradient Synchrotron (AGS), an essential component 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 (up to 1 GeV/nucleon) of interest to the space radiobiology community. This capability has been in place since 1995 with radiobiology experiments, funded by NASA, performed with silicon, iron, and even gold beams. In FY 2003, a NASA-funded facility, named the NASA Space Radiation Laboratory (NSRL), was completed at BNL. Commissioning was carried out in late FY 2003 (NSRL-0 experiment). In early FY 2004, a total of 27 radiobiology experiments (NSRL-1) were approved and run with beams of protons, carbon, iron, and titanium for 21 institutions from the United States and two from Italy. This facility continued to operate as an effi-

cient and effective radiation simulation facility for human space exploration. The SC and NASA continued to work on a range of technical resources that can be mutually beneficial for experimentation and data analysis at BNL. For example, discussions were undertaken regarding a possible future upgrade to the RHIC's ion source called an Electron Beam Ion Source. This source, if realized, would enhance the range and intensities of heavy ion beams available to the RHIC complex, including the NSRL.

In FY 2004, the DOE Nuclear Physics Program continued to support astrophysicists using the National Energy Research Scientific-computing Center (NERSC), funded by DOE's Office of Advanced Scientific Computing Research, for simulations of supernovae explosions, such as those observed by the Hubble Space Telescope.

Other space-related aspects of the Nuclear Physics Program have relevance to NASA, other Federal agencies (e.g., National Reconnaissance Office and the U.S. Air Force), and the private sector. In the area of radiation effects, the Nuclear Physics Program regularly provided beams from accelerator facilities (BNL Tandem, LBNL 88-Inch Cyclotron, Texas A&M Superconducting Cyclotron) to NASA, DOE applied laboratories, European and Japanese space agencies, and private companies for testing of electronic components used in high-radiation space environments and investigation of radiation effects on biological systems such as described above for the NSRL at BNL.

Through the use of plasma and fusion propulsion, NASA-funded research activities have the potential of revolutionizing interplanetary space travel. Transfer of knowledge to NASA and the Agency's use of research capabilities developed in the SC's fusion energy program continued in FY 2004.

NASA studied fusion propulsion concepts for advanced interplanetary missions based upon the spherical torus and plasma-jet-driven magneto-inertial fusion. The DOE's SC investigated the physics of the spherical torus in its National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL) as part of its fusion energy program

The DOE's SC investigated plasma-jet-driven magneto-inertial fusion for magnetic fusion energy applications at General Atomics, Lawrence Livermore National Laboratory, and the University of Wisconsin at Madison. Researchers at the University of Wisconsin completed a preliminary computational study on the

feasibility of the plasma-jet-driven magneto-inertial fusion for space propulsion for NASA MSFC using a computer code developed in the inertial fusion energy program of the SC.

The two fusion rocket concepts based upon the spherical torus and the magneto-inertial fusion approach have the potential of reducing traveling times to the planets by more than a factor of 10.

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

DOE's Oak Ridge National Laboratory (ORNL), PPPL, the Institute of Fusion Studies at the University of Texas in Austin, and NASA Johnson Space Center continued to collaborate on the development of an advanced plasma rocket technology called the Variable Specific Impulse Magneto Plasma Rocket that has the potential of cutting in half the time required to reach Mars. A key to the technology is the capability to vary the plasma exhaust to maintain optimal propulsive efficiency.

PPPL worked on several other basic plasma science projects that complement and enhance the science activities at NASA. These projects focused on magnetic reconnection and other work on ionosphere and space-related plasma physics topics, and they are partially funded under the DOE/NSF Plasma Science Partnership. The Magnetic Reconnection Experiment investigates the coupling between microscale reconnection layers and global forcing and plasma topology evolution.

The SC and NASA worked together to calculate the daily primary productivity of terrestrial ecosystems at diverse sites in Northern and Central States. Research initiated in FY 2002 continued in FY 2004 with the SC's AmeriFlux program. The program provided real-time meteorological, solar radiation, and CO_2 flux data for these calculations, where NASA provided data from the MODIS platform on gross primary productivity and leaf area. This joint work investigated continental-scale seasonal and geographic patterns of carbon-cycle processes related to the North American carbon program. The AmeriFlux program produced unique ground-based measurements of net ecosystem production from some 30 locations across the United States. These results provided inde-

pendent corroboration of NASA's productivity calculations derived from remote sensing observations.

Future NASA missions, Cloudsat and Calipso, will include passive remote sensors for characterizing clouds. In FY 2004, NASA conducted a campaign over the SC's Atmospheric Radiation Measurement (ARM) Southern Great Plains site as part of their effort to develop and validate algorithms for these instruments. These missions, when taken together, advance our understanding of the coupling between various components of the hydrologic cycle and atmospheric circulation and may lead to significant improvements in the characterization of cloud feedback in global climate models. Data from the ARM site was used in these algorithm development and validation activities. ARM also is providing ground validation support for NASA's Atmospheric Infrared Sounder (AIRS) instrument. The AIRS is a high-spectral-resolution infrared sounder on the EOS Aqua platform. The ARM data are being used to improve the water vapor and temperature profiles retrieved from the AIRS sensor. Information on water vapor and temperature is an important parameter for the development and validation of climate models.

In 2004, the first in a series of proposed workshops jointly sponsored by NASA, NOAA, and DOE was held on the use of Uninhabited Aerial Vehicles (UAVs) for making critical measurements needed for climate-change research. The workshop brought together distinguished scientists from the agencies, universities, and private industry to identify key scientific questions that could be addressed using the unique capabilities of UAVs and to identify aircraft or instrument technology gaps that would require future investment in the development of UAV capabilities and their applications in research on climate change and other environmental systems. One goal of the proposed collaboration is to define how to efficiently use the resources of the three agencies to extend climate-relevant measurements, using UAVs, to regions of Earth that are currently underrepresented.

The SC, NSF, and NASA continued close three-way collaboration on the development and implementation of climate models. All three agencies supported a variety of collaborative activities associated with the Community Climate System Model. SC's Scientific Discovery through Advanced Scientific Computing project to develop software framework and implement efficient software engineering practices for complex climate models coordinated its activity with NASA's Earth-System Modeling Framework project. NASA, DOE, NOAA, and NSF par-

ticipated in the interagency Climate Model Evaluation Project to support the evaluation of U.S. coupled-climate model simulations. The aim of this effort was to increase communitywide diagnostic research into the quality of model simulations to improve evaluations of model predictions and quantification of uncertainty in projections of future climate.

The SC's Low Dose Radiation Research Program continued to interact with the Space Radiation Health Program in NASA's Office of Biological and Physical Research. The focus of research in the DOE Low Dose Radiation Research Program was 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 to understand the biological effects of space radiation that account for radiation risks. In FY 2001, NASA and DOE developed a Memorandum of Agreement (MOA) to better coordinate their common interests. This close collaboration between NASA and DOE was intended to enhance progress in understanding and predicting the effects and health risks resulting from low-dose radiation. DOE and NASA also issued joint Requests for Applications in FY 2002, 2003, and 2004 for research that addressed both DOE and NASA needs to understand the human health effects and risks of exposures to low doses of radiation. Ten jointly funded projects were in existence in 2004.

DOE's Energy Sciences Network (ESnet) and NASA's Research and Education Network (NREN) continued to maintain a close working relationship. For a number of years, ESnet has used its contracts to procure the long-haul telecommunications circuits and some of the associated equipment that NREN uses to build its network. ESnet also has one of its major peering points (where it connects to other networks) at NASA ARC.

In FY 2004, DOE and NASA jointly organized a high-capacity optical networks workshop. The purpose of the workshop was to identify the network requirements of next-generation data optical networks to provide access to distributed national terascale supercomputing facilities. The workshop also focused on developing interagency strategies to coordinate the development of experimental ultra-high-capacity optical network technologies to support large-scale distributed application and petabyte-scale data archives. NASA and DOE also collaborated in the deployment and testing of advanced networking technologies, such as high-speed transport protocols, high-speed data transfer services, and end-to-end network

monitoring toolkits developed by researchers at Los Alamos National Laboratory, Argonne National Laboratory, and the Stanford Linear Accelerator Center.

DOE's Office of Nuclear Energy, Science, and Technology continued to support NASA's space exploration program by pursuing development of specific technologies for future space missions and by maintaining the necessary program and nuclear facilities infrastructure to provide radioisotope power systems and heater units. In FY 2004, DOE continued to develop two new radioisotope power systems for future use in multiple mission environments, including planetary surfaces and deep space.

These two systems, a multimission Radioisotope Thermoelectric Generator and a Stirling Radioisotope Generator, will each provide greater than 100 Watts-e for over 10 years. DOE also is supporting the fabrication of the Radioisotope Thermoelectric Generator for the New Horizons mission to Pluto scheduled to launch in early 2006. As part of maintaining the required infrastructure, DOE completed construction of the Space and Security Power Systems Facility at its Idaho site. This facility serves as the fueling and test facility for multiple types of radioisotope power systems and will support a variety of future missions. This facility is operational and is being used to fuel and test the generator for the New Horizons mission. DOE's Office of Nuclear Energy, Science, and Technology also conducted long-term space reactor science and technology development efforts directed at supporting the long-term vision for space exploration.

In FY 2004, Secretary of Energy Spencer Abraham assigned DOE's Office of Naval Reactors responsibility to support space-reactor activities for NASA's proposed Jupiter Icy Moons Orbiter mission. This was an ambitious proposed mission to orbit three planet-sized moons of Jupiter—Callisto, Ganymede, and Europa—which may harbor vast oceans beneath their icy surfaces.

Many of the NASA-funded activities listed above enter the DOE system through the Work for Others program. This program allows non-DOE sponsors access to SC laboratories' unique and specialized facilities and expertise. Other scientific and technological efforts NASA supported 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.

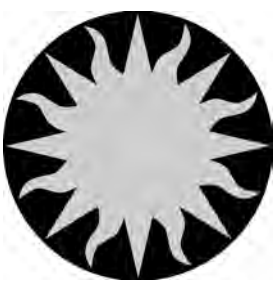
SMITHSONIAN INSTITUTION

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 (NASM) in Washington, DC, also contributed to national aerospace goals through its research and education activities.

This year, SAO gained a new director with the appointment of Dr. Charles Alcock, who also will head the Harvard College Observatory. Alcock succeeded Dr. Irwin Shapiro, who served as director for 21 years. Alcock will manage a staff of more than 900 employees and an organization that includes leading ground-based and space-based observatories.

FY 2004 marked the fifth year of the success of the Chandra X-ray Observatory, a spacecraft operated by SAO on behalf of NASA. Astronomers presented discoveries regarding objects ranging from nearby solar system bodies to distant galaxy clusters, the largest gravitationally bound structures in the universe.

Chandra's data on galaxy clusters proved to have implications for the nature and amounts of dark matter and dark energy that mysteriously dominate the universe. For example, Chandra revealed that two particular clusters contain thousands of galaxies immersed in enormous clouds of multimillion-degree gas. Scientists can use x-ray observations of the hot gas to glean clues about the cloud of dark matter that confines the gas and galaxies. Also in FY 2004, astronomers announced that they had used Chandra to study 26 different galaxy clusters to estimate the amount of dark energy in the universe. Their results provided important independent confirmation of



calculations using optical observations of supernovae in distant galaxies. Both the x-ray and optical results indicate that the expansion of the universe stopped slowing down about 6 billion years ago and then began to accelerate. Astronomers now conclude that dark energy contributes about 75 percent of the energy density in the universe, dark matter about 21 percent, and normal matter about 4 percent.

Chandra also continued to probe the behavior and characteristics of black holes in FY 2004. Along with other x-ray telescopes, Chandra found evidence that a star wandered too close to the supermassive black hole in the center of the galaxy RX J1242-11 and was torn apart by the black hole's enormous gravitational tidal forces. The supermassive black hole at the center of the Milky Way, known as Sagittarius A* (A-star), was revealed by Chandra to be immersed in a giant cloud containing 100-million-degree gas.

FY 2004 marked the first year of operations for NASA's Spitzer Space Telescope (SST), whose Infrared Array Camera (IRAC) was developed at SAO. Spitzer studies the universe at infrared wavelengths of light, enabling it to spot distant, highly redshifted galaxies and peer into nearby dust-obscured regions. The first results from SST were released in December 2003 and featured spectacular infrared images of objects ranging from nearby star formation regions to distant galaxies. SAO astronomers have developed new ways of dissecting and classifying galaxies based on Spitzer observations. The unique capabilities of IRAC provided a direct way of separating the stars from the warm dust, thereby dissecting a galaxy into its individual components and revealing its true nature. IRAC also has produced a more complete view of galaxies in collision, which will help us better understand the evolution of such systems and the eventual fate of our own galaxy. Observations of very distant galaxies at high redshift provided important tests of the theory of galaxy structure and formation in the early universe. IRAC observations of galaxies at a redshift of 3, seen as they were when the universe was only 2 billion years old, demonstrated that these objects were massive, star-forming galaxies that may be the ancestors of today's large galaxies.

A special issue of the *Astrophysical Journal* (Supplement Series), which was published in September 2004, contained 85 papers describing the first observations with SST. SAO scientists are lead authors or coauthors on 31 of those papers. Spitzer is operated by NASA Jet Propulsion Laboratory.

This year, a team including SAO researchers made a key find in the field of extrasolar planets, or planets around other stars. They located a Jupiter-sized world 500 light-years away using a telescope only 4 inches in diameter, demonstrating that even humble telescopes can make huge contributions to planetary searches. SAO astronomers also discovered several oddities in the stellar "zoo," including a speeding star whizzing through space at 40,000 miles per hour, a diamond star weighing 10 billion trillion trillion (1 followed by 34 zeros) carats, and a pair of heavyweight stars each containing 80 times the mass of the Sun.

Solar scientists at SAO continued to study solar storms, which can have a strong impact on Earth's local space environment, on radio frequency communications with aircraft, and on electrical power grids. NASA's new space exploration vision has focused attention on the production of solar energetic particles produced by solar storms. Because these particles have extremely high energies, they pose a radiation hazard to astronauts and their equipment. Astronauts venturing outside the protection of Earth's magnetosphere en route to the Moon and Mars would encounter much higher doses of radiation than spacecraft in low-Earth orbit. New observations from SAO's UltraViolet Coronagraph Spectrometer (UVCS) aboard the Solar and Heliospheric Observatory (SOHO) spacecraft are being used to obtain detailed descriptions of the source regions of solar energetic particles near the Sun. These descriptions, in concert with theoretical studies, are aimed at understanding the physical processes that produce the hazards to both people and electronics, and ultimately at developing a predictive capability. The UVCS measurements are coordinated with those of 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.

Construction of SAO's Submillimeter Array (SMA) with its initial complement of receivers was completed at the beginning of FY 2004, and the instrument was dedicated on November 22, 2003, in a joint ceremony for both the instrument and the support facility in Hilo, HI. The SMA, located near the summit of Mauna Kea, consists of eight individual antennas separated by up to 500 meters that are electronically interconnected so as to produce astronomical images in the little-explored wavelength band of 0.3 to 1.3 millimeters with extremely fine resolution. In the first year of operation, more than 100 proposals were submitted for the study of a wide range of astrophysical phenomena. Several results already have emerged.

For example, scientists measured the ratios of isotopes of carbon and nitrogen in the atmosphere of Titan, a moon of Saturn, to further understand its atmospheric evolution. Also, astronomers have studied many star-formation regions in our galaxy, gaining new insight into how molecular clouds collapse to form stars. Another topic of investigation has been the dynamics of interacting galaxies, where SMA images of emission from carbon-monoxide gas trace the regions of collision-induced star formation. In another study, a very distant, highly redshifted galaxy was detected and was investigated for clues about star formation in the early universe. A special issue of the *Astrophysical Journal* (Letters), published on November 22, 2004, contains 18 papers detailing the results of these initial observations and of others.

During FY 2004, the "Cosmic Questions" traveling museum exhibition developed by SAO's Science Education Department (SED) staff had a successful run at the National Geographic Explorer's Hall in Washington, DC, capped by an event that brought together administrators from NASA, the NSF, the Smithsonian Institution, and National Geographic. The exhibition continued its tour at the Ontario Science Centre in Toronto, ON, Canada, and the Flandrau Science Center at the University of Arizona in Tucson, AZ, and has been enjoyed by more than 1 million visitors to date. In conjunction with "Cosmic Questions," the Structure and Evolution of the Universe (SEU) Forum partnered with the Boston Museum of Science to create materials and programs that help teachers and museum docents to enhance their own content knowledge and prepare them to effectively use the exhibition to meet science and mathematics education standards. All museums or science centers that hosted the exhibition received a supply of "Cosmic Questions" educator guides for teachers, a train-the-trainers session for professional development providers, and a set of workshop templates that outlined an adaptable professional development syllabus.

SED activities also included the MicroObservatory Program, a curriculum of investigations using four online, fully robotic 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. In FY 2004, users in 20 States took more than

30,000 images, and 20,000 images were requested by visitors to "Cosmic Questions" on its tour.

In FY 2004, SED's Science Media Group (SMG) continued to lead the charge, producing television materials for teacher professional development. This year, the SMG completed two new television programs—"Essential Science for Teachers: Earth and Space Science" and "Essential Science for Teachers: Physical Science"—complementing the work completed last year in life sciences. These programs are now being made available to the Nation's elementary school teachers free of charge through the Annenberg/CPB Channel. New work is underway to build professional development materials for high school teachers—work being carried out through a project in collaboration with the NASA SEU Forum.

The SMG completed its work (in collaboration with the American Association for the Advancement of Science) to build a digital video library of educational materials as part of the NSF's National Science Digital Library. The SMG, in collaboration with NASA as well as its partners at Harvard, also began providing DVD copies of its award-winning teacher professional development programs "A Private Universe" and "Minds Of Our Own" to educators free of charge. On the public outreach front, the SMG continued to press forward with the development of a large-format film (IMAX) about the history of Earth. The SMG also began developing a children's television series on science and sports to help women, minorities, and people with disabilities alter their image of science. Additionally, SMG continued to manage the Annenberg/CPB Channel, a satellite/Web service broadcasting free educational programming nationwide to schools, colleges, and communities with a reach of 93,000 schools and 78 million households.

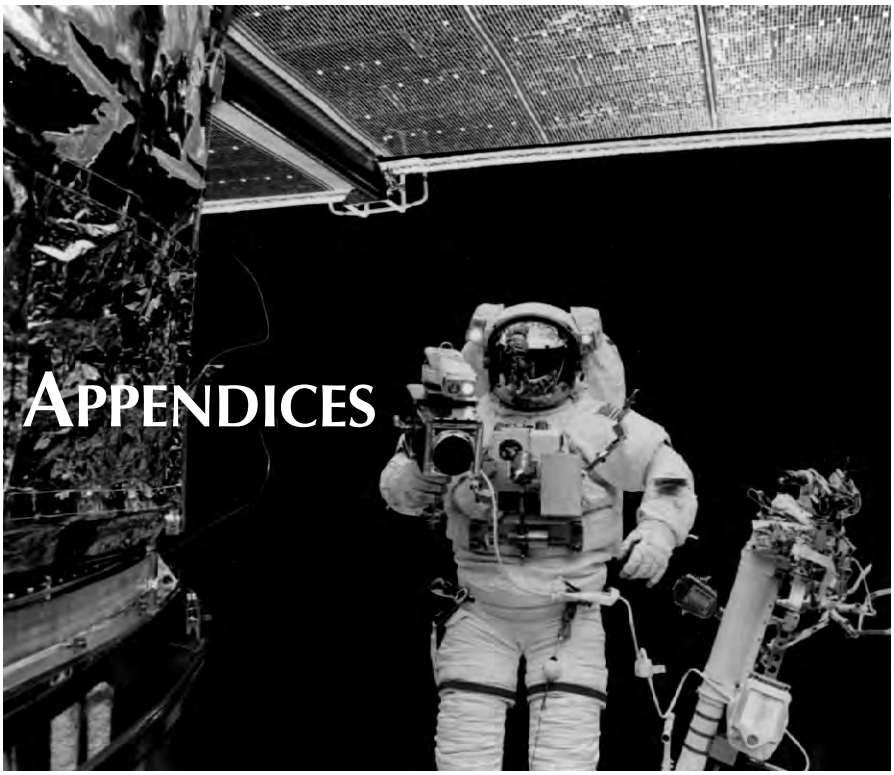
This year, SAO took a major step forward in its public outreach programs by adding a new public telescope to Oak Ridge Observatory in Harvard, MA. The Oak Ridge facility offers accommodations for much larger crowds than can attend events at the usual Cambridge, MA, location. SAO also continued to offer its popular Observatory Night lectures and telescope observation to the public on a monthly basis, as well as Kids' Night programs for younger audiences and Sci-Fi Movie Nights to explore the theme "Everything I Learned About Science, I Learned at the Movies." Observatory Night programs in particular were frequently so well attended that lectures were standing room only.

In FY 2004, NASM opened its spectacular new Steven F. Udvar-Hazy Center with over 140 aircraft and spacecraft on display (and more to come), including an SR-71, a Concorde, and the Space Shuttle Enterprise. In just under 6 months, the Udvar-Hazy Center welcomed its millionth visitor. This year, NASM also opened a major exhibition on the 100th anniversary of the Wright brothers' achievement.

Staff members in NASM's Center for Earth & Planetary Studies (CEPS) continued to participate on the science teams of several spacecraft missions in FY 2004. Dr. John Grant is a participating scientist for the MER mission that is currently operating on Mars; he is also Chair of the MER Science Operations Working Group. In that capacity, he directs the science team to consensus on targets and operations for the rovers. He conducts real-time mission planning from a control station installed on site at CEPS. CEPS staff are also on the science teams for Mars Express, the upcoming Mars Reconnaissance Orbiter, and MESSENGER, which was recently launched to Mercury. In addition, NASA appointed Dr. Bruce Campbell to the team that defined science priorities for the planned 2008 Lunar Reconnaissance Orbiter, a mission being developed in response to the President's new space initiative.

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, Earth, Moon, and Mars, resulting in 25 peer-reviewed publications. Research topics included Martian aeolian processes, MER results, physical properties of lunar impact ejecta, paleolakes on Earth and Mars, ground-penetrating radar at Martian analog sites in the Arctic, Martian valley networks, and continued acquisition of radar imagery of the Moon collected using the Arecibo and Greenbank telescopes.

CEPS staff also participated in the development and presentation of exhibits and public programs, including a Mars rover exhibit and a hands-on, drivable rover activity where students can learn about space technology, robotics, and planetary science. As a NASA Regional Planetary Imagery Facility (RPIF), CEPS continued to house an extensive collection of images of the planets and their satellites that serves as a reference library for science researchers and the public in the Mid-Atlantic and southeastern United States. The CEPS RPIF holds the most complete collection of lunar images of any RPIF in the world.



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	18	0	0	1 [b]
2003	28 [c, g]	0	2	0
2004 *(through September 30, 2004)*	6 [c]	0	1	0
TOTAL	1,558	153	100	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.
g. This includes American spacecraft not launched in the U.S.

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	18	23			3	4			12	1	1
2003	25 [e]	22			2	6			4	2	
2004	15	14				5			2	1	
(through September 30, 2004)											
TOTAL	1,298	2,724	10	8	59	80	1	1	156	16	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.
e. Launches from U.S.-Russia joint platform included in U.S. totals.

APPENDIX B

Successful Launches to Orbit on U.S. Launch Vehicles
October 1, 2003–September 30, 2004

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Oct. 18, 2003 DMSP F-16 2003-048A Titan 2	Military scientific satellite	853 km 843 km 101.9 min 98.9°	Also known as USA 172
Dec. 2, 2003 USA 173 2003-054A Atlas 2AS	Military reconnaissance satellite		National Reconnaissance Office
Dec. 18, 2003 USA 174 2003-057A Atlas 3	Military communications satellite	Geosynchronous	Also known as UFO 11
Dec. 21, 2003 Navstar 2003-058A Delta 2	Navigational satellite	20,327 km 5319,966 km 716.5 min 55.1°	
Feb. 5, 2004 AMC 10 2004-009A Delta 2	Communications satellite	Geosynchronous	Also known as GE 10
Feb. 14, 2004 USA 176 2004-004A Titan 4B	Military surveillance	Geosynchronous	Also known as DSP 22
Mar. 13, 2004 MBSat 2004-007A Atlas 3	Communications satellite	Geosynchronous Cape Canaveral using American launch vehicle	Japanese-South Korean satellite launched from
Mar. 20, 2004 USA 177 2004-009A Delta 2	Navigational satellite	20,277 km 20,090 km 718 min 55.1°	Also known as Navstar 54
Apr. 16, 2004 Superbird 6 2004-011A Atlas 2AS	Communications satellite	Geosynchronous	Japanese satellite launched from Cape Canaveral using American launch vehicle
Apr. 20, 2004 Gravity Probe-B 2004-014A Delta 2	Scientific satellite	645 km 641 km 2,895 min 90.0°	

APPENDIX B
(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles
October 1, 2003–September 30, 2004

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
May 19, 2004 Rocsat 2 2004-018A Taurus XL	Remote sensing satellite	767 km 764 km 100.1 min 99.1°	Taiwanese satellite launched from Vandenberg Air Force Base (AFB) by American launch vehicle
May 19, 2004 AMC 11 2004-017A Atlas 2AS	Communications satellite	Geosynchronous	Also known as GE 11
June 23, 2004 USA 178 2004-023A Delta 2	Navigational satellite	20,368 km 145 km 355.8 min 39°	Also known as Navstar 55
Aug. 3, 2004 MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) 2004-030A Delta 2	Interplanetary probe	15,000 km 200 km 720 min 80°	
Aug. 31, 2004 USA 179 2004-034A Atlas 2AS	Military satellite		Final flight of the Atlas 2 models

* U.N. Committee on Space Research

APPENDIX C

Human Space Flights

October 1, 2003–September 30, 2004

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TMA 3	Oct. 18, 2003	Alexander Kaleri Michael Foale Pedro Duque	194:18:33	Carried crew to the International Space Station (ISS). The crew conducted microgravity life science experiments code-named Cervantes.
Shenzhou 5	Oct. 15, 2003	Yang Liwei	0:21:22	Orbited Earth for 21 hours.
Soyuz TMA 4	Apr. 19, 2004	Gennady Padalka Edward Fincke Andre Kuipers	187:13:22	Carried three astronauts to the ISS.

APPENDIX D-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	1,196	169	644	74	31	266	12	30,807
2003	15,364	14,360	19,388	1,305	191	649	74	42	337	12	35,053
2004	15,351	14,294	20,019	1,456	209	745	71	62	366	12	35,778

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

* Transition Quarter

APPENDIX D-1B

Space Activities of the U.S. Government

BUDGET AUTHORITY IN MILLIONS OF EQUIVALENT FY 2004 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	5.1953	1,720	1,356	2,546	177	177						4,078
1960	5.1152	2,680	2,363	2,870	220	220				0		5,453
1961	5.0543	4,872	4,680	4,114	344	344						9,138
1962	4.9831	9,094	8,955	6,468	992	737	254					16,414
1963	4.9276	18,099	17,867	7,638	1,266	1,055	212					26,772
1964	4.8666	24,820	24,411	7,782	1,037	1,022	15					33,229
1965	4.8092	25,249	24,710	7,570	1,159	1,101	58					33,439
1966	4.7278	24,467	23,947	7,985	1,012	884	128					32,944
1967	4.6289	22,987	22,357	7,702	986	852	134					31,046
1968	4.4842	20,569	19,865	8,619	781	650	126	0.9	4			29,265
1969	4.3305	17,283	16,551	8,717	738	511	87	0.9	4	135		26,006
1970	4.1412	15,513	14,689	6,949	584	427	33	4	4	116		22,222
1971	3.9267	13,001	12,177	5,937	636	373	106	8	4	145		18,750
1972	3.7400	12,368	11,485	5,262	499	206	116	22	7	147		17,246
1973	3.5713	12,164	11,046	5,796	526	193	143	36	7	148		17,369
1974	3.4206	10,388	9,437	6,041	541	144	205	31	10	151		16,019
1975	3.1903	10,301	9,300	6,036	503	96	204	26	6	172		15,839
1976	2.8897	10,259	9,319	5,730	486	66	208	29	12	171		15,536
TQ*	2.6953	2,512	2,288	1,240	116	13	59	8	3	32		3,644
1977	2.6124	9,974	8,987	6,301	506	57	238	26	16	169		15,793
1978	2.5074	10,180	9,084	6,865	567	85	258	25	20	178		16,516
1979	2.3493	10,797	9,468	7,132	583	139	230	23	19	171		17,183
1980	2.1741	11,392	10,175	8,366	502	87	202	26	30	157		19,043
1981	1.9989	11,030	9,978	9,651	468	82	174	24	32	156		20,097
1982	1.8206	11,004	10,064	12,160	569	111	264	22	27	145		22,793
1983	1.7040	11,715	10,783	15,368	557	66	303	9	34	145		26,708
1984	1.6319	12,171	11,192	16,637	644	55	385	5	31	168		28,473
1985	1.5738	11,919	10,899	20,095	919	54	666	3	24	173		31,912
1986	1.5243	11,901	10,922	21,533	727	53	471	3	35	164		33,181
1987	1.4897	16,272	14,612	24,262	694	72	414	12	28	167	1	39,569
1988	1.4518	13,156	12,082	25,666	1,076	350	511	20	26	167	1	38,824
1989	1.4075	15,439	14,212	25,203	788	137	424	24	30	170	4	40,203
1990	1.3549	16,697	15,527	21,158	685	107	329	42	34	168	5	37,369
1991	1.3063	18,310	17,042	18,525	1,009	328	328	38	34	276	5	36,576
1992	1.2591	18,026	16,619	18,915	1,004	281	412	43	37	228	5	36,538
1993	1.2282	17,575	16,045	17,325	898	203	398	41	31	221	5	34,267
1994	1.2010	17,498	15,639	15,812	760	89	375	37	37	215	6	32,210
1995	1.1757	16,288	14,747	12,514	892	70	414	36	38	327	7	28,152
1996	1.1514	15,987	14,472	13,258	953	53	543	41	43	266	7	28,683
1997	1.1297	15,488	14,073	13,249	892	40	506	47	44	248	7	28,214
1998	1.1104	15,154	13,681	13,723	932	114	483	48	43	237	7	28,336
1999	1.0971	14,978	13,668	14,484	1,077	115	631	65	41	219	7	29,230
2000	1.0828	14,728	13,558	14,013	1,143	178	623	65	48	224	6	28,714
2001	1.0614	15,104	14,121	15,206	1,127	154	612	64	38	246	13	30,454
2002	1.0369	15,417	14,383	16,321	1,240	175	668	77	32	276	12	31,945
2003	1.0180	15,641	14,619	19,738	1,329	194	661	75	43	343	12	35,685
2004	1.0000	15,351	14,294	20,019	1,465	209	745	71	62	366	12	35,778

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

* Transition Quarter

APPENDIX D-2

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority				Budget Outlays	
	2003 actual	2004 actual	2005 est.	2006 est.	2003 actual	2004 actual
NASA[1]	14,360	14,294	15,133	15,571	13,553	14,548
Defense	19,388	20,019	21,677	22,663	18,612	17,858
Energy	191	209	223	228	191	202
Commerce	649	745	814	889	579	670
Interior[2]	74	71	70	83	75	72
Agriculture[3]	42	62	71	81	43	65
Transportation	12	12	12	12	12	12
NSF[4]	337	366	365	368	256	313

1. NASA's totals do not include 2005 emergency supplemental funding for hurricane damage to NASA facilities.
2. In 2003, the Department of the Interior began to report the U.S. Geological Survey's digital orthoimagery program within its totals.
3. In 2004, the Department of Agriculture began to report the National Agriculture Imagery Program within its totals.
4. In 2003, the National Science Foundation (NSF) began to report the Antarctic aeronomy and astrophysics program budget within its totals.

APPENDIX D-3

Federal Aeronautics Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority				Budget Outlays	
	2003 actual	2004 actual	2005 est.	2006 est.	2003 actual	2004 actual
NASA	1,004	1,057	906	852	974	641
Defense	9,432	10,301	9,396	9,390	8,314	9,687
Transportation	2,924	2,981	2,638	2,562	2,839	2,873

ACRONYMS

A

AEDT	aviation environmental design tool
AFB	Air Force Base
AFOSR	Air Force Office of Scientific Research
AGS	Alternating Gradient Synchrotron
AIAA	American Institute of Aeronautics and Astronautics
AIRS	Atmospheric Infrared Sounder
ALI	Advanced Land Imager
AMISR	Advanced Modular Incoherent-Scatter Radar
AMS	Alpha Magnetic Spectrometer
APFO	Aerial Photography Field Office
ARC	Ames Research Center
ARM	Atmospheric Radiation Measurement
ARS	Agricultural Research Service
ASAP	Aerospace Safety Advisory Panel
AST	FAA Office of the Associate Administrator for Commercial Space Transportation
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATST	Advanced Technology Solar Telescope
AVHRR	Advanced Very High Resolution Radiometer

B

BIS	Bureau of Industry and Security
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory

C

CAAC	Civil Aviation Administration of China
CAC	Civil Applications Committee
CAIB	Columbia Accident Investigation Board
CCMC	Community Coordinated Modeling Center
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions
CEOS	Committee on Earth Observation Satellites
CEPS	Center for Earth & Planetary Studies
CEV	Crew Exploration Vehicle
CLU	Common Land Unit
CNES	French Space Agency
CORS	Continuously Operating Reference Stations
CRP	Conservation Reserve Program
CSOC	Consolidated Space Operations Contract
CSREES	Cooperative State Research, Education, and Extension Service
CSU	Colorado State University
CTAS	Center-TRACON Automation System
CXO	Chandra X-ray Observatory

D

D2	Direct-To
DARPA	Defense Advanced Research Projects Agency
DEM	digital elevation model
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOQQ	digital orthophoto quarterquads
DOS	Department of State
DOT	Department of Transportation

E

EDA	En Route Descent Advisor
EDMS	Emissions and Dispersion Modeling System
e.d.t.	eastern daylight time
EELV	Evolved Expendable Launch Vehicle
EFB	electronic flight bag
EO-1	Earth Observing-1
EOS	Earth Observing System
ESMD	Exploration Systems Mission Directorate
EPA	Environmental Protection Agency
EPO	Education and Public Outreach
ERS	Economic Research Service
ESnet	Energy Sciences Network
ETM+	Enhanced Thematic Mapper Plus
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EVA	extravehicular activity
EVI	Enhanced Vegetation Index

F

FAA	Federal Aviation Administration
FAS	Foreign Agricultural Service
FCC	Federal Communications Commission
FCIC	Federal Crop Insurance Corporation
FRDSS	Forage and Rangeland Decision Support System
FS	Forest Service
FSA	Farm Service Agency
FY	fiscal year

G

GDW	Geospatial Data Warehouse
GEM	Geospace Environment Modeling
GEOSS	Global Earth Observation System of Systems
GGCM	Geospace General Circulation Model

GIS	**geographic information systems**
GLIMS	**Global Land Ice Measurements from Space**
GLOBE	**Global Learning and Observations to Benefit the Environment**
GNSS	**Global Navigation Satellite System**
GOES	**Geostationary Operational Environmental Satellites**
GP-B	**Gravity Probe B**
GPS	**Global Positioning System**
GRACE	**Gravity Recovery and Climate Experiment**
GSFC	**Goddard Space Flight Center**

H

HiRISE	**High-Resolution Imaging Science Experiment**
HST	**Hubble Space Telescope**
HUD	**Department of Housing and Urban Development**

I

IFSAR	**Interferometric Synthetic Aperture Radar**
IGEB	**Interagency GPS Executive Board**
IGOS	**Integrated Global Observing Strategy**
IRAC	**Infrared Array Camera**
IRS	**Indian Remote Sensing**
ISOON	**Improved Solar Observing Optical Network**
ISS	**International Space Station**
ITA	**International Trade Administration**

J

JACIE	**Joint Agency Commercial Imagery Evaluation**
JCCT	**Joint Commission on Commerce and Trade**
JDEM	**Joint Dark Energy Mission**
JMA	**Japan Meteorological Agency**
JPDO	**Joint Planning and Development Office**
JPO	**GPS Joint Program Office**

K

KSC	**Kennedy Space Center**

L

LAS	**Local Action Strategies**
LAT	**Large Area Telescope**
LBIR	**Low Background Infrared**
LED	**light-emitting diode**
LIDAR	**LIght Detection And Ranging**

M

MEP	**Manufacturing Extension Program**
MER	**Mars Exploration Rover**

MESSENGER	**MErcury Surface, Space ENvironment, GEochemistry, and Ranging**
MISR	**Multi-angle Imaging Spectroradiometer**
MIT	**Massachusetts Institute of Technology**
MMS	**Minerals Management Service**
MOA	**Memorandum of Agreement**
MOBY	**Marine Optical Buoy**
MODIS	**Moderate Resolution Imaging Spectroradiometer**
MOU	**Memorandum of Understanding**
MRO	**Mars Reconnaissance Orbiter**
MSS	**Multispectral Scanner**
MSU	**Microwave Sounding Unit**
MUE	**Modernized User Equipment**

N

NAIC	**National Astronomy and Ionosphere Center**
NAIP	**National Agriculture Imagery Program**
NAS	**National Airspace System**
NASIC	**National Air and Space Intelligence Center**
NASM	**National Air and Space Museum**
NASS	**National Agricultural Statistics Service**
NDE	**nondestructive evaluation**
NDVI	**Normalized Difference Vegetative Index**
NEAR	**Near Earth Asteroid Rendezvous**
NED	**National Elevation Dataset**
NERSC	**National Energy Research Scientific-computing Center**
NESC	**NASA Engineering and Safety Center**
NGA	**National Geospatial-Intelligence Agency**
NIST	**National Institute of Standards and Technology**
NLCD	**National Land Cover Dataset**
NMD	**National Missile Defense**
NOAA	**National Oceanic and Atmospheric Administration**
NOAO	**National Optical Astronomy Observatory**
NPOESS	**National Polar-orbiting Operational Environmental Satellite System**
NPP	**NPOESS Preparatory Project**
NPR-A	**National Petroleum Reserve-Alaska**
NPS	**National Park Service**
NRAO	**National Radio Astronomy Observatory**
NRCS	**Natural Resources Conservation Service**
NREN	**NASA's Research and Education Network**
NRI	**National Resources Inventory**
NSF	**National Science Foundation**
NSO	**National Solar Observatory**
NSRL	**NASA Space Radiation Laboratory**
NSSO	**National Security Space Office**
NSTX	**National Spherical Torus Experiment**

NSWP	**National Space Weather Program**
NTIA	**National Telecommunications and Information Administration**
NWI	**National Wetlands Inventory**
NWR	**National Wildlife Refuge**

O

OHV	**off-highway vehicle**
ORNL	**Oak Ridge National Laboratory**
OSC	**Office of Space Commercialization**

P

PECAD	**Production Estimates and Crop Assessment Division**
PEL	**Payload Element Lead**
POES	**Polar-orbiting Operational Environmental Satellites**
PPPL	**Princeton Plasma Physics Laboratory**

R

R&D	**research and development**
RHIC	**Relativistic Heavy Ion Collider**
RLV	**reusable launch vehicle**
RMA	**Risk Management Agency**
ROLO	**Robotic Lunar Observatory**
RPIF	**Regional Planetary Imagery Facility**
RSA	**Russian Federal Space Agency**
RSAC	**Remote Sensing Applications Center**
RSIWG	**Remote Sensing Interagency Working Group**
RSL	**Remote Sensing Laboratory**
RWSL	**runway status light**

S

SAO	**Smithsonian Astrophysical Observatory**
SARSAT	**Search and Rescue Satellite-Aided Tracking**
SBIRS	**Space-Based Infrared System**
SBUV	**Solar Backscatter Ultraviolet**
SC	**DOE's Office of Science**
SCAWG	**Space Communication Architecture Working Group**
SDSU	**South Dakota State University**
SeaWiFS	**Sea-viewing Wide Field-of-view Sensor**
SED	**Science Education Department**
SEU	**Structure and Evolution of the Universe**
SHARE	**Safety, Health, and Return to Employment**
SHINE	**Solar, Heliosphere, and INterplanetary Environment**
SI	**International System of Units**
SLC	**Scan Line Corrector**
SMA	**safety and mission assurance; Submillimeter Array**

SMG	**Science Media Group**
SNAP	**Supernova Acceleration Probe**
SOHO	**Solar and Heliospheric Observatory**
Space PCC	**Space Policy Coordinating Committee**
SRTM	**Shuttle Radar Topography Mission**
SSAS	**Ship Security Alerting System**
SSC	**Stennis Space Center**
SSMI	**Special Sensor Microwave Imager**
SSP	**Space Shuttle Program**
SST	**Spitzer Space Telescope**
STA	**Special Temporary Authorization**
STIS	**Space Telescope Imaging Spectrograph**
SuperDARN	**Super Dual Auroral Radar Network**
SURF	**Synchrotron Ultraviolet Radiation Facility**

T

TCA	**Transformational Communications Architecture**
TDRSS	**Tracking and Data Relay Satellite System**
TFRSAC	**Tactical Fire Remote Sensing Advisory Committee**
THEMIS	**Thermal Infrared Imaging System**
TM	**Thematic Mapper**
TRACON	**Terminal Radar Approach Control**

U

UAF	**Upper Atmospheric Facilities**
UARS	**Upper Atmospheric Research Section**
UAV	**Uninhabited Aerial Vehicle**
U.N.	**United Nations**
U.S.	**United States**
USAID	**U.S. Agency for International Development**
USDA	**U.S. Department of Agriculture**
USFS	**U.S. Forest Service**
USFWS	**U.S. Fish and Wildlife Service**
USGS	**U.S. Geological Survey**
USNORTHCOM	**United States Northern Command**
UVCS	**UltraViolet Coronagraph Spectrometer**

V

VSO	**Virtual Solar Observatory**

W

WMM	**World Magnetic Model**
WRC	**World Radiocommunication Conference**
WSDM	**Weather Support to Decision Making**