Aeronautics and Space Report of the President

Fiscal Year 2006 Activities

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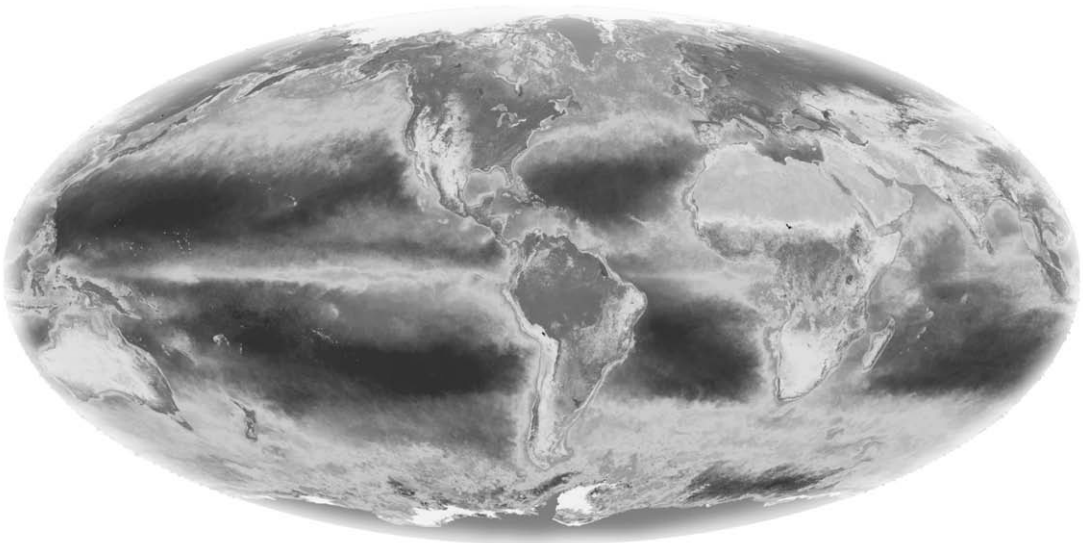

Fiscal Year 2006 Activities

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, 2005, through September 30, 2006.

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National Aeronautics and Space Administration

NASA

Exploration Systems Mission Directorate

NASA's Exploration Systems Mission Directorate (ESMD) worked toward its goal of conducting space expeditions of increasing scope that encompass the Moon, Mars, and other destinations. Building on the foundations and efforts of programs such as the International Space Station (ISS), the Space Shuttle, and the Apollo program, ESMD focused its programs and projects on fulfilling exploration architecture requirements in order to realize the Nation's vision of future space exploration.

In FY06, ESMD streamlined and reorganized to strengthen and enhance programmatic coordination, direction, and accountability. This was accomplished primarily through the transition of program management authority from Headquarters to Center program offices.

Constellation Program

ESMD has charged its Constellation Systems Program with bringing a new Crew Exploration Vehicle (CEV) into service as soon as possible after Shuttle retirement, but not later than 2014. This program currently includes the Orion CEV; Ares I, an expendable crew launch vehicle (CLV); Ares V, a heavy-lift cargo launch vehicle; spacesuits and tools required by the flight crews; and associated ground and mission operations infrastructure to support both lunar and initial low-Earth orbit (LEO) missions.

Orion CEV

As the crew exploration vehicle, Orion will carry crewmembers to the Moon, serve as the primary exploration vehicle for future missions, and will ferry astronauts (plus cargo) to and from the ISS if commercial transport services are unavailable.

In FY06, NASA continued CEV preliminary design work and began systems testing, including conducting heat shield tests at the Ames Research Center's (ARC) arc-jet facility. Johnson Space Center (JSC) engineers built a full-scale mock-up of the command module, which will be used to test systems in situ. Additionally, NASA established an intra-agency CEV Smart Buyer Team to perform trade studies and design analysis to help the CEV Project Office understand and verify requirements incorporated into the CEV Phase II solicitation. On August 31, 2006, NASA awarded the Orion development contract to Lockheed Martin, who will work with NASA to deliver Orion by 2014.

Ares I CLV

The Ares I, a solid rocket booster and upper stage, will carry Orion into LEO. In FY06, NASA subjected an Ares I partial model (including part of the upper stage, the spacecraft adapter, Orion, and the launch abort system) to over 80 wind tunnel tests at ARC. Test data provided insight into the vehicle's aerodynamic characteristics and the algorithms necessary for the flight control software that regulates the vehicle's ascent. NASA also successfully completed preliminary tests of an augmented spark igniter, a critical engine component that ignites a mixture of liquid hydrogen and liquid oxygen propellants while in flight.

Other important steps toward developing the CEV included selecting the RS-68 engine to power the core stage of the heavy-lift cargo launch vehicle, Ares V (superseding initial decision to use Shuttle main engine derivative), after life-cycle cost studies showed the engine to be the best choice.

Spacesuits

In addition to developing the Orion vehicle, JSC engineers continued work on developing a next-generation spacesuit capable of supporting exploration. In FY06, engineers conducted spacesuit configuration testing under various scenarios. One such test, an emergency "walk back" in which a crewmember walks from a stalled rover to a lunar lander or habitat, was conducted in June 2006 and provided guidance for spacesuit modifications. Set up to simulate different levels of gravity

(including lunar gravity), the test evaluated whether an astronaut could perform a strenuous walk in the spacesuit and still possess the mental and physical capabilities to operate the hatch on the lander or habitat.

Additional Field Center Activity

To capture skills and capabilities across multiple Field Centers in support of Constellation, NASA assigned the following development tasks to each of the Centers:

- ARC: develop the thermal protection systems and information technology systems for the spacecraft.
- Dryden Flight Research Center (DFRC): lead the abort flight test integration and operations.
- Glenn Research Center (GRC): manage Orion's service module work and Ares I upper stage development.
- Goddard Space Flight Center (GSFC): take on responsibility for communications, tracking, and support mechanisms.
- Jet Propulsion Laboratory (JPL): lead the systems engineering process planning as related to operations development and preparation.
- JSC: manage Constellation systems and astronaut corps, lead crew module development.
- Kennedy Space Center (KSC): develop Constellation ground systems; process and launch Orion and Ares.
- Langley Research Center (LaRC): lead Launch Abort System integration.
- Marshall Space Flight Center (MSFC): manage launch vehicle projects and launch vehicle testing.
- Stennis Space Center (SSC): test rocket propulsion systems.

Transition Activity

An important part of Constellation Program support and development is the carefully considered and planned transfer of beneficial assets from other NASA programs to Constellation. During FY06, ESMD worked with the Space Operations Mission Directorate (SOMD) to continue to develop a transition plan of action from the Space Shuttle to future space exploration vehicles that leverages for maximum

exploration benefit the rich experience base, key resources, and infrastructure of the Space Shuttle and ISS programs.

Commercial Orbital Transportation Services (COTS)

Another significant Constellation-related support effort initiated by ESMD involved the expansion of launch service providers who, after Space Shuttle retirement, will provide cargo delivery and return services to the ISS. As a result, ESMD established the Commercial Crew and Cargo Program Office at JSC that is responsible for managing NASA's COTS projects. On August 18, 2006, NASA entered into agreements with Space Exploration Technologies and Rocketplane–Kistler to demonstrate the vehicles, systems, and operations needed to move supplies, cargo, and crew between Earth and the ISS.

Advanced Capabilities Division

The Advanced Capabilities Division (ACD) addresses issues pertaining to human performance in the space environment according to recommendations made by the Exploration Systems Architecture Study (2005). Consequently, ACD refocused biomedical research and human life-support activities on new milestones and requirements that target the timely delivery of research products by creating the Human Research Program (HRP) and the Exploration Technology Development Program (ETDP).

The HRP researches and develops technologies that enable safe, reliable, and productive human space exploration. In FY06, HRP performed an exhaustive programmatic review of its focus areas (bone and muscle research, cardiology, etc.) to assess its research, data, and significance to current exploration missions. This review also served as an assessment of the forward work required to implement the Vision for Space Exploration (VSE).

The ETDP develops technologies (structures, thermal protection systems, non-toxic propulsion, life support systems, capabilities for in situ resource utilization, etc.) for future human and robotic exploration missions. In FY06, the program matured Orion CEV technologies through ground- and ISS-based research. Specifically, the Exploration Life Support project worked toward developing new concepts and technologies for removing carbon dioxide and humidity from spacecraft environments that are lighter and smaller in order to free up valuable mass on future exploration vehicles.

ETDP's Advanced Environmental Monitoring and Controls project prepared the following monitors for ISS deployment and testing: Vehicle Cabin Air Monitor (monitors gases in the air), the Electronic-Nose Monitor (detects air "events"), and a first-generation bacterial monitoring system. The program's technological contributions assisted in the successful completion of the Dust and Aerosol Measurement Feasibility Test (DAFT)—an experiment that tested fire safety technology effectiveness in detecting above-normal particle concentrations. Validated DAFT technology will fly as part of the Smoke Aerosol Measurement Experiment (SAME) in 2007.

During FY06, NASA established the Lunar Precursor and Robotic Program (LPRP) Office at MSFC. Previously called the Robotic Lunar Exploration Program, the program will conduct missions that support the overall lunar exploration effort and may include missions that investigate radiation protection and dust mitigation technologies. In 2006, LPRP's Lunar Reconnaissance Orbiter (LRO) mission, scheduled for launch in fall 2008, passed the preliminary design and confirmation reviews in which an external team reviewed plans for systems, software, and vehicle configuration.

An unmanned orbiter developed by GSFC, the LRO probe will emphasize obtaining the kind of data to facilitate returning humans safely to the Moon for extended stays. In addition to surveying lunar resources and identifying possible landing sites through high-resolution mapping, the LRO will investigate lunar topography, the characterization of deep space radiation in lunar orbit, and the lunar polar regions, including possible water ice deposits and the lighting environment. The LRO will orbit the lunar poles for one Earth year; however, its mission may be extended up to five years so that the LRO may provide a communications relay for potential ground lunar missions.

To take advantage of the LRO's cost of performance, NASA also selected a secondary lunar mission, the Lunar Crater Observation and Sensing Satellite (LCROSS), to launch with the vehicle. Designed to watch the LRO's Centaur upper stage impact a permanently-shadowed region near either the Moon's north or south poles, the LCROSS will provide spectral analysis and then impact itself into a crater. Its preliminary design review was completed in FY06.

Additional ESMD Activity: Centennial Challenges

In FY06, ESMD pursued a number of collaborative efforts to move forward exploration activities, such as the Centennial Challenges prize competitions. These competitions award prizes and intellectual property rights for achievements in creating space technologies and systems to stimulate the emerging U.S. entrepreneurial launch sector and accelerate the growth of the commercial space industry. Through these competitions, NASA continued to encourage both private sector breakthroughs across a broad range of technologies and designs and future collaborations with NASA.

Industry Collaboration

NASA's collaborations with industry included Bigelow Aerospace, which successfully launched the Genesis I inflatable Earth-orbit module—a proof-of-concept mission to show the feasibility of using inflatable structures to serve as modules for future space stations and habitats. Attractive for space exploration, inflatables offer large volume and easier launching because they weigh far less and pack up more compactly than other structures. Genesis I technology originated in the 1990s at JSC as part of NASA's TransHab project to create an inflatable module for the ISS. A second license provided Bigelow access to NASA's radiation shielding technology.

Bigelow's multiday Genesis I mission carried NASA's Genebox, a shoebox-sized prototype microlaboratory designed to fly in the near future on small-scale satellites called nanosats. Being able to perform research in such small-scale laboratories could lead to launching more experiments for less money and in less time than more costly and larger counterparts. The FY06 Genebox flight focused on microlab's systems and procedures testing.

International Collaboration

In FY06, ESMD entered into several international collaborations. For example, ESMD participated in the European Space Agency Workshop for International Cooperation for Sustainable Space Exploration held in Italy. Associate Administrator Dr. Scott Horowitz gave the keynote speech for the workshop, the goal of which was to facilitate the establishment of a global international cooperation framework to support the space exploration plans of various spacefaring nations, including the VSE and Europe's Aurora Programme.

On a more significant note, in response to a Congressional mandate and the Agency's VSE goals, ESMD initiated the development of a Global Exploration Strategy (GES) that focused on addressing two overarching issues: why we are returning to the Moon, and what we plan to do when we get there.

Through its work with the worldwide community of space agencies, academia, and private sector stakeholders, ESMD defined six primary lunar exploration themes that provide the high-level rationale for lunar exploration, along with a detailed set of over one hundred lunar exploration objectives. With the assistance of NASA's Office of External Relations, ESMD conducted discussions with both international space agencies and the private sector that broadened a mutual understanding of unique interests related to lunar exploration, identified where NASA's interests overlap with those of other organizations, and explored the roles that these groups may play in future lunar exploration efforts.

In addition to the GES development, NASA planners used the international, academic, and private sector input as the basis for sketching a U.S. blueprint for a return to the Moon. NASA's Lunar Architecture Team (LAT), chartered in May 2006, sought to concretely address the lunar return program by developing a lunar architecture that allows for the incremental buildup of a lunar outpost to support long-duration stays (i.e., <180 days) on the lunar surface beginning with the first human landing in 2020.

Space Operations Mission Directorate

The Space Shuttle has supported the Nation's space exploration programs for over 25 years, carrying crews and cargo to low-Earth orbit; performing repair, recovery, and maintenance missions on orbiting satellites; providing a platform for conducting science experiments; and supporting construction of the ISS. Until NASA retires the Space Shuttle fleet in FY10, the Agency will demonstrate its commitment to safety by promoting engineering excellence, maintaining realistic flight schedules, and fostering internal forums where mission risks and benefits can be discussed and analyzed freely.

NASA's Space Shuttle has inspired generations of schoolchildren to pursue dreams and careers in science, technology, engineering, and mathematics, and it is recognized around the world as a symbol of America's commitment to space exploration. The Space Shuttle program provides direct benefits to the Nation by

advancing national security and economic interests in space, as well as spurring technology development in critical areas such as navigation, computing, materials, and communications. Furthermore, due to its heavy-lift capacity, the Shuttle is the only vehicle capable of completing assembly of the ISS in a manner consistent with NASA's international partnership commitments and exploration research needs. The remaining Shuttle flights will be dedicated to ISS construction and a Hubble Space Telescope (HST) servicing mission.

The Space Shuttle flew two successful missions in FY06. NASA celebrated Independence Day 2006 by launching the Space Shuttle *Discovery* on mission STS-121. The second of two test flights (the first was STS-114 in July/August 2005), STS-121 helped validate the improvements made to the Space Shuttle system since the loss of *Columbia* on February 3, 2003. During the STS-121 mission, *Discovery* crewmembers conducted a series of hardware and procedural tests and delivered several tons of supplies to the ISS. The mission also delivered Flight Engineer Thomas Reiter of the European Space Agency to the ISS, increasing the Station's crew complement to three for the first time since 2003.

Atlantis (STS-115), launched on September 9, marked a return to sustained Shuttle operations and placed NASA on track to completing assembly of the ISS by 2010. *Atlantis* delivered the critical P3/P4 truss to the ISS, which will provide a quarter of the power, data, and communications services needed to operate the completed research facility. During the mission, *Atlantis* crewmembers conducted three spacewalks to attach the truss and its accompanying Solar Alpha Rotary Joint, a wagon wheel-shaped joint that will allow the solar arrays attached to the truss to turn toward the Sun.

As the Space Shuttle's retirement in FY10 approaches, the program faces two main challenges. First, NASA must maintain the skilled workforce and critical assets needed to safely complete the Shuttle manifest. Second, NASA must manage the process of identifying, transitioning, and dispositioning the resources that support the Shuttle in anticipation of the Shuttle's retirement. The Shuttle transition and phase-out effort will be complex and challenging, occurring at the same time as the Shuttle is set to carry out the most complicated sequence of flights ever attempted—carrying tons of hardware to the ISS, where astronauts and cosmonauts will conduct nearly 80 spacewalks to assemble, check out, and maintain the orbiting facility.

NASA will also conduct a fifth servicing mission to the HST to repair critical subsystems and improve the telescope's astronomical instruments.

The Space Shuttle program occupies 654 facilities and uses over 900,000 pieces of equipment. The total equipment value is over $12 billion, and this equipment is located in hundreds of Government and contractor facilities across the United States. The total facilities value is approximately $5.7 billion, which accounts for approximately one-fourth of the value of the Agency's total facility inventory. NASA currently has more than 1,200 suppliers located throughout the country. Retiring these assets and facilities, or transitioning them to new human exploration efforts, is a formidable challenge. NASA established a number of working groups and control boards to monitor and control the transition process. These boards and processes manage and reduce the risks associated with flying the Shuttle while transitioning from this craft to other exploration vehicles.

The Space Shuttle Transition and Retirement team completed initial planning in 2006 and began implementation. SOMD worked closely with ESMD to transition American human spaceflight from the Space Shuttle to the new Constellation vehicles, starting with the Orion CEV and Ares I CLV. The Shuttle's assets have been reviewed and categorized, with last use and last need date determined. Several items have already been transferred to the Constellation program for early engineering development, such as a Solid Rocket Booster Aft Skirt and Solid Rocket Booster Parachutes. Because the special aluminum-lithium metal used to make the high-performance external tank of the Shuttle was immediately needed for development of the Orion and Ares I, it was identified and transferred. SSC's A-1 Engine Test Stand conducted its final test of a Shuttle main engine, and the stand was transferred to Constellation for use in Ares engine development. In FY06, selected skilled technical workers assigned to the Shuttle program for continued fly out of the manifest began contributing to the system definition of the follow-on Constellation projects as part of the knowledge transfer between programs.

Assembly of the ISS resumed in FY06. Overall, ISS systems performance was excellent. The highlights of the year include achieving the five-year milestone of continuous human presence on ISS and returning three-member crew operations to the Station. During 2006, a total of 10 spacewalks were conducted for ISS maintenance, science, and assembly. At the end of FY06, ISS assembly was approximately 55 percent complete with over 467,000 pounds on orbit.

The Expedition 12 crew—U.S. Commander Bill McArthur and Russian Flight Engineer Valery Tokarev—replaced Expedition 11 on board the ISS on October 10, 2005. McArthur and Tokarev conducted two spacewalks safely and became the first two-person ISS crew to conduct a spacewalk in both Russian and U.S. spacesuits.

On November 2, 2005, NASA celebrated five years of continuous, onboard human presence on the ISS. In that timeframe, the ISS grew to a state-of-the-art laboratory complex and technology testbed. During more than 1,826 consecutive days, ISS crews conducted research and experiments related to areas such as physical and materials science, microgravity science, climatology, geology, manufacturing, medicine, and other life sciences. For example, knowledge gained by research and experiments in human health while exposed for long durations in a microgravity environment not only helps current crews but also provides greater capability to send humans on longer missions to farther locations. During the first five years of continuous presence, 97 people from 10 countries visited the ISS with 29 of those visitors living aboard as members of the 12 expedition crews.

The Expedition 12 crew returned to Earth on April 8, 2006, replaced by Expedition 13. Russian Commander Pavel Vinogradov, along with U.S. Flight Engineer and NASA Science Officer Jeff Williams, arrived at the ISS on March 31, 2006. During their stay on the ISS, the STS-121 Shuttle mission brought European Space Agency astronaut Thomas Reiter to the ISS, resulting in the first three-member crew complement since 2003. The crew conducted two successful spacewalks before the Expedition 13 crew—Vinogradov and Williams—were replaced by the Expedition 14 crew of U.S. Commander Michael Lopez-Alegria and Russian Flight Engineer Mikhail Tyurin in September 2006.

The Agency's Russian partners continued supporting crew and cargo transportation to the ISS. In FY06, automated Russian Progress vehicles resupplied the ISS crew three times, and Russian Soyuz vehicles transported three crews safely and reliably to and from the ISS. Each resupply vehicle contained several thousand pounds of food, fuel, oxygen, experiment hardware, spare parts, and other supplies. This cooperation enabled a continuous crew presence to be maintained on the ISS.

The resumption of regular Shuttle flights with greater transport capabilities, combined with the additional crew member, allowed greater opportunity to conduct research on the ISS. In FY06, the ISS conducted 26 experiments, such as

the Materials on International Space Station Experiments (MISSE) that investigated the effects of extremes in the space environment on various materials and coatings, and the Anomalous Long-Term Effects in Astronauts' Central Nervous System (ALTEA) experiment, which furthered our understanding of the impacts that radiation has on the human central nervous system and visual system. Through the end of FY06, approximately 650 hours of combined crew time were dedicated to research.

On March 2, 2006, the heads of the space agencies from Canada, Europe, Japan, Russia, and the United States endorsed a revision to the International Space Station's configuration and assembly sequence. Each of the partners reaffirmed their respective agency's commitment to meet their mutual obligations, to implement six-person crew operations, and to complete the assembly of the ISS by the end of the decade through an adequate number of Shuttle flights.

In June 2006, the European Space Agency's Columbus research module arrived at KSC. Columbus will expand the research facilities of the ISS by providing increased capability to conduct experiments in the areas of life science, physical science, and materials science.

Also in June, the ISS Independent Safety Task Force (IISTF) conducted its initial meeting in which it received a detailed briefing about the ISS. The IISTF was chartered to review the ISS program with the objective of discovering and assessing any vulnerabilities related to destruction of the ISS, compromising crew health, or necessitating premature abandonment. The task force met a second time in July and continued its activities into the next fiscal year.

In July 2006, Space Shuttle *Discovery* visited the ISS during mission STS-121. The Shuttle transferred more than 11,000 pounds worth of supplies and hardware to the ISS—including food, water, nitrogen, and scientific equipment—and returned more than 6,000 pounds worth of expended hardware and supplies from the ISS back to Earth.

Other highlights from *Discovery's* mission included the repair of a cable system that provides power, command, data, and voice connections to the ISS's mobile transporter (MT) rail car. (The MT is used to move a platform containing the ISS's robotic arm; movement of the arm along the truss is necessary for future assembly.) The Shuttle helped increase ISS's research capability by delivering the Minus Eighty-Degree Laboratory Freezer for the ISS (MELFI), which will be used to

store life science samples prior to their return to Earth, and the European Modular Cultivation System (EMCS), which will facilitate long-term plant growth studies. The Shuttle also delivered the U.S. Oxygen Generation System (OGS), which, when operational, will help enable an increase in ISS crew size from three to six.

In August 2006, NASA selected SpaceX of El Segundo, California, and Rocketplane-Kistler of Oklahoma City, Oklahoma, to develop and demonstrate COTS as part of an effort to open new commercial markets and pave the way for private contracts to launch and deliver cargo to the ISS. NASA plans to purchase cargo delivery services competitively in order to fill the ISS cargo requirements gap.

In September 2006, *Atlantis* arrived at the ISS for the STS-115/12A mission. *Atlantis* and its crew delivered and installed the 35,000 pound, 45-foot P3/P4 truss—an integral part of the ISS's backbone that contains the two sets of solar arrays that provide one quarter of the ISS's power. During three spacewalks, the crew installed the truss and performed the work to enable automated deployment of the solar arrays and radiator on the truss. The crew also installed a signal processor and transponder that transmits voice and data to the ground, delivered a high- definition television system that was developed in cooperation with NASA's Japanese partner, and performed other tasks to upgrade and protect the ISS systems.

During FY06, Space Communications provided high- proficiency services via the Tracking and Data Relay Satellite System (TDRSS) network and the NASA Integrated Services Network (NISN) to all NASA missions and a number of other national missions. Notable of these missions are the Shuttle and the ISS, as well as the Hubble Space Telescope and such Earth-observing satellites as Aqua and Aura. Communications services were provided also to launch vehicles including Sea Launch and the Atlas.

The Agencywide Space Communications Architecture work addressed in the FY05 report reached its first milestone, and the top-level architecture was published. This architecture sets forth a framework for NASA's space communications infrastructure consistent with the national goal to advance scientific, security, and economic interests through a robust space exploration program that encompasses all phases of our missions from launch to mission completion. The architecture also sets forth areas of emphasis for technology maturation to allow for the necessary new capabilities and capacities.

To implement the architecture most efficiently, NASA decided to centralize all space communications activities within the SOMD, meaning that Space Communications and Navigation will now encompass the total infrastructure rather than having parts distributed within the Agency. The complement of systems under this management framework now includes the Deep Space Network (DSN), the Ground Network, the Space Network, and the NISN.

Radio spectrum management remained an important focus in FY06 to ensure success of all NASA missions both aeronautical and astronautical. In support of the national space exploration goals, NASA worked with several other space-faring countries to ensure interoperability and interference free operations for lunar and Mars missions. NASA continued to work its spectrum agenda with multiple national agencies to ensure spectrum availability for future NASA activities and missions.

The SOMD Launch Services Program successfully managed the launches of three missions on expendable launch vehicles in FY06. Pluto New Horizons was launched from Cape Canaveral Air Force Station, Florida, and Space Technology 5 (ST5), Cloud-Aerosol LIDAR—Light Detection and Ranging—and Infrared Pathfinder Satellite Observation (CALIPSO), and Cloudsat were launched from Vandenberg Air Force Base, California. The 1,054-pound, piano-sized Pluto New Horizons launched January 19, 2006, on a Lockheed Martin Atlas V launch vehicle. The fastest spacecraft ever launched, it will use a Jupiter gravity-assist in February 2007 to reach Pluto in the summer of 2015 to conduct the first close-up, in-depth study of Pluto and its moons. The ST5 mission was launched on an Orbital Sciences Corporation Pegasus vehicle on March 22 for a 3-month mission. ST5 focused on technology validation using three 25-kilogram class satellites to obtain research-quality measurements of the Earth's magnetosphere and operate as a single constellation versus three separate spacecraft. On April 28, the CALIPSO and CloudSat missions launched on a Boeing Delta II launch vehicle. The two spacecraft then successfully joined NASA's "A-Train" constellation of environmental satellites. The CALIPSO satellite will examine the role that clouds and airborne particles play in regulating the Earth's weather, climate, and air quality. CloudSat is an experimental satellite using radar to measure the cloud properties to improve weather prediction and clarify climatic processes. For all of these missions, NASA competitively procured launch services from domestic commercial companies.

In an effort to encourage emerging commercial launch service providers in order to potentially provide significant cost savings to the science and exploration community, the Agency modified the NASA Launch Services contract to allow new proposers who have not yet had a successful flight. In addition, NASA conducted a study of emerging launch providers. During the summer of 2006, a cross-Agency team visited four out of an initial 40 emerging launch service providers to gather information and evaluate their maturity and ability to satisfy NASA's mission requirements.

In 2006, the Rocket Propulsion Test (RPT) Program provided a common entry point for RPT customers, including NASA, industry, the Department of Defense (DOD), other Government agencies, and academia. RPT developed and maintained a Propulsion Test Facility Management Plan "right sized" to align with the current Agency mission, evaluating what facilities should be maintained, consolidated, closed, and built to provide the appropriate propulsion test capabilities. RPT worked to increase DOD/NASA collaboration and cross utilization, to increase technical collaboration between RPT centers (i.e., cross-training development of workforce, cross-utilization of equipment and workforce, maintaining common standards and specifications), and to increase understanding of facility maintenance and operational requirements.

Science Mission Directorate

In January 2006, NASA's Science Mission Directorate (SMD) launched its spacecraft, New Horizons, on the Agency's first mission to Pluto, Pluto's moon Charon, and the Kuiper Belt. The National Academy of Sciences ranked the exploration of Pluto-Charon and the Kuiper Belt among the highest priorities for solar system exploration. Different from the inner, rocky planets (like Earth) or the outer gas giants, Pluto is a dwarf type of planet known as an "ice dwarf," commonly found in the Kuiper Belt region billions of miles from the Sun. Exploring Pluto and the Kuiper Belt is like conducting an archeological dig into the history of the outer solar system, a place where we can peek into the ancient era of planetary formation.

After a 2.88 billion mile round-trip journey, the Stardust mission returned cometary and interstellar dust particles back to Earth. Since the returned material has been unaltered since the formation of our solar system, scientists believe these dust particles will help provide answers to fundamental questions about comets and the origins of the solar system.

The Cassini spacecraft may have found evidence of liquid water reservoirs that erupt in Yellowstone-like geysers on Saturn's moon Enceladus. This discovery, along with the presence of escaping internal heat and very few (if any) impact craters in the south polar region, shows that Enceladus is geologically active today.

NASA's Mars Reconnaissance Orbiter (MRO) began its inspection of the Red Planet in fine detail. The orbiter carries six scientific instruments for examining the surface, atmosphere, and subsurface of Mars in unprecedented detail from low orbit. NASA expects to get several times more data about Mars from MRO than from all previous Martian missions combined. MRO's high data rate communications system relays information between Mars surface missions and Earth. The data regarding the history and distribution of Mars' water will improve understanding of planetary climate change and whether Mars ever supported life. The MRO also continued to evaluate potential landing sites for future missions.

On Mars, the rover Opportunity reached the rim of a hole in the Martian surface that is wider and deeper than any it had previously visited. The crater, known as Victoria, is approximately one-half mile wide and 230 feet deep. Initial images from the rover's first overlook after a 21-month journey to Victoria Crater show rugged walls with layers of exposed rock and a floor blanketed with dunes. The layers of rock offer information about the environmental conditions long ago. MRO recorded images of the rover at the site.

During hurricane season, NASA's airborne and orbiting science instruments contributed a great deal of information. NASA satellites provide critical detail in determining if and when a hurricane is forming. NASA provides researchers and forecasters with space-based observations, data assimilation, and computer climate modeling. NASA-sponsored measurements and modeling of global sea surface temperature, precipitation, winds, and sea surface height have also improved understanding of El Niño and La Niña events, which respectively tend to suppress and enhance Atlantic and Gulf hurricane development.

NASA's current hurricane-related products from orbiting science instruments include data from the Atmospheric Infrared Sounder (AIRS) on the Aqua satellite; the Microwave Limb Sounder (MLS) and the Ozone Monitoring Instrument (OMI) on the Aura satellite; the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Aqua and Terra satellites; the Tropical Rainfall Measuring Mission (TRMM) satellite; the Total Ozone Mapping Spectrometer (TOMS); and

the Ocean Color Time-Series Project. In addition, researchers investigated tropical storms and hurricanes in the eastern and mid-Atlantic Ocean regions, including those threatening Senegal and the Cape Verde Islands.

On April 28, 2006, the CloudSat and CALIPSO satellites were launched into space from Vandenberg Air Force Base in California. The CALIPSO and CloudSat are a pair of Earth-observing satellites designed to study clouds from orbit. CloudSat is an experimental satellite using radar to detect clouds and aerosols from space. CALIPSO is equipped to examine the role that clouds and airborne particles play in regulating Earth's weather, climate, and air quality. The satellites are the latest spacecraft to join NASA's A-Train constellation of environmental satellites.

Just 30 seconds after radar activation, CloudSat obtained its first image—a slice of the atmosphere consisting of a warm storm front over the North Sea and approaching Greenland. Unlike other satellite observations, the CloudSat radar image simultaneously showed the storm's clouds and precipitation—the storm front's warm air rising over colder air with precipitation below.

The first-ever millimeter wavelength radar, CloudSat's Cloud-Profiling radar is more than 1,000 times more sensitive than typical weather radar and possesses the ability to distinguish between cloud particles and precipitation. Its measurements have offered new insights into the manner in which fresh water is created from water vapor and how much of this water falls to the surface as rain and snow.

CALIPSO returned never-before-seen images of clouds and aerosols—tiny particles suspended in the air—that revealed how clouds and aerosols form, evolve, and interact with the atmosphere. In early June 2006, CALIPSO took its first images: a major lava dome collapse at the Soufriere Hills Volcano on the island of Montserrat. The dome had collapsed on May 20, 2006, sending ash clouds 55,000 feet into the sky.

In FY06, analysis of NASA data showed that Arctic perennial sea ice, which normally survives the summer melt season and remains year-round, shrank abruptly by 14 percent between 2004 and 2005. According to researchers, the loss of perennial ice in the East Arctic Ocean neared 50 percent during that time as some of the ice moved from the East Arctic to the West. Researchers have long suggested that the icy surface of the Arctic's waters is retreating due to a warming climate. Sea ice functions as an indicator of changing water, air, and sea surface temperatures, in addition to being an important factor in the continued

well-being of Arctic mammals such as polar bears. A research team that used NASA's QuikScat satellite to measure the extent and distribution of perennial and seasonal sea ice in the Arctic discovered that, while the total area of all the Arctic sea ice was stable in winter, the distribution of seasonal and perennial sea ice experienced significant changes.

In the most comprehensive survey ever undertaken of the massive ice sheets covering both Greenland and Antarctica, NASA scientists confirmed that climate warming is changing how much water remains locked in Earth's largest storehouses of ice and snow. The survey showed a net loss of ice from the combined polar ice sheets between 1992 and 2002 and a corresponding rise in sea level. The survey provided the first documentation of the extensive thinning of the West Antarctic ice shelves, an increase in snowfall in the interior of Greenland, and thinning at the edges. All these phenomena are indicators of a warming climate previously predicted by computer models.

NASA continued to monitor the polar ice sheets with the Ice, Cloud, and Land Elevation Satellite (ICESat), which uses a laser beam three times a year to measure the elevation of ice sheets with unprecedented accuracy. Scientists used ICESat data to develop Digital Elevation Models—three-dimensional high-resolution images of ice sheets in Greenland and Antarctica. ICESat's view of changes in the ice sheets provide information critical to understanding how the Earth's changing ice cover affects sea level.

NASA's Solar TErrestrial RElations Observatory (STEREO) mission lifted off at night in October 2006 from Cape Canaveral Air Force Station in Florida. With spacecraft on opposite sides of the Earth, STEREO provided three-dimensional mapping of the structure of solar storms as material leaves the Sun and flows around the planet. STEREO also compiled data on coronal mass ejections (CMEs)—solar storms that travel at nearly 1 million mph and can knock out power on Earth. The nearly identical twin observatories provided perspectives that are critical to improving our understanding of space weather and its impact on astronauts and Earth systems.

Dr. John C. Mather of GSFC received the 2006 Nobel Prize for Physics for his work that helped cement the Big Bang theory of the universe and deepened our understanding of the origin of stars and galaxies. This work was based on data from

NASA's Cosmic Background Explorer (COBE) satellite. Dr. Mather is the first NASA civil servant to receive a Nobel Prize.

Using the Chandra X-ray Observatory and the Hubble Space Telescope, scientists developed direct proof for the existence of dark matter. Hubble also found evidence of the existence of dark energy for most of the universe's history. These results provided new insights into gravity and the structure and growth of the universe.

NASA used the unique capabilities of the Hubble Space Telescope for a new class of scientific observations of the Moon. Hubble's resolution and sensitivity to ultraviolet light have allowed the telescope to search for important oxygen-bearing minerals on the Moon. Since the Moon does not have a breathable atmosphere, minerals such as ilmenite (titanium and iron oxide) may be critical for a sustained human lunar presence as they could provide a potential source of oxygen for breathing or to power rockets. The new Hubble observations are the first high-resolution ultraviolet images ever acquired of the Moon, providing scientists with a new tool to study mineral variations within the lunar crust. As NASA plans future expeditions to the Moon, such data—in combination with other measurements—will help target the best sites for robotic and human missions.

NASA's Spitzer Space Telescope made the first measurements of the day and night temperatures of a planet outside our solar system. The infrared observatory revealed that a Jupiter-like giant gas planet circling very close to its sun is always as hot as fire on one side while potentially as cold as ice on the other. The temperature difference between the day and night sides of the planet provides information about how energy flows in the planet's atmosphere. The finding represents the first time any kind of variation has been seen across the surface of an extrasolar planet.

NASA researchers using the Solar and Heliospheric Observatory (SOHO) spacecraft developed a method of seeing through the Sun to the star's far side. Because the Sun's far side faces away from the Earth, it is not directly observable by traditional techniques. This new method allows more reliable advance warning of magnetic storms brewing on the far side that could rotate with the Sun and threaten the Earth by disrupting satellites, radio communications, power grids, and other technological systems. Many of these storms originate in groups of sunspots—active regions with a high concentration of magnetic fields. Active regions situated on the near side of the Sun can be observed directly; however, previous methods

provided no information about active regions developing on the far side of the Sun. SOHO's insight into any large active regions on the far side of the Sun greatly improved forecasting of potential magnetic storms.

Aeronautics Research Mission Directorate

"We conduct the long-term, cutting-edge research needed to ensure revolutionary capabilities for both the air vehicles of the future as well as the air transportation system in which they will fly." This statement by Dr. Lisa Porter, Associate Administrator for the Aeronautics Research Mission Directorate (ARMD), captures the new focus for NASA aeronautics research set forth in FY06.

Restructuring

During FY06, ARMD underwent a comprehensive restructuring to ensure that it was enabling the pursuit of long-term, cutting-edge research for the benefit of the broad aeronautics community. The three principles that guided this restructuring were:

1. NASA will dedicate itself to the mastery and intellectual stewardship of the core competencies of aeronautics for the Nation in all flight regimes.
2. ARMD will focus its research in areas appropriate to its unique capabilities.
3. ARMD will directly address the fundamental research needs of the Next Generation Air Transportation System (NGATS) while working closely with its agency partners in the Joint Planning and Development Office (JPDO).

Using these principles, ARMD established four new programs: the Fundamental Aeronautics Program, the Aviation Safety Program, the Airspace Systems Program, and the Aeronautics Test Program. The Fundamental Aeronautics Program conducts cutting-edge research that produces innovative concepts, methods, tools, and technologies that enable the design of vehicles that fly through any atmosphere at any speed. The Aviation Safety Program focuses on developing the cutting-edge tools, methods, and technologies to improve the intrinsic safety attributes of current and future aircraft that will operate in the NGATS. The Airspace Systems Program directly addresses the Air Traffic Management (ATM) research needs of the NGATS initiative as defined by the

JPDO. The Aeronautics Test Program ensures the strategic availability and accessibility of a critical suite of aeronautics test facilities that are deemed necessary to meet aeronautics, Agency, and national needs.

ARMD established a four-step approach to putting together technical plans in the ten aeronautics projects in the four aeronautics programs. The approach was designed to facilitate the exchange of ideas and information among researchers at NASA, industry, academia, and other Government agencies, in a manner that provided fair and equal access to information and opportunities for collaboration, without providing preferential treatment to any one entity. The four steps were:

1. NASA researchers, with input from other Government agency partners, developed preliminary ten-year roadmaps for each program, including technical milestones for each project.
2. NASA released a Request for Information (RFI) to solicit interest from industry for nonreimbursable cooperative partnerships in precompetitive research that would allow NASA to leverage industry's systems-level expertise while facilitating the rapid transfer of knowledge and technology from NASA to industry. The Agency received over 230 responses from more than 100 different organizations, many of which resulted in working collaborations.
3. Using the preliminary roadmaps as a starting point, NASA researchers incorporated feedback from respondents to the RFI, as well as from colleagues in other Government agencies, to develop refined technical proposals for each project. Panels of Government subject-matter experts then reviewed and evaluated the proposals based on their technical, management, resource, and partnership plans. This rigorous proposal review process ensured that NASA had technically credible and relevant research objectives and a sound approach for pursuing these objectives. It also allowed NASA to identify research areas where it needed to supplement in-house capabilities with external expertise.
4. Finally, NASA released a NASA Research Announcement to solicit proposals, in a full and open competition, from the external community in those research areas. In the first evaluation round, the Agency

received more than 700 proposals from more than 110 universities and over 120 other organizations (companies and non-profits). More than 600 highly qualified technical and scientific experts from NASA and other organizations provided thorough reviews of these proposals, and 138 proposals representing 73 different organizations from 29 States plus the District of Columbia were ultimately selected for award.

New Aeronautics Programs

While most of FY06 was devoted to defining the research content and developing the research plans for the restructured programs, each program still achieved several technical accomplishments. The following sections are descriptions of the new programs and representative accomplishments for each.

Fundamental Aeronautics Program

The restructured Fundamental Aeronautics Program is dedicated to the mastery of the principles of flight in any atmosphere at any speed. The program develops physics-based, multidisciplinary design, analysis, and optimization (MDAO) tools that will make it possible to evaluate radically new vehicle designs and to assess, with known uncertainties, the potential impact of innovative technologies and concepts on a vehicle's overall performance. The program also develops advanced component technologies to realize revolutionary improvements in noise, emissions, and performance. The program supports the Agency's human and robotic exploration missions by advancing knowledge in aeronautical areas critical to entry, descent, and landing (EDL).

The restructured program has four projects. The Subsonic Fixed Wing Project addresses the challenge that future aircraft need to be quieter and cleaner to meet stringent noise and emissions regulations. These aircraft must also meet challenging performance requirements to make them economically viable alternatives to the existing fleet. The Subsonic Rotary Wing Project addresses the technical barriers that constrain rotorcraft from reaching widespread use in civil aviation. These barriers include range, speed, payload capacity, fuel efficiency, and environmental acceptance. The Supersonics Project conducts research to address the efficiency, environmental, and performance barriers to practical supersonic cruise, as well as the critical issue of supersonic deceleration to enable safe, precision planetary EDL of human and large science missions in any atmosphere. Because all access

to space and all entry from space through any planetary atmosphere require hypersonic flight, the Hypersonics Project tackles all the key fundamental research issues required to make hypersonic flight and reentry feasible.

The Fundamental Aeronautics Program achieved the following accomplishments in FY06:

- The Subsonic Rotary Wing Project conducted a helicopter flight test to provide data for rotorcraft acoustic analysis validation and to develop low-noise flight profiles.
- The Subsonic Fixed Wing Project completed a design of geared turbofan components that has the potential to reduce both noise and emissions relative to current engines.
- The Subsonic Fixed Wing Project completed testing of two scale Blended Wing Body (BWB) models. These tests will help validate aerodynamic and control characteristics on the BWB in preparation for flight tests at DFRC in early 2007.
- The Supersonics Project completed an initial study of the impact of atmospheric turbulence on very low-noise sonic boom waveforms.
- The Hypersonics Project, in partnership with the U.S. Air Force (USAF), completed Mach 5.0 testing of Pratt & Whitney Rocketdyne's Ground Demonstrator Engine No. 2 at LaRC's 8-Foot High Temperature Tunnel. These were the first tests of a hydrocarbon-fueled, fuel-cooled scramjet with full-authority digital engine control at hypersonic conditions.
- The Hypersonics Project completed a preliminary design review of the Hypersonic Boundary Layer Transition Flight Experiment (HyBoLT). This flight test will acquire data for the effects of protuberances and cavities on aerodynamic heating to support the Space Shuttle.

Aviation Safety Program

The restructured Aviation Safety Program provides aircraft safety-related concepts, tools, and technologies that will help ensure the safety of the U.S. Air Transportation System as it transitions to meet the future needs of the NGATS. These needs include the anticipated significant increases in air traffic, increased reliance on automation, increased diversity of air vehicles, and increased complexity

in the system. The long-range goals of the research include reduced occurrence of in-flight failures, onboard systems capable of self-correcting anomalies, improved crew workload allocation and situational awareness, and advanced flight controls to ensure flight safety during adverse flight conditions. In addition, the Aviation Safety Program technologies can be leveraged to improve the resilience of future space vehicles against the hazards of long-duration space travel, as well as operations in harsh and/or remote environments.

The restructured program has four projects. The Integrated Vehicle Health Management (IVHM) Project addresses the challenge of integrating, processing, and effectively using large amounts of information across highly integrated and complex flight critical systems. The Aircraft Aging and Durability (AAD) Project addresses the challenge of improving the operational resiliency of future structures and advanced materials. The Integrated Intelligent Flight Deck (IIFD) Project addresses the challenge of ensuring the proper integration of the human operator in a highly automated and complex operational environment. The Integrated Resilient Aircraft Control (IRAC) Project addresses the challenge of providing onboard control resilience to ensure safe flight in the presence of adverse conditions.

The Aviation Safety Program achieved the following accomplishments in FY06:

- The IVHM Project completed initial designs and a testbed of the Scalable Processor-Independent Design for Extended Reliability for IVHM architecture.
- The AAD Project developed a multiscale analysis methodology that models damage processes and more efficiently represents material behavior near crack tips. This work is critical to developing better criteria for crack growth propagation and to engineering more damage-tolerant and durable structural materials.
- The IIFD Project completed the Information Sharing Initiative demonstration in response to the industry's need for advanced tools and technologies that can query large sources of disparate data.
- The IRAC Project completed the Airborne Subscale Transport Aircraft Research (AirSTAR) testbed to support research in upset modeling, prevention, and recovery.

- The IRAC Project conducted a series of flight tests of the Intelligent Flight Control System (IFCS)—an integrated state-of-the-art direct adaptive neural network technology with flight control algorithms that correctly respond to changes in aircraft stability and control characteristics and that adjust to maintain the best possible flight performance during an unexpected failure. The tests showed that, with the direct adaptive neural networks turned on, the pitch rate of the aircraft more closely followed the pilot pitch commands than when the neural networks were off.
- Improvements were made to the Icing Research Tunnel at GRC and to a Viking S-3 aircraft to enable new icing physics research on large super-cooled droplet dynamics. Super-cooled droplets that hit freezing surfaces such as aircraft wings can form thin layers of ice and impede performance.

Airspace Systems Program

The primary goal of the Airspace Systems Program (ASP) is to develop revolutionary concepts, capabilities, and technologies in air traffic management that will enable significant increases in the capacity, efficiency, and flexibility of our National Airspace System (NAS).

Consistent with NGATS capabilities, ASP focuses on two major NGATS ATM projects: Airspace and Airportal. The NGATS ATM Airspace Project focuses on developing capabilities in traffic flow management, dynamic airspace configuration, separation assurance, and airspace super density operations, which are supported by cross-cutting, technical areas of trajectory synthesis, prediction, and uncertainty, performance-based services, and system-level design, analysis ,and simulation tools. The NGATS ATM Airportal Project focuses on developing airportal and terminal capabilities in three areas: safe and efficient surface operations, coordinated arrival/departure operations, and airportal transition and integration management. Research in the two projects will be integrated for gate-to-gate solutions.

The Airspace Systems Program achieved the following accomplishments in FY06:

- The Virtual Airspace Modeling and Simulation project completed development of its concept for enhancing future National Airspace System capacity.
- A flexible software tool called FACET (Future Air traffic management Concepts Evaluation Tool) was honored as NASA's Software of the Year for 2006. FACET's simulation capabilities can rapidly generate thousands of aircraft trajectories to enable efficient planning for traffic flows at the national level.

Aeronautics Test Program

The goal of the Aeronautics Test Program is to ensure the strategic availability of a critical suite of aeronautical test facilities that are necessary to meet the long-term needs and requirements of the Agency and the Nation. The program is responsible for the strategic and business management of the major wind tunnels and ground test facilities at ARC, GRC, LaRC, the Western Aeronautical Test Range (WATR), and for the Support Aircraft and Testbed Aircraft at DFRC. The program ensures the funding levels allow for continuous operations at its facilities and for the appropriate levels of maintenance and investments in test technology/test techniques. A major benefit of this program is that it establishes stable user pricing at its facilities.

The Aeronautics Test Program achieved the following accomplishments in FY06:

- Invested nearly $1 million in Agency-wide test technologies (aerodynamic force measurement system improvements, angle-of-attack measurement systems, virtual diagnostic interfaces, and facility control system simulations).
- Reduced maintenance backlog by $10 million, thereby cutting the number of lost-days-of-testing.
- Reached a 71 percent facility utilization goal, keeping it on track to a 90 percent utilization goal.

National Aeronautics R&D Policy

President George W. Bush issued Executive Order 13419, entitled "National Aeronautics Research and Development," on December 20, 2006. Section 1 of the order established a National Aeronautics Research and Development Policy:

> Section 1. National Aeronautics Research and Development Policy. Continued progress in aeronautics, the science of flight, is essential to America's economic success and the protection of America's security interests at home and around the globe. Accordingly, it shall be the policy of the United States to facilitate progress in aeronautics research and development (R&D) through appropriate funding and activities of the Federal Government, in cooperation with State, territorial, tribal, local, and foreign governments, international organizations, academic and research institutions, private organizations, and other entities, as appropriate. The Federal Government shall only undertake roles in supporting aeronautics R&D that are not more appropriately performed by the private sector. The National Aeronautics Research and Development Policy prepared by the National Science and Technology Council should, to the extent consistent with this order and its implementation, guide the aeronautics R&D programs of the United States through 2020.

The President's order and the National Science and Technology Council document to which it refers establish an aeronautics R&D policy for the Nation through 2020 and fulfill the request for such a policy in Section 101(c) of the National Aeronautics and Space Administration Authorization Act of 2005 (Public Law 109-155)(42 U.S.C. 16611(c)) and Section 628 of the Science, State, Justice, Commerce, and Related Agencies Appropriations Act, 2006 (Public Law 109-108).

NASA's aeronautics programs are well aligned with this first-ever national aeronautics R&D policy. The essence of the policy is captured in its overarching goal, which is to "advance U.S. technological leadership in aeronautics by fostering a vibrant and dynamic aeronautics R&D community that includes Government, industry, and academia." ARMD contributes to the realization of this national goal by:

- Focusing on high-quality, cutting-edge research that benefits the constituents of the entire aeronautics community, including foundational research across a breadth of core aeronautics competencies that supports aeronautics and space exploration activities; research in key

areas related to the development of advanced aircraft technologies and systems, including those related to aircraft safety, environmental compatibility, and fuel efficiency; and research that supports NGATS in partnership with JPDO.

- Disseminating the results of all its research to the widest practical and appropriate extent (consistent with national security and foreign policy).
- Pursuing a coordinated approach to managing the Nation's research, development, test, and evaluation (RDT&E) infrastructure.
- Fostering intellectual partnerships with industry and academia by means of cooperative Space Act Agreements and fully and openly competed research awards that emphasize true collaborations among all partners.
- Establishing strong partnerships with other Government agencies and organizations, especially the Federal Aviation Administration (FAA), DOD, and JPDO.

Forming Partnerships with Government and Industry

Creating strong intellectual partnerships with the broad aeronautics community was a focus of ARMD's activities during FY06.

NASA continued its work as a key member of the JPDO. In addition to conducting research that directly addresses the NGATS challenges, ARMD provides workforce, analysis tools, and funding directly to the JDPO in order to assist with the JPDO's responsibility of planning, coordinating, and overseeing the research and implementation for the NGATS.

In May 2006, NASA signed a new Memorandum of Understanding (MOU) with the FAA to outline cooperation in collaborative activities in aviation and space transportation. Potential areas of collaboration include aviation and space transportation safety, airspace system efficiency, environmental compatibility, and international leadership. Under this partnership, the agencies coordinate their planning efforts, and senior management monitors the collaborative activities between the two parties.

In August 2006, NASA announced an MOU forming an aeronautics research partnership between NASA and the U.S. Air Force (USAF). The agreement builds

upon the longstanding relationship between the two organizations and facilitates the exchange of research information, reduces duplication of research, and enhances long-term research planning for both organizations. The MOU covers areas such as advanced aircraft design, integrated propulsion concepts, multifunctional materials development, and advanced aviation safety technologies.

Examples of other aeronautics partnerships include:

- NASA's Fundamental Aeronautics Program continued its participation in the Versatile Affordable Advanced Turbine Engine (VAATE) Technology Program, which coordinates turbine engine science and technology (S&T) across Government agencies.
- The Aviation Safety Program participated in the Commercial Aviation Safety Team with the FAA and industry, a forum that worked to identify safety problems and solutions.
- NASA continued its participation in the Aircraft Icing Research Alliance, an international group that coordinates joint activities among NASA, the National Oceanic and Atmospheric Administration (NOAA), the FAA, Environment Canada, Transport Canada, the Canadian National Research Council, the National Defence of Canada, and the United Kingdom (UK) Defence Science and Technology Lab.

Developing the Future Workforce

On June 1, 2006, in Washington, DC, ARMD convened more than 50 representatives from academia, technical associations, and industry to explore issues associated with attracting students to aerospace and related engineering disciplines. "We all recognize that it is critically important to the U.S. aeronautics community to continue to foster new generations of highly-skilled scientists and engineers," stated Dr. Lisa Porter, ARMD Associate Administrator, in the workshop invitation.

In January 2007, NASA coordinated a followup workforce workshop in conjunction with the annual AIAA (American Institute of Aeronautics and Astronautics) Aerospace Sciences conference.

Aeronautics Research Benefits

With the restructuring of its aeronautics programs, NASA's ARMD improved its ability to serve the American public by conducting high-quality, innovative, integrated research across the fundamental disciplines of aeronautics, thereby creating revolutionary tools, concepts, and technologies that lead to a safer, more environmentally friendly, and more efficient national air transportation system. Some of the areas in which ARMD focused its efforts include:

- Reducing noise and emissions for fixed wing, rotary wing, and supersonic aircraft.
- Reducing pilot error.
- Improving the ability to avoid hazards.
- Improving fuel efficiency.
- Improving aircraft airworthiness and durability.
- Improving flight performance and control.
- Improving airspace capacity.
- Improving the collection, analysis, integration, and display of information for air and ground operations.
- Improving the viability and capabilities of our Nation's aeronautics testing facilities.

The Department of Defense

DOD

During FY06, the DOD engaged in a wide-ranging effort to develop and field next-generation space systems critical to maintaining the asymmetric advantage of the U.S. in the space domain. Modernization efforts covered the entire range of vital capabilities including missile warning, navigation, communications, weather, launch, surveillance, counterspace, and ground-based space systems.

The DOD Executive Agent for Space's Back to Basics initiative is a key component of the DOD's plan to improve space acquisitions and deliver capability to the warfighter. The Back to Basics initiative promotes a renewed emphasis on stabilizing and aligning requirements and resources, an increased emphasis on disciplined systems engineering, and moves issues of national security in space towards a more effective management system. This will deliberately spread development risk across the life cycle of the program as part of up-front acquisition strategy planning.

The Back to Basics initiative adopts an evolutionary block approach strategy to modernization, which is focused on delivering military capability through discrete value-added increments. In 2006, the USAF restructured several programs to comply with the Back to Basics strategy initiative. The GPS III, National Polar-orbiting Operational Environmental Satellite System (NPOESS), and Transformational Satellite Communication System (TSAT) programs were restructured to reduce risk and define executable block strategies, thereby delivering the best value warfighting capabilities in the least amount of time.

The Defense Support Program (DSP) continued to provide critical space-based missile warning. Preparations continued for the final DSP launch—DSP-23—in spring 2007. Development of the Space-Based Infrared System (SBIRS) progressed. To mitigate the risks associated with the SBIRS GEO (geosynchronous orbit) development, the USAF awarded risk-reduction contracts for the Alternative

Infrared Satellite System (AIRSS) flight-qualifiable infrared spectrometer (IR) sensor assemblies.

The Global Positioning System Wing (GPSW) successfully launched the second GPS IIR(M2) satellite in FY06. This new satellite provides a new military signal more resistant to jamming, as well as a new civil signal for improved position accuracy. Work also continued on the follow-on system, GPS IIF, which will provide IIR-M capabilities plus add an additional civil signal for aviation safety-of-life services, and the next-generation GPS III, which will further enhance navigation capabilities and provide increased power for improved resistance to jamming. A third civil signal compatible with the European Galileo System was also added. Consistent with Back to Basics, the GPS III program was restructured into a block approach to reduce risk, increase cost, and provide confidence in the ability of the team to meet the published schedule.

The operational DOD Military Satellite Communications (MILSATCOM) constellations—Defense Satellite Communications System (DSCS), Global Broadcast Service (GBS), Ultra High Frequency Follow-On (UFO), and Milstar—continued to provide space-based communications to U.S. and allied activities throughout the world, including operations in Afghanistan and Iraq, and to natural disaster response missions.

The DOD continued development of next generation systems to meet the ever-increasing user demand for satellite communication capabilities. The follow-on spacecraft program to DSCS and GBS, the Wideband Gapfiller System (WGS)—since renamed Wideband Global SATCOM—spacecraft Satellite Vehicle (SV) completed final assembly and integration, as well as most of the system-level testing required in preparation for launch in 2007. Additionally, in February 2006, the USAF awarded a contract for the Block II WGS SV 4-5 that will provide greater ISR (intelligence-surveillance-reconnaissance) capabilities than the Block I satellites (SV 1-3). The Advanced Extremely High Frequency (AEHF) program, the follow-on to Milstar, successfully completed its first End-To-End Communication Test with Milstar terminals in June 2006 and is on track for first launch in 2008. The Mobile User Objective System, the follow-on to UFO, executed the detailed design phase of the program.

TSAT, which will complete the AEHF constellation and thereby enable DOD net-centric operations, focused on maturing key technologies, such as the

laser-based communications components and pieces of the Internet Protocol (IP) router. TSAT is the first MILSATCOM acquisition fully implementing the USecAF's (Under Secretary of the Air Force) new Back to Basics approach to Space Acquisition and has become the flagship for future space acquisitions. The USAF awarded the TSAT Mission Operations System (TMOS) contract in January 2006 to improve development and horizontal integration with other Global Information Grid (GIG) systems.

Space Radar (SR), another key transformational space-based intelligence-surveillance-reconnaissance (ISR) program, continued risk-reduction activities on the path to KDP-B—the key decision point by which a funding baseline must be established—decision in FY09.

The NPOESS—a tri-agency program among the DOD, the Department of Commerce (DOC), and NASA—provides timely high-quality environmental data to warfighters, as well as to domestic first responders. In 2006, the NPOESS program was restructured to reduce integration risks by removing several of the planned sensors from the spacecraft. The restructured program provides data continuity and constellation management flexibility and delivers the greatest capability for the least cost.

The Evolved Expendable Launch Vehicle (EELV) program continued to provide assured access to space. In 2006, the EELV program conducted four successful launches, including two NASA missions. In addition to EELV, the USAF successfully launched the last remaining Titan IV, a National Reconnaissance Office (NRO) classified mission (B-26), culminating 50 years of Titan service to the U.S. space program. The Delta II Medium Launch Vehicle (MLV) program conducted three operational launches, including two successful DOD missions and one NASA mission. DOD missions included the Defense Advanced Research Projects Agency (DARPA) micro-satellite technology experiment (MiTEx) and the GPS II-R15(M2) modernized GPS satellite. In April 2006, the Rocket Systems Launch Program (RSLP) continued its string of 5/5 successful Minotaur launches with the DOD/DOC/Taiwanese Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) mission to study the atmosphere. The DOD also supported the March 2006 Pegasus launch of SpaceTech 5.

The USAF continued to modernize its fleet of Intercontinental Ballistic Missiles (ICBMs) with the deployment of the first Safety Enhanced

Reentry Vehicle (SERV) on an operational Minuteman III missile. In addition, by the end of 2006, the USAF had fielded 427 Guidance Replacement Program (GRP) guidance sets and 293 Propulsion Replacement Program (PRP) booster sets. Finally, the USAF conducted four successful Minuteman III flight tests within six months.

In 2006, the USAF established the Space Development and Test Wing, headquartered at Kirtland Air Force Base, New Mexico, to focus on the development and testing of orbital assets with the goal of reinvigorating innovation in the space mission area. One of the Wing's key responsibilities is the Operationally Responsive Space (ORS) effort. The ORS program has the ability to launch, activate, and employ low-cost and militarily useful satellites to provide surge capability, reconstitute damaged or incapacitated satellites, and provide timely availability of tailored or new capabilities.

Federal Aviation Administration

FAA

FY06 brought new accomplishments for scientists and engineers directed by the FAA Office of Aviation Research and Development. To accomplish their work, FAA researchers maintained many liaisons with public agencies, private companies, and academic institutions that share common safety goals at airports and aboard aircraft.

One major concern of the FAA is fire prevention. Recently, FAA scientists perfected a procedure that will greatly accelerate discovery of ultra-fire resistant plastics. The thermal analytical method known as pyrolysis-combustion flow calorimetry allows the FAA to measure quickly the flammability of hundreds of tiny milligram-sized samples of new plastics and compositions.

Researchers synthesized and evaluated nearly three dozen different polycarbonates to find one better suited to build the plastic portion of aircraft cabins. The material containing the chemical group 1,1-dichloro-2,2-diphenylethene had a lower heat release rate than the current plastics in use. This past year, fire safety researchers also contributed their expertise to writers of FAA Advisory Circular 25.856-2, which addressed the testing and installation of thermal acoustic insulation. Researchers resolved issues with evaluating burnthrough resistance and installing protection blankets that overlap. The voluntary guidelines will help airframe manufacturers, customizers, foreign regulatory authorities, and FAA-type certification engineers keep aircraft safe.

FAA researchers investigated the ignition hazard of electronic equipment near aircraft fuel tanks. They recreated real-life conditions to determine the lowest electric current needed to short circuit and spark a fire in types of steel wool.

Following several cargo fires involving lithium-ion batteries, other scientists discovered a relatively small source could ignite the power supplies for laptop computers. In looking at self-heating prepackaged meals, researchers decided flameless ration heaters release hydrogen gas, which pose a threat aboard airliners.

The FAA supported firefighting operations of the U.S. Forest Service (FS) by researching the tanker aircraft that carry loads heavier than originally intended. Loads experts determined the highest stress occurs while pilots are rushing tankers to the drop zone, not during the retardant's release. They recommend the FS adopt a structural health monitoring program and require aircraft certification to include a fatigue and damage tolerance assessment of critical areas. In addition, researchers used an international airline's loads data from more than 10,000 Boeing 777-200ER flights to analyze both ground and flight operations.

Specialists in aging aircraft continued their exploration of widespread fatigue damage by also calculating the effectiveness of 20 nondestructive inspection (NDI) techniques to detect small hidden cracks without disassembling aircraft. They created a database to share that information with engineering organizations so the aviation community could calibrate and validate methodologies for finding structural fatigue.

The FAA continued to work with industry to enhance the current life management processes for aircraft engines. In FY06, an FAA team made a giant stride to remove flawed aircraft engine components during the manufacturing process based on the probability of detection (POD). Researchers took advantage of more powerful computers to form better POD estimates of titanium alloy rotors. New probability curves for ultrasonic inspection of so-called hard alpha defects will help shape future damage-tolerant designs. Researchers developed a new version of the tool called Design Assessment of Reliability with Inspection (DARWIN®) that helps engine manufacturers enhance life management processes for rotating components in high-energy turbines. FAA researchers also worked with the Naval Air Warfare Center to release an improved version of the Uncontained Engine Debris Damage Assessment Model (UEDDAM), a tool that allows manufacturers to protect proprietary data within the code.

Several technological developments in FY06 will help engineers generate new power system protection technologies and safety guidelines. FAA-sponsored engineers developed a new risk analysis software package that checks a plane's electrical wire interconnect system (EWIS), making it easier to detect structural

hazards and potential fire sources, as well as helping certification officials analyze EWIS designs. Meanwhile, specialists at the FAA Arc Fault Evaluation Laboratory discovered a new method of quantifying damage from electrical hazards. They also determined minimum distances between certain wire bundles.

The FAA, the National Rotorcraft Technology Center, and the Center for Rotorcraft Innovation are adapting fixed-wing damage tolerance technologies for rotorcraft applications. In 2006, the FAA launched proposal solicitations and awarded multiyear research contracts to Bell Helicopter Textron Incorporation, Mississippi State University, and Vanderbilt University. The research team, which includes NASA, is finalizing a new test method to replace or supplement the existing standard test method for threshold crack growth, and the FAA has begun a rulemaking process to establish requirements for rotorcraft damage tolerance certification. In addition, researchers are analyzing U.S. Army data gathered from its Health and Usage Monitoring Systems (HUMS) in Sikorsky UH-60 Black Hawk helicopters. The FAA is collaborating with British researchers in establishing a uniform standard for rotorcraft HUMS applications.

FAA researchers continued their investigations of general aviation aircraft. They collaborated with colleagues at the South Dakota State University to find an alternative unleaded, high-octane fuel for general aviation use and evaluated an ethanol-based aviation fuel at the FAA Small Engine Test Facility. The FAA also worked closely with Cessna Aircraft to test and evaluate an ethanol derivative as a possible option to leaded aviation gasoline.

Two studies of aircraft deicing showed a Remote On-Ground Ice Detection System (ROGIDS) technology works better than the present sight and touch inspections by icing personnel. Both the FAA and Transport Canada endorsed future development of the special infrared ROGIDS camera, which captures reflections from ice on aircraft wings. Researchers also worked with Canadian counterparts in determining an acceptable window for an aircraft taking off after workers had applied anti-icing fluid when light ice pellets were falling. In addition, the FAA provided four technical notes as guidance on the variety of instruments used to analyze and measure properties of icing conditions during flights.

To help pilots avoid in-flight icing, the FAA upgraded its Current Icing Potential product during FY06. The renamed Current Icing Product shows finer detail, includes a severity index, and extends the vertical range to 30,000 feet.

Aviation weather improvements include an investment in new storm detection and nowcasting capabilities. Researchers hope to combine more than a dozen legacy forecast products into the Consolidated Aviation Storm Forecast system. The FAA also began Nationwide deployment of the Terminal Convective Weather Forecast product, a new tool that provides an animated one-hour forecast of thunderstorms—including growth and decay—and shows both summer and winter precipitation more vividly.

Researchers made other weather enhancements this past year. FAA-funded experts created the Graphical Turbulence Guidance product. Anyone may access this tool, which depicts turbulence at different altitudes, through the Web-based Aviation Digital Data Service at *http://adds.aviationweather.gov/*. A Volcanic Ash Coordination Tool, deployed in Alaska, allowed the FAA, the National Weather Service, and other agencies to synchronize efforts to avoid airspace made dangerous by volcanoes. Researchers also improved the Real-Time Verification System (*http://rtvs.noaa.gov/*) that the FAA, the National Weather Service, and the airlines' decision makers use to confirm the various forecasts by FAA weather products.

FAA and FAA-funded researchers studied possible improvements in the air traffic management system. One team is analyzing current air traffic control workstation procedures and evaluating proposed changes to both personal interfaces and automated functions to reduce controller workloads. Combining electronic flight data with the airport surface detection equipment, another research team designed two prototype touch-sensitive Electronic Flight Data Interfaces for use by local and ground controllers in airport traffic control towers. Other researchers are also investigating the roles, responsibilities, resources, and tasks of controllers' supervisors to identify the best ways to prevent operational errors. After examining exemplary performance at six Air Route Traffic Control Centers, researchers distributed an operations supervisor reference guide to the participating centers for feedback.

Researchers funded by the FAA are studying processes and procedures operations on board airliners, using a methodology to monitor and diagnose flight operations. They have conducted several thousand observations, called Line Operations Safety Audits, involving 25 carriers. Human factors researchers are also looking into how to integrate electronic flight bags onto the flight deck and the transition from paper flight operations documents to electronic ones. They published a report this past year detailing methods to help users inexpensively incorporate electronic flight bag technology.

To avoid design-induced human performance errors, the FAA has created a computer-based software program to help aircraft certification personnel ensure user-friendly flight deck technologies. The Aircraft Certification Job Aid is being deployed within the FAA, and the agency is noticing increased commercial interest in its use. In addition, human factors researchers have produced a handbook for pilots, instructors, and evaluators of technically advanced aircraft. The FAA also coordinated research to improve pilot training for automated flight decks, and regional airlines are already testing procedural changes for autopilot systems.

Because nearly three-fourths of the air traffic control workforce will reach mandatory retirement age within eight years, the Human Factors Subcommittee of the FAA's Research, Engineering, and Development Advisory Committee (REDAC) studied how to best find qualified replacements. The REDAC subcommittee contributed to the Controller Workforce Integrated Action Plan that proposes improvements in training and other areas. The FAA also recently adopted many recommendations of the REDAC Air Traffic Services Subcommittee Transition Working Group, which analyzed barriers to the transition of technology from research to operations. REDAC's Separation Standards Working Group provided the FAA Administrator with recommendations on what R&D activities would help reduce separation standards without jeopardizing safety.

At the FAA Civil Aerospace Medical Institute (CAMI), researchers are studying records of more than 20,000 pilots to determine ways in which risk may be reduced when establishing medical certification requirements. Another study, which examined how molecular changes caused by pilot fatigue affect a pilot's performance or perception, provided critical information that will help the FAA create regulations and develop intervention therapies for workers with extended-duty shifts. Also being studied are the regulations for which altitudes general aviation pilots would require supplemental oxygen.

FY06 ended with numerous improvements in the FAA's airport technology research and development program. Engineers determined the most conspicuous configuration and combination of color and materials for a screen to shield planes moving on end-around taxiways from those taking off from runways. With nearly 20 Engineered Material Arresting Systems installed to decelerate safely aircraft overrunning runways, researchers have constructed a testbed to assess their long-term environmental durability.

In addition, researchers worked to extend the lifetime of airport pavements. Rubblization testing, in which a machine breaks apart existing concrete before workers overlay a new asphalt surface, will help the FAA modernize its design guidance. Engineers conducted traffic testing on rigid (concrete) overlay pavements, updating 35-year-old data to reflect current construction practices and aircraft loads. They incorporated the latest information into a new computer program for airport runway construction managers. Called FAA Rigid and Flexible Iterative Elastic Layer Design (FAArfield 1.0), the program uses structural analysis to evaluate stresses for pavement and overlay thicknesses.

During the past year, FAA partners initiated 33 pavement and airport visual guidance projects under the Airport Cooperative Research Program. The program supports research on problems shared by airport operating authorities such as those listed below:

- Establishing data collection and use guidelines for airfield pavement management.
- Developing improved civil aircraft arresting systems or seeking alternatives.
- Developing guidebooks on the management of small airports, the implementation of airport Safety Management Systems, and the application of airport-user survey methodology.
- Studying new design concepts for airport terminal landside facilities.
- Studying use of LIDAR in obstruction surveys.
- Determining appropriate methods for using Lightning-Warning Systems.
- Analyzing hazard mitigation for runway end-approach lighting structures.
- Developing alternative aircraft and airfield deicing and anti-icing fluid formulas.

With NASA and Transport Canada, the FAA cosponsors a Center of Excellence called the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER). Ten universities comprise PARTNER, and projects are funded at three other colleges. The 50 members of PARTNER's advisory board include aerospace manufacturers; airlines and airports; National, State, and local

Governments; professional and trade associations; and nongovernmental organizations and community groups.

In 2006, PARTNER researchers completed a prototype of the Aviation Environmental Portfolio Management Tool (APMT). During the past year, PARTNER used AEDT to conduct the NOx (Nitrogen Oxide) Demonstration Study for the FAA that integrated aircraft noise readings to calculate aircraft emissions with the goal of developing benchmark relationships between noise and various emissions at the local, regional, and global levels. The FAA is expanding research into aviation-related health impacts and has asked the Harvard School of Public Health to look into air pollutants and the University of North Carolina-Chapel Hill to investigate how emissions affect air quality. In 2006, researchers made a preliminary evaluation of data from the project, measuring engine emissions that they say will shed new light on particulate matter, a known cause of respiratory diseases.

Other PARTNER projects involve an assessment of global emissions, aviation fuel conservation, finding alternative aviation fuels, a study of low-frequency noise, reducing sonic booms, implementing more gradual descent approaches, and managing airport land use.

The Commercial Space Launch Amendments Act of 2004 requires that spaceflight participants be informed of the health risks associated with short-duration spaceflight. Although much is known about how young, healthy individuals withstand the rigors of long-duration spaceflights, the medical risks of short-duration microgravity exposure are not well understood. In addition, the typical space tourist who boards a suborbital flight will not always be young and healthy. Hence, the regulatory community needs to understand better the physiological challenges of manned spaceflight to ensure optimal performance and safety for a wide range of passengers.

In 2006, the FAA Office of Commercial Space Transportation completed a research project in preparation for collecting voluntary medical data from commercial flight crew and spaceflight participants. Researchers defined the biomedical parameters recommended for preflight, in-flight, and post-flight monitoring to form a more complete understanding of the effects of suborbital flight on human physiology. The successful completion of this research project enabled the FAA to recommend to launch operators the specific types of biomedical

data—along with methodologies for their proper collection and processing—needed to clarify the physiological effects of short-duration spaceflight.

FAA researchers completed a milestone study on debris risk analysis. The agency often uses computer-based models to anticipate public casualties related to commercial launch accidents. Researchers examined how well current computer models predict the hazards to humans inside buildings subjected to external explosive forces by comparing model predictions to the outcomes of historic real-world incidents and to the results of explosive debris and blast forces on uninhabited test articles. The study found a correlation between predicted and actual results that reinforces the credibility of how insurance requirements and liability limits are currently established for commercial launch activities.

In a related 2006 project designed to further determine and refine the accuracy of debris dispersion models, FAA and NASA researchers studied characteristics of debris recovered from the Space Shuttle *Columbia* accident. As part of this study, researchers established a processing area and set up scales, cameras, computers, and other equipment for recording information into a database. Then they began to develop and optimize the procedures for the labor-intensive task of processing the large quantity of debris. The debris collection, stored in the Vehicle Assembly Building at KSC, contains over 84,000 items, most of which are associated with GPS latitude and longitude impact coordinates. The coordinates, along with physical measurements and aerodynamic features, such as shape and ballistic coefficient, can help researchers and analysts develop and refine debris dispersion models that are used for establishing safety requirements and evaluating public risk associated with space operations.

As the commercial space transportation industry evolves, so does the FAA as part of its responsibility to ensure public safety. With a focus on the rapid evolution and complexity of new launch vehicles, agency researchers are leading efforts to establish new processes to evaluate and approve the safety of critical launch vehicle components, systems, and space vehicle traffic. During FY06, researchers began a study on the separation requirements that will allow certain aircraft and commercial spacecraft to operate safely together within the national aerospace system.

In FY06, the FAA Office of Commercial Space Transportation issued licenses for eight commercial space launches. Information about the Office of Commercial Space Transportation, reports, and other documents can be found at *http://ast.faa.gov*.

Department of Commerce

DOC

In FY06, the Department of Commerce engaged in a wide variety of activities that furthered U.S. interests in aeronautics and space, including national policy development, satellite operations, technology development, measurement and calibration, international cooperation, trade promotion, and spectrum management.

At the departmental level, DOC continued its active role on the National Security Council's Space Policy Coordinating Committee (Space PCC), through the direct participation of the Deputy Secretary of Commerce and staff from NOAA, the International Trade Administration (ITA), the National Telecommunications and Information Administration (NTIA) and the Bureau of Industry and Security (BIS). Among the Space PCC's accomplishments was the release of the new National Space Policy. During the development of this policy, ITA arranged briefings to U.S. industry that ensured commercial interests were adequately addressed.

Also at the departmental level, DOC continued to play a key role on the National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee—the senior body that advises and coordinates Federal departments and agencies on matters concerning GPS and related systems. Deputy Secretary of Commerce David Sampson hosted the meetings of the Executive Committee and established the National Space-Based PNT Coordination Office to include DOC personnel and resources. In January 2006, Dr. Sampson delivered the keynote address at a media event organized by DOC and the U.S. Chamber of Commerce to announce the availability of civilian upgrades to GPS. DOC completed an economic study of the benefits of those upgrades and published the results in the trade press. DOC also contributed to the development of several strategic documents used by the Executive Committee to implement the President's 2004 policy on space-based PNT.

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, as well as various related technical working groups, and contributed to the Administration's review of the U.S. export control regime. Furthermore, NOAA is leading the Weather Integrated Product Team.

DOC participated in the review of Administration policies on aeronautical research and development through the National Science and Technology Council's (NSTC) Aeronautics S&T Subcommittee. Over the course of the year, ITA staff participated in the S&T Subcommittee development of a draft National Policy on Aeronautics Research and Development that establishes principles, goals, priorities, and processes for Federal aeronautics research and development investments and policies.

DOC continued to represent commercial remote sensing interests within the Remote Sensing Interagency Working Group (RSIWG). The 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. The group held consultations with several countries on remote sensing satellite cooperation and met with industry to understand the impact of this technology on their interests.

Within NOAA, space-related activities occurred across the entire organization. Two satellite launches during FY06 ensured continued access to geostationary and polar-orbiting satellite data for users. On May 24, 2006, GOES-N (Geostationary Operational Environmental Satellite) was successfully launched. Upon reaching final orbit, the satellite was renamed GOES-13. It is the first in a new series of geostationary satellites that feature a more stable platform, enabling improved instrument performance. NOAA instruments were launched on the European MetOp-A polar-orbiting satellite. Combined with NOAA and DOD satellites, MetOp will help provide global data regarding severe weather forecasts, disaster mitigation, and environmental monitoring. This launch ushered in a new era of U.S.-European cooperation in environmental observing.

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

and climate monitoring. The global data from these satellites are used extensively in NOAA's weather and climate prediction numerical models.

As part of the United States' contribution to the international Global Earth Observation System of Systems (GEOSS), NOAA agreed to reposition a geostationary satellite, GOES-10, over South America to provide better meteorological coverage for the region. In addition to increasing NOAA's ability to image the eastern Atlantic for hurricanes, the move helps South American meteorological centers in their efforts to improve weather forecasting and is a key demonstration of the type of international effort needed to achieve the integrated Earth observation benefits envisioned by the Group on Earth Observations (GEO).

In 2006, NOAA satellite operations and data processing groups began moving into their new home in the NOAA Satellite Operations Facility (NSOF). NSOF houses the NOAA satellite command, control functions, and data and distribution activities that are central to the NOAA mission. NSOF also houses the U.S. Mission Control Center for the Search and Rescue Satellite Aided Tracking program (SARSAT) and the National Ice Center (NIC), a joint NOAA/DOD mission to track ice floes and issue warnings to the Nation's maritime force.

In September 2006, NOAA convened a second International Commercial Remote Sensing Satellite Symposium. Attended by over 200 Government and industry leaders from around the world, this symposium brought together international business and Government leaders to explore the current policy issues facing the commercial remote sensing satellite sector. NOAA continued to license the operation of U.S. commercial remote sensing satellites and oversee technical analyses and support efforts to better characterize the remote sensing market and foreign commercial availability of these sensitive technologies. NOAA also continued to manage the Federal Advisory Committee on Commercial Remote Sensing (ACCRES).

In 2006, the GEONETCast (Group on Earth Observations Network) Implementation Group comprised of NOAA, EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites), and the World Meteorological Organization sought to identify other GEONETCast providers to assist in the development of a global dissemination capability. GEONETCast is a GEOSS-related dissemination system by which environmental in situ, airborne, and space-based observations, products, and services will be transmitted to users

through a global network of communications satellites. In August, discussions were held with China regarding its FengYunCast system, which has now been offered as a contribution to GEONETCast and will provide coverage for most of Asia, Australia, New Zealand, and the Western Pacific. A major thrust in 2006 for GEONETCast was to demonstrate an initial technical capability.

NOAA and EUMETSAT continued their cooperation in a joint polar-orbiting satellite system. Under a joint agreement, a EUMETSAT instrument has been provided to NOAA-18 and NOAA-N Prime. In return, EUMETSAT will provide and launch three European-built satellites, the MetOp series, which will carry key NOAA instruments. NOAA signed a four-partner agreement with NASA, the French Space Agency (CNES), and EUMETSAT for the Ocean Surface Topography Mission (OSTM). Under this agreement, the parties will cooperate in the development, launch, and operation of a Jason-2 satellite that will provide sea surface height information from satellite altimetry.

NOAA satellites helped save 272 people from potentially life-jeopardizing emergencies throughout the United States and its surrounding waters in 2006. This number is up from 222 the previous year. NOAA's polar-orbiting and geostationary satellites and Russia's COSPAS spacecraft, along with instruments from France and Canada, make up the powerful international Search and Rescue Satellite-Aided Tracking System, called COSPAS-SARSAT. Worldwide, the COSPAS-SARSAT system helped save over 1,500 lives in 2006.

Using commercially available, high-resolution color satellite imagery, NOAA mapped the estimated 36,800 square kilometers of shallow-water coral ecosystems in the Nation's tropical and subtropical waters. The availability of this imagery, which has minimal sun glint and cloud cover, has made possible the mapping of geographically and logistically remote areas, including the Northern Marianas and the Northwestern Hawaiian Islands.

NOAA combined satellite imagery with other data to monitor ocean conditions and predict probable harmful algal blooms (HABs) in the Gulf of Mexico. HABs, which can have devastating environmental, economic, and human health impacts, were monitored and mapped as they occurred so that officials and citizens in the impacted communities could be notified via the Internet. During FY06, 117 HAB bulletins were sent to 181 resource managers at 50 Federal, State, and local institu-

tions. NOAA's system synthesizes OrbView-2 ocean color imagery with field observations, meteorological data, and transport models to produce the HAB information.

NOAA worked with numerous satellite ocean data providers to develop an Integrated Ocean Observing System (IOOS) that routinely and continuously provided information on current and future states of the oceans and Great Lakes—from the global scale of ocean basins to local scales of coastal ecosystems. Satellites are one of the major observation platforms used by IOOS to measure parameters such as chlorophyll concentrations, sea surface temperature, winds, and other meteorological conditions.

Major improvements were made to NOAA's emergency response technology and procedures in 2006 due to the overwhelming response to NOAA's post-storm aerial imagery of areas affected by Hurricanes Katrina and Rita. As shown with Tropical Storm Ernesto, NOAA provides Web-accessible, geo-referenced imagery within six hours of survey aircraft touch down. This typically means within 18 hours of storm landfall. After Ernesto made landfall in September 2006, NOAA collected 1,131 images over northeastern North Carolina, an area damaged by extensive flooding. NOAA's emergency response technology supports safe navigation while providing critical baseline data for demarcating the Nation's territorial limits.

In the area of GPS data services, NOAA continued to expand the national and international network of Continuously Operating Reference Stations (CORS), providing highly accurate positional coordinates to GPS users through Web-based utilities such as NOAA's Online Positioning User Service (OPUS). OPUS allows users, such as professional surveyors, to submit their GPS observations via the Internet to NOAA. As a result, anyone with a single geodetic quality GPS receiver may position themselves in the National Spatial Reference System to an accuracy of two centimeters with just two hours of data.

Through CORS and OPUS, NOAA provided critical assistance to the U.S. Army in the design, development, and implementation of the Iraqi Geospatial Reference System (IGRS). The IGRS was modeled after the National Spatial Reference System used in the United States, which provides a consistent national coordinate system to support mapping, charting, navigation, boundary determination, property delineation, infrastructure development, resource evaluation surveys, and scientific applications. Currently, six Iraqi CORS are fully operational.

Army, Air Force, Marine, and civilian surveyors from many nations and disciplines used the CORS stations and NOAA's OPUS for projects in Iraq.

In response to the need to improve tropical cyclone prediction, NOAA scientists and the Cooperative Institute for Research in the Atmosphere created a new product for Tropical Cyclone Formation Probability (TCFP). Combining the vertical shear of the wind, the sea surface temperature, and images in the water vapor channel from the GOES-East satellite, the product determines the probability that a tropical cyclone will form within the next 24 hours. The product also indicates the climatological probability of cyclone formation for a given region. The product covers the area of forecast responsibility of the National Hurricane Center, including the Atlantic and eastern North Pacific Oceans. NOAA's product became operational in time for the 2006 hurricane season. In July 2006, Tropical Storm Carlotta was located in the Pacific Ocean west of Mexico. The product pinpointed an area where formation of a tropical cyclone was much more likely than average. Hurricane Daniel formed in this region the next day.

NOAA scientists developed methods to use bending angle and refractive index measurements from GPS satellites in the Global Forecast System (GFS) model. The signals from GPS satellites are used to probe the atmosphere and assist weather forecasters. Observations from the German Challenging Micro-Satellite Payload mission were used successfully to test these methods.

In June 2006, NOAA CoastWatch launched its newest region, the East Coast Node, at the Chesapeake Bay office of NOAA in Annapolis, Maryland. The new node provides a range of diverse data from multiple satellites and makes the products available via the Internet. Scientists, resource managers, and fishermen use the data to forecast atmospheric events, predict harmful algal blooms, and study the presence and distribution of fish and marine mammals along the eastern seaboard of the United States.

During FY06, NOAA's Office of Space Commercialization (OSC) reinvigorated its efforts to promote U.S. space commerce across a range of sectors, including space-based PNT, commercial remote sensing, space transportation, and space exploration. With new staffing, resources, and management, OSC re-established its capability to serve the commercial space industry's interests through policy and advocacy activities. Throughout the year, OSC engaged in significant outreach to the U.S. space industry, including speeches at various conferences

and testimony at a congressional hearing on the economic importance of space-based assets.

OSC worked closely with the State Department to develop strategies for international cooperation related to GPS, promote the U.S. message at international satellite navigation conferences, and participate in bilateral consultations with Russia on GPS and the Global Orbiting Navigation Satellite System (GLONASS). OSC also organized meetings with U.S. industry to discuss trade concerns under the auspices of the U.S.-European agreement on cooperation in satellite navigation.

Outside NOAA, the BIS, with involvement from OSC and ITA, initiated a comprehensive survey of the U.S. space industry to collect specific information regarding the industrial, economic, and financial performance of over 350 individual companies. The survey was requested by the DOD's National Security Space Office to investigate the health and competitiveness of the U.S. space industrial base with a focus on the impact of export controls.

The National Institute of Standards and Technology (NIST) performed a broad array of aeronautics and space-related measurements, technology development, and industry support activities in FY06. As described below, NIST activities addressed areas such as fire research, nanotechnology, manufacturing and materials, optics, sensors, electronics, and electromagnetics.

NIST worked with GRC to characterize and calibrate smoke measurement instrumentation for use in the SAME aboard the ISS. The instrument, which provides for better characterization of smoke particulate from various practical materials, is used for spacecraft fire safety applications and to obtain data critical to the design of reliable smoke detection for long-duration space missions and explorations. NIST performed the calibrations of the instruments using a wide range of smoke particle sizes and concentrations.

NIST initiated research in 2006 to study the feasibility of using temperature gradient focusing (TGF) to improve the detection limits of the Mars Organic Analyzer currently being developed at the University of California, Berkeley. Because organic molecules have not yet actually been detected on Mars, the detection limits that will be required for an instrument such as the Mars Organic Analyzer are not yet known. The last attempt to detect and measure organic molecules on

the surface of Mars failed because the detection limits of that instrument turned out to be inadequate.

NIST worked with the aerospace industry and their suppliers to standardize the exchange of feature-based part data between Computer-Aided Design (CAD) and computer-aided manufacturing (CAM) systems and machining systems. The international standard developed, called the Standard for the Exchange of Process Model data for Numerical Control (STEP-NC), allows the exchange of digital design data between the design team and the manufacturing team.

Engineers from NIST and GSFC had significant interactions aimed at developing ways to integrate multiple components into a functioning space qualified complex sensor.

Relating to nanotechnology, NIST signed an MOU involving GSFC, the Army Research Laboratory, Lehigh University, ARC, and the Maryland Department of Business and Economic Development. The MOU covered nanotechnology application development, facility access, and research collaborations.

The NIST Manufacturing Extension Partnership (MEP) continued its work with aerospace industry suppliers to develop a greater understanding of the technology drivers impacting the industry. The MEP system provided manufacturing improvements services to Boeing suppliers and expanded its partnership with the Boeing Company through state-supplier training programs in eight states—Alabama, Arizona, California, Florida, Illinois, Missouri, Ohio, and Washington. The Boeing Company and the MEP system reached over 1,400 aerospace suppliers to ensure they were in compliance with industry standards.

NIST hosted a meeting of the NASA Nondestructive Evaluation (NDE) working group in 2006 to further develop collaborations on new instrumentation and metrology for the evaluation of structural integrity. Joint development of acoustic emission technology also continued toward improved identification and location of defects in structural materials. This effort supports NASA's general NDE program for evaluation and inspection of aircraft and spacecraft structures with overall goals to improve sensitivity, reduce uncertainty, and ensure reliable use of NDE in the field.

NIST developed Superconducting Quantum Interference Devices (SQUID) multiplexers with two orders of magnitude greater immunity to stray fields from the environment. This immunity will be critical for systematic error control in high

precision systems to study the Cosmic Microwave Background (CMB). NIST also developed new microwave interrogation techniques to read out extremely large arrays of SQUIDs without power dissipation. These microwave SQUID multiplexers will make it possible to scale to even larger transition-edge sensor (TES) arrays.

NIST and international collaborators also successfully demonstrated prototype submillimeter imagers for the Submillimeter Common-User Bolometer Array (SCUBA-2) camera.

NIST researchers completed a series of liquid permittivity measurements for JPL. Using the improved measurement system, NIST successfully delivered in 2006 the required measurements of electrical permittivity as a function of temperature and frequency on three liquids that are needed to ensure proper calibration of the Mars Phoenix Lander's dielectric probe prior to launch, scheduled for 2007.

NIST continued to support the Shuttle program through electromagnetic shielding measurements, presenting shielding data to the Shuttle Evaluation Panel at JSC and delivering a final report to NASA that summarizes the measurement methods, shielding results, and measurement uncertainties.

The NIST measurements of the Shuttle are part of a broader NIST effort—supported by the FAA, the Transportation Security Administration (TSA), and Boeing—to support the aerospace industry through development of efficient techniques for measuring the shielding of aircraft to electromagnetic radiation. Shielding is needed to reduce interference between aircraft navigation systems, external radiation, and onboard laptops and cell phones. Over the past several years, NIST has developed new time domain techniques to enable fast, reliable measurements in scattering rich environments, such as an assembly hangar. The method has been successfully applied to a wide range of aircraft, including a Boeing 737 and 767-400, a Bombardier Global 5000 business jet, an Airborne Warning and Control System (AWACS) aircraft, and the Space Shuttle.

With strong NASA support, NIST continues production and critical compilation of atomic spectroscopic data needed by space astronomers. Critical data compilations include iron spectra; spectra of carbon, nitrogen, oxygen, argon; and spectra of other elements with relatively high cosmic abundance. The measured and tabulated spectroscopic quantities are transition energies (wavelengths), energy levels, oscillator strengths, and branching ratios.

NIST also signed a cooperative research agreement with Utah State University Space Dynamics Laboratory (SDL) to advance the development and calibration of optical sensors. The agreement emphasizes the calibration of satellite imagers and sensors that are important for climate-change research and remote sensing.

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 (EVE), part of NASA's Solar Dynamics Observatory mission. SURF III was also used to calibrate the NOAA-supported Avalanche-photodiode X-ray Spectrometer. SURF III also continued to provide the calibration standard for experimental determination of atomic radiation intensities required for interpretation of Hubble Space Telescope data.

In addition to the calibration work cited above, NIST worked with other agencies on a variety of calibration methods and standards for satellite and spacecraft sensors. With funding from NASA partner European Space Agency, NIST developed better calibration standards for the Space Telescope Imaging Spectrograph on the Hubble Space Telescope. NIST partnered with the Air Force Research Laboratory to improve the accuracy of infrared signature measurements on aerospace vehicles. NIST collaborated with NOAA and NASA on the GOES-R satellite program to aid the future calibration and validation of the satellite optical sensors, and participated in the review of calibration-validation plans and developed measurement technology to ensure that GOES-R measurements are tied to international standards.

The NIST Low Background Infrared (LBIR) facility, under a contract from the Missile Defense Agency (MDA), continued development of a cryogenic Fourier Transform Infrared Spectrometer/Transfer Standard Radiometer (MDXR) for characterizing their sensor test chambers. This will provide MDA new capability to characterize the chambers that test the performance of missile defense sensors. This work reduces the need for field testing and cuts down enormously the cost of missile defense development.

ITA continued to play an important role in promoting U.S. aerospace trade interests as the industry faced mounting competition from abroad. ITA participated in and organized trade events, as well as provided advocacy to support U.S. companies in international aerospace competitions.

ITA was involved in various aviation security activities throughout 2006, including participation in the DOC working group regarding the National Strategy for Aviation Security (NSAS). ITA authored the section on DOC roles and responsibilities within the main strategy document. ITA coordinated with interagency and other DOC staff to ensure that the strategy reflected the goals and aspirations of the NGATS Initiative. In addition, ITA facilitated greater interagency cooperation through representation in both the Global Harmonization and the Security Integrated Product Teams of the JPDO, the main coordinating body for the NGATS Initiative. ITA conducted industry outreach through various venues, including the JPDO and industry meetings.

In FY06, ITA developed new market and policy assessments for civil-use Unmanned Aerial Vehicle Systems (UAS). ITA initiated public outreach on UAS issues, including giving presentations at several industry conferences and publishing articles on the impact of Government policies on the establishment of domestic and international UAS markets.

ITA continued to support the U.S. Trade Representative (USTR) in its many meetings with the World Trade Organization and at negotiations for free trade agreements. In particular, support for the ongoing U.S./EU (European Union) trade dispute over Large Civil Aircraft has required detailed support and industry knowledge only found in the aerospace team. The USTR has been kept up to date regarding changes in the market, actions of the major stakeholders, and political analyses of the countries impacted. Close cooperation between the USTR and DOC has resulted in a united front in which industry has been well represented.

ITA continued to participate in negotiations at the Organization for Economic Cooperation and Development (OECD) aimed at revising the Aircraft Sector Understanding. The Governments of most countries with major aircraft manufacturers are signatories to the OECD Arrangement of Officially Supported Export Credits, which establishes rules for export credit agencies and the way in which they finance civil aircraft sales. The arrangement, along with an annexed Aircraft Sector Understanding, is aimed at ensuring that Government-provided export financing is not a competitive factor in civil aircraft sales competitions. ITA supported the U.S. delegation's successful efforts to engage Brazil as a full negotiating partner in these talks given the emergence of Brazilian-based Embraer as a leading exporter of

aircraft that will soon compete directly with U.S. firms. DOC has hosted ten meetings and two conference calls to consult with industry on this topic.

In June 2006, ITA organized and supported DOC's participation in the Farnborough International Air Show (London, UK) and arranged senior-level meetings for the Deputy Secretary with foreign Government and industry officials, as well as with U.S. industry executives.

In 2006, ITA initiated a dialogue with the Indian Ministry of Civil Aviation on the topic of possible reductions in the maximum age of aircraft imported into India. The Ministry of Civil Aviation is considering reducing the current limit of 15 years, which has been in place since 1993, to 12 years. In July 2006, ITA participated in a video conference with members of the Office of Directorate General Civil Aviation to discuss the proposed change in policy and possible alternatives. ITA formed an ad hoc committee comprised of DOC personnel, industry, and trade association representatives to monitor the status of the proposed change, and ITA continues to press for its nonadoption.

ITA's U.S. and Foreign Commercial Service (US&FCS) recorded 268 export successes in FY06 (a 22 percent increase from FY05) valued at over $16 billion. Commercial Service (CS) personnel impacted deals not only with small- and medium-sized companies, but also with larger corporations such as Boeing, Lockheed Martin, Raytheon, and Northrop Grumman.

ITA's Commercial Service held over 975 counseling sessions with U.S. aerospace companies, helping them to resolve international trade issues, identify new export markets, and develop strategies for entering those markets.

ITA's Commercial Service participated in 35 international trade events at which the CS Aerospace Team members provided U.S. industry support through one-on-one counseling sessions, arranging individualized buyer-to-buyer meetings with international business partners, and conducting additional export counseling services. ITA also sponsored Aerospace Products Literature Centers (APLCs) at several air shows, which offered to U.S. small- to medium-sized aerospace companies low-cost, efficient venues to explore international and niche aerospace markets. The APLCs generated hundreds of trade leads for participating companies, allowing them to enter or expand their exports to international markets. These international trade events included Asian Aerospace 2006 (Singapore), the Seoul International Air Show, the Dubai Air Show, 2006 FIDAE International Air Show (Chile), ILA

2006 Aviation Airshow (Germany), Africa Aerospace & Defense (South Africa), and the Farnborough International Air Show (London, UK).

DOC's NTIA undertook a number of policy initiatives regarding satellites and other space-based communications systems as the lead advisory agency for Federal Government telecommunications issues. NTIA provided policy guidance on issues concerning the International Telecommunications Satellite Organization and the International Mobile Satellite Organization. NTIA also continued to manage the Federal Government's assignments, nationally and internationally, for use of the radio spectrum for NOAA, NASA, DOD, and other Government agencies with satellite programs.

Department of the Interior

DOI

The U.S. Geological Survey (USGS) Landsat 5 Flight Operations Team was selected by the AIAA to receive the International Space Operations Award for Outstanding Achievement for 2006. The team received the award at the 9th International Conference on Space Operations in Rome, Italy, on June 19-23, 2006. Quoting the citation, the USGS team received the award, "for dedicated efforts in recovering Landsat 5 from two potentially mission-ending hardware anomalies and restoring the mission to full operations." In November 2005, the solar array that generates power for Landsat 5 stopped working properly; in March 2006, the downlink transmitter that sends image data to ground stations tripped a circuit breaker and stopped transmitting data. In each case, the Flight Operations Team was able to devise corrective procedures and restore the 22-year-old Landsat 5 spacecraft to full operations. As a result of the team's efforts, image data from Landsat 5 continues to be available to scientists around the globe.

The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) instrument is currently operating in SAM (Scan Angle Monitor) mode to control the motion of the scan mirror during imaging. Over time, wear of the scan mirror assembly will cause the instrument to lose the ability to synchronize the calibration shutter with the scan mirror. Current projections show this to occur between March 2007 and January 2008. As a result, changes to operations and software are necessary to switch the instrument to an alternate mode, known as "bumper mode."

In preparation for this event, on March 3 and 19, 2006, the Landsat 7 Flight Operations Team successfully tested bumper mode operations over several geometric calibration sites. Analysis of the preliminary data show the movement of one of the antennas impacted image acquisition, but this error can be corrected by the ground processing system. Additional in-depth research is underway, but

this successful bumper mode test is a positive indicator for the continuation of the Landsat 7 mission.

On December 23, 2005, the Office of Science Technology and Policy (OSTP) announced that the Landsat Data Continuity Mission (LDCM) was to be launched as a free flyer mission, with NASA responsible for the space segment and the launch segment, and the USGS responsible for communicating with and operating the LDCM satellite. The USGS is also working with NASA on science and mission requirements, operations concepts, and coordination processes. The USGS has organized a Landsat Science Team and begun research on the current and historic Landsat user community to gain user community insight, input, and advice. The USGS has been documenting its own ground system responsibilities and requirements and is working on requirements analysis, project planning, technology investigation, and implementation of earned value management for the entire USGS project.

There has been increasing demand for research utilizing all information generated from LIDAR remote sensing data. This technology is a proven mapping tool, effective for generating bare Earth Digital Elevation Models (DEM), although research on using the entire capability of this remote sensing data for scientific applications have been slowed by the high cost of collecting LIDAR and a steep learning curve on utilizing the complexities of LIDAR data.

The USGS Center for Earth Resources Observation and Science (USGS/EROS) launched a new Web portal designed to assist users in accessing LIDAR remote sensing data. The Center for LIDAR Information Coordination and Knowledge (CLICK) is designed to facilitate innovation in the scientific community by providing a place for all LIDAR users—inside and outside the USGS—to visit, ask and answer questions, and coordinate with others who are seeking or have data. By having ready access to LIDAR data and information, scientists have the opportunity to incorporate that data into their applications. CLICK's main mission is to invite people in the LIDAR community to exchange ideas, information, and even raw point cloud data for scientific needs. To learn more about CLICK, visit *http://lidar.cr.usgs.gov*.

CLICK currently holds and is disseminating over two terabytes of LIDAR data, has 127 registered members from 22 countries, and has seen over 10,000 views of the Web site since it went public in February 2006.

The USGS is offering Web-enabled access to selected Landsat satellite scenes that have been preprocessed to a consistent set of parameters, including orthorectification.

The Tri-decadal Global Landsat Orthorectified data collection is a global set of high-quality, relatively cloud-free orthorectified imagery totaling nearly 32,000 scenes. The sources of these images include Landsat 1-3 Multispectral Scanner (circa 1975), Landsat 4-5 Thematic Mapper (circa 1990), and Landsat 7 Enhanced Thematic Mapper Plus (circa 2000). Beginning in early FY06, users were able to download an entire scene, containing all bands, metadata, and header information.

Some data users, especially those requiring numerous Landsat scenes, continue to purchase these data on media. However, since the release of these data through the Global Visualization Viewer (GloVis) at *http://glovis.usgs.gov/* and Earth Explorer at *http://earthexplorer.usgs.gov/*, nearly 8,700 scenes have been downloaded over the Internet to the user.

USGS/EROS released a Web portal for the USGS Land Cover Institute on May 29, 2006. Recognizing the large and growing need for land cover data and information to support land cover research and applications, the USGS has established the Web-based Land Cover Institute. The Institute serves as an impartial advocate for land science research through seminars, workshops, and the Web site, *http://landcover.usgs.gov/*. The site is a resource for land cover scientists who use satellite images and other datasets to assess national and global land cover characteristics and to monitor the speed and manner of land cover changes.

Scientists from the Brazilian National Institute for Space Research (INPE) worked with USGS/EROS as part of an international effort to conduct a test downlink of satellite imagery from the China-Brazil Earth Resources Satellite-2 (CBERS-2). CBERS-2 was launched in October 2003 as a joint effort between INPE in Brazil and the Chinese Academy of Space Technology (CAST). On March 30 and again on March 31, 2006, INPE and USGS received and processed data from CBERS-2. This downlink marked the first time that CBERS-2 data were collected outside of Brazil and China.

With the successful downlink of CBERS-2 data to EROS, the USGS continues to evaluate the usability of the data for science and operational programs. It is part of an ongoing effort at USGS to assess the utility and value of alternative and complementary Landsat-like satellite data sources.

The USGS is also working directly with the Indian Space Research Organization to assess data from the ResourceSat-1 satellite and other satellite data providers, both internationally and in the U.S., to understand the quality and potential for data from existing and planned systems.

U.S. Fish and Wildlife Service (FWS) scientists use GPS technology and remotely sensed data in several ways to support their mission activities. The FWS has been using GPS and remote sensing data for many years to conduct trend analysis that monitors changes to vegetation and habitat in order to create new maps of their locations. In some cases, the data are used to monitor invasive species as well. Many of these applications are done in partnership with other governmental or conservation groups. Recent applications include:

- The Gulf of Maine Coastal Program is using real-time submeter GPS to conduct mapping work on seabird nesting islands off the Maine coast in coordination with the National Audubon Society and Maine Coastal Islands National Wildlife Refuge. This technology is especially useful in placing search grids designed with geographic information system (GIS) software on the islands without the use of bulky survey equipment. This helps biologists map habitat use over time and plan for future management that will aid in species recovery.
- Personnel at Big Stone National Wildlife Refuge in Minnesota, in coordination with personnel from the USGS, used infrared photo imagery and GPS units to create a digital vegetation cover map for refuge GIS applications. Refuge personnel also used GPS units to document location data for biocontrol agent releases for leafy spurge control.
- GIS support personnel from the Raleigh, North Carolina Ecological Services Field Station worked with the North Carolina Gap Analysis Project (NC-GAP) to use Landsat imagery to generate potential vertebrate species habitat data layers for a Web-based raster habitat analysis system.

Bureau of Reclamation (BOR) scientists used natural color 1-meter resolution National Agriculture Imagery Program (NAIP) imagery to map residential and commercial structures in the potential flood zone below the New Melones Dam in California's San Joaquin Valley. This map was used to derive population at risk estimates from a modeled dam failure scenario.

BOR staff also used high-definition video acquired from a helicopter to map exotic Russian olive stands along the Animas River in northwest New Mexico and southwest Colorado. Russian olive is an exotic species that consumes a significant proportion of the flow of the Animas River. The Russian olive stand maps are being used to plan efforts to remove this species from selected areas along the river.

Staff scientists continued to use Landsat TM imagery, Indian Remote Sensing satellite imagery, USGS digital orthophoto quarterquads, and NAIP imagery to map agricultural crops in the Colorado River basin, Southeastern California, and the Central Valley of California. Water managers used crop maps to verify crop fallowing agreements and combined them with crop water use coefficients and locally varying climate data to calculate agricultural consumptive water use. In the Lower Colorado River Basin, water usage by riparian vegetation was estimated in a similar fashion using riparian vegetation maps generated from Landsat TM imagery and high-resolution digital aerial imagery.

The Bureau of Land Management (BLM) has used an array of remote sensing technologies to inventory, monitor, and address concerns about resource conditions, as well as energy and mineral resource extraction on public lands. During FY06, remote sensing data from a variety of platforms, ranging from hand-held digital cameras to MODIS satellites, were combined with other spatial data from the Bureau's Enterprise Geographic Information System to support management activities associated with minerals, fire, oil and gas, cadastral, wildlife habitat, forestry, wilderness, land exchanges, recreation, rangeland, cultural resources, and hazardous materials. These projects provided information for the Federal, State, and local land managers to make better informed decisions regarding resources in the areas under their jurisdiction.

The largest source of remote sensing data used in the BLM comes from aerial photography programs. The BLM partners with the Farm Service Agency (FSA) for orthoimagery through the NAIP. The NAIP program acquires orthoimagery from airborne sensors over the entire country on an annual basis. Over the past three years, all of the Western U.S., except Arizona and Alaska, has been acquired. In FY06, Nevada, Wyoming, Utah, and Washington were acquired. As the NAIP is a national program, the FSA is able to leverage outstanding pricing for these products and pass this savings on to their partners, allowing the BLM to acquire orthoimagery coverage at a fraction of the cost than if procured separately.

BLM used the NAIP for a variety of resource management planning activities, such as changing detection and surface disturbance delineation; providing road development updates and route inventory creation; characterizing land exchanges, mining, reclamation and recreation facilities; monitoring the health of rangelands and the impact of oil and gas development; treating vegetation; and fire planning. No other dataset provides the level of flexibility and coverage that NAIP can provide.

Not all BLM's orthoimagery came from the NAIP. For example, the Oregon/Washington BLM completed acquisition of 1-foot natural color and color-infrared orthoimagery of the John Day River. The imagery provides baseline vegetation data (extent, percent cover, and category identification of forbs, shrubs, and trees) for managing the health of the river. Additionally, the BLM contracted for numerous photogrammetric projects to assist with a variety of engineering activities.

In addition to partnering with FSA, BLM continued to work with other Government and university partners to expand the use of remote sensing systems for resource management needs. Multiple groups within USGS, including the Center for EROS, Fort Collins Science Center, and the Rocky Mountain Geographic Science Center, in addition to partners Agricultural Research Service, University of New Mexico, Utah State University, USFS, and NASA all collaborated on a variety of projects with the BLM. Examples of successful partnerships include:

- Research into the use of VLSA (Very-Large Scale Aerial Photography) stereo imagery is currently being conducted in the Idaho Falls District, Upper Snake Field Office. During the summer of 2006, the Agricultural Research Service conducted an aerial flight of the Medicine Lodge project in which 1mm resolution data and 10mm stereo imagery was acquired for the project area. Approximately 5,000 images were taken on an area of 50,000 acres.
- A joint effort between USGS and Interferometric Synthetic Aperture Radar (IFSAR) collected historical water data over parts of the National Petroleum Reserve Area.
- USGS assisted BLM in the development of a protocol to delineate surface disturbance activities in oil/gas development regions using orthophotography and high-resolution satellite data.

- Utah State University and the Utah State Office explored the 30-year history of Landsat data to develop a standardized protocol for examining changes to rangelands over time.

New tools need to be developed in response to the changing demands placed on public rangeland managers tasked with overseeing vast areas. To address the spatial and temporal constraints imposed on the BLM's currently deployed decision support system, the BLM is exploring new ways of doing business. One such project, in collaboration with the University of New Mexico, is using established relationships between vegetation reactions to precipitation inputs. Predictive models of future vegetation greenness have been successfully developed by fusing high-temporal frequency remote sensing products from MODIS and precipitation products from the Next Generation Weather Radar (NEXRAD) program. When deployed, these models allow managers to assess ongoing management in a proactive and efficient manner by forecasting conditions 16 days into the future based on current vegetation and climate conditions. The ability to view forecast conditions for entire regions allows managers to target areas of concern before problems occur, thus achieving a cost-effective solution to efficiently manage public resources.

The Utah State Office is employing a combination of aerial photography and satellite imagery in order to complete a statewide inventory of forest stands in Utah. To date, nearly 4 million acres in Southwestern Utah has been mapped utilizing a new methodology of modeling vegetation with remote sensing; that is, digital orthophoto quadrangle-format natural color aerial photography and Landsat satellite imagery was evaluated in conjunction with other ancillary data, such as elevation, slope, aspect, and several vegetation indices created in the modeling process.

With the pressures of increased domestic energy development, the BLM in Wyoming is leading the way in exploring new ways of using remote sensing technologies to assist to land management responsibilities. The diversity of projects includes:

- In Southwest and Central Wyoming, BLM and its partners (Wyoming Game and Fish and the University of Wyoming) are utilizing Landsat, Quickbird, orthophotography, and other ancillary data to map land cover to characterize habitat and land cover change. Included in this mapping effort was a specific study to identify aspen stands within broader deciduous forest class to quantify changes to its distribution.

- The Wyoming State Office acquired Quickbird high-resolution satellite imagery for areas of high-profile energy development, such as Jonah Field, to quantify surface disturbance activities and assist land managers in monitoring Application for Permit to Drill (APD) processes in the area.
- In conjunction with the USGS, under the Central Region Integrated Science Partnership Funds (CRISP), BLM participated in additional projects using remote sensing data to help us better understand human impacts on the landscape. USGS is using high-resolution Quickbird imagery to develop methodologies to identify and map species, cover, and height classes of sagebrush. Physical impacts of reenacted Mormon Handcart Journeys on the Mormon Trail were studied by comparing historic and current aerial photography to quantify changes caused by modern hikers.
- Potential cheatgrass locations were identified for the Southeast Wyoming Cheatgrass Partnership. Modeling incorporated DEMs and a vegetation layer that the University of Wyoming created from Landsat imagery. Members of the partnership included the BLM, Wyoming Game and Fish, the Natural Resources Conservation Service (NRCS), FS, county weed and pest districts, and the University of Wyoming.

The Owyhee Uplands Assessment, Inventory, and Monitoring (AIM) project is one of several components of the BLM's National Monitoring Strategy, and it addresses the integration of resource inventory, monitoring, and assessment data at the regional scale. This pilot project focuses on a relatively intact sagebrush ecosystem in Idaho, Oregon, and Utah. It includes nearly 12 million acres of mostly public land administered by the BLM. The common issues that bind this area together revolve primarily around the health and resilience of its sagebrush communities, as well as the common threats or disturbance factors that bear on health and resilience. Three subprojects highlight the direction the BLM is taking to make operational use of remote sensing data to meet the requirements of the project:

1. Given the regional extent of this pilot project, a primary goal is to identify specific questions for, and uses of, remotely sensed data in documenting vegetation distributions and trends. For example, in

collaboration with Nevada Natural Heritage Program a cheatgrass (*Bromus tectorum*) canopy cover model was completed for Nevada and the Owyhee Uplands portion of Idaho and Oregon. This modeling effort used Landsat and MODIS time series imagery to construct a phenology-based model for presence and canopy cover estimates of cheatgrass. Cheatgrass is a non-native invasive species that, once established, can result in significant alterations to fire regimes of many fire-dependent Great Basin ecosystems. The resulting model and map will provide information for both current land management planning and baseline information for documenting future trends in Cheatgrass expansion. Detailed information about this project can be found at *http://heritage.nv.gov/gis/gis.htm#cheatgrass/*.

2. The Nature Conservancy (TNC) and BLM are exploring the use of various spatial modeling and image object analysis approaches as part of the Owyhee Upland project as well. This partnership has evaluated topology and hydrologic models that use various biophysical data (digital elevation models, aspect, slope, etc.) inputs to describe landforms. Specifically, scaling relationships were explored with these models to identify appropriate grain and extent required to characterize major landforms found in landscapes.
3. In collaboration with Boise State University and Battelle Pacific Northwest Laboratory, the Owyhee Uplands project evaluated the use of image object analysis to identify and classify developmental phases of western juniper (*Juniperous occidentalis*). This work involves the use of image-object analysis and NAIP data.

BLM Alaska is an active user of remote sensing data and products to fulfill its multiple-use mission. However, the main use of remotely sensed data centers around supporting these fire operations:

- The BLM Alaska Fire Service (AFS) and University of Alaska Fairbanks, Geographic Information Network of Alaska (GINA) cooperate though an MOU for the utilization of near real-time MODIS and Advanced Very High Resolution Radiometer (AVHRR) imagery and other derived products. These products include the detection of new fires, monitoring of remote fires, and the tracking of smoke plumes. In addition to imagery, GINA provides remote sensing expertise and

advice when needed to assist AFS in its mission. In return, the AFS provides GINA with fire and fuels information such as perimeters, data from the BLM Remote Automated Weather Station network, the BLM Fire Weather Index, and other fire indices.

- Landsat data were used extensively by AFS for the mapping and analysis of fires and their effects on the land. In 2006, AFS utilized Landsat for perimeter mapping of large fires. AFS has also collected Landsat images to build a statewide earthcover and Canadian Forest Fire Danger Rating System (CFFDRS) fuel model at a 30-meter scale. Previous statewide fuel models were developed using AVHRR data at a 1-kilometer scale.

USGS scientists use a variety of remotely sensed multispectral spatial data to develop statistically rigorous mapping products that assess habitat within the sagebrush ecosystem. The imagery used has a resolution range from 0.6m (Quickbird) pixels up to a 56m (IRS) pixel size. Scientists collected data for the entire State of Wyoming in FY06, and compiled initial analyses using the Quickbird imagery on a test site in Southwest Wyoming. Models will provide much needed habitat maps depicting the extent and abundance of sagebrush, herbaceous ground cover, and bare ground, which are essential to the management of habitats for sagebrush species of concern.

Concurrently, scientists spatially mapped all developments (roads, energy developments, infrastructure, etc.) using high-resolution satellite imagery to accurately depict all surface disturbance in Wyoming. Scientists have been testing models in the same habitat pilot study area in Southwest Wyoming, with the intent of developing a spatial map of infrastructure across Wyoming.

Saltcedar (*Tamarix sp.*) is a high-priority invasive species, contributing to the $120 billion economic loss suffered by the United States each year. The Invasive Species Group at the Fort Collins Science Center identified a habitat of saltcedar with very high accuracy using Landsat 7 data. This habitat map was created at a 30m resolution and was able to locate habitat patches on a scale that is useful to land managers. In conjunction with NASA, the USGS also created a national map of saltcedar (*Tamarix sp.*) habitat. This map, which used MODIS and GPS field data to locate saltcedar habitat and rank each state by area of saltcedar suitability, provided a broad look at the areas that expected to be invaded by saltcedar in the future.

The invasive species group at the USGS Fort Collins Science Center used vegetation indexes created from Landsat 7 data to locate butterfly species richness in Rocky Mountain National Park. This study suggested that spatial heterogeneity greatly influences patterns in butterfly species richness and that managers should consider wider landscape contexts in regards to butterflies.

The National Institute for Invasive Species Science in Fort Collins, Colorado, used Landsat 7 data and the Normalized Difference Vegetation Index derived from it to fill in data gaps in biodiversity, filling data gaps in poorly surveyed areas and estimating the density of native and non-native plant species. This information was used to set priorities for conservation and invasion mitigation, prevention, and control efforts.

USGS scientists obtained GPS locations from satellite transmitters on up to 24 American White Pelicans. The GPS data allow scientists to determine the locations of these pelicans throughout the year. Investigators were able to plot GPS locations on NAIP images or Landsat TM images to evaluate habitat use and assess distances between foraging and breeding sites. Together these data helped identify sites of importance to pelicans during breeding, migration, and wintering, as well as providing basic information needed to better understand the reproductive requirements of this species.

Scientists used NAIP images as a GIS map layer in studies on Valentine National Wildlife Refuge to help select sampling units and to guide deployment of transects in each of the grazing treatments (e.g., long-rest and short-rest). These images serve as the basis for field maps used during data collection. In turn, the data collected are being used to evaluate the effects of the refuge's grazing management on vegetation characteristics and on songbird diversity and density.

Scientists at the USGS's Northern Prairie Wildlife Research Center in cooperation with the U.S. Army Corps of Engineers are analyzing Quickbird imagery to inventory, map, estimate, and monitor habitat for least tern and piping plovers on four segments of the Upper Missouri River in Nebraska, South Dakota, North Dakota, and Montana. The purpose of this science is to develop cost-effective and semi-automated methods to quantify habitats for these endangered and threatened bird species. The scientists are also investigating the use of LIDAR data to quantify the elevation of the emergent sandbar habitats and changes in habitat availability with river discharge.

The USGS is at the forefront in using satellite imagery for mapping burn severity characteristics of current and historical wildfire fires. Research efforts by

USGS and National Park Service staff have resulted in a robust method to quantify size, spatial patterns, frequency, and the overall environmental effects of wildfires.

The USGS has been providing burned area emergency response (BAER) teams with rapid mapping support to minimize post-fire hazards of downstream flooding, landslides, and soil erosion. For FY06, the USGS mapped over 30 fires at the request of the BAER teams. Observations from the Landsat 5 and 7 satellites are the primary source of data for the burn severity assessments.

The USGS/EROS produces derived products for countries approved by the National Geospatial-Intelligence Agency from the Shuttle Radar Topography Mission (SRTM) data. Products completed and distributed by staff for Central America and the Caribbean and selected countries in South America can be found at *http://edcintl.cr.usgs.gov/iabin_datadownload.html/*. Derived products were prepared to assist the U.N. Food and Agriculture Organization (FAO) in flood control projects in Somalia. The products facilitate basin delineations that support land cover, conservation, specialty coffee, and biodiversity projects in Latin America and the Caribbean. These products and applications are available at the USGS/EROS and through NASA SERVIR (Sistema de Monitoreo y Visualizacion para Mesoamerica).

In cooperation with the International Institute of Tropical Forestry (IITF) and TNC, USGS/EROS scientists completed a Global Observation of Forest Cover (GOFC) project with land cover maps for seven countries in the Caribbean.

Scientists from the USGS and the National Weather Service's Climate Prediction Center are partners in the Famine Early Warning Project. The Climate Prediction Center produces daily gridded precipitation estimates for Africa and Asia by blending satellite and rain gauge observations. USGS scientists use the data to create a number of drought-monitoring products, such as a water requirement satisfaction index (crop water balance model); a standardized precipitation index (places current rainfall in historical, probable context); number of rain days/dry spells in the last 30 days; and snow/water equivalent mapping for Afghanistan.

USGS scientists investigated techniques for quantifying the effects of an urban forest in Seattle and Puget Sound, Washington, in response to environmental management issues. Neural networks were used to delineate vegetation and to estimate total biomass using Ikonos satellite imagery, natural color aerial photography and LIDAR point data.

The effectiveness of land cover mapping efforts in high arctic tundra environments composed of a mosaic of thaw lakes and drained thaw lake basins are likely significantly influenced by the spatial resolution of the available remote sensing data. Certain land cover types can most likely only be mapped with higher resolution imagery and classification techniques that utilize information from both the spectral and spatial domains. In FY06, scientists at the USGS Alaska Science Center used a 2.5m spatial resolution color infrared aerial photography mosaic to examine the changes in land cover types along a 800km2 transect of the arctic coastal plain of Alaska. Graphs of local variance for imagery resampled to resolutions ranging from 2.5m to 2000m indicated peaks in local variance at ~5m and ~500m, likely corresponding to the characteristics of within-basin polygon networks and the thaw lake basins, respectively.

Boreal lakes in Alaska provide food and habitat for a number of mammal and fishery resources. Recent observations, however, have reported that lakes in Alaska are changing. Analysis of Landsat ETM+ imagery from circa-2000 has revealed 7,356 lakes greater than 1 hectare with a total lake surface water area of 80,456 hectare. Comparing these results with a lake classification conducted from Landsat TM imagery from the mid-1980s indicates that total lake surface water area has decreased by 1.1 percent, while the number of lakes has increased by 0.9 percent over the 15-year period. The net decrease in lake surface water area with an associated increase in the number of lakes could reflect the disjunction of larger water bodies due to lake level lowering. Further, the changes that have occurred in the ecoregion have not been uniform across the study area, with some lakes expanding within a few kilometers of lakes that are drying.

The analysis of land cover trends provided important information on the understanding of rates, trends, causes, and consequences of contemporary land use and land cover change in both urban and non-urban areas. Scientists at the USGS Alaska Science Center used historical (circa 1970-1990) and recent (circa 2000) Landsat imagery and historical aerial photography (circa 1985) to document the types, rates, and temporal variability of land cover change over the Palmer, Alaska, urban area. Between 1973 and 2000, there were significant increases in urban development, mining (primarily gravel removal), and mechanical disturbance (primarily logging). These activities resulted in reductions to forest cover, agriculture, and a small amount of wetland loss.

In FY06, multidate topographic data was used for detecting and analyzing significant humanmade changes to the shape of the land surface. Historical data derived from USGS topographic maps reflected the condition of the land surface prior to disturbance, and recent data derived from satellite radar images reflect the conditions of the altered landscape. Comparing these two geospatial datasets produced maps useful for locating and studying the effects of earthmoving operations such as surface mining.

USGS/EROS and the National Drought Mitigation Center (NDMC) collaborated on the development and delivery of timely geographic drought information at a 1km resolution. The research team developed an experimental drought indicator, the Vegetation Drought Response Index (VegDRI), to provide subcounty scale information of drought effects on vegetation. VegDRI is currently available over seven states in the central U.S. Drought information is available at *http://gisdata.usgs.gov/website/Drought_Monitoring/* and *http://www.drought.unl.edu/index.html/*.

USGS scientists continued to use Landsat and Quickbird imagery, aerial photography, small format digital camera imagery, and GPS to monitor and assess the amount of on-land soil erosion and pollution to the nearshore coral reef environments in Moloka'i, Hawai'i. In addition, underwater camera imagery was used to assess the impacts of the onshore sediment loads to the coral reefs. Besides using very-high-resolution spaceborne and aerial imaging, the Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS) system was used to collect detailed bathymetry of the coral reef on the southern coastal waters of Moloka'i. These data were augmented using spectral radiometer information from the Hanalei river, Moloka'i. The spectral radiometer data were used to correlate the suspended sediment concentration values derived from the water sampling to the spectral values from the radiometer, and, ultimately, to estimates of sediment laden runoff.

To assist San Carlos Apache and White Mountain Apache Tribes in Arizona, USGS scientists used MODIS and Landsat satellite imagery and aerial photography to create a number of different reservation-wide, multidecade landscape change analysis datasets. These included the analysis of rangeland (grassland) health; evaluation of the spread of invasive species (such as introduced Cheatgrass and Red Brome; native Beargrass (*Nolina microcarpa*) and Cholla); production of a multiscale analysis of identification of existing water bodies; evaluation of ponderosa forest/stands for Bark Beetle infestation; and the development of long-term monitoring methods for use by the tribes.

Federal Communications Commission

FCC

The FCC's accomplishments for FY06 related primarily to commercial communications satellites and Earth observation satellites.

The FCC initiated two major rule-making proceedings in FY06 involving proposals to increase the radio-frequency spectrum available for the broadcast satellite service, which is the service by which most U.S. consumers receive satellite television. In one proceeding, the FCC proposed rules and policies for a new frequency band for the broadcast satellite service. In another proceeding, the FCC proposed revised rules and procedures for licensing broadcast satellite services in an existing frequency band. The FCC sought comment on the potential for interference to existing service and on rules and policies for the licensing of satellites at reduced orbital spacing.

The FCC authorized a number of commercial communication satellite launches and operations. The authorizations are as follows:

- Afrispace to launch and operate a satellite at the longitude 21º east orbit location.
- Orbimage to launch and operate an imaging satellite in LEO.
- Panamsat to launch and operate a replacement satellite at the longitude 99º west orbit location.
- Echostar to launch and operate a replacement satellite at the longitude 110º west orbit location.
- MEO to launch and operate satellites at the longitude 83º west, 121º west, 34º east, and 130º east orbit locations, and to construct three additional satellites that would operate in highly elliptical orbits.

- DIRECTV to launch and operate the DTV 9S satellite at the longitude 101º west orbit location.

The FCC granted a number of license modifications and Special Temporary Authorizations for satellite networks. Many involved routine testing or redeployment of satellites within a multiple-satellite system. Several actions, however, warrant particular mention:

- A number of companies were granted authority to continue earth station operations, previously performed using the Inmarsat 3F2 satellite, using the replacement Inmarsat 4F2 satellite.
- DIRECTV was granted authority to move the DIRECTV 2 satellite to the longitude 91º west orbit location, where the satellite would operate pursuant to a Canadian authorization and be used to enhance the reliability of Canadian service.
- SES Americom was granted authority to move the AMC-16 satellite to the longitude 118.75º west orbit location, and to transfer control of the satellite to Telesat Canada. At the new location, the satellite would operate pursuant to a Canadian authorization. The FCC also authorized reception of signals from AMC-16 in the United States in order to provide increased capacity for delivery of signals to U.S. consumers.
- Several companies were granted authority for earth station operations to provide mobile broadband service, including for any relief operations during hurricane season, using the Inmarsat 4F2 satellite.
- SES Americom was granted authority to move the Satcom C-4 satellite to the longitude 104.95 west orbit location, and to transfer control of the satellite to SES Gibraltar. At the new location, the satellite would operate pursuant to a Gibraltar authorization. The FCC also authorized reception of signals from Satcom C-4 in the United States to provide increased capacity for delivery of signals to U.S. consumers.

In addition to AMC-16 and Satcom C-4, the FCC added three non-U.S.-licensed space stations to the Commission's permitted space station list in order to allow these space stations to provide domestic and international satellite service to U.S. earth stations that have routine technical parameters. Specifically, the FCC added the Japanese Superbird-B2 satellite to its permitted list for Ku-band

frequencies, the Brazilian Brazil Star One C1 satellite to its permitted list for C- and Ku-band frequencies, and the Mexican Satmex 6 satellite to its permitted list for C- and Ku-band frequencies.

The FCC also authorized the following non-U.S.-licensed space stations to provide service in the United States on a nonroutine basis:

- One million receive-only terminals to access the Anik F3 satellite for direct-to-home services in certain Ku-band frequencies.
- Earth station to communicate with the Amazonas 1 satellite in certain Ku-band frequencies.
- One million receive-only terminals to access Mexico's Echostar 4 satellite.

As part of the FCC's efforts to coordinate international satellites, the agency reached an Administration-to-Administration Coordination Agreement for a U.S. network with Canada. In addition, the FCC reached a total of 240 Administration-to-Administration Coordination Agreements for U.S. networks with Argentina, Australia, Belarus, Canada, Malaysia, and Australia.

U.S. Department of Agriculture

USDA

Several agencies within the USDA used remote sensing data and related technologies to help fulfill departmental mandates.

FSA administers vital farm programs that ensure a strong and viable agriculture sector in the United States. FSA's geospatial and remote sensing activities play a fundamental role in the management of farm programs. The agency maintains a nationally consistent geospatial dataset representing farm and field boundaries known as Common Land Units (CLUs). FSA used CLUs, digital soil surveys, 1-meter imagery, and other datasets for program implementation and monitoring, as well as for response and recovery efforts during natural disasters.

Through the National Agriculture Imagery Program, FSA has been the primary source of aerial imagery for the USDA, acquiring imagery over the continental United States (CONUS) during the agricultural growing season. In many cases, NAIP has been the most current pre-event imagery available during a disaster event. In preparation for the 2006 hurricane season, FSA established a public Web service with the most up-to-date NAIP imagery for the southeastern and Gulf Coast States. Prepackaged hard drives available for delivery upon request were updated on a regular basis, and FSA leveraged existing technologies to provide emergency responders with a variety of methods for accessing NAIP imagery. NAIP imagery acquired over the rest of the country was available through the USDA Geospatial Data Gateway.

The Foreign Agricultural Service (FAS) Production Estimates and Crop Assessment Division served as the focal point within FAS and USDA for assessing the global agricultural production outlook and conditions that affected world food

security. The FAS also housed the USDA Satellite Imagery Archive (SIA). The SIA saved USDA millions of dollars through a USDA-wide data sharing agreement that employed a centralized acquisition strategy to eliminate redundant satellite purchases and decrease satellite data costs. 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 warnings of unusual crop conditions and production enabled more rapid and precise determinations of global supply conditions. FAS exploited many global imagery datasets, including vegetation health products from the University of Maryland and NASA, while continuing to purchase most of its satellite data from the commercial industry.

As the failures of the Landsat program continued, FAS was forced to move to alternate sensors provided by the commercial and international community. All the while, FAS supported the U.S. Government space agencies and the DOD through cooperative agreements in which the agency shared its satellite imagery and data products throughout the U.S. Government. In addition, FAS and NASA cooperated on many projects to exploit space technologies, including near-real-time satellite data acquisition and global reservoir monitoring. This Global Agriculture Monitoring partnership continued to expand to multiple universities, commercial companies, and international organizations. Information on the FAS remote sensing program could be found on the Internet at *http://www.pecad.fas.usda.gov/cropexplorer/*.

The Forest Service continued to process data from NASA's MODIS sensor on board the Terra and Aqua satellites as part of the MODIS Active Fire Mapping Program. These data were used to produce daily active wildland fire mapping products for the CONUS, Alaska, and Canada. The program utilized real time MODIS imagery and derived fire detection data for the Western United States collected by the receiving station located at the agency's Remote Sensing Applications Center (RSAC) facility in Salt Lake City, Utah, as well as additional real-time MODIS fire detection data for Alaska, Western Canada, and the Eastern United States. These products were posted on the Internet (*http://activefiremaps.fs.fed.us*), where they were accessible to national fire managers and the general public. During 2006, nearly one million users accessed the MODIS Active Fire Mapping Web site. The MODIS fire mapping products provided the interagency fire community with a synoptic view of the wildland fire situation, aiding in the strategic allocation of

firefighting resources and assets throughout the country. This service is an ongoing, collaborative effort with GSFC and the University of Maryland. Several major media entities, including the New York Times, the Cable News Network, and the Associated Press, used the maps and fire detection data.

The FS continued to work with both ARC and GSFC on a number of fire-related technologies. ARC's work included advanced sensor design and image processing from airborne platforms, as well as unpiloted aerial vehicle (UAV) development and mission profiling for tactical wildland fire mapping. The FS and ARC also collaborated on several significant flight demonstrations in 2006. A demonstration of a small UAV was held in June at Fort Hunter Liggett Garrison near King City, California. This demonstration utilized four vendor-supplied and vendor-operated UAVs flying over controlled burns during the day and night. Over 100 invited observers from the wildfire, aviation, and academic communities attended the event. In October 2006, a General Atomics (GA-ASI) Altair flew for 22 hours over Yosemite National Park and Inyo National Forest, providing near-real-time imagery in a Google Earth viewer throughout the course of the overflight. This flight was a collaborative effort between ARC, RSAC, DFRC, and GA-ASI. In addition, the Altair was flown over the Esperanza Fire in late October after the State of California requested an emergency "certificate of authorization" from the FAA. The unmanned aircraft flew over the fire for 16 hours overnight on October 28-29, taking infrared thermal images and other data with a sensor on its underbelly. The data was transported via satellite link to ARC at Moffett Field near San Jose, California, where it was transferred onto topographical maps and sent to Esperanza fire incident commanders within minutes. The FS continued to work with GSFC on a satellite communications system that will enable rapid transmission of FS airborne thermal image products to incident command personnel during the fire season.

The mission of the National Agricultural Statistics Service (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 five years, NASS conducts the Census of Agriculture—a comprehensive statistical summary of many aspects of U.S. agriculture. Remote sensing data and techniques are used to improve the accuracy of NASS statistics. During FY06, 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. For example, 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 and supplemental samples that was used to measure the completeness of the Agricultural Census in 2007. In addition, NASS constructed a new area-based sampling frame in Washington. Another project—the Remote Sensing Acreage Estimation Project—analyzed Landsat data over 11 States from the 2005 crop season and collected data for the 2006 crop season in 12 Midwestern and Mississippi Delta States. This project used the ResourceSat-1 Advanced Wide Field Sensor (AWiFS) to produce crop acreage estimates for major crops at the State and county levels, and a crop-specific categorization in the form of a digital mosaic of scenes distributed to users on DVD.

NASS also forged new remote sensing partnerships during FY06, as well as maintained existing partnerships. These partnerships included:

- Existing and new agreements with state organizations and universities to decentralize ResourceSat-1 AWiFS processing and analysis to produce additional or enhanced crop-specific categorizations.
- Existing agreements to maintain a GIS of the commercial citrus groves in Florida.
- A continuing partnership with the USDA's Agricultural Research Service (ARS) to conduct research using MODIS sensor data for setting small-area yield estimates in several Mid-Western States.

NRCS was the primary Federal agency working with private landowners to help protect and conserve the Nation's natural resources. For over 50 years, NRCS has used remote sensing products to carry out conservation programs. Aerial and satellite imagery processed in the form of digital orthoimagery remained the primary remote sensing product used by NRCS to inventory, monitor, manage, and assess our natural resources in GIS Nationwide. By partnering with FSA and other Federal and State agencies, NRCS acquired statewide one-meter or better resolution orthoimagery for 11 States and parts of Alaska and Hawai'i. All orthoimagery purchased by NRCS was made available to internal users and the general public via the USDA Geospatial Data Gateway Web site.

NRCS contracted for high-resolution aerial photography (4" ground resolving distance) over 70,000 confidential statistical sites to collect natural

resource data for the annual National Resources Inventory (NRI) program. One such contract was used to monitor Wetland Reserve Program (WRP) easements in 17 States. In addition, the NRCS awarded a multiyear contract for remote sensing services, NRI data collection, and WRP monitoring at three newly established remote sensing laboratories. High-resolution satellite imagery was also acquired for conducting the NRI in Alaska and Hawai'i. NRCS' use of Landsat has dropped significantly due to Landsat operational problems. NRCS continued to purchase licensed IFSAR digital elevation data at five-meter posting to use in automating soil survey three-dimensional mapping and improving the overall accuracy of digital orthoimagery.

The USDA Animal and Plant Health Inspection Service (APHIS) used remote sensing to support agency emergency and regulatory programs. The Centers for Epidemiology and Animal Health (CEAH) and the Center for Plant Health Science and Technology (CPHST) within APHIS sought to expand the understanding and application of remote sensing data within the animal and plant health and protection fields. AVHRR data from NOAA polar-orbiting satellites, Landsat 5 and Landsat 7 Thematic Mapper data, MODIS imagery, Ikonos data, Quickbird imagery, and aerial photography were used within APHIS for various projects.

Remote sensing data were used in several CEAH projects. CEAH used AVHRR data to evaluate habitat for the biting midge vectors of bluetongue viruses in the U.S., Italy, central Europe, and northern Africa. CEAH also used MODIS imagery to identify wetland areas relative to bird band recovery data as part of an H5N1 Avian Influenza surveillance effort. To examine factors that might lead to the mutation of enzootic forms of Venezuelan Equine Encephalitis (VEE) that make the virus more pathogenic and lead to epizootic transmission, CEAH used Landsat Thematic Mapper data to evaluate the role of deforestation in the natural cycle of VEE virus in Iquitos, Peru. A second study to develop a predictive model to forecast when and where epizootics of VEE virus might occur used Landsat imagery to characterize coastal vegetation and mosquito habitat in Chiapas, Mexico. These remote sensing studies facilitated the understanding of disease transmission and helped in planning for a U.S. response to a possible outbreak of VEE virus. CEAH also used Ikonos, Quickbird, and aerial photography to evaluate areas in Southwest Texas where cattle fever ticks might be introduced into the U.S. on wildlife species

crossing the Rio Grande and entering the quarantine zone. A similar project used this imagery to evaluate habitat for feral swine.

CPHST utilized remote sensing hyperspectral imagery to discriminate ash trees from other deciduous trees, in order to identify ash trees under infestation by the emerald ash borer (EAB) beetle. CPHST also evaluated pattern recognition software that performs automated feature extraction from three band aerial photographs in order to extract various landscape features that support invasive weed distribution analysis. To evaluate the use of remote sensing data as a performance measure of a biocontrol effort, CPHST used airborne collected hyperspectral image data to examine the effectiveness and accuracy of remote sensing tools in mapping the distribution of saltcedar (*Tamarix sp.*) in a biocontrol study site. CPHST developed remote sensing techniques that monitored the establishment and spread of biological control insects at a release site and measured the changes of the targeted weed.

The Economic Research Service (ERS) used a host of derived datasets, such as USGS's National Land Cover and Global Land Cover datasets, to quantify domestic and international agricultural efficiency, as well as to track environmental responses to changes in agricultural markets and policies. ERS also used USDA imagery-derived products—FSA's CLU and Conservation Reserve Program boundaries, NRCS' detailed soils database and NRI data, and NASS' survey area frames and cropland datasets—to support a host of research projects informing natural resource agricultural policy decisions.

Through the ERS farm and field-level survey program, ERS collected and tabulated information on the usage of remote sensing and GPS technologies by farmers.

In 2006, the Risk Management Agency developed and offered a pilot Group Risk Protection risk management program for pasture, rangeland, and forage. This pilot program, developed to provide livestock producers with the ability to purchase insurance protection for losses of forage produced for grazing or harvested for hay, was based on vegetation greenness derived from satellite data. This program is intended to become a risk management tool for the 588 million acres of U.S. pastureland and the 61.5 million acres of hayland. Beginning with the 2007 crop year, the pilot program will be available for a limited number of acres for testing in selected States.

The Vegetation Index used the Normalized Difference Vegetation Index (NDVI) data from the U.S. Geological Survey Earth Resources Observation and

Science data center. The NDVI is an alternative measure of vegetation greenness and correlated to forage condition and productive capacity in approximately 4.8 by 4.8 mile grids. In general, the healthier the plants are in a given grid, the higher the NDVI value. With this plan of insurance, producers could select one or more three-month time periods, called index intervals, that represent a producer's forage species production. The losses calculated using the Vegetation Index were indemnified based on the deviation from normal within the grid and the index interval(s) selected.

ARS, the primary research agency for USDA, conducts basic and applied research to solve problems affecting food and fiber production. ARS scientists researched how remote sensing could be used to address water quality, soil productivity, and global change issues, as well as detecting and mapping invasive species and managing crops. The sensor systems used included on-the-go sensors mounted on field equipment, airborne systems such as UAVs, and satellite systems. ARS partnered with NASA and other USDA agencies (e.g., NRCS, FAS, NASS) to develop operational systems that would help the agencies carry out their missions.

Hydrology was a major emphasis of ARS remote sensing research. Thermal infrared data were explored as a means of mapping evapotranspiration and plant moisture stress across CONUS. These procedures appeared to work well on spatial scales appropriate for use by farmers seeking to improve irrigation efficiency and at regional and continental scales for quantifying and mapping drought. Analysis of data collected during soil moisture experiments addressed operational algorithm development for future satellites to be used in soil moisture mapping. The research also developed algorithms that will improve the accuracy of the satellite-based soil moisture estimates.

Several ARS laboratories worked on procedures to parameterize hydrologic models with remotely sensed information. Forested wetlands mapping using radar, biomass mapping for nutrient content using optical data, and mapping and measuring tillage intensity at multiple scales were investigated as inputs to water quality models. A combined modeling and remote sensing approach was used to infer distributed soil hydraulic properties. Assimilation of remotely sensed soil moisture from satellite into simple water balance models was shown to improve the model's ability to forecast runoff from storm events. Much of this research was conducted at the request of NRCS to satisfy NRI and conservation program requirements.

National Science Foundation

NSF

The National Science Foundation 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 (OPP), 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 nearby stars and planets, including our own planetary system.

In FY06, the NSF supported the development of advanced technologies and instrumentation for astronomical sciences, in addition to providing core support for the optical and radio observatories whose state-of-the-art instrumentation and observing capabilities are accessible to the community on the basis of scientific merit. The NSF's national astronomical facilities include 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 also served as the executive agency for the Gemini Observatory—an international partnership operating optical/infrared telescopes in both the Northern and Southern Hemispheres—by providing the U.S.'s share of support for the program.

In partnership with Europe, Canada, and Japan, construction continued on the Atacama Large Millimeter Array (ALMA), an interferometer located near San Pedro de Atacama, Chile. FY06 saw the completion of project rebaselining—in which the complement of antennas was reduced from 54 to 60—and the approval

of a new budget. The ALMA site camp currently houses the 200-300 construction workers erecting operations buildings at the mid-level (9000 feet elevation) and high-level (17000 feet elevation) sites. The front-end integration center at NRAO in Charlottesville, Virginia, is operational, and preproduction models of each of the first four receivers have been integrated into the first cryostat.

In FY06, the NSF's Division of Astronomical Sciences and the Office of Multidisciplinary Activities continued to fund a four-year technology development and design effort for the Large Synoptic Survey Telescope (LSST). The LSST will be a 6.5-meter effective aperture telescope with a field of view exceeding three degrees. In addition, the LSST will use a three-gigapixel camera to repeatedly image the entire accessible sky, producing approximately 20 terabytes of data nightly. The science goals of the LSST project are extremely broad, spanning the fields of cosmology, galactic structure, and solar system astronomy. The LSST will undertake both a census of distant (trans-Neptunian) solar system objects, as well as surveys of near-Earth and potentially hazardous asteroids. Over a ten-year lifetime, the LSST should provide a 90-percent complete sample of potentially hazardous objects with diameters greater than 250 meters and an 80-percent sample down to 140 meters.

The NSF's Division of Astronomical Sciences, in collaboration with the Division of Atmospheric Sciences, continued support for the development of the Advanced Technology Solar Telescope (ATST), the next-generation U.S. ground-based solar telescope. The ATST, a collaboration of scientists from 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. In FY06, the ATST advanced to the Readiness Stage in NSF's Major Research Equipment Facilities Construction queue. The ATST Site Selection and Science Working Groups selected the Haleakala Observatories on the Hawaiian island of Maui as the preferred site for the telescope. Selection criteria included measurements of atmospheric turbulence, fraction of clear skies, and sky brightness.

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, partial support to ground-based solar telescopes and instruments, and a wide-ranging portfolio of basic research in space physics. 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. In addition, a formal NSF Science and Technology Center called the Center for Integrated Space Weather Modeling (CISM) continued to develop and test an end-to-end computer simulation for space physics research and applications. CISM's coupled models simulated the processes by which energy from the Sun and solar wind propagates to Earth, as well as the resulting effects on Earth's magnetosphere, ionosphere, and thermosphere. CISM researchers integrated these results with educational and outreach activities. An effective knowledge transfer program also ensured that CISM models were transferred for use in operational space weather forecasting centers.

Research facilities have always been a key component of UARS' efforts. The major goal of the UAF program in FY06 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. The recent addition of the Advanced Modular Incoherent-Scatter Radar (AMISR) as a UAF asset, which was under construction in 2004 and saw first light in 2005, has been a true success story. AMISR is deployable to any geographic location on the globe for ionospheric research. In 2006, 25 percent of a complete AMISR radar system was constructed and successfully operated at Poker Flat, Alaska. Two small prototype AMISR systems were used for a variety of science experiments at Jicamarca, Peru and Gakona, Alaska.

In response to several recent community surveys of the health and vitality of solar and space sciences within university teaching faculties, UARS provided awards intended to create new tenure-track faculty positions under the Faculty Development in the Space Sciences (FDSS) program. FDSS awards were targeted to facilitate the integration of solar and space physics research with university programs in basic physics, astronomy, electrical engineering, geoscience, meteorology, computer science, and applied mathematics. Eight FDSS awardee institutions began their faculty selection process in 2005.

A multiagency Federal program, the NSWP seeks 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. 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 (OFCM). In 2005, OFCM, under its broad mandate to coordinate U.S. environmental research, initiated a formal yearlong assessment of the accomplishments and progress of the NSWP over the last decade. OFCM commissioned a panel of eight scientists, including Dr. Louis Lanzerotti—a member of the National Science Board of the NSF—to perform this function and solicit input from the space weather community. The Lanzerotti panel presented its report to OFCM and the multiagency NSWP in 2006, and the recommendations have been discussed with the community.

In FY06, a NASA HQ senior review panel gave a high rating to the NSF and NASA cosponsored Community Coordinated Modeling Center (CCMC), resulting in an increased multiyear budget allocation. The CCMC, located at GSFC, was incorporated into a new Space Weather Laboratory, with the CCMC Director promoted to Laboratory Chief. Also in FY06, the UARS entered into a partnership with NASA's Living With a Star (LWS) program to promote medium-size space weather modeling efforts. These were collaborative space weather modeling projects with annual costs in the range of approximately $400,000. A total of six projects were funded, each for a duration of five years.

The Division of Atmospheric Science's high-altitude aircraft project HIAPER (High-performance Instrumented Airborne Platform for Environmental Research) centers on a highly structurally modified Gulfstream V midsize jet aircraft certified to operate at 51,000 feet. It is certified to fly at the highest altitude of any civilian aircraft, and its long duration (over 12 hours), range (over 6,000 kilometers), and scientific payload (6,000 pounds) will enable scientific research heretofore not possible. The aircraft represents the most advanced airborne research platform in the U.S. civilian fleet. After concluding a number of progressive science missions (for systems and flight verification) in early FY06, the research aircraft participated in a large international field program called T-REX (Terrain-Induced Rotor Experiment). The aircraft met or exceeded its performance goals, which included two other research aircraft and a suite of ground-based observing systems. During the acquisition and

modification phases of the project, HIAPER was managed from a Project Office at the National Center for Atmospheric Research (NCAR), an NSF federally funded research and development center. The research facility has now transitioned into the operations phase and is operated and maintained by the Research Aircraft Facility of NCAR, which also operates and maintains NSF's C-130Q research aircraft. Because the aircraft's expected lifetime is 10–25 years, the airframe design allows for new instrumentation innovations to be integrated as appropriate.

A globe-spanning constellation of six satellites was launched in FY06 to improve weather forecasts, monitor climate change, and enhance space weather research. The low-orbiting satellites are the first to provide atmospheric data daily, in real time, over thousands of points on Earth for both research and operational weather forecasting by measuring the bending of radio signals from GPS as the signals pass through Earth's atmosphere. Called COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) in the U.S. and FORMOSAT-3 in Taiwan, the $100 million satellite network is the product of an agreement between the American Institute in Taiwan and the Taipei Economic and Cultural Representative Office in the United States. The array is based on a system design provided by the University Corporation for Atmospheric Research (UCAR).

Temperature and water vapor profiles derived from the GPS data by COSMIC not only improve many areas of weather prediction, but also help meteorologists observe, research, and forecast hurricanes, typhoons, and other storm patterns over the oceans. The stability, consistency, and accuracy of the measurements should be a boon to scientists quantifying long-term climate change trends. COSMIC's measurements of electron density in the ionosphere are expected to improve analysis and forecasting of space weather, including geomagnetic storms that can interrupt sensitive satellite and communications systems and affect power grids on the ground.

The primary activities of the OPP in ground-based space science and astronomy were the continued construction of the ten-meter, off-axis telescope to survey galaxy clusters and the IceCube neutrino telescope.

While the ten-meter telescope was still being erected, the analysis of the IceCube South Pole Neutrino Telescope data was beginning, and included filtering and reconstruction of the data from the South Pole, simulations of data from the

IceCube monte carlo model, and data comparisons. Topics under study included searches for weakly interacting massive particles (WIMP), neutrino point sources, and monopoles. Scientists detected the first muon neutrino candidates from the nine detector strings.

Continuing research programs were maintained in the study of the polarization of the cosmic microwave background. Increased precision in the measurements on medium-to-large angular scales is allowing BICEP (Background Imaging of Cosmic Extragalactic Polarization), a millimeter-wave telescope/camera consisting of 98 bolometers, to probe directly for the gravitational wave signature of inflation, which can answer crucial questions about the beginnings of the universe.

Other continuing programs included a search for extrasolar planets and a number of ground-based experiments investigating the structure of Earth's upper atmosphere, Earth's interactions with the solar wind, and auroral radio emissions.

Department of State

DOS

The DOS supports U.S. space activities through the negotiation of bilateral and multilateral agreements of scientific and technical cooperation with partner countries. Through its outreach programs, DOS supports key U.S. foreign and space policy objectives, including sustained economic growth and sound environmental and safety management.

Advancing Presidential Diplomacy

In 2006, President Bush authorized a new national space policy that reflects an expanded commitment to the long-term security of our space assets. The policy establishes the goal of ensuring access to space-based imaging, communication, positioning, navigation, and timing assets that are critical to U.S. diplomatic, intelligence, military, and economic activities.

The policy puts emphasis on strengthening interagency coordination, collaboration, and information sharing. It also gives prominence to several goals only touched upon in previous policy documents, including strengthening the space science and technology base, developing space professionals, and strengthening U.S. industrial competitiveness through the use of U.S. commercial space capabilities. Equally important, the new policy is designed to foster the use of U.S. commercial space capabilities.

FY06 provided many opportunities to continue integration of space issues into U.S. diplomacy, including:

- The development of a strategic partnership between NASA and the Indian Space Research Organisation (ISRO) regarding a collaboration on two instruments on the Chandrayaan-1 lunar mission.

- The first official meeting of the U.S.-Brazil Joint Commission on Science and Technology in which space cooperation was among the topics reviewed.
- Participation in the Fifth Space Conference of the Americas held in Quito, Ecuador, that led to several new U.S. initiatives for cooperation on Earth observation programs for the Latin American region.
- Participation in a workshop on Geoinformation for Sustainable Cities that was held in Amman, Jordan.
- Several international conferences to enhance global understanding of the VSE, to encourage international collaboration, and to exchange information on a global exploration strategy that will include both commercial and international participation for lunar science activities, lunar robotics and operations, and human exploration beyond low-Earth orbit.

Supporting Presidential Initiatives

As called for at the U.S.-EU Summit in 2005, the United States and the European Union held the first session of the U.S.-EU Dialogue on Civil Space Cooperation in Brussels on March 24-25, 2006. The meeting facilitated the exchange of information on civil space policy and promoted closer ties in the area of Earth observation, an issue of particular importance in light of the establishment by the EU of its new Global Monitoring for the Environment and Security system of Earth observation satellites.

The DOS led negotiations on a new framework agreement covering civil space cooperation with France, which was signed in late 2006. Negotiations began in FY06 on a similar agreement with Canada. These agreements provide the framework for continued and expanded cooperation between the space and Earth observation agencies of the countries involved.

In support of the 2004 National Security Presidential Directive on U.S. Space-Based Positioning, Navigation, and Timing Policy, DOS in FY06 continued to lead Government interagency efforts to ensure that GPS remains an essential component of internationally accepted positioning, navigation, and timing services. DOS participated in the PNT Executive Committee on the implementation of the PNT Policy.

In January 2006, DOS led GPS consultations with Japan on the continuing cooperation between the countries on the civilian use of GPS. Among the topics discussed were Japan's plans to construct a regional satellite positioning system—the Quasi-Zenith Satellite System (QZSS)—designed to be both supplementary and interoperable with GPS. QZSS is expected to strengthen cooperative relations between the United States and Japan, provide new economic and public transportation safety benefits to Japan and its neighbors, and contribute to the peaceful development of the Asia-Pacific region.

In FY06, DOS set up working group meetings under the 2004 U.S.-EU Agreement on cooperation between GPS and Europe's planned Galileo satellite navigation system to ensure radio frequency compatibility and interoperability for GPS. Significant progress has been made in ensuring interoperability between the two systems. DOS also initiated several technical and policy working group meetings with Russia in pursuit of greater interoperability between GPS and the Russian GLONASS satellite navigation system. In cooperation with the Government of China, the European Space Agency, and the UN Office of Outer Space Affairs, DOS participated in an Asia-Pacific regional workshop to promote the use of GPS and its applications, and provided key speakers on the U.S. space-based PNT policy, GPS modernization, Global Navigation Satellite System (GNSS) applications, and GPS international cooperation activities.

Promoting U.S. Exports

As part of the U.S.-India New Strategic Partnership, the United States and India began preparations in 2006 for the second U.S.-India Joint Working Group on Civil Space Cooperation.

DOS continued to represent the U.S. on the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), and led negotiations on the establishment of the International Committee on Global Navigation Satellite Systems (ICG). The ICG is a unique mix of systems providers, UN organizations, and major international user groups dedicated to promoting GNSS applications, particularly in the developing world. DOS also proposed the establishment of a GNSS Providers Forum to discuss common issues, such as interoperability and compatibility. DOS provided funding for the administration of the ICG and for the regional GNSS workshops and experts meetings held under the auspices of

the UN Programme on Space Applications. These workshops brought together regional experts and decision makers to advance awareness of and support for the use of GNSS applications for sustained growth, transportation safety, and environmental management.

Promoting the Safe Use of Space

With so many countries now participating in space, promoting its safe use remained an important DOS effort. In FY06, DOS promoted an international strategy for mitigating orbital debris. In addition, DOS modernized and placed online the U.S. Registry of Objects Launched into Outer Space. In September, the USG offered to provide China with advance warning if its Shenzhen VI manned spacecraft became in danger of colliding with space objects. China agreed, although ultimately Shenzhen VI returned safely to Earth without having coming close enough to such objects to trigger such a warning. At UNCOPUOS, DOS led USG efforts on the problem of orbital space debris, meteorology, astronomy and astrophysics, space transportation, nuclear power sources in space, and legal issues related to the international liability and responsibility of the launching nations.

Department of Energy

DOE

In FY06, the Department of Energy's Office of Science (SC) cooperated with NASA on 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. In late 2005, NASA and DOE (Naval Reactors) mutually agreed to bring to orderly closure all activities associated with this space reactor engineering development work for Prometheus-1, the Jupiter Icy Moons Orbiter mission. This decision was made in view of NASA's need to properly support near-term space exploration goals, such as developing and launching the CEV.

Through an Implementing Arrangement with NASA signed in 1995, SC continued to work on the Alpha Magnetic Spectrometer (AMS) for use on the ISS. In FY06, this work focused on the integration of the instrument at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland. 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 AMS will study the properties and origin of cosmic particles and nuclei, including antimatter and dark matter. Detailed information on 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 FY06 to support the research group at the Massachusetts Institute of Technology (MIT) that is leading the AMS program.

SC and SMD have collaborated since FY00 on the Large Area Telescope (LAT), the primary instrument for NASA's Gamma-ray Large Area Space Telescope (GLAST) mission scheduled for launch in early 2008. This device, using the techniques of experimental particle physics research, will be used by the GLAST international scientific collaboration to detect gamma rays emitted by the most energetic objects and phenomena in the universe. The Stanford Linear Accelerator Center (SLAC) has responsibility for the overall management of the LAT project. Fabrication of the LAT was completed in early FY06. The LAT then underwent commissioning and began integration on the spacecraft. DOE provided funding in FY06 in conjunction with NASA and international partners for GLAST commissioning and preoperations activities.

DOE and NASA both have the determination of the nature of dark energy, which is causing the acceleration of the expansion of the universe, as a high-priority science objective in their planned programs. The Joint Dark Energy Mission (JDEM) is a plan for a space-based mission endorsed by both DOE and NASA for the study of dark energy. In this plan, both DOE and NASA are responsible for the success of the mission, with NASA leading the space mission management. In FY06, DOE supported R&D activities for the Supernova Acceleration Probe (SNAP) collaboration, led by the Lawrence Berkeley National Laboratory (LBNL). NASA awarded grants in FY06 to three collaborations—Advanced Dark Energy Physics Telescope (ADEPT), Dark Energy Space Telescope (Destiny), and SNAP, to begin mission concept studies for JDEM.

The Office of Nuclear Physics within SC 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. It allows for radiobiology experiments funded by NASA to be performed with silicon, iron, and gold beams. The NASA Space Radiation Laboratory (NSRL) also is in place at BNL, operating as an efficient and effective radiation simulation facility for human space exploration. The SC and NASA continued to develop mutually beneficial technical resources for experimentation and data analysis at BNL. For example, DOE and NASA supported the design and fabrication of the Electron Beam Ion Source (EBIS) at BNL

in FY06. NASA is contributing approximately 25 percent of the project cost of EBIS to accelerate project completion. This joint DOE/NASA project will enhance the range and intensities of heavy ion beams available to the RHIC complex, including the NSRL.

In FY06, the Office of Nuclear Physics continued to support astrophysicists who used 2.4 million processor hours at the National Energy Research Scientific-computing Center (NERSC), which is funded by DOE's Office of Advanced Scientific Computing Research. Most of these processor hours were for simulations of supernovae explosions, such as those observed by the Hubble Space Telescope. NERSC computer capabilities were also used for studies on galaxy formation and black holes.

Other space-related aspects of the Nuclear Physics Program have relevance to NASA, other Federal agencies (e.g., National Reconnaissance Office and USAF), and the private sector. To facilitate testing of electronic components used in high-radiation space environments, Nuclear Physics Program accelerator facilities (BNL Tandem, LBNL 88-Inch Cyclotron, Texas A&M Superconducting Cyclotron) regularly provide beamtime to NASA, DOE-applied laboratories, European and Japanese space agencies, and private companies.

In FY06 the SC Office of Fusion Energy Sciences (OFES) continued to transfer knowledge and research capabilities to NASA. Through the use of plasma and fusion propulsion, NASA-funded research activities have the potential of revolutionizing interplanetary space travel. Specifically, NASA studied fusion propulsion concepts for use in advanced interplanetary missions based upon the spherical torus and plasma-jet-driven magneto-inertial fusion. OFES supports exploration of the physics of the spherical torus in its National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory (PPPL) as part of its research program. OFES also investigated plasma-jet-driven magneto-inertial fusion at General Atomics, LLNL, HyperV Technologies Corporation, and the University of Wisconsin at Madison as part of its high-energy density physics program. 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 MSFC using a computer code developed in the OFES high-energy density physics program. 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. The advanced plasma jet research has potential as a very high-power plasma thruster as well. 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 sending 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 JSC continued to collaborate on the development of an advanced plasma rocket technology—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 complemented and enhanced the science activities at NASA. Partially funded under the DOE/NSF Partnership in Basic Plasma Science and Engineering, these projects focused on magnetic reconnection and other work on ionosphere and space-related plasma physics topics. The Magnetic Reconnection Experiment investigates the coupling between microscale reconnection layers and global forcing and plasma topology evolution.

SC and NASA worked together to calculate the daily primary productivity of terrestrial ecosystems at diverse sites in Northern and Central States. SC's AmeriFlux program continued to provide real-time meteorological, solar radiation, and CO_2 flux data, which were combined with NASA/MODIS data to calculate annual net and gross primary productivity. 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 and atmospheric CO_2 concentration from some 30 locations across the United States. Radiometric instrumentation upgrades have been initiated at select AmeriFlux sites to provide improved calibration information for Terra platform observations. Collectively, the ground surface observations from AmeriFlux sites are providing critical baseline data for calibrating existing and planned NASA satellite data streams.

SC's Atmospheric Radiation Measurement (ARM) provided ground validation support for NASA's AIRS instrument—a high-spectral resolution infrared sounder on the Earth Observing System (EOS) Aqua platform. Additional measurements were conducted to coincide with overpasses of the Aqua satellite carrying the AIRS sensor

at the Tropical Western Pacific (TWP) and North Slope of Alaska sites. The ARM data have been used to improve the water vapor and temperature profiles retrieved from the AIRS sensor. Information on water vapor and temperature are important parameters for the development and validation of climate models. In FY06, ARM continued support of NASA's solar-viewing Bruker 125 HR (high-resolution) Fourier transform spectrometer (FTS) at the TWP facility. The FTS validates space-based column CO_2 retrievals. This validation procedure has been used to ensure the accuracy of CO_2 source and sink information derived from Orbiting Carbon Observatory (OCO) space-based data.

NASA, NOAA, and DOE jointly sponsored a series of workshops on the use of Uninhabited Aerial Vehicles (UAV) for weather research and measuring climate change. The focus of these workshops was to identify the key scientific questions that could be addressed using the current capabilities of UAVs, and to identify aircraft or instrument technology gaps that would require future development of UAV capabilities and their applications. The workshops brought together distinguished scientists from Federal agencies, universities, and private industry. Three agencies are presently formulating an MOU in order to facilitate a collaborative, cost-sharing partnership among NASA's Science Mission Directorate, NOAA's Office of Oceanic and Marine Operations (NMAO), and DOE's Office of Science. One of their goals is to define how UAVs may extend climate and weather-related measurements over regions of Earth that are currently undersampled.

SC, NSF, and NASA continued their collaborative effort to develop and employ climate models, supporting a variety of activities associated with the Community Climate System Model. SC's Scientific Discovery through Advanced Scientific Computing project (SciDAC) continued to develop and increase the level of sophistication in complex climate models. NASA, DOE, NOAA, and NSF participated in the interagency Climate Model Evaluation Project to support the evaluation of U.S. coupled-climate model simulations. The aim of this effort is to increase community-wide diagnostic research into the quality of model simulations to improve evaluations of model predictions and quantification of uncertainty in projections of future climate.

DOE and NASA principal investigators coordinated an effort to use computing resources at the National Leadership Computing Facility (NLCF) at ORNL to incorporate biogeochemistry in coupled-climate models.

SC's Low Dose Radiation Research Program continued to interact with the Space Radiation Project within NASA's HRP. The Low Dose Radiation Research Program focuses on doses of radiation that are at or below current workplace exposure limits. The primary area of emphasis of the NASA Space Radiation Project is to understand the biological effects of space radiation so that radiation risks may be accurately accessed. In FY01, NASA and DOE developed a Memorandum of Agreement (MOA) to better coordinate their efforts to understand and predict the health risks associated with exposure to low-dose radiation. Seventeen jointly funded projects were ongoing in FY06, including two NSCOR (NASA Specialized Center of Research) projects.

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

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 SC researchers at Los Alamos National Laboratory (LANL), Argonne National Laboratory, and SLAC.

DOE's Office of Nuclear Energy 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 FY06, DOE delivered a Radioisotope Thermoelectric Generator for the New Horizons mission to Pluto, which was launched in January 2006.

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 Multi-Mission Radioisotope Thermoelectric Generator and an Advanced Stirling Radioisotope Generator, will each provide greater than 100 watts of electricity for over 14 years. As part of maintaining the required infrastructure, DOE continued operation of facilities at ORNL, Idaho National Laboratory (INL), and LANL. In FY06, the INL, ORNL, LANL, Sandia National Laboratory, and Argonne National Laboratory supported NASA studies of surface reactor power and nuclear thermal propulsion technologies and systems. The national laboratories also participated in development activities related to the design of a fission surface power system that may be launched in the year 2020.

SMITHSONIAN INSTITUTION

The Smithsonian Institution continued to contribute to national aerospace goals through the activities of the Smithsonian Astrophysical Observatory (SAO), which together with the Harvard College Observatory in Cambridge, Massachusetts, forms the Harvard-Smithsonian Center for Astrophysics. Through this organization, 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 educational activities.

In FY06, SAO scientists participated in the first astronomy press conference held at the Smithsonian Castle in Washington, DC. They presented the discovery of a swollen planet orbiting a distant star that may be the archetype for a new class of "puffy" planets. This press conference also featured an alien identification chart that used Earth's atmospheric history to classify the atmospheres of distant Earth-like worlds that potentially may contain extraterrestrial life.

SAO astronomers discovered that the North Star is actually a triple star system, and that a moon-forming dusty disk orbits an 8 Jupiter-mass extrasolar planet. Theoretical findings included the finding that most Milky Way stars are single, and that so-called "super-Earths" may be three times more common than the Jupiter-sized planets orbiting distant stars.

FY06 marked the third year of operations for NASA's Spitzer Space Telescope—operated by JPL—whose Infrared Array Camera (IRAC) was developed at SAO. Spitzer studies the universe at infrared wavelengths of light, enabling it to peer into nearby dust-obscured regions, as well as to spot distant, highly red-shifted galaxies.

Findings made by the Spitzer Space Telescope include:

- A nebula that resembled a giant tornado shaped by a cosmic jet plowing through clouds of interstellar gas and dust.

- The first substellar companion (brown dwarf) directly imaged around a nearby star that harbors a close-in planet, whose existence supports the idea that the high eccentricities of close-in planets may be the result of perturbations by low-mass companions at wide separations.
- New IRAC large-area images of the Orion Cloud Complex—including the Orion Nebula—that revealed new wonders in the intricate nebulosity, particularly the billowing clouds of the gigantic ring extending from the Nebula.
- Nearly 2,300 planet-forming disks in the Orion Cloud Complex.
- Improved images of the Andromeda galaxy—red waves of dust over a blue sea of stars—confirmed there are approximately one trillion stars in that galaxy and showed the distribution of dust in Andromeda.
- Massive galaxies that existed when the universe was less than 800 million years old.
- IRAC measurements of fluctuations in the universe's diffuse infrared background—radiation that was emitted from the first stars when the universe was less than 200 million years old.

FY06 marked the successful launch of the Solar-B Hinode satellite into an orbit that provides continuous viewing of the Sun. SAO's X-ray Telescope (XRT)—launched on board Hinode—is the highest resolution telescope of its type ever flown for solar studies and can be operated in collaboration with the other telescopes on board Hinode, as well as with other satellites and ground-based observatories. The XRT observes x rays from the solar corona and is ideally suited for determining both the large-scale global configurations responsible for solar activity and the small-scale processes that initiate instabilities and eruptions. A science operations center at SAO serves as the focal point from which both satellite operations and scientific studies are coordinated.

SAO scientists using the Ultraviolet Coronagraph Spectrometer (UVCS) on the SOHO spacecraft continued to make new discoveries about the explosive ejections of matter and magnetic fields from the Sun called coronal mass ejection events. A three-dimensional model of a CME expansion was developed from observed ultraviolet intensities and Doppler shifts. This model can be used to specify how the energy of the CME plasma is distributed. A 2006 paper reported the first measurements of a super-hot CME current sheet seen sideways.

The UVCS measurements indicated that the material in the current sheet—a region where oppositely directed magnetic fields meet and annihilate each other—has temperatures above six million degrees Celsius. UVCS researchers were able to track this material out to the distance of the Ulysses spacecraft at four astronomical units (four times the Sun-Earth distance) from the Sun. High ionization charge states of iron were confirmed with measurements by instruments on both SOHO and Ulysses. The strong fluctuations in the highly ionized iron measurements suggest burst-like, rather than smooth, magnetic reconnection in the current sheet. Current sheets are thought to be sources of energetic particle hazards.

Another UVCS study is designed to track the changes in the physical properties of solar coronal holes over the 11-year solar-activity cycle. Coronal holes are "open" regions in the Sun's magnetic field that produce fast solar wind, which expands to fill a large part of interplanetary space. UVCS spectroscopic observations of more than 160 coronal holes have demonstrated that different coronal holes exhibit different acceleration rates, and the material that escapes from them can have a broad range of temperatures. In the Sun's vicinity, the winds from coronal holes near the poles of the Sun are faster and hotter than the winds produced from coronal holes near the Sun's equator.

Scientists using NASA's Chandra X-ray Observatory, which is operated by SAO, announced a number of discoveries in FY06. Research with Chandra contributed to many areas of astrophysics such as supernovas, neutron stars, black holes, galaxy clusters, and cosmology.

One of the year's most spectacular results came from combining images from Chandra and optical telescopes of the tremendous collision of two large clusters of galaxies. Scientists found that dark matter and normal matter had been wrenched apart by the collision, a discovery that provided the first direct evidence for the existence of dark matter.

Astronomers also continued to use Chandra to make significant advances in understanding black holes. One study demonstrated that black holes are the most fuel-efficient engines in the universe. Another team found evidence that the supermassive black hole at the center of the Milky Way may have helped spawn an unusual generation of massive stars. Other scientists showed that jets and winds from the vicinity of supermassive black holes could have profound effects on host galaxies and beyond.

In FY06, Chandra independently determined the Hubble constant, a critically important number that specifies the expansion rate of the universe. This new value matches recent measurements using other independent methods and extends the validity of the measurements to greater distances, thus allowing astronomers to probe earlier epochs in the evolution of the universe.

Using its unique ability to make high angular resolution images at submillimeter wavelengths, the Smithsonian's Submillimeter Array (SMA), located near the summit of Mauna Kea, Hawai'i, explored a wide range of cosmic phenomena. Antennas 7 and 8 came up to their full specifications, and efficiency was improved in the wavelength range around one millimeter—where the SMA is most sensitive to emission from the cool universe. Observing time with the SMA continued to be oversubscribed by a large factor in this wavelength range. More than 30 papers with SMA results were published or submitted to refereed journals. Using the unique submillimeter polarization capability, SMA observations of Faraday rotation in the ionized gas around Sagittarius A-star (SgrA*)—the compact radio source at the center of the Galaxy believed to be a supermassive black hole—provided new constraints on the accretion mechanism, free from obscuration and confusion, as well as evidence of variability. Astronomers also imaged the magnetic field shape in a protostar envelope through observations of polarized dust emission, providing the first conclusive evidence that magnetic fields regulate the formation of stars like the Sun.

SMA observations provided further evidence for the growth of dust grains from submicron to millimeter sizes in the disks around a sample of young stars, an important early step in making planets. The SMA also made some of the best images of the dust and gas in disks around young stars with twice the mass of the Sun, showing that properties such as mass, size, and motions (and by inference the potential to form planetary systems) are similar to young Sun-like stars. SMA observations in nearby regions of star formation in the Milky Way provided new insight into the powerful bi-directional outflow phenomenon that occurs during star birth, with high-resolution images showing gas motions consistent with jet-driven bow shock models. The SMA explored more distant star-forming regions in the galaxy, finding previously unknown, deeply embedded, small groups of young massive stars in the centers of young star clusters.

SMA imaging of the interstellar medium of a nearby starburst galaxy showed unexpected "superbubbles" in the gas that contained properties consistent with formation by explosions produced in star clusters with a million times the mass of the Sun. The SMA also made the first high-resolution observations of the cold gas and dust in the most luminous galaxy in the neighborhood of the Milky Way, showing new details in the starburst fuel and revealing a powerful galactic wind that plays an important role in dispersing the gas. Finally, the SMA detected in ionized carbon emission a galaxy more than 90 percent of the way back to the Big Bang—a new and important diagnostic of galaxy gas properties.

During FY06, the Cosmic Questions traveling museum exhibition developed by SAO's Science Education Department (SED) completed its official Nationwide tour with appearances at the Lafayette Museum of Natural History and Planetarium in Lafayette, Louisiana, and at the Boonshoft Discovery Museum in Dayton, Ohio. During its tour, over 1.5 million visitors learned about advances in our understanding of the universe. Ancillary programs and materials reached an additional 250,000 people. Cosmic Questions, a 5,000-square-foot exhibition for science centers and museums, invites audiences to examine fundamental questions and recent discoveries about the origin, evolution, and structure of the universe.

Aimed at increasing the quantity and quality of classroom investigations of concepts from the middle and high school science standards related to astronomy, SED initiated its Beyond the Solar System (BtSS) Professional Development Project. A team of SAO scientists and educators, through the NASA-funded Universe Education Forum, collaborated to develop a DVD-based teaching and learning tool for teachers of Earth science, physical science, physics, and chemistry to grades 8-12. The DVD contains resources for teaching about the structure and evolution of the universe, including the evidence and explanations for the Big Bang model and the expansion of the universe. In the summer of 2006, a national leadership team of 25 teacher-educators attended an institute to learn how to use the BtSS DVD in professional development settings, and through them over 500 teachers representing over 50,000 students received training in science content, inquiry-based classroom materials, and student assessment.

SAO's NASA-funded Universe Education Forum supports a network of online robotic telescopes called MicroObservatory that allows students and teachers in middle and high schools Nationwide to investigate the night sky from the

convenience of their classrooms. Users control the telescopes by means of an intuitive Web interface. MicroObservatory telescopes are also accessible to museum visitors through the Cosmic Questions exhibition. SED continued to expand its audience to afterschool programs that target teens from urban districts with large populations of underserved youth. The MicroObservatory telescopes delivered over 30,000 images to users in all 50 states and 22 foreign countries.

Associated with the 2005 World Year of Physics, Inside Einstein's Universe (IEU)—an educational outreach program for museums, planetariums, and other venues across the country—celebrated the Einstein Centennial and the astronomical implications of his 1905 "miracle year." Over 100 participating organizations received educational and content support surrounding the topics of cosmology, black holes, general astronomy, and space science explorations. Over 95,000 participants took part in IEU events.

In public outreach, SAO sponsored a program featuring women in science, including a special panel discussion held at the Harvard Science Center. SAO continued to offer to the public its monthly Observatory Night lectures and telescope observing, as well as its Author's Night programs and Sci-Fi Movie Nights that explored the theme, "Everything I learned about science, I learned at the movies." SAO also tested a new program of Family Friendly Nights aimed at families with younger children.

In FY06, NASM celebrated the 60-year anniversary of President Truman signing the law creating the National Air Museum. With numerous educational family events, the Exploring Space and General Electric Aviation Lecture series, installation of a unit on the Wilkinson Microwave Anisotropy Probe in the Explore the Universe gallery, and the start of construction of a brand new air transportation gallery called America by Air.

Staff members in NASM's Center for Earth and Planetary Studies (CEPS) continued to participate on the science teams of several spacecraft missions. Dr. John Grant is Chair of the Mars Exploration Rover (MER) mission Science Operations Working Group. CEPS staff are also on the science teams for the Messenger mission to Mercury, the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) radar instrument on Mars Express, and both the High Resolution Imaging Science Experiment (HiRISE) and Shallow Subsurface Radar (SHARAD)

instruments on the MRO that arrived at Mars in 2006 and has begun returning new data detailing the surface and subsurface of the planet.

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, the Moon, and Mars, resulting in 20 peer-reviewed publications. Research topics included MER results, Martian fluvial processes, properties of lunar regolith, radar studies of the Martian subsurface, Venus geologic mapping, Mars hemispheric dichotomy, Mercury basin structure, and terrestrial analogs to Martian features. In addition, CEPS scientists used new capabilities in focused Earth-based radar imaging to study the surface and deep deposits of the Moon at resolutions comparable to those of photos taken from lunar orbit. This work has great importance for understanding potential mineral resources and landing hazards for future human exploration.

As a NASA Regional Planetary Image Facility (RPIF), CEPS continued to house a collection of over 300,000 images of the planets and their satellites that is a reference library for science researchers and the public, serving the Mid-Atlantic and Southeastern U.S. 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]		Earth Escape[a]	
	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2
1962	55	12	4	1
1963	62	11	0	0
1964	69	8	4	0
1965	93	7	4	1
1966	94	12	7	1[b]
1967	78	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1
1972	33	2	8	0
1973	23	2	3	0
1974	27	2	1	0
1975	30	4	4	0
1976	33	0	1	0
1977	27	2	2	0
1978	34	2	7	0
1979	18	0	0	0
1980	16	4	0	0
1981	20	1	0	0
1982	21	0	0	0
1983	31	0	0	0
1984	35	3	0	0
1985	37	1	0	0
1986	11	4	0	0
1987	9	1	0	0
1988	16	1	0	0
1989	24	0	2	0
1990	40	0	1	0
1991	32[c]	0	0	0
1992	26[c]	0	1	0
1993	28[c]	1	1	0
1994	31[c]	1	1	0
1995	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, f]	0	2	0
2004	8[c]	0	1	0
2005	10	0	2	0
2006 (through September 30, 2006)	14[d]	0	1	0
TOTAL	1,584	153	103	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 various sets of microsatellites as a single payload.
e. This includes the Small Spacecraft Technology Initiative (SSTI) Lewis spacecraft that began spinning out of control shortly after it achieved Earth orbit.
f. This includes American spacecraft not launched in the U.S.

Appendix A-2

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

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

Calendar Year	United States [b]	USSR/ CIS	France [c]	Italy [c]	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	1	1					
1971	30	83	1	2	2	1		1			
1972	30	74		1	1						
1973	23	86									
1974	22	81		2	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	62			2	1			9	1	
1992	31	55			2	3			7	2	
1993	24	45			1	1			7		
1994	26	49			2	5			6	2	
1995	27	33			1	2			12		1
1996	32	25			1	3			10	1	
1997	37	28			2	6			12	1	
1998	34	24			2	6			11		
1999	32	26				4			10	1	
2000	30	34				5			12		
2001	23	23			1	1			8	2	
2002	18	23			3	4			11	1	1
2003	26	21			2	6			4	2	
2004	19	22				8			3	1	
2005	16	26			2	5			5	1	
2006	15	16			5	3			5		
TOTAL	1,333	2,768	10	8	67	91	1	1	167	18	4

a. This includes commercial expendable launches and launches of the Space Shuttle as well as launches to useless orbit.
b. Launches from U.S.-Russia joint platform are included in U.S. totals.
c. Since 1979, all launches for ESA member countries have been joint and are listed under ESA.

Appendix B

Successful Launches to Orbit on U.S. Launch Vehicles

October 19, 2005–April 28, 2006

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Oct. 19, 2005 USA 186 2005-042A Titan 4B	Military reconnaissance satellite		NRO satellite
Nov. 8, 2005 INMARSAT 4-F2 2005-044A Zenit-3SL	Communications satellite	Geosynchronous	
Jan. 19, 2006 New Horizons 2006-001A Atlas 5	Interplanetary probe		Pluto and other bodies in Kuiper Belt
Feb. 15, 2006 Echostar 10 2006-003A Zenit-3SL	Communications satellite	Geosynchronous	
Mar. 22, 2006 ST5A, B, and C 2006-008A, 008B, 008C Pegasus XL	Technology test satellites	4,550 km 303 km 137 min 105.6 degrees	ST5 mission of New Millennium Program
Apr. 12, 2006 JCSAT 9 2006-010A Zenit-3SL	Communications satellite	Geosynchronous	
Apr. 15, 2006 Formosat 3A, 3B, 3C, 3D, 3E, and 3F 2006-011A-F Minotaur	Scientific satellites	540 km 496 km 95 min 7.2 degrees	Also known as COSMIC-A…COSMIC-F
Apr. 20, 2006 Astra 1KR 2006-012A Atlas 5	Communications satellite	Geosynchronous	
Apr. 28, 2006 CALIPSO and Cloudsat 2006-016A-B Delta 2	Weather satellites	A 689 km B 690 km A 687 km B 689 km A 98.5 min B 98.6 min A 98.2 degrees B 98.2 degrees	

Appendix B
(Continued)

SUCCESSFUL LAUNCHES TO ORBIT ON U.S. LAUNCH VEHICLES

May 24, 2006–September 25, 2006

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
May 24, 2006 GOES 13 2006-018A Delta 4	Weather satellite	Geosynchronous	
June 18, 2006 Galaxy 16 2006-023A Zenit-3SL	Communications satellite	Geosynchronous	PamAmSatCorp. satellite
June 21, 2006 USA 187, 188, 189 2006-024A, 024B, 024C Delta 2	Military micro-satellites DARPA/NRL (Naval Research Laboratory)	Geosynchronous	MiTEx
June 28, 2006 USA 184 2006-027A Delta 4	Military reconnaissance satellite	Unknown	
July 4, 2006 STS-121/Discovery 2006-028A Space Shuttle	ISS docking	351 km 332 km 91.4 min 51.6 degrees	Shuttle safety testing and delivery of Expedition 13 to ISS.
Aug. 22, 2006 KoreaSat 5 2006-034A Zenit-3SL	Communications satellite	Geosynchronous	Also known as Mugungwha 5
Sep. 9, 2006 STS-115/Atlantis 2006-036A Space Shuttle	ISS docking	350 km 335 km 91.4 min 51.6 degrees	Installed P3/P4 ISS Truss
Sep. 25, 2006 GPS-2R-15 2006-042A Delta 2	GPS/Navigational satellite	20,414 km 173 km 357 min 40.0 degrees	

Appendix C

HUMAN SPACE FLIGHTS

October 1, 2005–September 18, 2006

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TMA 7 (Expedition 12)	Oct. 1, 2005	Valery I. Tokarev William S. McArthur Gregory Olsen	189:19:53	Carried crew and third American tourist to ISS. Soyuz TMA 7 returned to Earth Apr. 8, 2006 with Tokarev, McArthur, and Pontes. Olsen returned on Soyuz TMA 6.
Shenzhou 6	Oct. 12, 2005	Fei Junlong Nie Haisheng	4:19:33	Second Chinese human spaceflight. First two man crew of taikonauts.
Soyuz TMA 8 (Expedition 13)	Mar. 30, 2006	Pavel Vinogradov Jeffrey Williams Marcos Pontes	182:23:44	Carried crew and first Brazilian astronaut to ISS. Pontes returned on Soyuz TMA 7.
Space Shuttle *Discovery* (STS-121)	July 4, 2006	Steven W. Lindsey Mark E. Kelly Michael E. Fossum Lisa M. Novak Stephanie D. Wilson Piers J. Sellers Thomas Reiter	12:18:37	Shuttle safety testing and delivery of ESA astronaut Thomas Reiter to Expedition 13 on ISS.
Space Shuttle *Atlantis* (STS-115)	Sep. 9, 2006	Brent W. Jett, Jr. Christopher J. Ferguson Heidemarie M. Stefanyshyn-Piper Joseph R. Tanner Daniel C. Burbank Steven G. MacLean	11:19:06	Installed P3/P4 Truss on ISS. Unfolded solar arrays.
Soyuz TMA 9 (Expedition 14)	Sep. 18, 2006	Mikhail Tyurin Michael Lopez-Alegria Anousheh Ansari	215:08:23	Carried crew to ISS. Included Ansari, first female space tourist and fourth overall. She returned on Soyuz TMA 8 spacecraft.

Appendix D-1A

Space Activities of the U.S. Government

HISTORICAL TABLE OF BUDGET AUTHORITY

(in millions of real-year dollars)

FY	NASA Total	NASA Space	DOD	Other	DOE	DOC	DOI	USDA	NSF	DOT	Total Space
1959	331	261	490	34	34						785
1960	524	462	561	43	43						1,066
1961	964	926	814	68	68						1,808
1962	1,825	1,797	1,298	199	148	51					3,294
1963	3,673	3,626	1,550	257	214	43					5,433
1964	5,100	5,016	1,599	213	210	3					6,828
1965	5,250	5,138	1,574	241	229	12					6,953
1966	5,175	5,065	1,689	214	187	27					6,968
1967	4,966	4,830	1,664	213	184	29					6,707
1968	4,587	4,430	1,922	174	145	28	0.2	1			6,526
1969	3,991	3,822	2,013	170	118	20	0.2	1	31		6,005
1970	3,746	3,547	1,678	141	103	8	1	1	28		5,366
1971	3,311	3,101	1,512	162	95	27	2	1	37		4,775
1972	3,307	3,071	1,407	133	55	31	6	2	39		4,611
1973	3,406	3,093	1,623	147	54	40	10	2	41		4,863
1974	3,037	2,759	1,766	158	42	60	9	3	44		4,683
1975	3,229	2,915	1,892	158	30	64	8	2	54		4,965
1976	3,550	3,225	1,983	168	23	72	10	4	59		5,376
TQ*	932	849	460	43	5	22	3	1	12		1,352
1977	3,818	3,440	2,412	194	22	91	10	6	65		6,046
1978	4,060	3,623	2,738	226	34	103	10	8	71		6,587
1979	4,596	4,030	3,036	248	59	98	10	8	73		7,314
1980	5,240	4,680	3,848	231	40	93	12	14	72		8,759
1981	5,518	4,992	4,828	234	41	87	12	16	78		10,054
1982	6,044	5,528	6,679	313	61	145	12	15	80		12,520
1983	6,875	6,328	9,019	327	39	178	5	20	85		15,674
1984	7,458	6,858	10,195	395	34	236	3	19	103		17,448
1985	7,573	6,925	12,768	584	34	423	2	15	110		20,277
1986	7,807	7,165	14,126	477	35	309	2	23	108		21,768
1987	10,923	9,809	16,287	466	48	278	8	19	112	1	26,562
1988	9,062	8,322	17,679	741	241	352	14	18	115	1	26,742
1989	10,969	10,097	17,906	560	97	301	17	21	121	3	28,563
1990	12,324	11,460	15,616	506	79	243	31	25	124	4	27,582
1991	14,016	13,046	14,181	772	251	251	29	26	211	4	27,999
1992	14,317	13,199	15,023	798	223	327	34	29	181	4	29,020
1993	14,310	13,064	14,106	731	165	324	33	25	180	4	27,901
1994	14,570	13,022	13,166	632	74	312	31	31	179	5	26,820
1995	13,854	12,543	10,644	759	60	352	31	32	278	6	23,946
1996	13,884	12,569	11,514	828	46	472	36	37	231	6	24,911
1997	13,709	12,457	11,727	789	35	448	42	39	219	6	24,973
1998	13,648	12,321	12,359	839	103	435	43	39	213	6	25,519
1999	13,653	12,459	13,203	982	105	575	59	37	200	6	26,644
2000	13,601	12,521	12,941	1,056	164	575	60	44	207	6	26,518
2001	14,230	13,304	14,326	1,062	145	577	60	36	232	12	28,692
2002	14,868	13,871	15,740	1,180	166	644	64	28	266	12	30,791
2003	15,364	14,360	19,388	1,305	191	649	74	42	337	12	35,053
2004	15,379	14,322	19,115	1,464	209	745	71	61	366	12	34,901
2005	16,198	15,234	19,690	1,551	229	807	70	73	360	12	36,475
2006	16,623	15,765	22,114	1,647	245	860	82	84	364	12	39,526

*TQ: Transition Quarter. This was created because the Federal Government redefined the parameters of a fiscal year.

Appendix D-1B

Space Activities of the U.S. Government

HISTORICAL TABLE OF BUDGET AUTHORITY
(in millions of equivalent FY 2006 dollars)

FY	Inflation Factors	NASA Total	NASA Space	DOD	Other	DOE	DOC	DOI	USDA	NSF	DOT	Total Space
1959	5.5071	1,823	1,437	2,698	187	187						4,323
1960	5.4222	2,841	2,505	3,042	233	233						5,780
1961	5.3576	5,165	4,961	4,361	364	364						9,687
1962	5.2822	9,640	9,492	6,856	1,051	782	269					17,399
1963	5.2233	19,185	18,940	8,096	1,342	1,118	225					28,378
1964	5.1586	26,309	25,876	8,249	1,099	1,083	15					35,223
1965	5.0979	26,764	26,193	8,024	1,229	1,167	61					35,445
1966	5.0116	25,935	25,384	8,465	1,072	937	135					34,921
1967	4.9067	24,367	23,699	8,165	1,045	903	142					32,909
1968	4.7533	21,803	21,057	9,136	828	689	133	1	5			31,021
1969	4.5904	18,320	17,544	9,240	782	542	92	0.9	5	143		27,567
1970	4.3898	16,444	15,571	7,366	619	452	35	4	4	123		23,556
1971	4.1624	13,782	12,908	6,294	674	395	112	8	4	154		19,875
1972	3.9644	13,110	12,175	5,578	529	218	123	24	8	156		18,281
1973	3.7857	12,894	11,709	6,144	558	204	151	38	8	157		18,411
1974	3.6258	11,012	10,004	6,403	573	152	218	33	11	160		16,980
1975	3.3817	10,920	9,858	6,398	534	101	216	27	7	182		16,789
1976	3.0632	10,874	9,879	6,074	516	70	221	31	12	182		16,469
TQ*	2.8570	2,663	2,426	1,314	123	14	63	9	3	34		3,863
1977	2.7691	10,573	9,526	6,679	536	61	252	28	17	179		16,741
1978	2.6579	10,791	9,630	7,277	601	90	274	27	21	189		17,508
1979	2.4903	11,445	10,036	7,560	618	147	244	25	20	182		18,214
1980	2.3046	12,076	10,785	8,868	533	92	214	28	32	166		20,186
1981	2.1188	11,692	10,577	10,230	496	87	184	25	34	166		21,303
1982	1.9298	11,664	10,668	12,889	604	118	280	23	29	154		24,161
1983	1.8062	12,418	11,430	16,290	591	70	322	9	36	154		28,311
1984	1.7299	12,901	11,863	17,636	683	59	408	5	33	178		30,182
1985	1.6683	12,634	11,553	21,301	974	57	706	3	25	183		33,828
1986	1.6158	12,615	11,577	22,825	770	57	499	3	37	174		35,173
1987	1.5791	17,248	15,489	25,719	736	76	439	13	30	177	2	41,943
1988	1.5389	13,946	12,807	27,206	1,140	371	542	22	28	177	2	41,154
1989	1.4920	16,365	15,064	26,715	836	145	449	25	31	181	4	42,615
1990	1.4362	17,699	16,459	22,427	726	113	349	45	36	178	6	39,612
1991	1.3847	19,408	18,065	19,637	1,069	348	348	40	36	292	6	38,772
1992	1.3346	19,108	17,616	20,050	1,065	298	436	45	39	241	5	38,731
1993	1.3019	18,630	17,008	18,365	951	215	422	43	33	234	5	36,324
1994	1.2730	18,548	16,577	16,761	805	94	397	39	39	228	6	34,143
1995	1.2462	17,265	15,632	13,265	946	75	439	39	40	346	7	29,842
1996	1.2205	16,946	15,341	14,053	1,010	56	576	44	45	282	7	30,405
1997	1.1976	16,417	14,918	14,044	945	42	537	50	47	263	7	29,907
1998	1.1770	16,064	14,502	14,547	988	121	512	51	46	251	7	30,037
1999	1.1629	15,877	14,488	15,354	1,142	122	669	69	43	233	7	30,984
2000	1.1478	15,612	14,372	14,854	1,212	188	660	69	51	237	7	30,438
2001	1.1251	16,010	14,968	16,118	1,195	163	649	68	41	261	14	32,281
2002	1.0992	16,342	15,246	17,301	1,297	182	708	70	31	292	13	33,844
2003	1.0785	16,570	15,487	20,910	1,407	206	700	80	45	363	13	37,805
2004	1.0571	16,258	15,140	20,207	1,548	221	788	75	64	387	13	36,895
2005	1.0305	16,692	15,699	20,291	1,598	236	832	72	75	371	12	37,587
2006	1.0000	16,623	15,765	22,114	1,647	245	860	82	84	364	12	39,526

*TQ: Transition Quarter. This was created because the Federal Government redefined the parameters of a fiscal year.

Appendix D-2

FEDERAL SPACE ACTIVITIES BUDGET

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority				Budget Outlays	
	2005 actual	2006 actual	2007 est.	2008 est.	2005 actual	2006 actual
NASA [1]	15,234	15,765	15,568	16,755	14,747	14,459
Defense	19,690	22,114	22,418	25,949	19,662	19,959
Energy	229	245	228	234	223	243
Commerce	807	860	913	911	727	780
Interior [2,3]	70	82	86	87	70	82
Agriculture [2,4]	73	84	65	69	68	71
Transportation	12	12	12	13	12	12
NSF [5]	360	364	392	482	329	298

1. This indicates the 2006 Budget Authority estimate from initial NASA Operating Plan, February 6, 2006.
2. This includes aerial remote sensing activity.
3. In 2003, the Department of Interior began to report the U.S. Geological Survey's digital orthoimagery program within its totals.
4. In 2004, the Department of Agriculture began to report the National Agriculture Imagery Program within its totals.
5. In 2003, 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	
	2005 actual	2006 actual	2007 est.	2008 est.	2005 actual	2006 actual
NASA [1,2]	962	893	717	554	866	722
Defense	9,327	9,295	9,576	8,742	9,586	9,346
Transportation	2,638	2,636	2,632	2,587	2,643	2,632

1. This total does not include the Inspector General budget.
2. This indicates the 2006 Budget Authority estimate from initial NASA Operating Plan, February 6, 2006.

Acronyms

A

AAD	Aircraft Aging and Durability
ACCRES	Advisory Committee on Commercial Remote Sensing
ACD	Advanced Capabilities Division
ADEPT	Advanced Dark Energy Physics Telescope
AEHF	Advanced Extremely High Frequency
AFS	Alaska Fire Service
AGS	Alternating Gradient Synchrotron
AIAA	American Institute of Aeronautics and Astronautics
AIM	Assessment, Inventory, and Monitoring
AIRS	Atmospheric Infrared Sounder
AIRSS	Alternative Infrared Satellite System
AirSTAR	Airborne Subscale Transport Aircraft Research
ALMA	Atacama Large Millimeter Array
ALTEA	Anomalous Long Term Effects in Astronauts' Central Nervous System
AMISR	Advanced Modular Incoherent-Scatter Radar
AMS	Alpha Magnetic Spectrometer
APD	Application for Permit to Drill
APHIS	Animal and Plant Health Inspection Service
APLC	Aerospace Products Literature Center
APMT	Aviation Environmental Portfolio Management Tool
ARC	Ames Research Center
ARM	Atmospheric Radiation Measurement
ARMD	Aeronautics Research Mission Directorate
ARS	Agricultural Research Service
ASP	Airspace Systems Program
ATM	Air Traffic Management
ATST	Advanced Technology Solar Telescope
AVHRR	Advanced Very High Resolution Radiometer
AWiFS	Advanced Wide Field Sensor

B

BAER	Burned Area Emergency Response
BICEP	Background Imaging of Cosmic Extragalactic Polarization
BIS	Bureau of Industry and Security
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory
BOR	Bureau of Reclamation
BtSS	Beyond the Solar System
BWB	Blended Wing Body

C

CAD	Computer-Aided Design
CALIPSO	Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observation
CAM	Computer-Aided Manufacturing
CAMI	Civil Aerospace Medical Institute
CAST	Chinese Academy of Space Technology
CBERS-2	China-Brazil Earth Resources Satellite-2
CCMC	Community Coordinated Modeling Center
CEAH	Centers for Epidemiology and Animal Health
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions
CEPS	Center for Earth and Planetary Studies
CERN	European Organization for Nuclear Research
CEV	Crew Exploration Vehicle
CFFDRS	Canadian Forest Fire Danger Rating System
CISM	Center for Integrated Space Weather Modeling
CLICK	Center for LIDAR Information Coordination and Knowledge
CLU	Common Land Unit
CLV	Crew Launch Vehicle
CMB	Cosmic Microwave Background
CME	Coronal Mass Ejection
CNES	French Space Agency
COBE	Cosmic Background Explorer
CONUS	Continental United States
CORS	Continuously Operating Reference Stations
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
COTS	Commercial Orbital Transportation Services
CPHST	Center for Plant Health Science and Technology
CRISP	Central Region Integrated Science Partnership Funds
CS	Commercial Service

D

DAFT	Dust and Aerosol Measurement Feasibility Test
DARPA	Defense Advanced Research Projects Agency
DARWIN	Design Assessment of Reliability with Inspection
DEM	Earth Digital Elevation Model
Destiny	Dark Energy Space Telescope
DFRC	Dryden Flight Research Center
DOC	Department of Commerce
DOE	Department of Energy
DOD	Department of Defense
DOI	Department of the Interior
DOS	Department of State
DSCS	Defense Satellite Communications System
DSN	Deep Space Network
DSP	Defense Support Program

E

EAB	Emerald Ash Borer Beetle
EBIS	Electron Beam Ion Source
EDL	Entry, Descent, and Landing
EELV	Evolved Expendable Launch Vehicle
EMCS	European Modular Cultivation System
EOS	Earth Observing System
ERS	Economic Research Service
ESMD	Exploration Systems Mission Directorate
ESnet	Energy Sciences Network
ETDP	Exploration Technology Development Program
ETM+	Enhanced Thematic Mapper Instrument Plus
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EVE	Extreme-ultraviolet Variability Experiment
EWIS	Electrical Wire Interconnect System

F

FAA	Federal Aviation Administration
FAArfield	FAA Rigid and Flexible Iterative Elastic Layer Design 1.0
FACET	Future Air traffic management Concepts Evaluation Tool
FAO	Food and Agriculture Organization
FAS	Foreign Agricultural Service
FCC	Federal Communications Commission
FDSS	Faculty Development in the Space Sciences
FS	U.S. Forest Service
FSA	Farm Service Agency
FTS	Fourier Transform Spectrometer
FWS	U.S. Fish and Wildlife Service

G

GA-ASI	General Atomics Aeronautical Systems, Inc.
GBS	Global Broadcast Service
GEM	Geospace Environment Modeling
GEO	Geosynchronous Orbit
GEO	Group on Earth Observations
GEONETCast	Group on Earth Observations Network
GEOSS	Global Earth Observation System of Systems
GES	Global Exploration Strategy
GFS	Global Forecast System
GIG	Global Information Grid
GINA	Geographic Information Network of Alaska
GIS	Geographic Information System

GLAST	Gamma-ray Large Area Space Telescope
GLONASS	Global Orbiting Navigation Satellite System
GloVis	Global Visualization Viewer
GNSS	Global Navigation Satellite System
GOES-N	Geostationary Operational Environmental Satellite
GOFC	Global Observation of Forest Cover
GPS	Global Positioning System
GPSW	Global Positioning System Wing
GRC	Glenn Research Center
GRP	Guidance Replacement Program
GSFC	Goddard Space Flight Center

H

HAB	Harmful Algal Bloom
HIAPER	High-Performance Instrumented Airborne Platform for Environmental Research
HiRISE	High Resolution Imaging Science Experiment
HR	High-Resolution
HRP	Human Research Program
HST	Hubble Space Telescope
HUMS	Health and Usage Monitoring Systems
HyBoLT	Hypersonic Boundary Layer Transition Flight Experiment

I

ICBM	Intercontinental Ballistic Missile
ICESat	Ice, Cloud, and Land Elevation Satellite
ICG	International Committee on Global Navigation Satellite Systems
IEU	Inside Einstein's Universe
IFCS	Intelligent Flight Control System
IFSAR	Interferometric Synthetic Aperture Radar
IGRS	Iraqi Geospatial Reference System
IIFD	Integrated Intelligent Flight Deck
IISTF	ISS Independent Safety Task Force
IITF	International Institute of Tropical Forestry
INL	Idaho National Laboratory
INPE	Brazilian National Institute for Space Research
IOOS	Integrated Ocean Observing System
IP	Internet Protocol
IR	Infrared Spectrometer
IRAC	Infrared Array Camera
IRAC	Integrated Resilient Aircraft Control
ISR	Intelligence-Surveillance-Reconnaissance
ISRO	Indian Space Research Organisation
ISS	International Space Station
ITA	International Trade Administration
IVHM	Integrated Vehicle Health Management

J

JDEM	Joint Dark Energy Mission
JPDO	Joint Planning and Development Office
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center

K

KDP	Key Decision Point
KSC	Kennedy Space Center

L

LANL	Los Alamos National Laboratory
LAT	Large Area Telescope
LAT	Lunar Architecture Team
LBIR	Low Background Infrared Facility
LBNL	Lawrence Berkeley National Laboratory
LCROSS	Lunar Crater Observation and Sensing Satellite
LDCM	Landsat Data Continuity Mission
LEO	Low-Earth Orbit
LIDAR	LIght Detection and Ranging Remote Sensing
LPRP	Lunar Precursor and Robotic Program
LaRC	Langley Research Center
LRO	Lunar Reconnaissance Orbiter
LSST	Large Synoptic Survey Telescope
LWS	Living With a Star

M

MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MDA	Missile Defense Agency
MDAO	Multidisciplinary Design, Analysis, and Optimization
MDXR	Fourier Transform Infrared Spectrometer/Transfer Standard Radiometer
MELFI	Minus Eighty-Degree Laboratory Freezer for the ISS
MEP	Manufacturing Extension Partnership
MER	Mars Exploration Rover
MILSATCOM	Military Satellite Communications
MISSE	Materials on ISS Experiments
MIT	Massachusetts Institute of Technology
MiTEx	Micro-Satellite Technology Experiment
MLS	Microwave Limb Sounder
MLV	Medium Launch Vehicle
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding

MRO	Mars Reconnaissance Orbiter
MSFC	Marshall Space Flight Center
MT	Mobile Transporter

N

NAIC	National Astronomy and Ionosphere Center
NAIP	National Agriculture Imagery Program
NAS	National Airspace System
NASM	National Air and Space Museum
NASS	National Agricultural Statistics Service
NCAR	National Center for Atmospheric Research
NC-GAP	North Carolina Gap Analysis Project
NDE	Nondestructive Evaluation
NDI	Nondestructive Inspection
NDMC	National Drought Mitigation Center
NDVI	Normalized Difference Vegetation Index
NERSC	National Energy Research Scientific-computing Center
NEXRAD	Next Generation Weather Radar
NGATS	Next Generation Air Transportation System
NIC	National Ice Center
NISN	NASA Integrated Services Network
NIST	National Institute of Standards and Technology
NLCF	National Leadership Computing Facility
NMAO	NOAA's Office of Oceanic and Marine Operations
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NOx	Nitrogen Oxide
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRAO	National Radio Astronomy Observatory
NRCS	Natural Resources Conservation Service
NREN	NASA's Research and Education Network
NRI	National Resources Inventory
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office
NSAS	National Strategy for Aviation Security
NSCOR	NASA Specialized Center of Research
NSF	National Science Foundation
NSO	National Solar Observatory
NSOF	NOAA Satellite Operations Facility
NSRL	NASA Space Radiation Laboratory
NSTC	National Science and Technology
NSWP	National Space Weather Program
NTIA	National Telecommunications and Information Administration

O

OCO	Orbiting Carbon Observatory
OECD	Organization for Economic Cooperation and Development
OFCM	Office of the Federal Coordinator for Meteorology
OFES	Office of Fusion Energy Sciences
OGS	Oxygen Generation System
OMI	Ozone Monitoring Instrument
OPP	Office of Polar Programs
OPUS	Online Positioning User Service
ORNL	Oak Ridge National Laboratory
ORS	Operationally Responsive Space
OSC	Office of Space Commercialization
OSTM	Ocean Surface Topography Mission
OSTP	Office of Science Technology and Policy

P

PARTNER	Partnership for Air Transportation Noise and Emissions Reduction
PNT	Positioning, Navigation, and Timing
POD	Probability of Detection
POES	Polar-orbiting Operational Environmental Satellites
PPPL	Princeton Plasma Physics Laboratory
PRP	Propulsion Replacement Program

Q

QZSS	Quasi-Zenith Satellite System

R

R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
REDAC	Research, Engineering, and Development Advisory Committee
RFI	Request for Information
RHIC	Relativistic Heavy Ion Collider
ROGIDS	Remote On-Ground Ice Detection System
RPIF	Regional Planetary Image Facility
RPT	Rocket Propulsion Test
RSAC	Remote Sensing Applications Center
RSIWG	Remote Sensing Interagency Working Group
RSLP	Rocket Systems Launch Program

S

S&T	Science and Technology
SAM	Scan Angle Monitor

SAME	Smoke Aerosol Measurement Experiment
SAO	Smithsonian Astrophysical Observatory
SARSAT	Search and Rescue Satellite Aided Tracking program
SBIRS	Space-Based Infrared System
SC	Office of Science
SciDAC	Scientific Discovery through Advanced Scientific Computing project
SCUBA	Submillimeter Common-User Bolometer Array
SDL	Space Dynamics Laboratory
SED	Science Education Department
SERV	Safety Enhanced Reentry Vehicle
SERVIR	Sistema de Monitoreo y Visualizacion para Mesoamerica
SgrA*	Sagittarius A-star
SHARAD	Shallow Subsurface Radar
SHINE	Solar, Heliosphere, and INterplanetary Environment
SHOALS	Scanning Hydrographic Operational Airborne LIDAR Survey
SIA	Satellite Imagery Archive
SLAC	Stanford Linear Accelerator Center
SMA	Submillimeter Array
SMD	Science Mission Directorate
SNAP	Supernova Acceleration Probe
SOHO	Solar and Heliospheric Observatory
SOMD	Space Operations Mission Directorate
SpacePCC	Space Policy Coordinating Committee
SQUID	Superconducting Quantum Interference Devices
SR	Space Radar
SRTM	Shuttle Radar Topography Mission
SSC	Stennis Space Center
SSTI	Small Spacecraft Technology Initiative
ST5	Space Technology 5
STEP-NC	Standard for the Exchange of Process Model Data for Numerical Control
STEREO	Solar TErrestrial RElations Observatory
SURF	Synchrotron Ultraviolet Radiation Facility
SV	Satellite Vehicle

T

TCFP	Tropical Cyclone Formation Probability
TDRSS	Tracking and Data Relay Satellite System
TES	Transition Edge Sensors
TGF	Temperature Gradient Focusing
TMOS	TSAT Mission Operations System
TNC	The Nature Conservancy
TOMS	Total Ozone Mapping Spectrometer
T-REX	Terrain-Induced Rotor Experiment
TRMM	Tropical Rainfall Measuring Mission
TSA	Transportation Security Administration

TSAT	Transformational Satellite Communication System
TWP	Tropical Western Pacific

U

UAF	Upper Atmospheric Facilities
UARS	Upper Atmospheric Research Section
UAS	Unmanned Aerial Vehicle Systems
UAV	Unpiloted Aerial Vehicle
UAVs	Uninhabited Aerial Vehicles
UCAR	University Corporation for Atmospheric Research
UEDDAM	Uncontained Engine Debris Damage Assessment Model
UFO	Ultra High Frequency Follow-On
UK	United Kingdom
UN	United Nations
UNCOPUOS	U.N. Committee on the Peaceful Uses of Outer Space
U.S.	United States
US&FCS	U.S. and Foreign Commercial Service
USAF	U.S. Air Force
USDA	United States Department of Agriculture
USecAF	Under Secretary of the Air Force
USGS	U.S. Geological Survey
USGS/EROS	USGS Center for Earth Resources Observation and Science
USTR	U.S. Trade Representative
UVCS	Ultraviolet Coronagraph Spectrometer

V

VAATE	Versatile Affordable Advanced Turbine Engine
VEE	Venezuelan Equine Encephalitis
VegDRI	Vegetation Drought Response Index
VLSA	Very-Large Scale Aerial Photography
VSE	Vision for Space Exploration

W

WATR	Western Aeronautical Test Range
WGS	Wideband Gapfiller System
WIMP	Weakly Interacting Massive Particles
WRP	Wetland Reserve Program

X

XRT	X-ray Telescope

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