Aeronautics and Space Report of the President

Fiscal Year 2007 Activities

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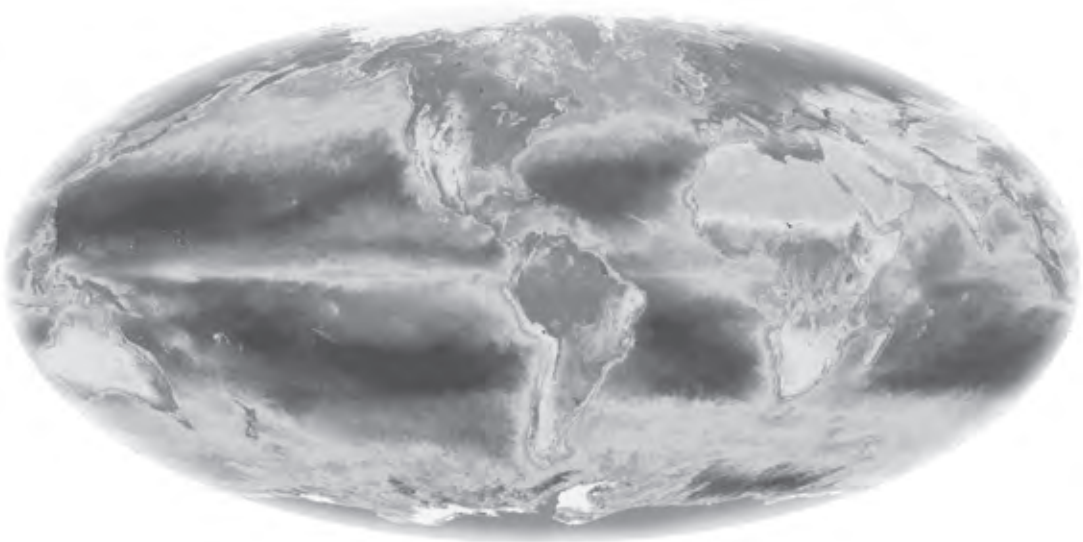


Fiscal Year 2007 Activities

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, 2006, through September 30, 2007.

Table of Contents

National Aeronautics and Space Administration

NASA

Exploration Systems Mission Directorate

NASA's Exploration Program develops capabilities to enable human space expeditions of increasing evolutionary scope and ambition. Beginning in low-Earth orbit (LEO), these expeditions will first support the International Space Station (ISS) and then expand to encompass missions that will take humankind back to the Moon and eventually to Mars and other destinations. During each stage of the exploration effort, the knowledge, technology, operational experience, and systems developed will provide a foundation for more extensive exploration activities.

In FY07, through its programs and projects, the Exploration Systems Mission Directorate (ESMD) continued to build on the initial steps of this evolutionary process by leveraging flight-proven technologies and techniques of earlier human exploration efforts, including the ISS, Space Shuttle, and Apollo programs. The ESMD also further developed the planning, technology, and hardware to support the exploration effort and continued to plan and transition Agency assets in preparation for Space Shuttle retirement.

Lunar Architecture Team

In FY07, the ESMD further developed its lunar architecture (addressing how humans will live and work on the Moon) through the work of the Lunar Architecture Team (LAT), staffed by ESMD members along with other science, exploration, and technology experts from NASA Centers and Headquarters. Based on the architecture foundation established in the Exploration Systems Architecture Study (ESAS) completed in 2005, and the 180 lunar objectives and

six themes derived from NASA's collaboration with 13 other space agencies, the ESMD commissioned the LAT to conduct an internal study of the lunar surface system architecture.

During FY07, the LAT studied and evaluated six lunar surface system campaign options, assessing each architecture against numerous figures of merit, such as crew safety, mission success, cost, performance, schedule, and extensibility. From this, the LAT provided recommendations for exploration mission requirements, technology needs, and schedule. The mission requirements recommendations served as the basis for the ESMD Exploration Architecture Requirements Document (EARD) Level 1, signed in August 2007.

In addition, based on LAT recommendations, the ESMD instituted changes that impacted the allocation and plans for ESMD investments. This included realigning the research and technology portfolio, placing focus on the near-term requirements for lunar missions. In addition, in conjunction with LAT requirements, the ESMD ensured the close coordination of technology investments with Constellation Program requirements for initial missions, providing an integrated technology match to requirements.

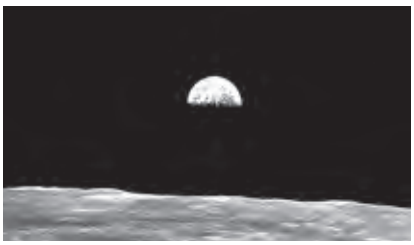
Constellation Systems Division

Constellation Program

Orion (Crew Exploration Vehicle) and Ares (Launch Vehicles)

Both the Orion and Ares projects made significant progress during FY07. This included the ongoing, on-schedule work to finalize Orion and Ares I design concepts.

The Constellation Program's development began with the successful completion of the Systems Requirements Review (SRR) for the Constellation Program in November 2006, kicking off a "season of SRRs" for the Constellation elements, including Orion, Ares I, Ground Operations, Mission Operations, and Extravehicular Activity Systems (EVA). The SRR serves as the initial phase of a formal process that ensures that project requirements are properly defined, implemented, and traceable, and that the hardware and software are designed and built to the authorized, baseline configuration requirements. This "season of SRRs" culminated in a Program Baseline Synchronization Review (PBS) in May 2007, which

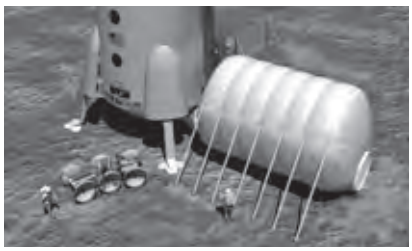


Human Civilization

Global Partnerships

Scientific Knowledge

Economic Expansion



Exploration Preparation

Public Engagement

Figure 1. Six Themes Derived from Global Strategy Inputs

integrated individual element SRR findings and paved the way for Systems Design Reviews (SDR). All Constellation projects now have baselined requirements and can move forward to the next design phase.

As part of the normal systems engineering process, the baseline architecture for Orion and Ares I, as well as other Constellation Program elements, was continually refined as the program conducted key system-level and element-level trades and analyses to validate the design concepts against the requirements, and/or determine whether changes to the baseline design concepts were warranted. This activity initiated the project's SDR phase in late FY07.

Ground Operations

In FY07, the Constellation ground operations project (ground support for exploration) developed a comprehensive set of requirements for ground operations and baselined a concept of operations around the Orion and Ares vehicles being developed at other NASA Centers. Reviewed thoroughly, the concept of operations benefited from a Kennedy Space Center (KSC) Broad Agency Announcement, which solicited input and suggestions from industry to improve the new Constellation ground architecture. Four aerospace corporations with extensive operations experience responded with input and suggestions that were incorporated back into the concept of operations, refining ground processing approaches to improve efficiency and lower life-cycle cost.

The Constellation Program stepped up efforts in FY07 to ensure that the facilities and infrastructure would be in place to provide efficient and timely support to Ares and Orion vehicle development. The program began modifying existing structures at several locations to reuse key capabilities and lower facility start-up costs in support of exploration efforts. This included modifications of the Space Power Facility at Glenn Research Center's Plum Brook Station, which will provide the largest facility in the world for spacecraft environmental testing under one roof. In addition, the Constellation Program began construction on a rocket engine test stand at Stennis Space Center, which will allow engineers to test the J-2X engine to provide power to both Orion and Ares in realistic space conditions, while performing a full-duration firing of almost 10 minutes.

Another cooperative effort between the Constellation Program and the Space Florida Foundation began in FY07 with the modification of the Apollo-era operations and check-out facility at KSC. When complete, the modification will provide modern facilities for Orion integration, testing, and refurbishment. To add to this project, ongoing KSC Launch Pad 39B modifications included adding new lightning protection towers to support future Constellation flights, being careful not to impact the Space Shuttle Program's ability to use the launch pad if needed. Finally, at the Army's White Sands Missile Range, construction started to provide facilities for the Orion Launch Abort System's (LAS) development and qualification testing. The LAS will protect the crew in the event of anomalies during the launch and flight.

Acquisitions

Constellation Program acquisition activity involves a strategy that includes a combination of sole source and full and open competition opportunities. The overall goal, however, is to maximize competition whenever possible, ensuring that a strong industrial base will be maintained across the Nation.

In 2006, NASA awarded the Orion development contract to Lockheed Martin. During FY07, Lockheed Martin continued to make significant progress supporting Constellation Program milestones. Also in FY07, NASA awarded the sole source contracts related to the Ares I Reusable Solid Rocket Motor 1st Stage and J-2X Upper Stage Engine to ATK-Thiokol and to Pratt & Whitney Rocketdyne, respectively. On August 28, 2007, after a full and open competition, NASA awarded to the Boeing Company the Ares I upper stage production contract to manufacture the NASA design for the upper stage. These awards mark a milestone in the Constellation Program. These awards, along with the proposed selection of the Ares Upper Stage Avionics contract in December 2007, complete all major hardware acquisitions for the Ares-Orion integrated stack elements.

In addition to vehicle-related contracts, extravehicular activity-related acquisition activities commenced with the Constellation Space Suit System Request for Proposal (RFP) released in October 2007. Finally, the Ground Operations Project initiated procurement activities related to the lightning protection system for the launch pad and released an RFP for the construction of a new mobile launch platform.

Commercial Crew & Cargo Program Office (C3PO) FY07 Highlights

Administered out of the C3PO, the Commercial Orbital Transportation Services (COTS) project progressed toward the goal of demonstrating an orbital capability to the ISS to encourage a commercial market in ISS resupply. During FY07, five new entrepreneurial space companies with unfunded Space Act Agreements --Constellation Services International, PlanetSpace, SpaceDev, SpaceHab, and Transformational Space (t/Space)—joined the C3PO's two current COTS partners with funded Space Act Agreements: Space Exploration Technologies (SpaceX) and Rocketplane Kistler (RpK). Funded partner SpaceX made considerable progress toward its goal of demonstrating an orbital capability by 2010 by manufacturing

flight hardware, conducting successful engine development testing, and successfully passing its initial ISS Safety Review. The other funded competitor, RpK, encountered difficulty in its search for funding that was not resolved during FY07.

Advanced Capabilities

The ESMD's Advanced Capabilities Division (ACD) develops and provides the type of critical products that reduce operational and technical risks for Constellation Systems projects. These products include high-priority technology needs for lunar exploration; risk mitigation related to astronaut health and performance using the ISS, free-flyers, and round-based laboratories; and lunar robotic missions to gather data relevant to future human missions.

Lunar Precursor Robotic Program (LPRP)

The LPRP plans and executes robotic missions to the Moon to conduct research and prepare for future human exploration. Precursor activities include topographic mapping, mineral identification and mapping, and radiation and dust characterization. Data from LPRP missions is critical to Constellation Systems' efforts to return humans to the Moon by 2020 and will support astronaut safety, landing-site selection, and engineering requirements for lunar surface hardware.

The first lunar robotic mission is the Lunar Reconnaissance Orbiter (LRO), which will provide detailed mapping for human landing site selection. A secondary payload, the Lunar Crater Observation and Sensing Satellite (LCROSS), will provide additional data on lunar resources.

In FY07, the LPRP completed the Critical Design Reviews for the Lunar LRO and the LCROSS.

Human Research Program (HRP)

The HRP investigates and mitigates the highest risks to astronaut health and performance in support of NASA's exploration missions. The program's primary goal is to develop and provide human health and performance countermeasures, knowledge, technologies, and tools that enable safe, reliable, and productive human space exploration.

During FY07, the HRP:

- Solicited and initiated studies aimed at more accurately understanding the effect of space radiation dose rate on cancer risk, with the goal of allowing longer stays in space for exploration missions. The HRP also continued evaluating increased risk of carcinogenesis from space radiation exposure as a function of age, age at exposure, radiation quality, latency, and gender.
- Delivered radiation design tools to the Government and industry that provided current best practices for evaluating spacecraft design for radiation exposure. These tools were used in Orion's design cycles to assess the radiation protection provided by the vehicle for lunar missions.
- Delivered human performance data that will significantly affect EVA suit design for lunar surface missions. The human performance data characterizes metabolic costs of a planetary suit related to suit weight, center of gravity, pressure, inertial mass, and biomechanics. This data is used to evaluate the new, surface EVA suit architectures, and it provides a testing methodology for new suit designs. One significant test evaluated the capability of a suited crew member to walk 10 km to perform a self-rescue in case of a rover failure. Results indicated that a 10 km lunar traverse is possible.
- Matured several medical capabilities to higher technology-readiness levels for space exploration missions, including rapidly deployed sensors that are used in monitoring health status during EVA, systems to make medical-grade water in space, systems to concentrate oxygen from cabin air instead of stored oxygen for ventilation, and information management tools to track the incidence of medical events during space flight missions. These technologies allow NASA to meet the required level of care standards for long-duration space exploration missions.
- Initiated a suite of studies evaluating the human toxicity of long-term exposure to lunar dust and produced an inhalation standard to support lunar surface systems. Significantly, the program developed techniques to create lunar dust simulants with chemical and size distribution properties similar to actual lunar dust.

- Completed two important investigations on the ISS related to space microbiology. The Surface, Water, and Air Biocharacterization (SWAB) experiment—A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft Environment—evaluated improving microbial population monitoring on spacecraft. The microbe experiment (Effect of Space Flight on Microbial Gene Expression and Virulence) measured increased virulence of a common food-borne microbe, Salmonella, due to exposure to the space flight environment.
- Conducted investigations on the ISS and on Earth aimed at evaluating factors related to crew performance degradation, which could lead to errors during critical mission operations. The investigations included sleep loss and circadian rhythm changes, medication side effects, and fatigue related to team cohesion. The program also tested a quick, effective method of assessing cognitive status using flight analogs.
- Completed flight-testing of a compound to prevent renal stone formation. Factors leading to renal stone formation are present during space flight due to the resorption of bone minerals including calcium. Results indicate that the use of potassium citrate reduces the risk factors for renal stone formation.
- Initiated a study on the ISS that tracks the status of nutritional markers such as vitamins and minerals. The study requires in-flight blood and urine samples. The first frozen samples have recently been returned from the ISS for analysis.

Exploration Technology Development Program (ETDP)

The ETDP develops new technologies that will enable NASA to conduct future human and robotic exploration missions and reduce mission risk and cost. The ETDP's primary customers are the Constellation Program's flight systems designers. The ETDP also works to reduce the risk of infusing new technologies into flight projects by maturing them to the level of demonstration in a relevant environment. The ETDP does this in time to support the Preliminary Design Review of a target flight system. The ETDP is maturing near-term technologies to enable the first flight of Orion in 2014 and developing long-lead technologies needed for the lunar exploration missions in 2020.

During FY07, the ETDP:

- Fabricated a prototype, 5-meter diameter ablative heat shield for the Orion crew exploration vehicle.
- Tested a prototype carbon dioxide and moisture removal system for the Orion crew exploration vehicle.
- Demonstrated 11-to-1 throttling of a prototype liquid hydrogen-liquid oxygen RL-10 rocket engine for the lunar lander descent stage.
- Test-fired a liquid oxygen-liquid methane rocket engine for potential use on the lunar lander ascent stage.
- Conducted a helicopter flight test of a laser sensor for detecting and avoiding hazards during lunar landings.
- Demonstrated oxygen production from simulated lunar regolith in the laboratory. The regolith was heated in the presence of hydrogen gas to produce water vapor, which was then split into hydrogen and oxygen using electrolysis.
- Launched and tested a lab-on-a-chip instrument for detecting harmful bacteria on the ISS.
- Discovered a new fluid behavior in microgravity using the Capillary Flow Experiment on the ISS.
- Launched the Smoke and Aerosol Measurement Experiment (SAME) to the ISS and conducted experiments to measure the size of smoke particles in microgravity.
- Demonstrated a hydrogen-air fuel cell power system for a lunar rover that can carry large payloads over rough terrain.
- Fabricated a proof-of-concept inflatable habitat for the lunar outpost.
- Developed a lithium-ion battery for powering a spacesuit portable life support system and demonstrated the battery in field tests.
- Developed, in collaboration with the Department of Energy (DOE) and industry partners, a conceptual design for an affordable, 40-kilowatt fission surface power system to provide power for the lunar outpost.
- Demonstrated an advanced video guidance sensor for automated rendezvous and docking operations on the Defense Advanced Research Projects Agency (DARPA) Orbital Express mission.

Transition Activity

NASA defines "transition" as the cross-cutting activities associated with completing the Space Shuttle Program and the beginning of exploration activities. It involves the careful planning and responsive disposition of personnel, processes, resources, and real and personal property. It focuses on leveraging existing Shuttle and ISS assets for the Exploration programs' safety and mission success. Successful transition is critical to the future of the Exploration programs' success.

NASA's accomplishments in supporting transition during FY07 began in November of 2006 with the publishing of the Human Space Flight Transition Plan, which describes the Agency's transition approach to safely fly out the Space Shuttle Program, completing the ISS, and developing the Constellation Program. Both the Space Operations Mission Directorate (SOMD) and ESMD approach transition tasks in a measured and disciplined manner. As such, both Directorates and the Constellation Program accomplished the following during FY07:

- Began a revision of the NASA Transition Plan and refined the Multi-Program Integrated Milestones chart that captures all major NASA developmental and operational milestones through 2020.
- Used a previously defined board and governance structure, such as the Transition Control Board and the Joint Integrated Control Board, to make substantial transition progress in the areas of Human Capital Planning, instilling project management discipline, and proceeding with Constellation Development.
- Worked a concerted effort to share the workforce between multiple programs, enabling people to build cross-over skills and personal connections to the future workforce, in a process called workforce synergy, or the sharing of skilled personnel among two or more programs. In addition, human resources professionals from Headquarters and the four major space flight Centers formed a working group to coordinate activities, share best practices and lessons learned, and to interact with the contractor community.
- The Office of Human Capital Management also initiated a Shuttle-to-Constellation Workforce mapping initiative to identify critical skills existing in the current program and what the level and need for those skills will be on future programs. The first phase, focused on civil service employees, was completed in September 2007. A follow-on

effort was performed in conjunction with the contractor community in December 2007.

- Conducted a second Space Shuttle Program workforce survey, in addition to quarterly transition updates, that were supplied to Shuttle Project managers and Center management.
- Created transition-related Web sites that included policy documents, points of contact for transition-related inquiries, and links to most of the Agency's transition activities.
- Conducted a series of meetings with affected Centers to discuss transition manager plans and their progress on the receiving end of the transition process. This facilitated open communication and involved the workforce in developmental planning activities.
- Injected more discipline into program management processes that govern transition and retirement activities consistent with the intent of NASA's Program Management document, NASA Procedural Requirement (NPR) 7120.5. Specifically, developed a preliminary schedule for Space Shuttle Program asset disposition based on the budgeted manifest along with a set of transition metrics to maintain cognizance and influence on progress at both the Mission Directorate and Agency levels.
- Assisted the Agency in creating detailed planning guidance for the FY09 budget planning cycle that specifically focused on workforce and property disposition. This helped to identify major cost drivers to transition and retirement, and initiated a requirements refinement exercise to reduce projected costs, streamline processes, and optimize the life-cycle costs for transition and retirement. NASA also revalidated the ISS Shuttle Transition and Retirement (STaR) budget.
- Through the Human Space Flight Capabilities forum, reviewed and evaluated the range of human space flight capabilities affected by Shuttle retirement, identified stranded capabilities and overlapping requirements, and provided insight to Agency management for realignment of institutional capabilities.

Space Operations Missions Directorate

The Space Shuttle has supported the Nation's space exploration programs for more than 26 years, carrying crews and cargo to LEO; performing repair,

recovery, and maintenance missions on orbiting satellites; providing a platform for conducting science experiments; and supporting construction of the ISS. Mission success continued to depend on a commitment to safety through engineering excellence, maintaining realistic flight schedules, and fostering a culture that encourages an informed and open discussion of risks and benefits. Those traits will continue to characterize NASA's management of the Space Shuttle through the last flight in 2010.

The Space Shuttle Program provided 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 Space Shuttle continued as the only vehicle capable of completing ISS assembly 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 servicing mission.

Assembly of the ISS continued in FY07 with the addition of the P5, S3/S4, and S5 truss segments. Eleven of the twelve truss segments and three of the four U.S. solar arrays are now on-orbit. At the end of FY07, ISS assembly became approximately 57 percent complete with about 250 tons on orbit. Overall, ISS systems performance remained excellent. Permanent power and thermal control systems were activated in FY07 and are operating as designed. The U.S. Oxygen Generation System, part of the Regenerative Environmental Control and Life Support System, was also activated and is performing nominally. During 2007, astronauts conducted a total of 20 spacewalks for ISS maintenance, science, and assembly, as well as research on 35 experiments, bringing the total number of experiments conducted on the ISS to 115.

On November 2, 2006, NASA celebrated six 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 test bed. During more than 2,190 consecutive days, ISS crews conducted research and experiments related to areas such as human life and medical sciences, materials and microgravity sciences, Earth observations, plant growth, and technology development. 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 six years of continuous presence, 129 people from 13 countries visited the ISS, with 37 of those visitors living aboard as members of the 15 expedition crews.

The Space Shuttle flew three successful missions during FY07. The Space Shuttle continues to demonstrate new technology and capabilities on nearly every flight, and the first flight of the year, STS-116 (December 2006), was no exception. The first night launch of a Space Shuttle since 2002, *Discovery*'s mission to the ISS was the first flight of one main engine with the Advanced Health Monitoring System, an upgrade package that allows the main engines to safely shutdown in the event of an anomaly. STS-116 continued ISS assembly with the installation of the P5 truss segment. STS-116 also reconfigured ISS power and thermal control systems into its permanent form. As planned, the docked mission also retracted half of the P6 solar array. The retraction was more complicated than originally thought due to grommets snagging the guide wires. A spacewalk was needed to clear the array panels and assist with the retraction. During these activities, astronaut Robert Curbeam set an EVA record for a single Space Shuttle mission with four EVAs totaling more than 25 hours. STS-116 also transported U.S. astronaut Sunita Williams to the ISS as a replacement for European Space Agency astronaut Thomas Reiter. Williams joined her Expedition 14 crewmates, Russian Commander Mikhail Tyurin and American Flight Engineer Michael Lopez-Alegria, already aboard the ISS.

An intense hailstorm struck the Space Shuttle *Atlantis* stack as it awaited launch in February 2007, causing extensive damage to the insulating foam on the top of the external tank. This damage led NASA to roll *Atlantis* back into the cavernous Vehicle Assembly Building for repairs to the tank. During the next few months, engineers and technicians leveraged the new tools and techniques developed during the previous three years to assess, analyze, and repair more than 6,000 individual areas of foam damage. These repairs proved very successful, and STS-117 launched in June 2007 without incident.

STS-117 installed the S3/S4 truss segment and deployed its solar arrays and photovoltaic radiators. This is the third of four sets of solar arrays to arrive on orbit. During the mission, the second half of the P6 solar array was retracted in preparation for its relocation during STS-120 (ISS 10A). However, while the

Space Shuttle was docked to the ISS, three redundant Russian Service Module computers suddenly went offline. Loss of these computers could have affected ISS attitude control through the use of Russian thrusters; environmental control through operation of Elektron oxygen generation and Vozdukh carbon dioxide removal systems; thermal control through Service Module external cooling loops; and Soyuz return vehicle power. Close cooperation between U.S., Russian, and European experts enabled quick resolution of the computer problems and a return to normal ISS operations.

STS-117 also transported U.S. astronaut Clay Anderson to the ISS and returned crewmember Sunita Williams. During her stay on the ISS, Williams set records for the longest duration spaceflight by a woman (195 days) and for the most time outside a spacecraft by a woman (29 hours and 17 minutes).

During a spacewalk on July 23, Clay Anderson jettisoned the Early Ammonia Servicer (EAS) from the ISS. The EAS was no longer needed on the ISS; its safe lifetime was expiring, and there was no safe way to return the EAS to the ground or continue storage on the ISS exterior. Weighing 1,410 pounds and about the size of a refrigerator, there is a one in about 4,630 chance of human casualty when the EAS reenters the atmosphere likely sometime in 2008. The Space Control Squadron (1 SPCS) of the U.S. Air Force Space Command, inside Cheyenne Mountain Air Force Station in Colorado Springs, Colorado, is tracking the object and will provide notification to the appropriate agencies when reentry is imminent.

The last Space Shuttle mission of FY07, STS-118, launched without incident in August 2007. STS-118 was also notable for a number of firsts: first flight of the Station-Shuttle Power Transfer System (which allows the ISS to feed electricity to a docked Space Shuttle and extend the mission duration; 1,186 kWh of electricity was transferred during STS-118), first flight of a new Global Positioning System avionics package, and first flight of the Advanced Health Monitoring System on all three main engines. STS-118 also featured the first flight of astronaut Barbara Morgan, a mission specialist and teacher who was also Christa McAuliffe's backup at the time of the *Challenger* accident in January 1986. The primary mission objectives were all completed, including continued preparations for the P6 truss relocation, replacement of the Russian Service Module computers, and transfer of 14,740 pounds of equipment and supplies to the ISS.

Damage was found on an insulating tile underneath *Discovery* (likely caused by a small piece of foam coming off the external tank during ascent), but NASA determined that the damage did not warrant the risks of an on-orbit repair. Just as weather played a role in delaying the launch of STS-117, STS-118 safely landed a day earlier than planned to avoid the consequences of Hurricane Dean in the Gulf of Mexico.

In April, Expedition 15 crewmembers Russian Commander Fyodor Yurchikhin and Flight Engineer Oleg Kotov were launched to the ISS on Soyuz TMA-10 14S and replaced Mikhail Tyurin and Michael Lopez-Alegria. Sunita Williams remained on board as part of Expedition 15. In June, Yurchikhin and Kotov conducted two spacewalks, completing the mounting of 17 conformal panels on the Russian Service Module. These panels provide additional micrometeroid and orbit debris protection for the Russian Segment, partially mitigating one of the top risks to the ISS.

The Agency's Russian partners continued supporting crew and cargo transportation to the ISS. During FY07, automated Russian Progress vehicles resupplied the ISS crew four times, and Russian Soyuz vehicles safely transported the ISS crew to and from the ISS. Each resupply vehicle contained several thousand pounds of food, fuel, oxygen, experiment hardware, spare parts, and other supplies. In 2007, NASA and Roscosmos extended the crew-cargo contract through 2011. This cooperation will enable continuous uninterrupted crew presence to be maintained on the ISS through assembly complete and into the early stages of full ISS research mission operations.

During FY07, the ISS initiated 25 new experiments and continued 26 experiments, including the Nutritional Status Assessment (Nutrition), which became the most comprehensive in-flight NASA study to date of human physiologic changes during long-duration space flight. This study will impact both the definition of nutritional requirements and development of food systems for future space exploration missions to the Moon and Mars. Three initiated experiments, the Threshold Acceleration of Gravisensing (Gravi), the Optimization of Root Zone Substrates (ORZS) and the Analysis of a Novel Sensory Mechanism in Root Phototropism (Tropi), will develop plant growth models to support long-duration transits to Mars.

Through the end of FY07, approximately 778 hours of combined crew time were dedicated to research.

KSC received several International Partner elements for launch processing. On March 12, 2007, the Japanese Experiments Module - Pressurized Section (JEM-PS) arrived at KSC. JEM-PS will be launched on ISS Flight 1J/A (STS-123) and installed temporarily on top of Node 2 Harmony. The module will later be relocated to its permanent home on top of Kibo Laboratory's Japanese Experiment Module - Pressurized Module (JEM-PM). JEM-PS will provide support and storage for research facilities and experiments.

The Japan Aerospace and Exploration Agency's (JAXA) JEM Remote Manipulator System (RMS) arrived at KSC on January 15, 2007. The RMS is being prepared for launch along with Kibo JEM-PM on ISS Flight 1J (STS-124). This robotic manipulator will allow remote access and handling of experiments exposed directly to the space environment on JEM's External Facility.

The Canadian Space Agency's Special Purpose Dexterous Manipulator or "Dextre" arrived at KSC on June 19, 2007. Dextre will be launched on ISS Flight 1J/A (STS-123). This two-armed robotic manipulator will enhance current Space Station Remote Manipulator System (SSRMS) capabilities for ISS maintenance and servicing and reduce crew spacewalk requirements.

On July 27, 2007, the final U.S. pressurized element planned for ISS, Node 3, completed development and test. This element, similar to Node 2 Harmony, was built by Alcatel Alenia Space-Italia (AASI) and remains in storage at AASI. Node 3 will be shipped to KSC in July 2009 for launch on ISS Flight 20A in 2010. At the end of FY07, ISS development is substantially complete.

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 a number of spacewalks to assemble and maintain the orbiting facility.

The Space Shuttle Program occupies 654 facilities and uses more than 900,000 pieces of equipment. The replacement cost is more than $12 billion and located in hundreds of Government and contractor facilities across the United States. The net book value of Shuttle equipment is $948 million. The total facilities cost is approximately $5.7 billion, which accounts for approximately one-fourth of the value of the Agency's total property, plant, and equipment. NASA currently has more than 1,200 suppliers located across the country. Retiring these assets and facilities, or transitioning them to new human exploration efforts, remained 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 Shuttle flight while transitioning from this spacecraft to other exploration vehicles.

A number of significant transition and retirement activities took place in FY07. Rocket engine test stand A-1 at the Stennis Space Center in Mississippi, which the Space Shuttle Program used to conduct tests of the main engines, was turned over to the Constellation Program for J-2X engine use. At KSC in Florida, the Operations and Checkout Building and Firing Room 1 in the Launch Control Center were transferred to the Constellation Program for modifications to support Orion processing and launch activities. Completed during FY07, the Constellation Program refined its understanding of what Space Shuttle assets would be needed to support future programs through a series of System Requirements Reviews. The Constellation and Space Shuttle Programs continued to document their first and last need dates for facilities and capabilities to minimize gaps and produce the best value from the Nation's investments in exploration. Also, in FY07 there was an increase in the number of contractors and civil servants sharing time between the Space Shuttle, ISS, and Constellation Programs. This kind of workforce sharing is vital for maintaining critical skills and migrating the expertise and experience from existing programs to NASA's future exploration missions.

NASA's COTS projects, directed from the C3PO at the Johnson Space Center, made considerable progress toward the goal of encouraging the demonstration of an orbital capability to the ISS. In FY07, five new entrepreneurial space companies with unfunded Space Act Agreements joined C3PO's two COTS partners with funded Space Act Agreements—SpaceX and RpK. These companies were

Constellation Services International, PlanetSpace, SpaceDev, SpaceHab, and t/Space. One of the funded partners, SpaceX, made considerable progress toward its goal of demonstrating an orbital capability by 2010 by manufacturing flight hardware, conducting successful engine development testing, and successfully passing the initial ISS safety review. NASA plans to purchase cargo delivery services competitively from these or other commercial companies to fill the ISS cargo requirements gap.

During FY07, Space Communications provided high-proficiency services via the Tracking and Data Relay Satellite (TDRS) system network, the Near Earth Network, the Deep Space Network, and the NASA Integrated Services Network (NISN) to all NASA missions and a number of other national missions. Notable missions included the Shuttle and the ISS; the Hubble Space Telescope; such Earth-observing satellites as Aqua and Aura; and the Mars Exploration Rovers and Mars Reconnaissance Orbiter. Communications services also were provided to launch vehicles including Sea Launch and the Atlas.

The Space Communications and Navigation (SCaN) office completed the centralization of all NASA space communications activities within the SOMD. SCaN now oversees the total Agency space communications infrastructure as a single entity, as contrasted with the distributed oversight of the past several years.

The NASA Authorization Act of 2005 directed the Agency to "develop a plan . . . for updating NASA's space communications architecture for both low-Earth orbital operations and deep space exploration so that it is capable of meeting NASA's needs over the next 20 years." NASA delivered the report to Congress during the summer of 2007. It outlined key SCaN program goals based on the Agency's strategic plan. The report addressed potential major upgrades and development activities during the next 20 years to support the Vision for Space Exploration, as well as missions in near-Earth orbit.

During FY07, NASA initiated the acquisition of two replenishment TDRS system satellites, in partnership with other U.S. Government agencies.

Radio spectrum management remained an important focus in FY07 to ensure success of all NASA aeronautical and astronautics missions. NASA worked with U.S. Government agencies to ensure adoption of NASA's interests at the 2007 World Radiocommunication Conference.

NASA also continued dialogue with several other spacefaring countries to ensure space communications interoperability and radio spectrum-free operations for future lunar/Mars missions.

The SOMD Launch Services Program (LSP) successfully managed the launches of five missions on expendable launch vehicles (ELVs) during FY07. Solar Terrestrial Relations Observatory (STEREO), Time History of Events and Macroscale Interactions during Substorms (THEMIS), Phoenix, and Dawn were launched from Cape Canaveral Air Force Station, Florida. Aeronomy of Ice in the Mesosphere (AIM) launched from Vandenberg Air Force Base, California. A two-year mission that will provide a unique and revolutionary view of the Sun-Earth System, the STEREO, launched aboard a Delta II rocket on October 25, 2006. The third mission in NASA's Solar Terrestrial Probes Program, the STEREO, is tracing the flow of energy and matter from the Sun to Earth. Taking multitasking to new heights, NASA launched the five THEMIS satellites aboard a single Delta II rocket on February 27, 2007. NASA took on this mission to investigate what causes auroras in Earth's atmosphere to change in appearance and dissipate. Phoenix, a Mars Lander, also launched aboard a Delta II rocket on August 4 and will face a challenging seven-minute descent through the Mars atmosphere to land on the far northern face on May 25, 2008. After landing, it will use a robotic digging arm and other instruments during a three-month period to investigate whether the icy soil of the Martian arctic could have ever been a favorable environment for microbial life. On September 28, Dawn launched on a Delta II heavy rocket to study a pair of very different asteroids, Vesta and Ceres, that never grew large enough to become planets. By observing both minor planets with the same set of instruments, Dawn will provide new answers to questions about the formation and evolution of the early solar system. The AIM mission embarked on a Pegasus XL Rocket on April 25, and it is the first mission dedicated to the exploration of mysterious ice clouds that dot the edge of space in Earth's polar regions. For all of these missions, NASA competitively procured launch services from domestic commercial companies.

In a continuing effort to encourage emerging commercial launch service providers to provide significant cost savings to the science and exploration community, the LSP completed an Agency strategic review of medium ELV options. The

recommendation accepted by the Agency gave significant attention to enabling emerging launch services providers to become certified for NASA use. The LSP also coordinated an Agency review of NASA Policy Directive (NPD) 8610.7, Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions, to evaluate the feasibility of changes to Agency policy that would enable the use of emerging launch service providers sooner. In 2007, the Rocket Propulsion Test (RPT) Program continued to provide a common entry point for RPT customers, including NASA, industry, the Department of Defense (DOD), other Government agencies, and academia. The RPT Program has worked to develop and coordinate RPT activities to support Constellation rocket propulsion testing milestones by providing an Agency-level RPT Plan to prioritize and implement facility maintenance and modernization projects to ensure the continued safe and reliable operation of test facilities and associated infrastructure/systems.

Science Mission Directorate

NASA's Science Mission Directorate (SMD) successfully launched four new space science missions designed to improve our understanding of solar processes, Earth, and the history of the solar system:

- The THEMIS mission successfully launched on February 17, 2007. THEMIS became NASA's first five-satellite mission launched aboard a single rocket. The mission will help resolve the mystery of what triggers geomagnetic substorms, or atmospheric events, that appear in the Northern Hemisphere as a sudden brightening of the Northern Lights (Aurora Borealis). The findings from the mission may help protect commercial satellites and humans in space from the adverse effects of particle radiation. THEMIS' satellite constellation lined up along the Sun-Earth line and began collecting coordinated measurements and observing substorms. Data collected from the five identical probes will help pinpoint where and when substorms begin, a feat impossible with any previous single-satellite mission.
- The AIM mission launched on April 25, 2007. This became the first mission dedicated to the exploration of mysterious ice clouds that dot the edge of space in Earth's polar regions. The mission will study noctilucent clouds, which appear visible from the ground only at night when sunlight no longer visible from Earth's surface illuminates them.

AIM observed the first of these noctilucent clouds on May 25, 2007, nearly 2 weeks before they were visible to observers on the ground.

- The Phoenix mission to Mars blasted off on August 4, 2007, aiming for a May 25, 2008, arrival at the Red Planet for a close-up examination of the surface of the northern polar region. Phoenix will be the first mission to touch water-ice on Mars. Its robotic arm will dig to an icy layer believed to lie just beneath the surface. The mission will study the history of the water in the ice, monitor the weather of the polar region, and investigate whether the subsurface environment in the far-northern plains of Mars has ever been favorable for sustaining microbial life.
- The Dawn spacecraft began its 1.7 billion-mile journey through the inner solar system to study a pair of asteroids on September 27, 2007. Dawn will begin its exploration of Vesta in 2011 and Ceres in 2015. The two icons of the asteroid belt are located in orbit between Mars and Jupiter, and they have witnessed much of the solar system's history.

NASA and university scientists made substantial progress understanding the processes governing ice sheets and sea ice in the Arctic and Antarctic regions. A team of NASA and university scientists found clear evidence that extensive areas of snow melted in west Antarctica in January 2005 in response to warm temperatures. This was the first widespread Antarctic melting ever detected with NASA's QuikScat satellite and the most significant melt observed using satellites during the past three decades. The affected regions encompassed a combined area as big as California. Changes in the ice mass of Antarctica, Earth's largest freshwater reservoir, are important to understanding global sea-level rise. Large amounts of Antarctic freshwater flowing into the ocean also could affect ocean salinity, currents, and global climate. The 2005 melt created an extensive ice layer when water refroze after the melt. However, the surface melt was not prolonged enough for the melt water to flow into the sea.

In another study, scientists using NASA satellites discovered an extensive network of waterways beneath a fast-moving Antarctic ice stream; the discovery provides clues as to how "leaks" in the waterway network impact sea level and the world's largest ice sheet. This exciting discovery of large lakes exchanging water under the ice sheet surface radically altered scientists' view of what is happening at the base of the ice sheet and how ice moves in that environment.

In 2005, scientists found that the Arctic replaced very little of the thick sea ice it normally loses and replenishes each year. In 2005--from another NASA study--replenishment of this thick, perennial sea ice each year remains essential to the maintenance and stability of the Arctic summer ice cover. Using satellite data from NASA's QuikScat and other data, scientists studied six annual cycles of Arctic perennial ice coverage from 2000 to 2006. The scatterometer instrument on QuikScat sent radar pulses to the surface of the ice and measured the echoed radar pulses bounced back to the satellite. These measurements allowed scientists to differentiate the seasonal ice from the older, perennial ice. The scientists found that after the 2005 summer melt, only about four percent of the nearly 965,000 square miles of thin, seasonal ice that formed the previous winter survived the summer and replenished the perennial ice cover. This was the smallest replenishment seen in the study. As a result, perennial ice coverage in January 2006 decreased about 14 percent from January 2005.

NASA satellite data helped scientists solve a decades-old puzzle about how vast blooms of microscopic plants can form in the middle of otherwise barren mid-ocean regions. The research team published findings in May that used the data to show that episodic, swirling current systems (known as eddies) can act to pump nutrients up from the deep ocean to fuel such blooms. Data sets came from NASA's TOPEX/Poseidon, Jason, Aqua, and QuikScat satellites. The fate of all this biomass becomes important because plankton blooms can remove substantial amounts of carbon dioxide from surface waters and sink the carbon dioxide into the deep oceans. The plants can die and sink when the bloom runs its course, or animals consume them, producing fecal pellets that drop to the sea floor.

In July 2007, NASA's Tropical Composition, Cloud and Climate Coupling (TC4) field campaign began in San Jose, Costa Rica, with an investigation into how chemical compounds in the air get transported vertically into the stratosphere and how vertical transport affects cloud formation and climate. The campaign became an unprecedented opportunity to use NASA's complete suite of satellite and airborne Earth-observing capabilities to investigate a largely unexplored region of the atmosphere. A NASA ER-2 aircraft soared high above the cloud systems, which can reach an altitude of 70,000 feet, or three miles into the stratosphere. A NASA WB-57 aircraft flew into the cirrus clouds, measured cloud properties, and

sampled the chemical make-up of the storm systems' outflow. NASA's DC-8 aircraft probed the troposphere and the region between the troposphere and stratosphere (the tropopause transitional layer) with remote-sensing and in situ instruments. The DC-8 sampled cloud particles and air chemistry at lower altitudes. NASA deployed weather radar and meteorological balloons in Panama to support the campaign. NASA launched additional balloons from Costa Rica and San Cristobal Island in the Galapagos Archipelago. Observations from seven satellites provided the observational framework for the aircraft measurements with large-scale views of many different features of the atmosphere. For example, the Aura spacecraft focused on the chemical composition of the tropopause transitional layer and measured ozone, water vapor, carbon monoxide, and particles. NASA's Aqua satellite mapped thin cirrus clouds, some of which appear so faint that they are almost invisible to the naked eye. Instruments on the CALIPSO and CloudSat satellites pierced the atmosphere to provide vertical profiles of clouds and aerosol particles that can control how clouds form.

Using some of the first observations from the Mars Reconnaissance Orbiter, scientists were able to view both layers in exposed areas and minerals within those layers. This allows scientists to match mineralogy with topography and identify the most interesting areas for study by future landers and rovers. The most powerful telescopic camera ever sent to Mars began examining the planet last year and revealed these ancient patterns. The camera showed features as small as approximately three feet across.

During 2007, after having explored Mars for 3.5 years in missions originally designed for three months, NASA's Mars rovers faced perhaps their biggest challenge as severe storms blanketed the planet. The rovers faced dusty winds, power starvation, and other challenges; they survived. Now the rovers will continue their groundbreaking field work on Mars.

NASA's Spirit rover analyzed a patch of Martian soil so rich in silica that it may provide some of the strongest evidence yet that ancient Mars was much wetter than it is now. The processes that could have produced such a concentrated deposit of silica require the presence of water. The evidence also reinforced the fact that significant amounts of water were present in Mars' past, which continues to spur the hope that Mars was once habitable and possibly supported life.

NASA's New Horizons spacecraft came within 1.4 million miles of Jupiter on February 28, 2007, using the planet's gravity to trim three years from the spacecraft's travel time to Pluto. For several weeks before and after this closest approach, the piano-sized robotic probe trained its seven cameras and sensors on Jupiter and its four largest moons, storing data from nearly 700 observations on its digital recorders and gradually sending that information back to Earth. These new views included the closest look yet at the Earth-sized "Little Red Spot" storm churning materials through Jupiter's cloud tops, detailed images of small satellites herding dust and boulders through Jupiter's faint rings, and views of volcanic eruptions and circular grooves on the planet's largest moons.

In August, scientists from the Cassini-Huygens mission announced that they might have identified the source of one of Saturn's more mysterious rings. Saturn's rings are an enormous, complex structure, and their origin remains a mystery. The relatively large, icy particles that reside within a bright arc on the ring's inner edge likely produced Saturn's "G ring." The plasma in the giant planet's magnetic field sweeps through this arc continually, dragging out the fine particles, which create the G ring. The finding provides evidence of the complex interaction between Saturn's moons, rings, and magnetosphere. One of the mission's objectives focuses on studying this interaction. The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency, and the Italian Space Agency.

Instruments on NASA's Cassini spacecraft also found evidence for seas, likely filled with liquid methane or ethane, in the high northern latitudes of Saturn's moon Titan. Cassini viewed one such feature larger than any of the Great Lakes of North America and about the same size as several seas on Earth. Titan is the second largest moon in the solar system and about 50 percent larger than Earth's Moon.

NASA's twin STEREO spacecraft made the first three-dimensional images of the Sun. The new view will greatly aid scientists in understanding solar physics and thereby improving space weather forecasting. STEREO's depth perception also will help improve space weather forecasts. Scientists remain particularly concerned about a destructive type of solar eruption called a Coronal Mass Ejection (CME). CMEs cast large clouds of electrically charged gas, called plasma, into space from the Sun's atmosphere. A CME cloud can contain billions of tons of plasma and move at one million miles per hour.

In April, one of the STEREO satellites captured the first images of a collision between a comet and a solar hurricane caused by a CME. The collision resulted in the complete detachment of the plasma tail of Encke's comet. Observations of the comet revealed the brightening of its tail as the coronal mass ejection swept by and the tail's subsequent separation as it was carried away by the front of the ejection.

A new technique using the Solar and Heliospheric Observatory (SOHO) now enables scientists to forecast solar radiation storms, giving future astronauts traveling to the Moon and Mars time to seek shelter and ground controllers time to safeguard satellites. The new method, for the first time, offered as much as one hour of advance notice when a storm approaches. Spacecraft and satellites would also benefit. Subatomic particles striking computer processors and other electronics can cause on-board computers to suddenly reboot or issue nonsense commands. If a satellite operator knows about a coming storm, the craft can be placed in a protective "safe mode" until the storm passes. The SOHO project showcases international cooperation between the European Space Agency and NASA.

Astronomers using NASA's Hubble Space Telescope announced in May 2007 that they have discovered a ghostly ring of dark matter, which formed long ago during a titanic collision between two galaxy clusters. Dark matter makes up most of the universe's material. Ordinary matter, which makes up stars and planets, comprises only a small percentage of the universe's matter. The ring's discovery was among the strongest evidence yet that dark matter exists. Astronomers have long suspected the existence of the invisible substance and theorized about it as the source of additional gravity that holds galaxy clusters together. Also using Hubble, an international team of astronomers created the first three-dimensional map of the large-scale distribution of dark matter in the universe. This new map provided the best evidence to date that normal matter, largely in the form of galaxies, accumulates along the densest concentrations of dark matter.

The brightest stellar explosion ever recorded may be a long-sought new type of supernova, according to observations by NASA's Chandra X-ray Observatory and ground-based optical telescopes. This discovery indicated that violent explosions of extremely massive stars were relatively common in the early universe, and a similar explosion may occur in this galaxy. Astronomers think that many of the first generation of stars became this massive, and this new supernova may provide

a rare glimpse of how these stars died. It is unprecedented, however, to find such a massive star and witness its death.

In August 2007, NASA's Galaxy Evolution Explorer spotted a surprisingly long comet-like tail behind a star streaking through space at supersonic speeds. The star, named Mira after the Latin word for "wonderful," has been a favorite of astronomers for approximately 400 years. It is a fast-moving, older red giant that sheds massive amounts of surface material. The space-based Galaxy Evolution Explorer scanned the popular star during its ongoing survey of the entire sky in ultraviolet light. Astronomers then noticed what looked like a comet with a gargantuan tail. Material blowing off Mira forms a wake 13 light-years long, a wake about 20,000 times the average distance of Pluto from the Sun. Nothing like this has been seen before around a star.

NASA's Spitzer Space Telescope captured the light, for the first time, from two known planets orbiting stars other than the Sun. The findings announced in March marked the beginning of a new age in planetary science, in which extrasolar planets can be directly measured and compared. Scientists indirectly discovered all confirmed extrasolar planets, including the two recently observed by Spitzer. Scientists mainly used the "wobble" technique to find these extrasolar planets and, more recently, the "transit" technique. In the first method, a planet is detected by the gravitational tug that it exerts on its parent star, which makes the star wobble. In the second, a planet's presence is inferred when it passes in front of its star, causing the star to dim, or blink. Both strategies use visible-light telescopes and reveal the mass and size of planets.

Aeronautics Research Mission Directorate

NASA's Aeronautics Research Mission Directorate (ARMD) remained committed to expanding the boundaries of aeronautical knowledge for the benefit of the Nation and the broad aeronautics community. The ARMD conducted cutting-edge research that included:

- Foundational research across a number of core competencies that supported 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.

- Research that supported the Next Generation Air Transportation System (NextGen) in partnership with the Joint Planning and Development Office (JPDO).

The ARMD's research plans directly supported the goal and objectives of the National Aeronautics Research and Development (R&D) Policy established by Presidential Executive Order 13419 in December 2006. The ARMD ensured that it aligned with the National Aeronautics R&D Policy by focusing on the following five strategic objectives:

1. Conduct high-quality, cutting-edge research that benefits the constituents of the entire aeronautics community.
2. Disseminate the results of all research to the widest practical and appropriate extent (consistent with national security and foreign policy). During FY07, the ARMD generated one book, 132 peer-reviewed journal articles, 11 NASA technical publications, 39 NASA technical memorandums, and 426 papers presented at technical conferences not requiring review.
3. Pursue a coordinated approach to managing the Nation's research, development, test, and evaluation (RDT&E) infrastructure. In January 2007, the ARMD established the National Partnership for Aeronautics Testing.
4. Foster intellectual partnerships with industry and academia by means of cooperative Space Act Agreements (SAA) and full and open competitive research awards that emphasize true collaborations among all partners by means of the NASA Research Announcements (NRA). In FY07, the ARMD received 625 proposals through the NRA process and selected 179 for negotiation of an award. The ARMD also established 23 SAAs.
5. Establish strong partnerships with other Government agencies and organizations, especially the Federal Aviation Administration (FAA), DOD, and the JPDO. In FY07, the ARMD established a Memorandum of Understanding with the U.S. Army. In addition, the ARMD continued its strong participation with the USAF and with its partner Federal agencies in the JPDO.

As a member Agency of the JPDO, NASA, along with its partner agencies, worked on solutions that will mitigate the forecasted increase in air traffic demand during the next two decades, ranging from a factor of two to three, by 2025.[1] The

JPDO predicted that noise and emissions will become a bigger problem at airports and already constrain the growth of the air transportation system. The JPDO anticipates that emissions will also become a problem en route.[2]

NASA successfully flight tested one potential solution, the Blended Wing-Body (BWB), in partnership with the Air Force Research Lab (AFRL) and Boeing Phantomworks, at the Dryden Flight Research Center. The BWB is a hybrid aircraft configuration combining the best attributes of a conventional tube-and-wing aircraft with a flying wing. Potentially, if optimized for noise, a BWB could achieve a 52 decibel cumulative reduction below Stage III standards;[3] or alternatively, reduce nitrous oxide emissions by 80 percent over Committe on Aviation Environmental Protection (CAEP)/2 levels;[4] or reduce fuel consumption by at least 40 percent; or most likely, some intermediate "global optimum."

Also, NASA and its partners continued to work together on powered lift concepts to enable aircraft to operate from much shorter runways. Such aircraft could lead to better utilization of smaller airports and provide direct service to more communities. The BWB is one advanced aircraft configuration that might benefit from that research, and while the BWB concept may not be the ultimate solution, the concept represents the improvements possible in future aircraft.

Theoretically, the BWB should be more stable than a pure flying wing, but less stable than a conventional aircraft with a prominent tail. Wind tunnel tests demonstrated this, but until FY07, no realistic, properly scaled model of a BWB had ever been flown to test its true flying qualities. During this past year, the ARMD conducted several flight tests on an aerodynamically scaled, mass balanced BWB. Boeing Phantomworks and Cranfield Aerospace built the experimental aircraft, with a wingspan of 21 feet (8.5 percent of full scale). The flight tests explored the basic low-speed flying qualities of the BWB, including stability and control, and tested the onboard flight control system. The aircraft successfully flew under a wide range of flight conditions and has not shown any unsafe or anomalous behavior.

The BWB represented a mutually beneficial partnership. Boeing Phantomworks supplied the test vehicle; NASA provided proven ground and flight test expertise; and the AFRL provided wind tunnel access for transonic stability and control tests, as well as contractual and project management support. Coupled with recent

ground tests at NASA facilities, the ARMD established an extensive ground-to-flight database that brings this concept closer to reality.

In addition, the following describes and represents the technical accomplishments of the ARMD Programs during FY07.

Aviation Safety Program

The Aviation Safety Program built upon the unique safety-related research capabilities of NASA to develop tools, methods, and technologies that will improve the intrinsic safety attributes of current and future aircraft, as well as overcome aircraft safety technological barriers that would otherwise constrain the full realization of NextGen.

The Aviation Safety Program consisted of four projects. The Integrated Vehicle Health Management (IVHM) project addressed the challenge of using a prognostic approach to vehicle health management, in particular the integration, processing, and effective use of large amounts of data across highly integrated and complex flight critical systems. The Aircraft Aging and Durability (AAD) project addressed the challenge of improving the operational resiliency of future structures and advanced materials against aging-related hazards. The Integrated Intelligent Flight Deck (IIFD) project conducted research to ensure the proper integration of the human operator in a highly automated and complex operational environment. The Integrated Resilient Aircraft Control (IRAC) project addressed the challenge of using advanced adaptive control concepts to prevent the loss-of-control of an aircraft in the event of an upset or off-nominal condition.

During FY07, researchers in the AAD project assessed capabilities at NASA, other agencies, and the aerospace industry to establish a baseline for state-of-the-art aircraft aging and durability technologies, refine the approach for subsequent research tasks, and initiate partnerships for collaborative research. For example, researchers evaluated existing and emerging methods for the analysis of damage progression on several materials systems, including integral lightweight metallic, high-temperature metallic, hybrid laminate, and polymer matrix composite materials. Further, they developed novel materials modeling approaches, mainly coupling molecular dynamics and continuum methods for metallic materials with variable fidelity methods for the development of progressive damage models in composite

materials. The assessment focused on in-house research and identified topics for partnerships through the NRA process.

The IVHM project conducted hardware-in-the-loop testing of selected fault modes for Electro-Mechanical Actuators (EMA) in collaboration with Moog, Inc. Measurements using actuator instrumentation showed distinguishable fault signatures between nominal and injected fault conditions. These signatures will be used to develop prognostic algorithms to predict remaining useful life while operating under degraded operations. By predicting remaining useful life of an EMA, a vehicle health management system can assist the vehicle to maintain safe operations, whether the EMA operates as designated or begins to exhibit characteristics of future failure.

In addition, a silicon carbide (SiC) differential amplifier integrated circuit chip, fabricated and packaged for the IVHM propulsion systems activity, demonstrated 2,000 hours (and still counting) of continuous electrical operation at 500° C. Prior to this work, such integrated circuit chips only operated at such high temperatures for a few hours before degrading or failing. These extremely durable transistors and packaging technologies will enable highly functional, but physically small, integrated circuitry to be used for sensing and control electronics within harsh environments such as hot-sections of jet engines as well as long-duration spacecraft.

The IIFD project conducted initial experiments to measure the influence of vision-aiding technology on pilot performance while flying a critical phase of flight such as the final approach segment. The project began the definition for quantitative, experimentally derived, performance-based criteria for all-weather Equivalent Visual Operations (EVO). Twenty-three pilots conducted approaches and landings in visibilities ranging from 2,400 feet down to 1,200 feet, with various simulated airport approach lighting systems. Subjective results indicated that vision-based displays offer improvements in situational awareness, workload, and approach and landing performance. Subsequent work will characterize the pilot's awareness and reaction to the non-normal events that were introduced into the experiment.

The IRAC project successfully tested a dynamic tool on the Airborne Subscale Transport Aircraft Research (AirSTAR) flight research testbed. The project intended AirSTAR to allow testing that appears too high risk for manned aircraft, especially in off-nominal conditions that are critical for assessing safety

concepts and technologies. The dynamic tool consisted of a parameter identification algorithm developed to learn and predict changes in aircraft dynamics and aerodynamic coefficients. Such dynamic tools will enable advanced flight control systems to automatically detect and adapt to off nominal situations such as a malfunctioning flight actuator or damaged control surface.

Airspace Systems Program

The main objective of the Airspace Systems Program directly addresses the fundamental air traffic management research needs of NextGen in collaboration with member agencies of the JPDO. The program consisted of two projects, NextGen-Airspace and NextGen-Airportal, and the ARMD expects each project to make major contributions to air traffic needs of the future by the development of en route, transitional, terminal, and surface capabilities. Both projects remain highly integrated, much like the airspace system itself, as they pay close attention to information management at critical transition interfaces in the national airspace system.

The Airspace project developed an operational concept and procedural document, safety analysis, and simulation of oceanic in-trail procedures. The project also conducted human-in-the-loop (HITL) simulation on very closely spaced parallel approaches addressing techniques for safely getting more and varied aircraft types into the terminal domain. In addition, the project developed an initial concept for Airspace Super Density Operations that met the multiple objectives of NextGen terminal airspace operations: significantly increased capacity, robustness to varied and chaotic weather conditions, reduced environmental impact, and coordination of arrival and departure operations to/from multiple proximate airports in a Metroplex.[5] The project conducted initial assessments of core elements, including: closely spaced approach procedures, continuous descent arrival operations, 4D trajectory navigation, and delegated spacing function and dynamic routing to avoid adverse weather. This work provided an example of the close interplay between the Airspace and Airportal projects. Ongoing efforts directed at the integration of surface movement and airport planning functions will be closely coordinated between the Airspace and Airportal projects, leading toward a comprehensive assessment of proposed capabilities and potential benefits.

To ensure wide dissemination of research results to the broad aeronautics community, the Airspace project held its first Technical Interchange Meeting (TIM) in March 2007, focusing on foundational research. This event included discussions about the project's research thrust areas and technical presentations by the principal investigators for each of the 15 FY06 NRAs. More than 150 participants from NASA, the FAA, industry, and academia shared ideas across the research community. Additionally, in February 2007, the project sponsored an international workshop on Dynamic Airspace Configuration with more than 65 participants from the U.S. and Europe including academia, industry, and government. This workshop addressed the challenges of migrating from the current structured, static homogenous airspace to a dynamic, heterogeneous airspace that adapts to user demand and meets changing constraints (weather, traffic congestion, diverse fleets).

The Airportal project moved into implementation in May 2007 after completing reformulation. Whereas the Airspace project is aimed at the en route and approach airspace, the Airportal project develops and validates algorithms, concepts, and technologies to increase throughput of the runway complex and achieve high efficiency in the use of airportal resources, such as gates, taxiways, runways, and final-approach airspace. Since every airport has a unique environment and demand is not expected to increase equally at each airport as the system grows, the project will develop and evaluate a suite of capacity-increasing concepts and system analysis capability to aid in tailoring solutions to specific needs. During FY07, the project identified key airport capacity constraint factors and ranked them according to airport demand forecasts as a basis for future research and study to accomplish this long-term goal. The project developed the initial Airportal operational concepts, including Airportal functions, requirements, and procedures to supplement the Airspace project's definition of the initial concept for NextGen superdensity operations. Additionally, the Airspace and Airportal projects jointly selected three NRA proposals to conduct research on the characteristics and roles of a Metroplex.

Fundamental Aeronautics Program

The main goal of the Fundamental Aeronautics Program ensures the intellectual stewardship of key core competencies of aeronautics for the Nation across all flight regimes. For this purpose, the Fundamental Aeronautics Program conducted long-term research focused and integrated across disciplines that provided feasible

solutions to the performance and environmental challenges of future air vehicles. The program also pursued innovative research ideas and modeling techniques relevant to low-cost and reliable access to space, as well as the entry and descent phase of planetary exploration. The program pursued and developed technological capabilities that range from basic knowledge of underlying physical phenomena to the understanding of system-level interactions.

The program was structured by flight regime and encompassed research in the four thrust areas of Subsonic Rotary Wing, Subsonic Fixed Wing, Supersonics, and Hypersonics. The Subsonic Fixed Wing project addressed the challenge of future aircraft to be quieter and cleaner to meet stringent noise and emissions regulations resulting from the expected growth in the air transportation system (two to three times higher capacity by 2025). These aircraft must also meet challenging performance requirements to provide greater efficiency and expanded service to the public. The Subsonic Rotary Wing project addressed the technical barriers that constrain rotorcraft from reaching widespread use in civil aviation. These barriers included improved range, speed, payload capacity, fuel efficiency, and environmental acceptance. The unique ability of rotorcraft to operate independent of a runway could greatly expand access to air travel. The Supersonics project conducted research to address the efficiency, environmental, and performance barriers that prevent practical supersonic cruise over land, as well as the critical issue of supersonic deceleration to enable safe, precision planetary entry/descent/landing (EDL) of human and large science missions in any atmosphere. Because all access to space and all entry from space through any planetary atmosphere requires hypersonic flight, the Hypersonics project addressed the key fundamental research issues required to facilitate hypersonic flight and reentry. Specifically, the Hypersonics project focused on air-breathing technologies for the first stage of a highly reusable two-stage-to-orbit launch system and technologies for hypersonic entry and descent of very heavy payloads into planetary atmospheres, unique to NASA missions.

As noted previously, in FY07, the Subsonic Fixed Wing project, in partnership with the USAF and Boeing, successfully completed flight experiments of the X-48B BWB advanced aircraft at NASA's Dryden Flight Research Center.

The Subsonic Rotary Wing project, in partnership with Bell Helicopter Textron and the University of Maryland, conducted a helicopter noise test near Hollister,

California, to acquire ground-based acoustic data for maneuvering flight. This test measured the noise from a Bell Model 206 helicopter in both steady and maneuvering flight. The NASA Portable Programmable Guidance Display (PPGD) guided aircraft flight conditions and maneuvers to enable precision, repeatable trajectories to be flown. This critical step moved the project toward enabling commercial rotorcraft to operate quietly over populated areas.

The Supersonics project successfully completed a flight validation experiment at NASA's Dryden Flight Research Center (DFRC), in which a series of reduced-strength, noncoalescing shocklets produced by the Gulfstream QuietSpike™ device were measured and propagated to the ground to assess the effectiveness as a sonic boom mitigation strategy. Increasing aircraft length and slenderness effectively reduces sonic boom; however, this results in a very heavy aircraft with little usable interior volume and poor low-speed performance. Gulfstream Aerospace developed the QuietSpike, an innovative approach that extends a specially tailored "spike" from the nose of the aircraft, during cruise, to simulate a much longer, much more slender aircraft. The tests conducted on a modified NASA F-15 aircraft demonstrated the feasibility of the QuietSpike concept and could lead to a commercial supersonic aircraft without a disturbing sonic boom.

The Hypersonics project completed 10 successful engine tests of the X-1 scramjet engine in NASA Langley Research Center's (LaRC) 8-foot High Temperature Tunnel at simulated Mach numbers of 4.6 and 5.0, with two partially successful tests at 6.5. The most notable accomplishments included quantifying engine performance and operability, developing an engine start approach, similar to that planned for flight, and demonstrating fuel staging between fuel injection sites. Fuel staging remains one of the most critical issues in developing a viable hypersonic propulsion system, or the ability to accommodate the transition from partly subsonic flow in the engine combustor (dual-mode) to fully supersonic flow (scram mode) operation as the vehicle accelerates through the hypersonic regime. Failure to properly manage this transition potentially causes an engine flameout or unstart, both of which would likely result in a loss of mission. The tests conducted at the Langley Research Center provided the necessary data and confidence to allow the AFRL to proceed toward a series of flight tests in FY09.

Aeronautics Test Program

The Aeronautics Test Program (ATP) supported the NASA ARMD objective to ensure the continuous availability of a portfolio of NASA-owned wind tunnels/ground test facilities and flight operations/test infrastructures that are strategically important to meeting national aerospace program goals and requirements.

In FY06 and FY07, the ATP invested approximately $25 million in targeted facility maintenance projects to improve the reliability and ensure the continuous availability of a portfolio of NASA-owned wind tunnels and ground test facilities. This investment reduced the NASA deferred-maintenance liability for these national assets by an estimated 10 percent.

In FY07, the ATP collaborated with the NASA Centers to establish a clear and consistent pricing structure and charging policy for wind tunnel testing across its facility portfolio. As a result of this effort, the facility cost elements recovered by the wind tunnel charge rates are now standardized across all NASA Centers, and the charge rates will be stabilized to the greatest extent possible through the continued ATP involvement. This approach assisted test customers in their cost-estimating activities and long-range test planning.

In addition, the ATP involved the USAF's Arnold Engineering Development Center in its quarterly aeronautics test facility meetings with the NASA Centers. This collaboration included sharing information on charge rate structure and content, maintenance and capital investment activities, and test facility schedules and long-range planning. By collaborating with the USAF on facility planning, operation, investments, and test schedules, the ATP continued to develop a vision and funded plan that reflects the priorities of the long-term needs of the Nation. This activity also broadened the vital network of wind tunnel test professionals with exchange of staff and experiences among NASA Centers and between NASA and the DOD.

As part of its continuous efforts to improve facility operational efficiencies, the ATP sponsored a National Strain Gage Balance Team, which completed a technical review and concluded that NASA's capability to use strain gage balances in wind tunnel testing has severely eroded. The ARMD reviewed several recommendations for FY08 implementation.

National Aeronautics R&D Plan

During FY06, the Aeronautics Science and Technology Subcommittee of the National Science and Technology Council, co-chaired by the ARMD Associate Administrator, developed the Nation's first Presidential Policy for Aeronautics R&D. The policy, along with its accompanying Executive Order (EO) 13419, "National Aeronautics Research and Development," signed by President Bush on December 20, 2006, will guide U.S. aeronautics R&D programs through 2020. The policy defined the principles upon which Federal Government aeronautics R&D will be based and describes the roles and responsibilities of the involved executive departments and agencies. In addition, the policy called for the development of a national aeronautics R&D plan to set R&D priorities and objectives and produced roadmaps to achieve the identified objectives with timelines. During FY07, the NASA ARMD Associate Administrator continued to co-lead the subcommittee as it worked to develop the follow-on R&D plan released in December 2007.

Partnerships with Government and Industry

The ARMD continued to create strong intellectual partnerships with the broad aeronautics community during FY07 through the NRA process and SAAs, as described above.

In addition to conducting research that directly addresses NextGen challenges, NASA worked in conjunction with all partner agencies of the JPDO to develop core planning documents for NextGen, such as an enhanced version of the NextGen Concept of Operations (ConOps), which provided a common vision of "what" the NextGen future state will be in the 2025 timeframe and beyond; the NextGen Enterprise Architecture, which stated "how" NextGen will operate; the NextGen R&D Plan, which described the "needs" for R&D to achieve the NextGen capabilities; and the first draft of the NextGen Integrated Work Plan (IWP), which laid out "who, when, and how" the NextGen capabilities will be researched, developed, and implemented. In addition, the documents placed significant emphasis on enhancing communications with the JPDO in FY07 by the initiation of quarterly reviews between NASA and JPDO senior management teams. NASA also worked with the JPDO to promote a consistent long-term vision for NASA's NextGen R&D by developing and vetting a white paper describing

how NASA R&D supports NextGen and assisting in characterizing NextGen work in terms of near-, mid-, and far-term "epochs."

In January 2007, NASA signed a memorandum of understanding (MOU) with the DOD that created the National Partnership for Aeronautical Testing (NPAT) to facilitate the establishment of an integrated national strategy to manage their respective aeronautics test facilities. The MOU considered all aeronautical test facilities owned and operated by NASA and the DOD within the purview of the NPAT. The MOU defined aeronautical test facilities as facilities used for testing of vehicles (e.g., aircraft, missiles, or space vehicles) or for related scientific and engineering studies of the flow of a test medium around or through objects. Aeronautical test facilities included wind tunnels, air breathing propulsion test facilities, simulation facilities, and open-air ranges.

In September 2007, NASA and the U.S. Army signed an MOU that built upon and expanded the longstanding relationship between the two organizations. "Although NASA and the Army have different missions, we share a common goal of pursuing innovative research that will enable revolutionary capabilities in rotorcraft," said Lisa Porter, former NASA Associate Administrator, Aeronautics Research Mission Directorate. "There are common challenges facing rotorcraft for both the military and civilian sectors—payload, range, noise, and efficiency, to name just a few. It just makes sense for us to work together to advance our rotorcraft aeronautical capabilities for the nation's benefit." The MOU covered rotorcraft aeronautics and includes flight dynamics and control, vehicle structures, propulsion, avionics, aeromechanics, safety, and airspace management. The MOU ensures the free exchange of research information, reduces duplication, and enhances long-term research planning for both organizations.

The following are examples of other aeronautics partnerships:

- NASA's Fundamental Aeronautics Program continued its partnership with Alliant Techsystems, Inc. (ATK) to conduct the Hypersonics Boundary Layer Transition (HyBoLT) and Sub-Orbital Aerodynamics Re-Entry Experiment (SOAREX), a small flight experiment scheduled to launch in 2008. ATK will provide space on the initial flight of their new launch vehicle. It will deploy NASA's HyBoLT entry vehicle at about 500 km. The vehicle will enter at about Mach 11 and provide fundamental data on hypersonic transition between laminar and

turbulent flow. SOAREX, which will be deployed from the HyBoLT entry vehicle, will test a new small-scale decelerator concept.

- The Aviation Safety Program participated with the FAA and the Commercial Aviation Safety Team (CAST) to develop the Aviation Safety Information and Analysis Sharing (ASIAS) system. ASIAS enabled a system-wide conduit to various sources of operational aviation data that will be continuously monitored and analyzed, as necessary, to detect and identify trends or anomalies that could lead to an unsafe situation in the Air Transportation System. During 2007, NASA worked collaboratively with the FAA to transition a proof-of-concept research system developed by NASA into the operational ASIAS system. For FY08 and beyond, NASA will continue to develop new data-mining tools and techniques to help further evolve the capabilities of the ASIAS system to meet the needs of NextGen.
- The ATP collaborated with several national organizations and sponsored or cosponsored several working group meetings for the purpose of promulgating the National Aeronautics R&D Policy and fostering effective partnerships and working relationships. National partners included the DOD Test Resource Management Center and the American Institute of Aeronautics and Astronautics's (AIAA) U.S. Industry Test Facilities Working Group. The program held meetings at several sites during FY07.

Aeronautics Research Relevance and Benefits to the Public

NASA's aeronautics program ensures long-term focus in fundamental research in both traditional aeronautical disciplines and relevant emerging fields for integration into multidisciplinary, system-level capabilities for broad application. This approach will enable revolutionary change to both the airspace system and the aircraft that fly within it, leading to a safer, more environmentally friendly, and more efficient national air transportation system.

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[1] JPDO Progress Report, December 2006.

[2] NASA & NextGen; *http://www.aeronautics.nasa.gov.*

[3] Stage III refers to a limit imposed by the ICAO (International Civil Aviation Organization) on the maximum allowable noise levels for current aircraft.

[4] CAEP/2 refers to the second stage of regulation recommended by the Committee on Aviation Environmental Protection.

[5] A group of two or more airports whose arrival and departure operations are highly interdependent.

Department of Defense

DOD

During FY07, the DOD remained involved in a wide variety of exciting and challenging space activities, from continuing efforts to grow the Evolved Expendable Launch Vehicle (EELV) program into a world-class system to supporting our Nation's military operations and combat activities around the world including Iraq and Afghanistan. The DOD also continued its close relationship with NASA to further our Nation's civil space programs. The DOD launched three NASA spacecraft during FY07: the Dawn mission to the asteroid belt, the THEMIS scientific and robotic spacecraft, and the Phoenix mission to Mars. All three successfully launched from U.S. Air Force space launch ranges on board a Delta II expendable rocket. All four total launches of the Delta II launch vehicle during FY07 proved successful. The Delta II launch on September 18 marked the 75th time in the program's history that the Air Force successfully launched a vehicle. This historic launch also took place on the 60th Anniversary of the United States Air Force's founding in 1947.

The EELV program matured significantly during FY07, paving the way for critical Atlas V and Delta IV launches of long-anticipated Air Force and National Reconnaissance Office spacecraft. These launches, scheduled for the first quarter of FY08, will include the first operational launch of the EELV Delta IV Heavy carrying the last Air Force Defense Support Program satellite (DSP). This launch will herald the transition of that mission to the Space Based Infra-Red System (SBIRS), a multiple payload and satellite system designed to provide missile warning, technical intelligence battle space characterization data, and support missile defense.

FY07 also became a historic year in the Nation's military space programs. June 11 marked the 50th anniversary of the first Atlas launch vehicle in

1957. The Atlas launch vehicle continued to serve as the mainstay of America's launch programs, supporting national needs first as the original operational Intercontinental Ballistic Missile (ICBM), then as the vehicle of choice during NASA's Mercury program, and lately as the most dependable vehicle in our Nation's expendable fleet. Variants of the Atlas launched almost 600 times; and since 1993, they hold a 100-percent record of success in 80 consecutive launch attempts.

December 1 marked the first anniversary of the forming of United Launch Alliance (ULA), a joint Lockheed Martin and the Boeing Company venture combining the two defense giant's rocket programs. The goal of this venture is to provide world-class launch services to America's space industry and ensure multiple avenues of access to space for national security and defense payloads for the foreseeable future.

On March 8, the first Atlas V EELV (ninth Atlas V launch overall) lifted off at Cape Canaveral Air Station, Florida, and it also became the first launch for the ULA. This successful launch of a DOD Space Test Program (STP) mission carried space experiments designed to fly on the EELV Secondary Payload Adapter (ESPA). Located between the rocket and the main payload, the ESPA ring can carry up to six small satellites. This mission, known as STP Sat-1, placed a total of six satellites into two different LEOs. The main payload consisted of the DARPA 2 satellite Orbital Express mission and four small satellites on the ESPA ring. Orbital Express successfully validated the technical feasibility of robotic, autonomous on-orbit refueling and reconfiguration of satellites for future national security and commercial space programs. The other four small satellites included the following:

- STPSat-1, built by Aero Astro for the STP, was a 343-pound (156-kilogram) satellite carrying two Naval Research Lab experiments to collect atmospheric data and demonstrate spacecraft technologies.
- Cibola Flight Experience, built by Surrey Satellite Technology Limited (SSTL) for Los Alamos National Laboratory, was a 350-pound (159-kilogram) satellite testing inflatable boom antennas, a new power supply, and a prototype supercomputer designed to process data on board rather than sending raw information directly to Earth.
- FalconSAT-3, built by the U.S. Air Force Academy, was a 119-pound (54-kilogram) satellite carrying five experiments to study the near-

Earth space plasma environment, test new hardware, and demonstrate a Micropropulsion Attitude Control System.

- MidSTAR-1-1, built by the U.S. Naval Academy, was a 265-pound (116-kilogram) satellite carrying the Eclipse experiment to examine electrochemical membranes in space for NASA and Eclipse Energy Systems; it also carried a prototype microdosimeter sponsored by the National Space Biomedical Research Institute (NSBRI) to make a pair of space computer payloads.

Since the first Gulf War, Desert Storm, the DOD has worked hard to ensure that its space-based capabilities support the warfighter. These efforts provided successful results, as space professionals forward deploy to support the Global War on Terrorism (GWOT) and participate in combat activities in the Mid-East and wherever American forces deploy. These deployed space professionals remained the key to ensuring that space assets remain responsive to the operational forces and to driving the requirements to better provide communications, increased bandwidth, more precise navigation support, and earlier warning of threats. The talent needed to operate these more sophisticated systems continued as a key factor in developing a professional, dedicated space cadre to support the DOD and the national security community.

To better manage the rapidly evolving needs of the national security space community, the Air Force moved to a block acquisition approach to acquire new systems. This block approach allowed updated systems to move to operational status faster and provide better capability to end users, while still developing advanced future capabilities in the system. The back-to-basics approach already revealed rapid results as industry and the DOD worked together to provide systems to support national security space programs. The Global Positioning System (GPS) Block III will be one of the first programs to benefit from this approach.

Two new communications spacecraft programs, the Wideband Global System (WGS) and the Advance Extremely High Frequency Satellite Communications System (AEHF), will greatly increase the bandwidth available to end-users. These systems will provide increased and new capabilities to complement the existing Defense Communications System (DSCS). Following these two systems, the DOD designed the Transformational Satellite Communications System (TSAT) to support many of the bandwidth needs. These new satellite communications

systems will greatly increase the bandwidth available to the combat forces facing challenging new threats on the battlefield.

The DOD found the militarization of space by other nations of growing concern. China's interception and destruction of one of their own dead weather satellites became highly provocative and resulted in a thousand-fold increase in space debris. This debris will potentially remain in orbit for hundreds of years and remains a threat to all spacecraft passing near that orbit. The efforts to prevent on-orbit collisions and conjunctions will require significant additional efforts by the Space Surveillance System to track and identify dangerous debris. Recognizing these growing threats to orbital safety, the DOD increased its efforts to improve Space Situational Awareness (SSA).

Throughout 2007, the DOD made significant progress establishing program management structures and processes for Operationally Responsive Space (ORS), as well as executing ORS-related research and development efforts. In April, the DOD provided Congress with a plan that laid out an organizational structure and defined the responsibilities of the Joint ORS Office, which was created in May. The plan also described an approach for satisfying warfighter needs. With regards to operational experimentation and research and development, TacSat-2, launched in December 2006, operated in orbit until December 2007, meeting significant technical and operational milestones. TacSat-3 and TacSat-4 missions continued through their design phases into integration and testing on schedule for launches in 2008 and 2009, respectively. In addition, the ORS Office initiated the mission selection process for TacSat-5. Progress continued in developing interface standards for satellite buses and in sponsoring efforts aimed at acquiring low-cost launch vehicles.

From providing launch facilities and range support to civil and commercial programs and providing critical battlefield support to combat forces involved in dangerous missions around the world, the DOD shows unwavering commitment to providing first-class space professionals and assets for the national security space mission. From sharing the advanced technologies of the GPS, at no cost to all users, to developing the next generation metrological satellites with our civil partners, the DOD remains fully committed to keeping the United States the world's premier spacefaring Nation.

Federal Aviation Administration

FAA

Aviation is a vital resource with critical strategic, financial, and social impact on nearly every aspect of the global economy. The United States aviation system is the world-class leader, attracting investment in business, local and state economies, and opening new domestic and international markets and supply chains. To continue to realize and expand on these benefits, the United States must have an aviation system that is responsive to rapidly changing and expanding transportation needs.

Fiscal Year 2007 saw significant R&D success for researchers, scientists, and engineers directed by the FAA Office of Research and Technology Development. Additionally, the office maintains many liaisons with public agencies, private companies, and academic institutions that share common safety goals at airports and aboard aircraft.

The strain of increasing air traffic demand is especially apparent in the arrival and departure airspace surrounding major metropolitan areas, particularly those where there are multiple airports whose arrival and departure flows interact. In 2007, the FAA conducted a simulation study, Integrated Arrival/Departure Control Service or "Big Airspace" (BA), to develop and validate an operational concept for improving operational efficiencies in major metropolitan areas. The FAA performed the study with a combination of procedures, integrating arrival and departure airspace into one control service and one facility and employing other concepts such as dynamic airspace reconfiguration of bi-directional arrival/departure routes. Each technique showed unique strengths, thus enabling a comprehensive evaluation of the BA concept regarding impacts on efficiency, capacity,

safety, and human performance. The study also helped drive operational and technical requirements for further development of the concept. Using generic airspace as a platform for analysis, the simulation evaluations supported the BA concept by demonstrating service provider improvements and operational efficiencies. These benefits were evaluated in terms of workload, task performance, safety, and controller acceptance. Operational efficiencies included savings in flight time and distance flow with more efficient flow strategies. A preliminary cost-benefit analysis showed that all of the sites evaluated are expected to produce cost benefits with a short payback period.

The Wake Turbulence Research Program also met a milestone in 2007 in support of reduced separation for departures from Closely Spaced Parallel Runways (CSPRs). NASA and the FAA developed and evaluated a wind-dependent departure solution prototype, called Wake Turbulence Mitigation for Departures (WTMD), at Lambert-St. Louis International Airport and Houston's George Bush Intercontinental Airport. NASA and the FAA evaluated a simple WTMD decision support tool and found it suitable for performing reduced separation operations for departures from one runway when a Heavy or B757 aircraft departed from the adjacent parallel runway.

In the continental United States, 72 percent of low cloud ceiling and poor visibility related accidents result in fatalities. To mitigate these types of accidents, FAA-funded researchers developed a National Ceiling and Visibility Analysis (NCVA) and a forecast capability to warn users of areas with low ceilings and poor visibility. The NCVA provides users in the lower continental states with an automated graphical display, updated every 15 minutes, showing current ceiling, visibility, and flight category conditions along their route of flight. The NCVA capability also incorporates tools that allow concurrent examination of other weather data, including satellite and radar imagery. The joint FAA/National Weather Service (NWS) Aviation Weather Technology Transfer Board approved the NCVA for experimental use in FY05. User feedback obtained during the experimental phase resulted in NCVA improvements, including an enhanced cloud-mask that identifies cloud free areas between data sites. The NCVA completed development this year, and it is expected to be approved for full operational use in FY08.

The FAA and the International Aircraft Material Fire Tests Working Group conducted a series of full-scale fire tests to determine the performance of lightweight seat cushions under realistic post-crash fuel fire conditions. These seat cushions performed as well as heavier cushions that were compliant with the FAA fire test criteria. Therefore, a new criterion, Corrected Allowable Weight Loss (CAWL), was developed for lightweight seat cushions. CAWL is a sliding scale that specifies an increasing allowable percentage weight loss as the weight of the foam cushion decreases. To be conservative, more restrictive allowable cushion surface burn lengths are imposed as the foam weight decreases. The recently published FAA Final Report DOT/FAA/AR-06/49, "Laboratory-Scale and Full-Scale Fire Testing of Lightweight Aircraft Seat Cushion Materials," authored by Tim Marker, described the full-scale test results and the development of the CAWL for lightweight aircraft seat cushions. Based on this report, the Transport Airplane Directorate will issue an FAA policy letter, ANM-100, which addresses the CAWL fire test criteria for lightweight aircraft seat cushions.

In 2007, human factors researchers completed a Future En Route Workstation (FEWS) simulation test. The researchers designed the FEWS test on the principles of integrating currently independent automation tools, providing information when and where needed, and reducing the number of housekeeping tasks that controllers currently perform, thus freeing resources to focus on critical tasks of sequencing and separating aircraft. The results indicated that two controllers using the FEWS along with data communications can safely and efficiently manage approximately 30 percent more traffic than a single controller with Display System Replacement (DSR) and voice communications only. The FEWS interface resulted in a near 50-percent reduction in the number of data entries that controllers must make with either DSR or En Route Automation Modernization (ERAM). The FEWS design features (e.g., automatic handoff acceptance, automatic data block drop off, preferred leader line orientations, and data block dragging) will be ready to incorporate in the near term. Work begins with a follow-on simulation to include airborne capabilities envisioned in the Next Generation Air Traffic Management System (e.g., pilot self-spacing) and ways to reduce the number of objects that controllers need to actively monitor on the radar screen.

On February 13, 2007, new regulations established requirements for crew and space flight participants involved in private human space flight. These regulations required launch vehicle operators to provide safety-related information and identify what an operator must do to conduct a licensed or permitted launch with a human on board. Launch operators must inform space flight participants of the risks inherent in space travel in general and the risks of travel in their particular vehicle. The regulations also established requirements for medical qualifications and training as well as requirements governing environmental control and life support systems. These regulations resulted from the Commercial Space Launch Amendments Act (CSLAA), passed by Congress in December 2004. Recognizing that human space flight is a fledgling industry, Congress required a phased approach in regulating commercial human space flight, with regulatory standards evolving as the industry matures.

To facilitate research, development, and testing of new vehicle designs, including those intended to carry humans into space, the FAA also issued regulations for experimental permits that allow a more streamlined approach to testing prior to, or instead of, issuance of a commercial launch license. The permits are only allowed for suborbital Reusable Launch Vehicles (RLVs). A single experimental permit will cover multiple launch vehicles of a particular design and allow an unlimited number of suborbital launches. Permit authority also came from the 2004 CSLAA.

Ten commercial suborbital experimental permit launches took place in 2007, the first of their kind. Armadillo Aerospace conducted seven low-altitude flights from locations in both New Mexico and Oklahoma, and Blue Origin, LLC carried out three low-altitude flights from their launch site in Texas.

The FAA licensed four orbital commercial space launches in 2007, including two by the Sea Launch multinational partnership from a mobile platform in the Pacific Ocean and two by the Boeing Company using the Delta II launch vehicle from Vandenberg Air Force Base in California.

The FAA also released a Notice of Proposed Rulemaking for Requirements for Amateur Rocket Activities in 2007. Since current regulations were outdated and did not reflect industry practice, the FAA proposed revisions to amateur rocket regulations and activities to preserve the level of safety associated with amateur rocketry in the National Airspace System.

The FAA completed three R&D projects: *Human Space Flight Training Preparation Study*; *Safety and Operations Personnel Duty and Rest Analysis;* and *Historical Database of Failures and Reliability of Rocket-Powered Vehicles*. In addition, the FAA advanced the fidelity of its flight safety analysis tools by researching better methods of estimating vulnerability of aircraft from launch vehicle debris and better methods of estimating appropriately sized buffer areas around Reusable Launch Vehicle operating areas.

Applying lessons learned from the Space Shuttle *Columbia* failure, the FAA coordinated with NASA in real time during each Space Shuttle reentry. The FAA has the ability to void appropriate airspace of air traffic in case of a reentry failure.

In partnership with the U.S. Air Force, the FAA signed an agreement on safety for space transportation and range activities, assisted in the development of Air Force requirements for Reusable Launch Vehicles at Federal ranges, and cohosted a second Reusable Launch Vehicle Summit in Colorado.

The FAA completed an environmental assessment for rockets competing in the 2007 X Prize Cup at Holloman Air Force Base. The FAA developed a draft Environmental Impact Statement for Spaceport America in New Mexico and a draft Programmatic Environmental Impact Statement to analyze environmental impacts for rockets operating under experimental permits.

The FAA released several informative reports of interest to the public, the space industry, and the U.S. Government including the following: *FY-2007 Research and Development Accomplishments*; *2007 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports*; Quarterly Launch Reports; *Commercial Space Transportation: 2006 Year In Review*; and the *2007 Commercial Space Transportation Forecasts*. The forecasts, prepared by the industry-led Commercial Space Transportation Advisory Committee and the FAA, projected an average worldwide demand of about 15 launches per year to geosynchronous orbit and eight launches per year to nongeosynchronous orbits between 2007 and 2016.

Department of Commerce

DOC

In FY07, the Department of Commerce (DOC) engaged in a wide variety of activities that furthered U.S. interests in aeronautics and space, including national policy development, satellite operations, technology development, measurement and calibration, international cooperation, trade promotion, and spectrum management.

At the departmental level, the DOC continued its active role on the National Security Council's Space Policy Coordinating Committee (SpacePCC) through the direct participation of the Deputy Secretary of Commerce and staff from the National Oceanic and Atmospheric Administration (NOAA), the Office of Space Commercialization (OSC), the International Trade Administration (ITA), the National Telecommunications and Information Administration (NTIA), the National Institute of Standards and Technology (NIST), and the Bureau of Industry and Security (BIS).

The Office of Space Commercialization

The OSC continued to play a key role in the national management of the GPS. It continued to host the meetings and offices of the National Executive Committee for Space-Based Positioning, Navigation, and Timing, which advises and coordinates Federal departments and agencies on matters concerning the GPS and related systems. As part of this activity, the OSC continued to support the *www.PNT.gov* and *www.GPS.gov* Web sites, expanding the latter into five international languages for broader outreach and education.

In January 2007, the OSC hosted the first meeting of the GPS-Galileo Working Group "B" on Trade and Civil Applications, opening a dialogue with the European Union on nondiscrimination as Europe's Galileo satellite navigation system enters

the market. Among other things, the meeting resulted in the issuance of a joint statement on cooperation and joint fact sheet on GPS-Galileo cooperation. During FY07, the OSC also participated in successful U.S. consultations with Australia and Japan, both of which produced joint announcements on GPS cooperation.

On October 19, 2006, the OSC and the Space Enterprise Council of the U.S. Chamber of Commerce cohosted a public workshop on Geographic Information Systems (GIS). The event brought together commercial providers and civilian Government users of GIS technology. More than 100 participants attended the event.

The OSC released a strategic plan in early 2007 that outlines its vision, mission, functions, objectives and outcomes, and plan of action based on inputs from stakeholders in the space commerce community.

In 2007, the DOD's National Security Space Office (NSSO) and the U.S. Air Force partnered with the DOC's BIS to conduct a comprehensive survey of the U.S. space industrial base. The OSC worked with the BIS to identify companies to participate in the survey and provide key inputs and guidance into the survey and final report. The BIS data was presented to the Space Industrial Base Council (SIBC) of the NSSO in June 2007 and was used in the U.S. Air Force Defense Industrial Base Assessment Report of the U.S. Space Industry issued on August 31, 2007.

On September 10, 2007, the OSC cohosted the NASA Commercial Crew and Cargo Program Office's LEO Working Group "kick-off" meeting to discuss the development of LEO commercial markets. Representatives from NASA, the FAA, the DOC, and the entrepreneurial space industry participated in the day-long event.

National Oceanic and Atmospheric Administration

In 2007, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program completed full restructuring of this tri-agency satellite program. A $4.2 billion modification of the contract culminated in a rigorous year-long effort to replan virtually every aspect of the NPOESS program. The new plan included two development satellites and an option for two additional production satellites. In 2013, the first NPOESS satellite will begin to collect and disseminate data on Earth's weather, atmosphere, oceans, land, and near-space environment.

Additionally during 2007, the NPOESS Preparatory Project (NPP) completed all Engineering Design Unit interface testing with the spacecraft. NOAA also added the Ozone Mapping and Profiler Suite Limb back to the NPP manifest, marking the first reintroduction of an instrument after its removal during the Nunn-McCurdy certification. When operational, the improved capabilities in NPOESS will improve NOAA's ability to save lives and property.

Early in 2007, as part of the United States' contribution to the international Global Earth Observation System of Systems (GEOSS), NOAA repositioned a geostationary satellite, GOES-10, over South America to provide better meteorological coverage for that region. In addition to increasing NOAA's ability to track eastern Atlantic hurricanes, the move helps South American meteorological centers improve weather forecasting and demonstrates the goals of the intergovernmental Group on Earth Observations (GEO). Shifting GOES-10 will also help protect lives and property in North, Central, and South America by significantly improving satellite detection of such natural hazards as severe storms, floods, drought, landslides, volcanic ash clouds, and wildfires.

During 2006, NOAA's Polar-orbiting Operational Environmental Satellites (POES) continued to provide an uninterrupted flow of global environmental information. The POES supported oceanic and space environmental modeling, tropical storm analysis and forecasting, local weather forecasting, ecosystem monitoring, and climate monitoring. NOAA's weather and climate prediction numerical models extensively used the global data from these satellites. NOAA and NASA's contractor, Lockheed Martin, successfully completed the rebuild of the last POES satellite, NOAA-N Prime, and began preparations for environmental testing of the satellite in 2007. This satellite will be launched in 2009.

NOAA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) continued their cooperation in an initial joint polar-orbiting satellite system. Under a joint agreement, NOAA provides NOAA-18 and NOAA-N Prime, for an afternoon orbit of the globe, carrying a EUMETSAT instrument. In return, EUMETSAT will provide and launch three European-built satellites carrying key NOAA instruments, the MetOp series, into morning orbits during the next ten years, NOAA provided critical support to EUMETSAT in its preparation for the launch of the first European Polar System satellite, Metop-A.

NOAA also signed a four-partner agreement with NASA, the French Space Agency Centre National d'Études Spatiales (CNES), and EUMETSAT for the Ocean Surface Topography Mission (OSTM).

The international satellite-aided tracking search and rescue system, called COSPAS-SARSAT, celebrated 25 years of success, resulting in more than 22,000 rescues worldwide. During 2007 alone, this program rescued more than 330 people. The program involves 38 nations and two independent search and rescue organizations. The SARSAT system uses NOAA satellites in low-Earth and geostationary orbits to detect and locate aviators, mariners, and land-based users in distress. The satellites relay distress signals from emergency beacons to a network of ground stations and ultimately to the U.S. Mission Control Center (USMCC) in Suitland, Maryland. The USMCC processes the distress signal and alerts the appropriate search and rescue authorities to who is in distress and their location.

On October 12, 2007, the Intergovernmental Panel on Climate Change (IPCC) received the Nobel Peace Prize along with former Vice President Al Gore "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change." Several National Environmental Satellite Data and Information Service (NESDIS) scientists and staff members contributed to this effort, serving as authors, editors, and contributors for IPCC reports. These scientists contributed key information that led to this prestigious award. The international recognition highlighted the importance of oceanic and atmospheric research and climate data to the global community and how critical NOAA's work is to this effort.

Smoke from wildfires leads to significant air pollution and deteriorates air quality in the United States every year. Lightning-ignited or accidental wildfires inject large amounts of smoke aerosols into the atmosphere. This smoke becomes detrimental to human health and the economy. Smoke plumes can cause upper respiratory problems leading to increased emergency hospital visits. Satellite instruments, such as NOAA's Geostationary Operational Environmental Satellite (GOES) Imager, detect and track the movement of these smoke plumes. In 2007, a newly developed smoke product from the GOES Imager became operational. This product used a pattern-recognition technique that combines GOES Aerosol Optical Depth (AOD) imagery and fire hot spots. The NWS used this new GOES smoke product

in its operational smoke forecast verification system. Air quality forecasters used GOES aerosol imagery and other air quality forecasting tools to warn the public of elevated smoke concentrations so preventive measures could be taken.

Satellite-based analysis of the potential for heavy rainfall from tropical systems is integral to determining the magnitude and extent of flooding due to these systems. The Tropical Rainfall Potential (TRaP) product, which was completely automated in 2007, objectively analyzes the amount of rainfall associated with tropical systems. This product provided significantly more information to users. In addition, NOAA redesigned the TRaP customer portal to simplify and increase the efficiency of information searches and display capabilities for users. The TRaP product can help forecast flooding conditions from tropical systems, thereby helping to save lives and property.

In 2007, scientists in NOAA's National Oceanographic Data Center studied the relationship between salinity and freshwater distribution in the North Atlantic during the past half century using in situ data and an ocean circulation model. This distribution relationship is an essential aspect of the global climate system and variations can impact global climate change. Their findings, published in three papers during 2007, showed that net precipitation (precipitation minus evaporation plus melted ice) has a strong influence on the salinity distribution in the North Atlantic Ocean, which has a strong influence on the strength of the overturning circulation in that ocean. As surface waters become less saline, overturning circulation weakens (and vice versa). This overturning circulation is a component of the global ocean salinity conveyor belt, the system of currents that links the different ocean basins; and increased salinity in the North Atlantic can lead to downstream changes in overturning circulation in the North Pacific. The amount of heat the ocean moves from one part of the globe to another reflects such circulation changes. This in turn can cause changes in seasonal weather patterns around the world. The results of this research assist in verifying the accuracy of climate change prediction models. It also will improve understanding of the global climate system and how to predict and respond to climate change.

In 2007, the Washington Volcanic Advisory Center (W-VAAC), a joint office between NESDIS and the National Centers for Environmental Prediction (NCEP), contributed to the *National Volcanic Ash Operations Plan for Aviation*.

This plan, completed in July 2007, will improve the safety of flight operations in U.S.-controlled airspace by establishing interagency agreements for the detection of volcanic ash. Volcanic ash presents hazards to aircraft, and introducing common standards for volcanic ash-based advisories and warnings and providing universal formats will improve public safety. The Federal Coordinator for Meteorological Services and Supporting Research prepared and published the plan after many working group meetings among the FAA, U.S. Air Force, NOAA, the USGS, NASA, and the Smithsonian Institution's National Museum of Natural History.

The U.S. Total Electron Content (US-TEC) product became fully operational in 2007. This system, established by the National Geophysical Data Center (NGDC) during several years of development, provided measurements of the ionosphere's TEC. Active electrons in the atmosphere delay GPS signals traveling toward Earth; US-TEC provided measurements of the delay magnitude for different GPS satellites at different times of day. Incorporating US-TEC products allowed GPS users to obtain more accurate positions with their standard GPS receivers. The US-TEC system contained GPS data from the Continually Operating Reference Stations, the International GPS Services, and GPS/Met networks to estimate vertical and slant TEC every 15 minutes. Real-time US-TEC output is available at *https://www.sec.noaa.gov/ustec*, and historical data can be found at *http://www.ngdc.noaa.gov/stp/IONO/USTEC*.

NOAA's National Climatic Data Center continued to work with other U.S. Government agencies on the National Integrated Drought Information System (NIDIS). The NIDIS is a drought risk information system that provides users with the ability to determine the potential impacts of drought. Using data collected from airborne and satellite sensors, it also provides decision support tools necessary to better prepare for and mitigate the effects of drought. In November 2007, the U.S. Government unveiled a new Web site for public and civic managers to monitor U.S. drought conditions; get forecasts; know how drought impacts their communities; and know what mitigation measures exist. Called the U.S. Drought Portal, the *http://www.drought.gov* site provided a weekly updated map on drought conditions. Along with the existing international cooperation on a monthly product called the North American Drought Monitor, these tools served as an international model to help coordinate drought preparedness, response, mitigation, and recovery activities.

Drought blankets about a third of the United States at any given time. These efforts affect many aspects of everyday life, from water management to human health to energy consumption and conservation.

During FY07, NOAA delivered more than 300 terabytes of climate data online, an 84-percent increase compared to FY06. Rapid growth in the in situ, radar, satellite, and model data availability meant that 1.5 petabytes of data are now accessible from NOAA's National Climatic Data Center (NCDC) Web site. New software and online services included the following: 1) numerous GIS services enhancements; 2) a new National Solar Radiation Database; and 3) surface data "climograms," in which colorized graphical displays show frequency distributions of various parameters. These new products and services provided many benefits to decision makers and the public, such as enhanced and more efficient data availability via GIS services; easier access to solar radiation data to support issues like solar energy studies and heating/cooling loads for buildings; and data visualization that collects more than 100,000 weather observations for a location into a single image. The online services improved access to climate data and associated information products for the public.

The System-Wide Monitoring Program operating at National Estuarine Research Reserves in Alaska, Washington, and Oregon allowed shellfish growers in the Pacific Northwest to get near real-time water quality data. The monitoring stations at all 27 National Estuarine Research Reserves transmitted water quality and weather data every 30 minutes via satellite, which strengthens the growing Integrated Ocean Observing System (IOOS). The telemetering capabilities, which measure, receive, and transmit data automatically from distant sources, make the data available. Through a Web site (*http://www.nanoos-shellfish.org/*) established by NOAA's Office of Ocean and Coastal Resource Management and IOOS and jointly sponsored by the National Estuarine Research Reserve System and the Northwest Association of Networked Ocean Observing Systems (NANOOS), growers view up-to-date water temperature, salinity, oxygen, turbidity, pH, and chlorophyll data from reserves in Kachemak Bay, Alaska; South Slough, Oregon; and Padilla Bay, Washington, as well as from four buoys in Hood Canal--a long arm of Puget Sound west of the main basin--operated by the University of Washington. The project received funding support from NOAA, the National Estuarine Research Reserve

Association, and NANOOS. The Pacific Coast Shellfish Growers Association and the Pacific Shellfish Institute provided technical assistance.

Changes in the ocean, ranging from sea-level rise and coastal flooding to harmful algal blooms and dead zones, impact U.S. society. To prepare for and help manage these changes, NOAA established the U.S. IOOS Program. The IOOS Program will advance data integration and support regional IOOS development within the long-term goals of improving the Nation's understanding of climate change, safety and efficiency of marine operations, mitigation of natural hazards, and protection and restoration of marine ecosystems.

Ocean observations increased in importance for scientists who characterize, understand, predict, and monitor changes in coastal and ocean environments and ecosystems. Integration of data from ocean observations also became critical to commercial fisheries incorporating climate forecasts into management and harvest decisions. Ocean observation networks potentially improve NOAA's storm surge forecasts and allow emergency managers to make better decisions about evacuation plans. In 2007, NOAA announced an IOOS merit-based competition to support regional IOOS development as an opportunity for FY08. In addition, the IOOS Program published the first version of the National High Frequency radar plan, representing needs of Federal and state governments and established a formal requirement for this system within NOAA. Working with interagency partners, NOAA published a national near-shore waves plan, which documents a national requirement for wave measurement that will define type and location of systems, applicable standards, and data products.

To build a comprehensive IOOS and provide quality-controlled ocean and Great Lakes data, NOAA worked with numerous ocean data providers. The IOOS used satellites as one of the major observation platforms. During 2007, NOAA worked with NASA to identify the needs of IOOS end users to ensure that the appropriate data is being gathered. NOAA's Coastal Services Center used Coastal Land Cover Baseline Completed Remote sensing technology, which offered the best way to document and monitor land cover changes over time. The resulting land cover maps became useful in a variety of ways, from land use planning to evaluation of the cumulative impacts of development. The NOAA Coastal Change Analysis Program provided the land cover data. NOAA completed a multiyear effort to

create a baseline of coastal land cover changes for the lower 48 United States and Hawaii. The standardization of collection methods and data products will allow users to compare maps over a period of years to more accurately document changes in land cover. The goal is to update the baseline every five years.

NOAA's Center for Operational Oceanographic Products and Services completed a three-year effort to upgrade the technology of its National Water Level Observation Network (NWLON). The NWLON station provides mariners, first responders, and the public with real-time tide and water-level information. Network stations normally equipped to transmit water level and other environmental data at hourly increments via NOAA GOES now transmit data every six minutes, enabling users to access it much more quickly. Real-time data from the NWLON supports safe and efficient navigation, tsunami and storm-surge warnings, and HAZMAT emergency response efforts. In addition, the data supports marine boundaries, habitat restoration, long-term sea-level trends, and other important applications.

Through a partnership with Elkhorn Slough National Estuarine Research Reserve and the Elkhorn Slough Foundation, NOAA's Center for Operational Oceanographic Products and Services installed two water level stations at the California reserve in May 2007. Both stations will support ongoing monitoring efforts at the reserve and provide data for hydrodynamic models to predict water movement in the estuary and address increasing tidal range (greater distances between low and high tides). NOAA provided assistance with global positioning system techniques, geodetic heights, and biological monitoring. Field personnel from the reserve and NOAA conducted surveys to establish a project baseline for long-term monitoring.

In 2007, NOAA's National Centers for Coastal Ocean Science mapped a total of 3,755 square kilometers of shallow-water benthic habitat in the Republic of Palau and on the Main Hawaiian Islands using high-resolution color satellite imagery from GeoEye's IKONOS sensor. The habitat maps of Palau revealed that live coral covers approximately 35 percent of the sea floor, one of the higher percentages of coral relative to other areas that NOAA has mapped. The habitat maps of Palau and Hawaii will enhance local monitoring efforts and identify new areas for conservation including ecological hot spots. NOAA also used high-resolution, IKONOS satellite imagery to generate benthic habitat maps of the Florida Keys, the third

longest reef tract in the world. Mapping the estimated 13,000 square kilometers of coral ecosystems in the Florida Keys will be complete in 2012.

In addition, NOAA and a contractor collected airborne bathymetric Light Detection and Ranging (LIDAR) for 889 square kilometers in Southwest Puerto Rico. This technology provided efficient characterization of shallow-water topography and also enhances identification of habitat type.

The U.S. Coral Reef Task Force charged NOAA with the development and implementation of a plan to produce comprehensive digital coral-reef ecosystem maps for all U.S. States, Territories, and Commonwealths, as well as jurisdictional partners. To date, NOAA has mapped six of seven U.S. States and Territories, along with Freely Associated States, like Palau.

Harmful algal blooms (HABs) are naturally occurring events that can have a negative impact on marine life, human health, tourism, and the local economy. NOAA's National Centers for Coastal Ocean Science synthesized satellite imagery along with other data to monitor ocean conditions and predict the onset, transport, and potential impact of these blooms to the coastal states along the Gulf of Mexico. Operational for three years in Florida, the HAB forecast system extended to include Texas in a demonstration phase. NOAA sent a detailed analysis of bloom conditions to state/local managers to guide their sampling and mitigation efforts. In addition, NOAA offers a public Web site that provides information regarding expected conditions at the coast during an ongoing event. In its third year of operation, the system provided forecasts for both Texas and Florida on a biweekly basis during an ongoing event, and weekly during nonbloom conditions. This system synthesized SeaWiFS OrbView-2 and/or MODIS-aqua ocean color imagery with field observations, meteorological data, and transport models to produce the HAB information. NOAA plans similar near real-time advance warning systems for other HAB species in the Great Lakes, Gulf of Maine, Central California coast, and the Pacific Northwest.

Following the 2005 mass coral bleaching event in the Caribbean, NOAA's National Centers for Coastal Ocean Science conducted an island-scale bleaching assessment for Buck Island in the U.S. Virgin Islands. Using high-resolution multispectral IKONOS satellite imagery from before and after the event, analyses indicated that severe bleaching of reefs could be detected. This methodology was

also applied to remote islands in the Pacific, which remain difficult to monitor on a short-term basis for seasonal bleaching events. Further refinement of this technique may yield powerful tools for quantitatively assessing coral bleaching on large spatial scales, particularly in remote or underserved locations.

The NWS now provides the official national smoke products on the National Digital Guidance Database (NDGD) air quality Web site at *http://www.weather.gov/aq/*. NOAA's Air Resources Laboratory produces smoke forecasts using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) dispersion model. Fire locations for the dispersion simulation are obtained daily for previous fires from the NESDIS Hazard Mapping System. Fire products from satellite imagery from GOES, POES, and MODIS provide key input at the regional and local levels as fire fighting resources are positioned to battle fires at their most critical times and locations. During the past year, NOAA's National Geodetic Survey used the GPS to achieve a number of goals and applications to better serve America, as well as other nations, in terms of protecting lives and property from the possibility of extreme weather and climatic occurrences.

NOAA published new elevations for more than 340 benchmarks in Southern Louisiana during 2007. The published values provided official elevations in 27 parishes across the southern portion of the state, which suffered extensive damage from hurricanes Katrina and Rita. NOAA's Height Modernization program conducted this effort, which provides accurate height information by integrating GPS technology with existing survey techniques. For years, NOAA used the GPS to determine accurate positions (latitude and longitude), but now, by following Height Modernization standards, specifications, and techniques, the GPS can efficiently establish accurate elevations for all types of positioning and navigational needs. A cooperative agreement between NOAA and the Federal Emergency Management Agency (FEMA) provided much of the funding, and the Louisiana Spatial Reference Center at Louisiana State University in Baton Rouge was involved in the project.

NOAA, in cooperation with the University of New Orleans and the U.S. Geological Survey, measured coastal wetland elevations in southeastern Louisiana in March 2007. The project promoted the integration of ecosystem observations through Height Modernization techniques that increase the accuracy of elevation

measurements, and provided baseline data to help researchers differentiate between the many potential causes of relative sea-level change in coastal areas, including land subsidence (sinking), land accretion due to water-borne sediment deposits, erosion, and local sea-level rise. As a program within NOAA, Height Modernization provides accurate height information by integrating GPS technology with existing survey techniques.

NOAA completed a two-year project to readjust the National Spatial Reference System (NSRS) in March 2007. NOAA defines and maintains the NSRS, which provides the Nation's positioning infrastructure for transportation and communication, mapping and charting, and a multitude of scientific and engineering applications. The NSRS readjustment updated all GPS survey control point positions in North America. NOAA released the readjusted coordinates with local and network accuracies and made them available through online data sheets. This accomplishment significantly improved the Nation's fundamental positioning infrastructure.

Representatives from NOAA traveled to Benin in West Africa in January 2007 to provide technical assistance to the Institut Géographique National (IGN), in support of its efforts to modernize the country's spatial reference frame. With funding support from the Millennium Challenge Corporation (MCC) and working with technical specialists from IGN, NOAA staff traveled to six major communities to review sites for the installation of a network of Continuously Operating Reference Stations. The stations will provide the spatial framework for the efficient use of global positioning to support multimillion-dollar, MCC-sponsored efforts for land and port improvements over the next five years. They also will have a positive impact on the activities of GPS users in neighboring countries, which will contribute to the development of the unified African Reference Frame initiative.

In 2007, NOAA started work on a five-year project with the Commonwealth of Puerto Rico to create Puerto Rico's first geodetic network. Licensed Puerto Rican surveyors will work primarily under NOAA oversight. This will be Puerto Rico's first geodetic network and will build the capacity for performing high-accuracy, vertical control surveys in the commonwealth, which did not previously exist. This geodetic network will also provide the foundation for transportation and communication; mapping and charting; and a multitude of scientific, GPS, and engineering applications requiring precise elevations.

In 2007, NOAA was selected as the Analysis Center Coordinator (ACC) for the International Global Navigation Satellite Systems Service (IGS) for the next four years, beginning in January 2008. Of the ten current IGS Analysis Centers, one center will perform the main product combination and quality-control operations. NOAA will be responsible for the basic integrity and quality of all the IGS products, which are widely used for most high-accuracy Global Navigation Satellite Systems (GNSS) applications. The core efforts for which NOAA will be responsible are the Ultra-rapid (for real-time uses), Rapid (for high-accuracy, near-term uses), and Final (for definitive results) products, which consist of satellite orbits, clocks, and associated Earth-orientation parameters. NOAA handles the clock, station coordinate, troposphere, and ionosphere functions jointly with other specialized product coordinators, but the ACC holds general oversight. The IGS became a service of the International Association of Geodesy in 1994, with NOAA as a founding participant. The IGS exists as a voluntary federation of more than 200 worldwide organizations that pool resources to provide continuous, global satellite-tracking data, as well as precise analysis products and GNSS expertise.

For almost two decades, NOAA generated accurate GPS orbits by processing data collected by a global network of ground-based satellite tracking stations. During 2007, NOAA collaborated with seven other international GPS-analysis organizations to provide valuable meteorological information in the vicinity of 150–200 tracking stations around the world. At stations with known barometric pressure, the meteorologists can accurately infer the amount of water vapor situated above the tracking station. This information helps meteorologists improve weather forecasts because adverse weather usually correlates with water-vapor content.

NOAA installed the 1,001st Continuously Operating Reference Station (CORS) in January 2007. The station ushered in a new generation of CORSs by becoming the first to provide precise global positioning data in real time from both the U.S.-based GPS and the Russian-based GNSS. The 1,001st CORS also takes part of the IOOS and is co-located with a NOAA tide station in Key West, Florida, where it collects local sealevel data for the globally consistent, rigorously defined International Terrestrial Reference System.

Managed by NOAA, the CORS is a cooperative effort involving 175 organizations. Each CORS sits at a known, precise location and receives GPS radio signals

24 hours a day, 7 days a week. The National Ocean Service (NOS) processed information collected through the CORS network and made it available to surveyors, engineers, scientists, and others around the world. CORS data remains essential for ensuring the reliability of transportation and communication systems, mapping and charting, and many scientific and engineering applications.

Bureau of Industry and Security

The BIS, with involvement from the OSC and ITA, completed a comprehensive survey of the U.S. space industry that collected specific information regarding the industrial, economic, and financial performance of more than 350 individual companies. The DOD's National Security Space Office requested the survey to investigate the health and competitiveness of the U.S. space industrial base with a focus on the impact of export controls. The U.S. Air Force published an industrial base assessment of the U.S. space industry, based on the survey responses, on August 31, 2007.

The National Institute of Standards and Technology

The NIST performed a broad array of aeronautics and space-related measurements, technology development, and industry support activities in FY07. As described below, NIST efforts included development, transfer, and implementation of measurements and standards, as well as manufacturing expertise. NIST research ranged from the insides of jet engines to satellites studying the outer reaches of the cosmos, from climate change on Earth to surviving fires in space, from optics and electronics to sensors, all with relevance to aircraft, spacecraft, and astronomy.

The NIST used unique facilities and expertise to improve the effectiveness of existing and planned devices and facilities. NIST's SURF III Synchrotron Ultraviolet Radiation Facility continued to be used to calibrate mirrors, detectors, and spectrometers used in NASA spacecraft with a wide range of missions, including the atomic radiation intensities required for interpreting data from the Hubble Space Telescope. With funding from NASA and its partner, the European Space Agency, the NIST measured the properties and assessed the lifetimes of platinum/neon hollow cathode lamps, such as the lamps that will be used for in-flight calibration of the Cosmic Origins Spectrograph scheduled to be installed during the 2008 Hubble Servicing Mission. The NIST also developed a highly effective technique

for deblurring color imagery that has generated striking enhancements of images from the Hubble Space Telescope as well as the Kitt Peak Observatory.

With NASA funding, the NIST continued to expand online numerical and bibliographic databases that facilitate the interpretation of observations carried out with NASA space observatories, including the Hubble Space Telescope, the Chandra X-Ray Observatory, the Far Ultraviolet Spectroscopic Explorer, and the Spitzer Infrared Observatory. This included production and critical compilation of atomic spectroscopic data that are needed by space astronomers. The NIST effort centered on the spectra of neutral chlorine and nitrogen with critical data compilations including spectra of iron, neon, fluorine, and other elements with relatively high cosmic abundance.

Collaborating with the Harvard-Smithsonian Center for Astrophysics to improve the metrology used in x-ray astronomy, the NIST used a ground-based plasma to simulate astrophysical plasmas and studied it along with a calibrated x-ray source using a microcalorimeter developed for future astronomy missions. The results will help resolve discrepancies that have limited the utility of some of the strongest potential diagnostic lines for x-ray astronomy.

The NIST also worked with many partners on satellite studies focused on assessing factors related to climate change: with NASA's Earth Observing System (EOS) to address discrepancies in satellite measurements of the top-of-the-atmosphere solar irradiance; with NOAA and NASA in characterization and calibration of the Marine Optical Buoy (MOBY) used to calibrate ocean-color satellites that assess carbon levels in the ocean as well as the next generation Advanced Hyperspectral Autonomous Buoy (AHAB); with NOAA and NASA on the GOES-R and NPOESS satellite programs to aid future calibration and validation of the satellite optical sensors; with NASA, NPOESS, and the Utah State University Space Dynamics Laboratory in preparation of the final report from the May 2006 workshop on "Achieving Satellite Instrument Calibration for Climate Change (ASIC3)"; with NASA to develop a test plan and measure thermal noise standards that support the Aquarius Satellite mission (launch 2009) to resolve processes that link the water cycle, the climate, and the ocean by measuring global sea surface salinity; with NASA's Orbiting Carbon Observatory mission (launch 2008) to track worldwide sources and sinks of atmospheric carbon dioxide by providing high-accuracy

spectral information for both oxygen and carbon dioxide that will underpin the calibration of this and other atmospheric composition determinations.

NIST efforts addressed National Security needs. With the DOD to improve the accuracy of optical signature measurements on ground and aerospace vehicles, the NIST provided optical standards, measurement comparisons, and sensor characterizations to help assess and improve measurement accuracy. Under a contract from the Missile Defense Agency (MDA), the NIST improved the accuracy of missile defense infrared sensor calibrations. With the Utah State University Space Dynamics Laboratory, the NIST worked to advance the development, calibration, and characterization of satellite imagers and sensors. The NIST also continued development of new measurement capabilities for sensor calibrations to improve the accuracy of missile-threat detection in space.

The NIST also worked with the U.S. Air Force, NASA, and industry in fuels research geared toward alternative fuels, as well as worked to generate an understanding upon which to base innovative designs for jet and rocket propulsion systems. As part of this effort, the NIST established a reliable database of properties required to understand combustion kinetics. An improved distillation curve measurement provided a variety of improved and new capabilities, including evaluation of energy content, trace chemical analysis, and corrosivity of each distillate. The NIST studied multiple rocket and aviation fuels, including fuels made from natural gas and coal and an ultra-low sulfur formulation of traditional rocket propellant, using this new method, and others, to inform theory and yield predictive models for each fluid.

The NIST impacted a variety of programs focused on understanding the cosmos around us. Working with collaborators at NASA Centers and in universities, the NIST initiated an effort to develop large arrays of cosmic microwave background polarimeters to detect the exceedingly faint signature of primordial gravitational waves that date to the infancy of the universe. The NIST also calibrated a blackbody optical radiation standard built by ATK Corporation to calibrate equipment on the James Webb Space Telescope that will explore the formation of stars and galaxies, including solar systems with planets capable of supporting life. With funding from NASA, the NIST improved the performance of a voltage-biased superconducting transition-edge sensor (TES); the achievement of energy

resolution goals for TES x-ray calorimeters for the Constellation-X satellite mission will enable improved probing of the General Relativity Theory through observations of the x-ray emissions of iron falling into black holes. The NIST also coupled field-amplified sample injection with temperature gradient focusing to obtain a ten-fold improvement in the detection limit of equipment being developed to analyze organic molecules that could be signs of life on Mars. Another technique, termed gradient elution isotachophoresis, became a second potential method for in situ biomarker analysis that could be run on the same instrument. The use of two different methods for confirmation potentially hold great importance if such materials are detected in a non-Earth environment.

Other sensor-related work, with NASA funding, included the development of Superconducting Quantum Interference Devices (SQUIDs) and SQUID-based multiplexers to read out large arrays of superconducting transition-edge sensor detectors. The NIST already provided SQUID systems to researchers at NASA Centers (Goddard Space Flight Center and the Jet Propulsion Laboratory) and in academia working on NASA-funded projects. In 2007, the NIST began deploying SQUID multiplexers with 100-fold improved immunity to stray fields and demonstrated microwave SQUID multiplexers without power dissipation. The latter breakthrough will allow the read out of much larger arrays of TES detectors than before.

The NIST participated in numerous industry-focused efforts that built upon its measurement and manufacturing expertise. The NIST's Manufacturing Extension Partnership (MEP) network of centers completed process improvement, waste reduction, and quality system implementation projects with 120 aerospace manufacturing companies. MEP centers, working through aerospace prime companies, including United Technologies (Sikorsky Helicopter, Hamilton-Sunstrand, and Pratt & Whitney), Rockwell Collins, and the Boeing Company, also conducted projects with more than 200 aerospace suppliers resulting in reduced supplier lead times, improved quality, and on-time delivery. The NIST undertook a DARPA Phase III effort with Honeywell Aerospace to develop a commercially viable "Navigation-Grade Integrated Micro-Gyroscope" based on NIST research in "Chip-Scale Atomic Clock" technology. The NIST also provided key diffusion mobility data and analysis to collaborators at QuesTek Innovations and NASA Glenn Research Center for predicting the microstructural evolution of third-generation

nickel-based superalloys in gas turbines during heat treating and service conditions. NIST also developed improved models of the stability of bond coats that attach thermal barrier coatings used to extend the high-temperature lifetimes of nickel-based superalloy turbine blades. The NIST's Advanced Technology Program continued its support of NexTech Materials, Ltd., of Lewis Center, Ohio, in its development of an efficient, lightweight solid oxide fuel cell for use in auxiliary power units for aircraft.

The NIST also continued to provide the tools, methodologies, standards, training, and measurement services needed by aerospace parts manufacturers and assemblers to maintain accurate and traceable use of the International System of Units of length, mass, and time, as well as their derived units of force, acceleration, sound pressure, and ultrasonic power. Efforts included training metrologists from Boeing Primary Standards Laboratory, Sandia National Laboratory, Oakridge National Laboratory, Air Force Metrology and Calibration, and from two Lockheed Martin facilities, conducting more than 1,700 tests to calibrate nearly 200 instruments and artifacts, and accrediting Boeing's Electromagnetic Compatibility Laboratory and NASA's John H. Glenn Research Center to make their own measurements in certain areas. The NIST also continued to develop methods to measure the aspheric optics used in aerospace and space applications and led development of a standard for use of laser tracker instruments used by the aerospace industry to measure large manufactured components and align large structures.

The NIST and NASA continued their collaboration in the development of supply chain integration solutions. Both organizations cosponsored a workshop at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama. In addition, the NIST led the standardization effort to complete the ISO standard that allows a manufacturer to describe product data, such as airplane and component designs, throughout the life cycle of the product in a format independent of computer system. U.S. aerospace participants included NASA, Lockheed Martin, and BAE Systems. The NIST also continued to research smart machining techniques that show great promise for reducing cycle time while improving or maintaining part quality.

Looking forward to space exploration, the NIST worked with NASA to develop a comprehensive electromagnetic shielding test plan for the Orion Crew Exploration

Vehicle which will replace the Shuttle. The NIST previously provided electromagnetic shielding measurements for the NASA Shuttle program. As part of a broader effort, supported by the FAA, the Transportation Security Administration, and the Boeing Company, the NIST worked toward developing efficient techniques for measuring the shielding of aircraft from electromagnetic radiation; such shielding remains necessary to reduce interference between aircraft navigation systems and external radiation, on-board laptops, and cell phones. The NIST successfully applied the method to a Beechcraft composite business jet, expanding on previous studies of aircraft including a Boeing 737, an Airborne Early Warning and Control (AWACS) aircraft, a Space Shuttle, a Boeing 767-400, and a Bombardier Global 5000 business jet.

Because the longer duration of human exploration missions to Mars, the Moon, or on the ISS raises the chances for an accidental fire, NASA sponsored and collaborated with the NIST to examine material flammability. The NIST extended ground-based test methods computationally to examine how test results might change for gravity, pressure, and oxygen levels characteristic of habitats on the Moon, Mars, or spacecraft. Researchers used experiments and models to compare and contrast the suppression of flames in normal gravity and microgravity and studied the characterization of smoke in microgravity for improved spacecraft fire detection. NIST research also focused on understanding large fires in microgravity, mainly through modeling. Researchers made progress in understanding oxygen limitations to fire growth, prediction of solid material burn rates, fire behavior in space habitation modules, heat release from flames, and fire extinction.

The NIST also worked on a variety of other efforts including the demonstration of the field dependence of the magnetocaloric properties of doped $Gd_5Ge_2Si_2$ for magnetic refrigerators in aerospace applications and continued work in on-chip electrical cooling of cryogenic detectors, the development of submillimeter heterodyne receivers based on hot-electron bolometer technology, and the development of nanotextured Gallium-nitride and other III-V semiconductors. On-chip coolers based on superconducting tunnel junctions could greatly simplify how to meet spacecraft cryogenic requirements. Nanotextured semiconductors, being studied in collaboration with NASA's Goddard Space Flight Center (GSFC), potentially enable more efficient photodetectors for space applications.

The NIST also collaborated with NASA's Johnson Space Center (JSC) to promote standardization of test techniques for single wall carbon nanotubes. Accomplishments included a third joint workshop, advancement of ISO documentary standards, and the development of prototype reference materials. In response to a separate request from NASA to use NIST high-precision nanopositioners for nanomaterial testing, the NIST designed a new generation of high-precision devices that will be fabricated at the NIST Nanofabrication Facility.

The NIST's Cryptographic Module Validation Program (CMVP) and Cryptographic Algorithm Validation Program (CAVP) continued to provide NASA's Langley Research Center with technical assistance on Federal Information Processing Standard (FIPS) 140-2: Security Requirements for Cryptographic Modules and other cryptographic-based standards. NASA works with many vendors and the space agencies of other governments who develop cryptographic modules for unique environments including space-based or ground telemetry where interpretation of the FIPS standard is critical to development. In FY07, the CMVP validated cryptographic modules intended for space-based applications, all of which had underlying algorithm validations provided through the CAVP.

International Trade Administration

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

The ITA participated in various aviation security activities throughout 2006, including involvement in the DOC working group regarding the National Strategy for Aviation Security (NSAS). The ITA authored the section on DOC roles and responsibilities within the main strategy document and coordinated with interagency and DOC staff to ensure that the strategy reflected the goals and aspirations of the Next Generation Air Transportation System (NGATS) Initiative. In addition, the 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. The ITA conducted industry outreach through various venues, including the JPDO and industry meetings.

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

The ITA continued to support the U.S. Trade Representative (USTR) in meetings with the World Trade Organization and at negotiations for free trade agreements. In particular, support for the ongoing United States and European Union trade dispute over Large Civil Aircraft required detailed support and industry knowledge.

The 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, along with major aircraft manufacturers, signed 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, aimed to avoid government-provided export financing as a competitive factor in civil aircraft sales competitions. The 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. The DOC hosted ten meetings and two conference calls to consult with industry on this topic.

In June 2006, the ITA organized and supported the 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, the 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 considered reducing the current limit of 15 years, instituted in 1993, to 12 years. In July 2006, the ITA participated in a video conference with members of India's Office of the Director General of Civil Aviation to discuss the proposed change in policy and possible alternatives. The ITA formed an ad hoc committee comprised of DOC personnel, industry, and

trade association representatives to monitor the status of the proposed change. The ITA continues to press for its non-adoption.

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

The ITA's CS held more than 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.

The ITA's CS participated in 35 international trade events at which the CS Aerospace Team members provided U.S. industry with support through one-on-one counseling sessions, arranging individualized buyer-to-buyer meetings with international business partners, and conducting additional export counseling services. The ITA also sponsored Aerospace Products Literature Centers (APLCs) at several air shows, which offered 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 (Chile), ILA 2006 (Germany), Africa Aerospace & Defense (South Africa), and the Farnborough International Air Show (London, UK).

National Telecommunications and Information Administration

The 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. The NTIA provided policy guidance on issues concerning the International Telecommunications Satellite Organization and the International Mobile Satellite Organization. The 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

U.S. Geological Survey (USGS) scientists collaborated with the AGRHYMET (Agricultural-Hydrological-Meteorological) Regional Center in Niger, with support from the U.S. Agency for International Development (USAID), to map and monitor land use and land cover (LULC) trends in West Africa from 1972 to 2000. The team used Landsat imagery to complete time-series maps of LULC of Senegal, The Gambia, Mauritania, Burkina Faso, Ghana, Benin, and Togo. USGS scientists developed a practical and innovative tool for mapping LULC change using a GIS tool called the Rapid Land Cover Mapper. Environmental scientists from each country received training in the mapper tool and led the mapping process. The scientists presented the completed maps to numerous users, including agency directors in each country. The LULC maps will be used to run future scenarios showing landscape changes under several different population and climate-change regimes. For more information, see: *http://edcintl.cr.usgs.gov/rlcm/index.php.*

USGS scientists teamed up with ecologists from Niger and European partners to use high-resolution time-series remote sensing and field data to track significant environmental changes in the agricultural regions of southern Niger. They documented efforts by hundreds of thousands of farmers adapting to climate change using new practices that help them cope with drought and generally decreasing rainfall trends. Corona satellite photographs from 1967 and aerial photographs from 1975 provided a baseline for comparison to aerial photographs acquired in 2005. One of the most significant findings was the major increase in tree cover on farmlands in areas of high rural population density. Farmers are investing in the land using a variety of natural resource management techniques, including the enhancement of natural tree regeneration. Today, agricultural parklands have

replaced the barren, wind-swept fields of the 1970s. Image analysis showed that on-farm tree densities have increased 10- to 20-fold. These findings suggested a human and environmental success story at a scale not seen before in the West African Sahel. Rural people reacted proactively to the large-scale land degradation that occurred during the droughts of the 1970s and 1980s and massively started protecting their resources. Beyond the physical efforts, Niger's policy environment showed real change, especially reform in the rural development that empowered farmers to manage their own resources.

The Astrogeology Team of the USGS continued to be heavily involved in the Mars Exploration Rover (MER) mission whose twin rovers, Spirit and Opportunity, both surpassed 1,300 sols (Martian days) of surface operations in FY07. Since the rovers' landings in January 2004, USGS Astrogeology Team members have led efforts to plan, acquire, archive, and interpret data from the rover cameras, principally the Microscopic Imager on the instrument arm, along with analysis of color panoramic camera data of rocks, soils, and active processes on the surface of Mars.

The Opportunity rover spent most of the year navigating the northwestern rim of the 800-meter diameter impact crater, Victoria, and entered the crater in September 2007 to explore the layered rocks along the rim and interior. Spirit began the year by leaving its "winter haven" location to explore the eastern edge of the Home Plate structure, and it has driven on top of this feature for further investigations. Both rovers survived harsh dust storm conditions in the latter half of FY07 and are preparing for the upcoming Martian winter in early 2008.

The USGS Astrogeology Team directly supported the testing, calibration, operation, and data analysis of images acquired by the High Resolution Imaging Science Experiment (HiRise) camera aboard the Mars Reconnaissance Orbiter (MRO). This camera provides the highest resolution images of Mars from orbit (~30cm/pixel) and is being used to certify future spacecraft landing sites for the Mars Science Laboratory rover, as well as support numerous Mars science investigations.

The USGS supported a large portion of HiRise image processing and analysis software development in FY07. The Astrogeology Team used this software to develop high-resolution monochrome and color images acquired by HiRise, as well as construct the highest resolution digital elevation models of Mars ever made.

In particular, images of the terrain explored by the MERs served to guide the MER team in their journey.

The USGS Astrogeology Team members continued their participation as Science Team members on the NASA Cassini-Huygens Mission to Saturn and its moon, Titan, including: 1) the discovery of the lakes and larger seas of hydrocarbon around Titan's north pole; 2) the first measurement of Titan's rotational state, which strongly suggests that Titan is not solid but has an ice crust floating on an internal ocean; 3) generated preliminary estimates of Titan's topography from stereo pairs of radar images to provide quantitative information about processes such as cryo-volcanism; and 4) laid the groundwork for systematic production of Titan map products in FY08, products such as image mosaics, topographic models, and maps of microwave emission and scattering properties relevant to understanding surface composition.

Two Astrogeology papers on Titan were accepted for publication in *Planetary and Space Science* in FY07. The first used descent images from the European Space Agency's Huygens Probe to map Titan's surface topography. These topographic maps documented spectacular river drainages carved by rain and floods of liquid methane. The second publication used a combination of Cassini radar images and visible/near-infrared spectra to map compositional units on Titan's surface that included vast hydrocarbon sand seas, methane lakes, mantles of hydrocarbons, and bright aerosols that form and settle out of the thick, cold atmosphere. These studies expanded our understanding of this alien environment that in so many ways (river valleys, lakes, volcanic regions, mountain chains, and sand seas) resembles the geomorphic forms of Earth.

The U.S. Landsat series of satellites provided imagery of the entire Earth's surface on a seasonal basis since its beginnings in 1972. A wide variety of applications of land surface changes use the data from Landsat in land-use planning, agriculture, disaster reduction, water management, and analysis of human development. Currently, Landsat 5 and Landsat 7 actively collect data, but they are nearing the end of their functional lives. A successor to these satellites, the Landsat Data Continuity Mission, is scheduled to be launched in 2011. The creation of the National Land Imaging Program will ensure the availability of these key data far into the future.

Major actions on the Landsat Data Continuity Mission developed during FY07. NASA, responsible for the procurement and development of the Space Segment (satellite and land-imaging sensor) and the Launch Segment (rocket, launch services, and post-launch check-out), awarded contracts for design and development of the required systems.

At the same time, the USGS refined an acquisition strategy involving three ground system segments: 1) the flight operation segment includes a ground command and receiving station antenna network; 2) the data processing and archive segment, including satellite data archiving, image processing, and a user portal for data access; and 3) the ground system architecture analysis and integration segment. For more information, see: *http://ldcm.usgs.gov/*.

On June 4, 2007, the USGS began releasing selected Landsat 7 image data of the United States through the Web (*http://glovis.usgs.gov/* or *http://earthexplorer.usgs.gov/*). These data are of high quality with limited cloud cover. A wide range of applications finds the Landsat data useful. From disaster monitoring after Hurricane Katrina and the Indonesian tsunami to global crop condition analyses, scientists around the world use Landsat data. The Web-based distribution system provided the user community easier access to Landsat 7 data. In 17 weeks, 757 unique users downloaded almost 6,000 products (approximately 1.3 TB). This Web-enabled distribution of new and recently acquired data is a pilot project for the Landsat Data Continuity Mission, currently projected for launch in 2011.

On March 1, 2007, the Landsat 5 satellite began its 24th year in orbit. This milestone seems particularly impressive considering its creators thought the operational lifespan was no more than three years.

On April 15, 2007, Landsat 7 completed its 8th year of operation. Data gathered by Landsat 5 and Landsat 7 continued to form the backbone of the 35-year-old global Landsat archive, which contains millions of images of Earth's terrestrial environment and is maintained at the USGS's Center for Earth Resources Observation and Science (USGS EROS). Landsat data remained a vital component of an array of research that includes wildfire mapping, crop identification, timber harvesting, desertification, climate change, habitat suitability, and urban expansion. Barring component failures, recent fuel estimates indicate that both satellites will continue to fulfill the Landsat science mission for years to come.

The Bureau of Land Management (BLM) 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 FY07, remote sensing data from a variety of platforms, ranging from hand-held digital cameras to coarse-resolution NASA satellites, supported management activities associated within almost all business areas of the BLM. These projects provided information for the national, state, and local land managers to make better, informed decisions on resources in their areas.

During 2007, aerial photography remained the largest source of remote sensing data used in the BLM. In partnership with the Farm Service Agency (FSA), the BLM made extensive use of orthoimagery through the National Agriculture Imagery Program (NAIP). This data will provide a foundation for numerous projects within the BLM for years to come. The BLM and the NAIP, and other aerial photography sources, are key components in our toolbox for making timely and informed management decisions over a broad range of topics.

Several projects employing remote sensing-based technologies carried over from 2006 to 2007, including the following:

- The USGS assisted the BLM in developing 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.
- The Utah State Office employed a combination of aerial photography and satellite imagery to complete a statewide inventory of forest stands in Utah. An object-oriented approach fuses the imagery with ancillary data, such as elevation, slope, aspect, and several vegetation indices to map more than 200 classes.
- In conjunction with the USGS, under the Central Region Integrated Science Partnership Funds (CRISP), the BLM participated in projects using high-resolution commercial imagery to develop methodologies to identify and map species, cover, and height classes of sagebrush. These models will be extended to cover the entire state of Wyoming and provide key inputs to better understand sage grouse

habitat dynamics and the influences anthropogenic forces have on those habitats.

- The BLM Alaska Fire Service (AFS) and the University of Alaska–Fairbanks, Geographic Information Network of Alaska (GINA) continued cooperation through an MOU for the utilization of near real-time satellite imagery to develop derived products. The AFS and GINA used these products in the detection of new fires, monitoring of remote fires, and the tracking of smoke plumes. In addition to imagery, the GINA provided remote sensing expertise and advice when needed to assist the AFS in its mission. In return, the AFS provided the GINA with fire and fuels information such as perimeters, data from our Remote Automatic Weather Station (RAWS) network, the Fire Weather Index (FWI), and other fire indices.
- The AFS used Landsat data extensively to map and analyze fires and their effects on the land. During 2006, the AFS utilized Landsat for perimeter mapping of large fires.

During 2007, the BLM saw the expansion of use of commercial high-resolution satellite data. Several commercial satellite image acquisitions took over key study areas. This imagery provided baseline data on the current state of resources, as well as laid the foundation for monitoring changes in the landscape. The State of Wyoming took a proactive approach to monitoring surface disturbance due to oil/gas exploration by purchasing commercial satellite data that will be used to ensure that planning goals are met and to support restoration activities.

The Murphy Complex Fire in Idaho was one of the largest fires in the recorded history of the Great Basin. In response to this fire and the growing pressures from grazing, invasive species, climate change, altered fire regimes, and more, the BLM assembled a multidisciplinary team of scientists from a number of institutions to examine the dynamics and interactions of this fire to better guide management decisions in the future. Remote sensing data at multiple scales support the current research. Scientists used the data to quantify sagebrush cover, map fire severity and extent, examine range condition, guide field sampling, and provide a baseline for restoration initiatives.

In 2007, the USGS and the 11-member Federal interagency Multi-Resolution Land Characteristics Consortium (MRLC) announced the completion of the 2001

National Land Cover Database (NLCD 2001) that describes 16 classes of land cover, the percentage of tree canopy, and the percentage of imperviousness for each 30-meter cell across the conterminous United States. Based on Landsat satellite imagery taken during 2001, MLRC agencies constructed the database in a six-year collaborative effort. NLCD 2001 became a second-generation effort to update the Nation's land cover information. The first NLCD completed in 2000 used Landsat imagery acquired around the year 1992. Thousands of applications in the private, public, and academic sectors used information from the NLCD—applications that range from helping to site cell phone towers to tracking how diseases spread. NLCD products are available for download from the MRLC Web site at *http://www.mrlc.gov/*. Complete, updated coverage of NLCD 2001 data for Alaska, Hawaii, and Puerto Rico will be available as of December 2007. Future nation-wide updates of NLCD 2001 will continue to monitor land cover change across the Nation.

The USGS Michigan Water Science Center, in cooperation with the Michigan Department of Environmental Quality Cooperative Lakes Monitoring Program, adopted a method modeled after Olmanson and others (2001) to predicted water quality for inland lakes greater than 25 acres by relating field measurements to Landsat satellite imagery. The State of Michigan holds more than 11,000 inland lakes; approximately 3,500 of these lakes are greater than 25 acres. Predicted lake water-quality results are available for most of the 3,500 inland lakes. Continued water-quality predictions assist water-quality managers in identifying trends and issues for Michigan inland lakes. Additional project information with a link to the predicted water-quality results is available online at: *http://mi.water.usgs.gov/splan1/sp00301/remotesensing.php*.

Multiple Federal and state agencies prepared and evaluated the environmental assessment of the Sawyer County Airport Improvement project near Hayward, Sawyer County, Wisconsin. The U.S. Environmental Protection Agency and the Wisconsin Department of Natural Resources staff expressed concern regarding possible effects of tree topping/clearing on the hydrology of a wetland and trout stream at the site. The USGS Wisconsin Water Science Center refined an existing regional ground-water-flow model to improve local simulations of the shallow ground-water flow system near the airport. Accurate horizontal and vertical loca-

tions of water levels in test wells, the wetland, and along streams surrounding the airport were critical to accurately simulate the local hydrology.

The USGS used a real-time kinematic (RTK) GPS to survey horizontal and vertical locations of water levels near the Hayward Airport between February 21 and 23, 2007. This RTK-GPS system provides centimeter-level accuracy by differentially correcting GPS signals recorded at two separate GPS receivers — a base station and a rover. Use of the RTK-GPS allowed the USGS to accurately survey the area in a few hours, rather than several days as would be needed using traditional equipment. Based on simulations performed with the revised flow model, the agencies came to agreement on specific hydrologic implications of the proposed improvements and the environmental assessment moved forward.

The USGS/Upper Midwest Environmental Sciences Center (UMESC) remained an active user of remote sensing data and products. The UMESC used remote sensing data for approximately 20 years to develop vegetation maps/spatial databases and orthophoto mosaics for the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), and the Upper Mississippi River System (UMRS). FY07 applications included:

- In coordination with the FWS, the UMESC generated spatial vegetation databases for Big Stone National Wildlife Refuge (NWR) and Tamarac NWR using color-infrared aerial photography. These geospatial layers will aid the FWS in setting wildlife, habitat, and public use priorities and guide management decisions on the refuges for the next 15 years.
- As a product of the USGS-NPS Vegetation Mapping Program (VMP), the USGS/UMESC completed and delivered the Waterton-Glacier International Peace Park (WGIPP) spatial vegetation database to the USGS-NPS VMP. The UMESC mapped about 1.1 million acres of Glacier National Park with more than 200 plant communities using high-resolution aerial photography during the past nine years. This project was part of an international effort with Canada's Waterton Lakes National Park. The vegetation maps are a powerful tool for making sound scientific decisions about future vegetation patterns.
- As a product of the USGS-NPS VMP, the USGS/UMESC created color-infrared aerial photo mosaics for the Indiana Dunes National Lakeshore and the Buffalo National River in Arkansas. The aerial

photo mosaics will act as a background layer to the spatial vegetation database that will be produced from the same set of photography. Together, these layers will become a powerful tool for making sound scientific decisions about future vegetation patterns.

- The UMESC acquired high-resolution digital imagery (eight inches per pixel) on September 15, 2007, for Navigation Pools 5, 6, and 8 of the UMRS. This imagery documented the effects of experimental water- level reductions, or drawdowns, designed to compact sediment and stimulate vegetative growth in newly exposed substrate. This imagery will be compared to imagery collected previously to help assess the persistence of the resulting vegetation, as well as provide a baseline of condition prior to next year's planned water drawdown of Pool 6.
- The UMRS remained an important stopover area for migrating waterfowl and management concerns of resource managers often centered on providing adequate habitat to meet the needs of ducks, geese, and swans. A 14-megapixel Kodak single-lens reflex camera (the Kodak DCS Pro 14n) mounted in the belly of an FWS twin-engine plane successfully captured imagery of migrating swans in selected portions of Navigation Pools 4 through 9 each fall. Scientists referenced these photos to Earth and combined the images into a mosaic by study area. Scientists then used computer software to count swans and analyze their distribution by preferred vegetation types and water depths.

FWS scientists used GPS technology and remotely sensed data for years to support their mission activities. Common uses of these technologies included the creation of new habitat and vegetation maps, the verification or updating of data displayed on older maps, the execution of trend-analysis models for specific habitat types, and the creation of management plans. The applications included the following:

- The USFWS Sacramento Fish and Wildlife Office used urban high-resolution imagery provided by the USGS liaison for geospatial analysis work relating to: 1) locations of wetlands; 2) identification of potential wildlife habitats; 3) locations of boundaries for land use planning purposes; 4) USFWS recovery planning for the California Red-Legged Frog and Tidal Marsh Recovery plan that contains 33 species of fish and wildlife; and 5) updating geospatial urban land layers.

- The Western Washington Fish and Wildlife Office combined NAIP imagery with species and parcel data from the State of Washington to analyze and prioritize Cooperative Endangered Species Conservation Fund (Section 6) Grants. They also tracked existing grants to assist in locating areas where grants may coincide.
- Refuge planning staff produced a National Vegetation Classification System Alliance-level map for Bowdoin National Wildlife Refuge, located in Phillips County, Montana. Remote sensing imagery used in this project included one-meter resolution, color-infrared (CIR) imagery collected under the Farm Service Agency's NAIP program, true-color NAIP imagery (2005), and CIR imagery collected by an FWS-contracted pilot in April 2006. The pilot collected FWS imagery at a resolution of 0.6-meters and provided a spring "look" at the vegetation, while the NAIP provided a summer "look" at the vegetation. This temporal contrast aided in the delineation of plant groups.
- Fishery biologists in Arizona conducted a fish reintroduction effort in 2007 that relied on GPS coordinates to direct a helicopter pilot to sites where the young fish were picked up and dropped off. Using a helicopter, biologists moved 2,800 fish from three sources into five new locations in a single day.
- The Kenai National Wildlife Refuge completed a land cover classification for the entire Alaskan Kenai Peninsula (six million acres) using 2002 Landsat 7 satellite images and 4,074 ground locations collected from various sources. The refuge used ground locations associated with 26 land cover classes to assign classes to corresponding objects and, based upon their similarity to other objects (nearest neighbor), projected the classes across the landscape, producing a map of predicted land cover at a 0.1 ha minimum mapping unit.

The Invasive Species Science Branch, USGS's Biological Resources Discipline, in cooperation with NASA's Goddard Space Flight Center scientists, used NASA and USGS satellite data (e.g., MODIS, Landsat) to forecast the spatial and temporal patterns of harmful invasive species. Invasive plants, animals, and pathogens cost the United States an estimated $120 billion each year in lost cropland and rangeland productivity, direct control costs, and costs to the environment and human health. NASA data products are essential for mapping habitats vulnerable to invasion.

In FY06, the Information Science Branch initiated a study to compare a satellite-based (Landsat 5) vegetation mapping methodology with traditional aerial photo interpretation. The Discrete Classification Mapping Methodology (DCMM) developed by Geographic Resource Solutions provided quantitative vegetation metrics based on ground measurements and satellite imagery. The DCMM may prove to be more useful to managers and researchers because of the spatial accuracy, lower cost per unit area mapped, and quantitative vegetation metrics in the GIS database.

Federal Communications Commission

FCC

The Federal Communications Commission (FCC) formulates rules to facilitate the provision of commercial satellite services in the United States. The FCC also issues licenses for the launch and operation of all nongovernmental U.S. satellites. Internationally, the FCC coordinates satellite radio-frequency usage with other countries. The FCC's accomplishments for FY07 related primarily to commercial communications satellites and Earth observation satellites.

During FY07, the FCC issued its First Annual Report to Congress on the state of competition in the communications satellite services industry. The inaugural report examined six wholesale and two retail satellite services markets for the period from 2000 to 2006. The FCC found effective competition in the satellite markets were addressed. The FCC concluded that the commercial satellite services sector continues to benefit U.S. consumers, all levels of Government, and American industry by providing important connectivity and ongoing technology innovation.

The FCC took two significant actions in rule-making proceedings during FY07. In one proceeding, the FCC adopted rules for newly available radio frequencies to be used by the broadcast satellite service, which is the service by which most U.S. consumers receive satellite television. The rules included technical rules, licensing procedures, and other regulatory requirements for the new service. In another proceeding, the FCC proposed to adopt rules for vehicle-mounted Earth stations operating in the Ku-band. These mobile Earth stations operate with geostationary satellites licensed to provide fixed satellite service, and vehicle occupants can use them to transmit and receive video and data.

The FCC authorized a number of commercial communication satellite launches and operations. The authorizations include the following:

- November 29, 2006: Echostar to construct a satellite planned for the longitude 86.5° west orbit location.
- December 21, 2006: Virtual Geosatellite to construct an 18-satellite nongeostationary satellite system. They subsequently relinquished authorization at the deadline for submitting a required performance bond.
- April 16, 2007: Sirius Satellite Radio for a geostationary satellite planned for the longitude 96° west orbit location.
- July 18, 2007: Viasat for two geostationary satellites, one planned for the longitude 77.3° west orbit location and the other for the longitude 115° west orbit location. They subsequently relinquished authorization for the latter satellite at the deadline for submitting a required performance bond.

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 of these actions warrant particular mention:

- July 9, 2007: Intelsat received authority to operate certain frequencies on the Intelsat 709 satellite, at the longitude 85.15° east orbit location, to provide service to U.S. Government customers in the Middle East.
- August 7, 2007: PanAmSat received authority to operate the Galaxy 9 satellite at the longitude 81° west orbit location, consistent with satellite coordination arrangements with Argentina.

The FCC added two non-U.S.-licensed space stations to its permitted space station list to allow these space stations to provide domestic and international satellite service to U.S. Earth stations that have routine technical parameters. Specifically, on December 8, 2006, the FCC added the United Kingdom's AMC-18 satellite to its permitted list for C-band frequencies, and on January 19, 2007, the FCC added the Canadian Anik F3 satellite to its permitted list for C- and Ku-band frequencies.

The FCC also granted a number of requests for non-U.S.-licensed space stations to provide service in the United States on a nonroutine basis, including the following:

- October 10, 2006: WB Holdings received authorization to use multiple terminals in Ka-band frequencies to access Canada's Wildblue 1 satellite at the longitude 111.1° west orbit location.
- November 29, 2006: Spectrum Five reserved spectrum for two satellites to provide a broadcast satellite service at the longitude 114.5° west orbit location.
- December 20, 2006: ICO reserved spectrum to add an additional geostationary satellite at the longitude 85.15° west orbit location to its 2 GHz mobile satellite service system. The authorization for the latter satellite was subsequently relinquished at the deadline for submitting a required performance bond.
- March 7, 2007: Hawaii Pacific Teleport received authority in C-and Ku-band frequencies to access the Japanese JCSAT-5 at the longitude 132° east orbit location.

The FCC also remained active in international satellite coordination. During the first quarter of FY07, the FCC reached a total of ten Administration-to-Administration Coordination Agreements for U.S. networks with Australia, Brazil, France, Japan, and the Netherlands. During the second quarter of FY07, the FCC reached a total of 165 Administration-to-Administration Coordination Agreements for U.S. networks with Argentina and Malaysia. During the third quarter of FY07, the FCC reached a total of nine Administration-to-Administration Coordination Agreements for U.S. networks with Canada and Kazakhstan. During the fourth quarter of FY07, the FCC reached a total of 67 Administration-to-Administration Coordination Agreements for U.S. networks with Germany and the United Kingdom.

U.S. Department of Agriculture

USDA

Several agencies in the U.S. Department of Agriculture (USDA) used remote sensing data, tools, and related technologies to support research, program, and operational activities. Although each agency had a different mission and responsibilities, multiple agencies used similar data sets and technologies to help them accomplish their objectives.

The Agricultural Research Service (ARS) is the primary in-house research agency for the USDA. The ARS conducts basic and applied research to solve problems affecting food, fiber, and biofuel production, including the development of procedures that protect and enhance soil, water, and air resources. The ARS scientists investigated how remote sensing could be used to address water quality and quantity, soil productivity, and global change issues, as well as to detect and map invasive species and manage crops. The research addressed problems faced by producers and strategic decision makers from local to regional spatial scales and short-term (e.g., within growing season) to long-term (e.g., multiple year) time scales. The ARS partnered with NASA and other USDA agencies to develop operational systems that would help the USDA agencies carry out their missions.

Hydrology continued to be a major emphasis of ARS remote sensing research. The ARS conducted further development of algorithms and validated these algorithms using thermal infrared satellite data to map evapotranspiration and plant moisture stress. Collaboration with NASA, NOAA, and university researchers investigated how these procedures can be incorporated into the drought detection and mapping systems of the National Integrated Drought Information System. A USDA member of the Landsat Data Continuity Mission science team performed

some of this work. Work also continued on development of satellite-based soil moisture mapping technologies, including contributions to future NASA satellite systems and collaboration with international remote sensing researchers.

The USDA conducted collaborative research with NASA on remote sensing of the distribution of invasive species, the effectiveness of biocontrols, and the reestablishment of native species. This research emphasized aircraft and satellite remote sensing systems and showed great potential for improving the management of vast areas of western U.S. rangelands.

Part of the North American Carbon Program linked research on the use of remote sensing with models to map carbon in agricultural systems. The North American Carbon Program incorporated the results of this research into a Web-based research and decision support tool for scientists, producers, and those interested in environmental credit trading. This work program was built on ongoing work to enhance the use of NASA remote sensing satellite products for crop-yield estimation by USDA agencies. The USDA also conducted complementary work on the development of remote sensing tools for mapping crop residue (i.e., plant material left in crop fields following harvest). Management of crop residue reduces soil erosion, maintains and improves soil quality, and contributes to carbon sequestration for control of greenhouse gas emissions. This work demonstrated the potential for remote sensing as a tool for mapping the extent of tillage practices by farmers enrolled in USDA conservation programs.

The FSA administers vital farm programs that ensure a strong and viable agriculture sector in the United States. The FSA's geospatial and remote sensing activities play a fundamental role in the management of farm programs. The agency maintains a nationally consistent geospatial data set representing farm and field boundaries known as Common Land Units (CLUs). The FSA used CLUs, digital soil surveys, one-meter imagery, and other data sets for program implementation and monitoring, as well as for response and recovery efforts during natural disasters. The USDA also used remote sensing data for program analysis. For example, the FSA leveraged remote sensing data to determine program boundary delineation for a new habitat initiative. Through a partnership with the U.S. FWS, the USDA used remotely sensed data as a modeling input to identify the density of breeding ducks on a regional level. The results of the study were used to determine areas where program eligibility would return the highest benefit of program goals.

Through the NAIP, the FSA is the primary source of aerial imagery for the USDA, acquiring imagery over the continental United States (CONUS) during the agricultural growing season. Though budget constraints limited the acquisition of new imagery to 14 states in 2007, the NAIP continued to provide some of the most up-to-date imagery across the Nation, as well as some of the most current pre-event imagery after disaster events. The NAIP imagery is available through the USDA Geospatial Data Gateway. The FSA also leveraged existing technologies to provide emergency responders with a variety of additional methods for accessing NAIP imagery.

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, the NASS conducts the Census of Agriculture—a comprehensive statistical summary of many aspects of U.S. agriculture. Remote sensing data and techniques improve the accuracy of NASS statistics.

During FY07, the NASS used remote sensing data to construct and sample area frames for statistical surveys, estimate crop area and yield, and create crop-specific land-cover data layers for GIS. For example, the NASS used Landsat imagery, digital orthophoto quadrangles, and other remotely sensed inputs for the CONUS and Puerto Rico to select the yearly area-based samples and supplemental samples that were used to measure the completeness of the Agricultural Census in 2007. In addition, the NASS constructed new area-based sampling frames in Minnesota and South Dakota. The remote sensing acreage estimation project used ResourceSat-1's Advanced Wide Field Sensor (AWiFS) and NASA's MODIS data to produce crop acreage estimates for major crops at the state and county levels for 14 Midwestern and Mississippi Delta States for the 2006 and 2007 crop years. Because of a major reengineering effort, the NASS produced acreage estimates 75 days earlier and covered four additional states than previously possible using earlier systems. Because of the improved timeliness, the NASS Agricultural Statistics Board used the remote sensing estimates when setting the official October 2007 corn and soybean NASS estimates.

In addition, the NASS distributed a crop-specific categorization in the form of a digital mosaic of scenes for each of these states to users for the 2006 crop season on DVD and via the USDA Geospatial Data Gateway Web site. The NASS also continued its partnership with ARS to conduct research and implement the use of MODIS sensor vegetative index and surface temperature data for setting state and county corn and soybean yield estimates in Iowa, Indiana, and Illinois. The Agricultural Statistics Board held access to estimates from this algorithm when setting the official August and October yield estimates for these States.

The Natural Resources Conservation Service (NRCS) is the primary Federal agency working with private landowners to help protect and conserve the Nation's natural resources. For more than 50 years, the NRCS 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 the FSA and other Federal and state agencies, the NRCS acquired statewide 1-meter or better resolution orthoimagery for 11 states and parts of Alaska, Hawaii, and the Pacific Basin. The USDA Geospatial Data Gateway Web site made available all orthoimagery purchased by the NRCS to internal users and the general public.

The NRCS used the USDA Small Area Aerial Photography Contract to acquire high-resolution aerial photography (4" ground-resolving distance) and scans over 70,344 confidential statistical sites to collect natural resource data for the annual National Resources Inventory (NRI) program in the CONUS. The NRCS also contracted for aerial photography over 450 NRI sites in Puerto Rico and the U.S. Virgin Islands, and 581 NRI sites in Alaska. The NRCS also used the Small Area Aerial Photography Contract to acquire photos of over 3,207 Wetland Reserve Program (WRP) easements in 17 states. High-resolution satellite imagery continued to be acquired for conducting the NRI in Alaska and Hawaii. The NRCS continually needs data from a medium resolution, multiple-band satellite like Landsat. In addition, selected NRCS applications need orthorectified Landsat-like imagery. The transition to AWiFS acquisition by the USDA Satellite Imagery Archive (SIA) resulted in a significant drop in usage of Landsat imagery within the NRCS. The NRCS continued to purchase licensed Interferometric Synthetic Aperture Radar

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 Forest Service (FS) continued to process data from NASA's MODIS sensor on board NASA's Terra and Aqua satellites as part of the MODIS Active Fire Mapping Program. The data produced active wildland fire mapping products daily 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. The program also utilized additional real-time MODIS fire detection data for Alaska, western Canada, and the eastern United States. The FS posted these products on the Internet (*http://activefiremaps.fs.fed.us*), where they were accessible to national fire managers and the general public.

More than one million users accessed the MODIS Active Fire Mapping Web site during 2007. 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 fire-fighting resources and assets throughout the country. A collaborative effort with NASA's GSFC and the University of Maryland provided this service on a daily basis since July 4, 2001. In addition, several major media entities used the maps and fire detection data including the *Washington Post*, the *New York Times*, the Cable News Network (CNN), the Associated Press (AP), and the *Los Angeles Times*.

The FS also continued to work with NASA's Ames Research Center (ARC) on a number of fire-related technologies. ARC work included advanced sensor design and image processing from airborne platforms, utility of satellite communication data links, and unpiloted aerial vehicle (UAV) development and mission profiling for tactical wildland fire mapping.

The FS and ARC collaborated on significant flight demonstrations in 2007. In August and September, a General Atomics (GA-ASI) Reaper class aircraft (named Ikhana) flew four scheduled missions covering eight western states. The four missions (approximately one mission per week) acquired tactical imagery over a number of active fires during the height of the fire season and provided the imagery to numerous incident commands in near-real time via a Google Earth viewer

throughout the course of each flight. The flights varied in duration from 10 to 20 hours. These flights were a collaborative effort between RSAC, ARC, NASA Dryden Flight Research Center, and the National Interagency Fire Center.

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.

In support of the International Services' Screwworm Eradication Program, the CEAH created a Landsat mosaic to visualize and document the flight path used for release of sterile flies throughout Jamaica. The CEAH processed a limited set of Ikonos and Quickbird high-resolution imagery (one-meter) to provide greater detail for select areas of the island. The data came from the National GeoSpatial-Intelligence Agency's Web-Based Access and Retrieval Portal (WARP). The CEAH also used Landsat Thematic Mapper (TM) imagery and the Global Land Cover (GLC) 2000 dataset to generate a screwworm land cover/habitat map of a study area in Uruguay. Through identification of habitat, researchers with International Services could better place fly traps. Suitable placement of traps improves the effectiveness of the eradication program.

In 2010, for the first time, the Kentucky Horse Park in Lexington, Kentucky, will host the World Equestrian Games. To minimize the risk of exposure of native tick species to equine piroplasmosis, the USDA initiated a study to determine suitable tick habitats in the region and subsequently the risk of contact between horses and the American dog and winter ticks in Kentucky (both tick species are experimental vectors of the disease). The study used Landsat TM, NAIP, and GLC 2000 data-sets to characterize vegetation and land cover in the area.

The USDA used Landsat, NAIP, and Leica airborne imagery in a feasibility study that evaluates various remote sensing methods for extracting commercial poultry and other confined animal operations. The study developed methodologies to quickly locate animal operations for emergency response. Additionally, the CEAH evaluated the use of the Environment for Visualizing Images (ENVI) Feature Extraction module as part of this project. The module/extension is a

pattern-recognition application that uses spatial, spectral, and textural information to extract and classify features within imagery.

The CEAH also continued to use Landsat TM data to evaluate the role of deforestation in the natural cycle of the Venezuelan equine encephalomyelitis (VEE) virus in Iquitos, Peru. Deforestation may be a factor that influences the spread of VEE in the neotropics. The CEAH continued to develop and refine a predictive model in Chiapas, Mexico, to forecast when and where epizootics of VEE virus might occur. The model used coastal vegetation and mosquito habitat information derived from Landsat TM imagery. These remote sensing studies helped facilitate the understanding of disease transmission and were useful in planning for a U.S. response to an outbreak of VEE virus.

In addition to these activities, the APHIS frequently used high-resolution (e.g., Ikonos, Quickbird) and medium-resolution (e.g., Landsat TM) imagery as cartographic backdrops for a variety of domestic and international maps.

The APHIS CPHST used remote sensing information for two studies. One study identified saltcedar distribution in Wyoming and the other sought to identify trees damaged by the Emerald Ash Borer beetle.

The USDA completed research evaluating the application of remote sensing tools for mapping the distribution of saltcedar using airborne-collected hyperspectral imagery for a biocontrol site in Wyoming. The USDA developed the distribution data for three years, and a change detection analysis followed. Mapping accuracies averaged 80 percent and changes to saltcedar distribution were apparent in the final data. This information assisted in planning future saltcedar/remote sensing studies and to quantitatively validate the economic value of saltcedar biocontrol efforts.

The Emerald Ash Borer Study investigated the use of hyperspectral imagery, Light Detection and Ranging (LIDAR) data, and high-resolution panchromatic imagery in conjunction with ground-based spectral data. The study determined whether ash trees could be differentiated from other hardwood species and whether stressed ash trees could be differentiated from healthy ash trees. In 2006, the study collected one-meter hyperspectral imagery, 0.5-meter LIDAR data, and 0.25-meter panchromatic imagery. The study collected more than 150 square kilometers of data for locations in Northern Michigan (Lower Peninsula), Southeastern Michigan, and Northwestern Ohio. The study conducted analysis to determine the

best methodology for fusing all three data sets. Initial results indicated an overall accuracy of 77 percent for differentiating ash from other tree species.

The Cooperative State Research, Education, and Extension Service (CSREES) is the extramural research arm of the USDA. The CSREES primarily provides financial assistance, in the form of grants, to conduct high-priority agricultural research and education. The CSREES awarded many grants that use NASA data products to solve complex, environmentally related problems on topics such as water quality, atmospheric science, soil science, and land-use change. A few examples of current research supported by CSREES that use NASA data products include the following:

- MODIS data and products will be used to quantify crop residue burning by producing multiannual crop type and burned-area maps for large regions of the U.S.
- Satellite imagery and NASA-derived data products are used to assess the impacts of farming programs administered and managed by the NRCS on environmental quality in Michigan.
- Current methods quantifying changes in soil organic carbon stocks for U.S. agricultural lands will be advanced by incorporating remote sensing products into a dynamic model-based assessment framework.
- The writing of descriptions of tree canopy-soil nutrient relationships, in conjunction with remote sensing, to create pasture-scale inventories of soil and woody plant C and N pools in areas with contrasting land management histories.

The CSREES also funds long-term studies in Mississippi, Kentucky, Alabama, and Wisconsin that utilize remote sensing and geospatial technologies to develop precision management techniques for various agricultural production strategies and to evaluate land use practices. The CSREES jointly funded with the Science Mission Directorate of NASA several geospatial extension programs at land-grant, sea-grant, and space-grant institutions. These geospatial outreach programs will help train local and regional technologists to better utilize NASA data products and geospatial technologies. By leveraging the ongoing coordination in these state geospatial programs in the realm of geospatial technologies (i.e., interoperability, standards, metadata, architecture, etc.), the geospatial extension specialists will

help ensure that the vast quantity of data and information being collected by NASA and other Federal agencies is utilized effectively.

The Economic Research Service (ERS) used a host of derived data sets, such as the USGS's National Land Cover and GLC data sets, to quantify domestic and international agricultural efficiency, as well as to track environmental responses to changes in agricultural markets and policies. The ERS also used USDA imagery-derived products, such as the FSA's CLU and Conservation Reserve Program boundaries, the NRCS's detailed soils database and NRI data, and NASS's survey area frames and cropland data sets, to support a host of research projects informing natural resource agricultural policy decisions. Through the ERS farm and field-level survey program, the ERS collected and tabulated information on farmer usage of remote sensing and GPS technologies.

In 2006, the Risk Management Agency developed and offered a pilot Group Risk Protection risk management program for pasture, rangeland, and forage (PRF). 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. The Risk Management Agency intends for the program to become a risk-management tool for the 588 million acres of U.S. pastureland and the 61.5 million acres of hayland. The PRF program began in the 2007 crop year in selected counties in Colorado, Idaho, North Dakota, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, and Texas. During 2007, the Risk Management Agency's PRF program insured more than 30-million acres for a potential liability of $390 million. When the incremental increase is complete in 2009, approximately 450 million acres of grazing and forage land will be eligible for coverage.

The Foreign Agricultural Service's (FAS) Office of Global Analysis (OGA) (formerly Production Estimates and Crop Assessment Division) served as the focal point within FAS and the USDA for assessing the global agricultural production outlook and conditions that affected world food security. The FAS also housed the USDA SIA. The SIA saved the 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's 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. The FAS exploited many global imagery data sets, including vegetation health products from the University of Maryland and NASA, while continuing to purchase most of its satellite data from the commercial industry.

The FAS continued to rely on Earth observations from the commercial sector and international community, while supporting 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, the 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 (GLAM) partnership continued to expand to multiple universities, commercial companies, and international organizations. Information on the FAS remote sensing program can be found on the Internet at *http://www.pecad.fas.usda.gov/cropexplorer.*

National Science Foundation

NSF

The National Science Foundation (NSF) continued to serve as the lead Federal agency for the support of ground-based astronomy and space science during FY07. Through the Divisions of Astronomical Sciences, Atmospheric Sciences, and Physics, as well as the Office of Polar Programs, the NSF sponsored a broad base of observational, theoretical, and laboratory research aimed at understanding the states of matter and physical processes in the universe. Areas of research ranged from the most distant reaches of the universe and the earliest moments of its existence to nearby stars and planets, including our own planetary system.

The NSF also 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 included the National Radio Astronomy Observatory (NRAO), the National Astronomy and Ionosphere Center (NAIC), the National Optical Astronomy Observatory (NOAO), and the National Solar Observatory (NSO). The NSF also served as the executive agency for the Gemini Observatory, an international partnership operating optical/infrared telescopes in both the Northern and Southern Hemispheres, providing the United States' share of support for the program.

Division of Astronomical Sciences

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. FY07 saw the arrival of the first antennas at the mid-level (9,000 ft elevation) site in Chile, two from the U.S., and three from Japan. Alignment of the antenna panels and other tests have commenced. Also, the high-site (17,000 ft) technical building was completed during FY07. The first two cryostats containing pre-production receivers underwent acceptance testing at the Front-End Integration Center at NRAO, Charlottesville, VA, and they will be shipped to Chile for integration with the antennas. The ALMA Board accepted a comprehensive ALMA Operations Plan.

During FY07, the NSF's Division of Astronomical Sciences continued to fund a four-year technology development and design effort for the proposed Large Synoptic Survey Telescope (LSST). The LSST would be a 6.5-meter effective aperture telescope with a field of view exceeding three degrees. In addition, the LSST would 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 broad, spanning the fields of cosmology, galactic structure, and solar system astronomy. The LSST would undertake both a census of distant (trans-Neptunian) solar system objects as well as surveys of near-Earth and potentially hazardous asteroids. Spanning a ten-year lifetime, if built, the LSST should provide a 90-percent complete sample of potentially hazardous objects with diameters greater than 250 meters and provide an 80 percent complete sample of hazardous objects down to 140 meters.

The Division of Astronomical Sciences continued support for the development of the proposed 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, previously earned a strong recommendation as a medium-sized ground-based project by the National Research Council of the National Academies. In FY07, the ATST passed a comprehensive preliminary design review. Preparations for a final Environmental Impact Statement and application for a land use permit are ongoing.

HIAPER

The Division of Atmospheric Science's high-altitude aircraft, the High-performance Instrumented Airborne Platform for Environmental Research

(HIAPER), centers on a highly structurally modified Gulfstream V (GV) mid-size jet aircraft. The GV is FAA certified to operate at 51,000 feet. Its long-duration (more than 12 hours), range (more than 6,000 km), and scientific payload (6,000 pounds) will enable scientific research previously not possible with existing platforms in the U.S. fleet. The GV represents the most advanced airborne research platform in the U.S. civilian fleet. The DLR (German Aerospace Center) is currently modifying and equipping a Gulfstream 550 that will be a "partner" aircraft with the NSF GV.

In FY05, the GV project was brought in on schedule and under budget ($81.5 million). 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 the Terrain Induced Rotor Experiment (T-REX). The aircraft met or exceeded its performance goals during the experiment, which included two other research aircraft and a suite of ground-based observing systems. After the T-REX, the GV supported the Pacific Dust Experiment (PACDEX), which evaluated the effects of Asian- borne dust on climate issues. The GV is now being equipped with new instruments, and it will go through a test and evaluation period. Later in FY08, the GV will initiate the first of several long-duration flights for the HIAPER Pole-to-Pole Observations (HIPPO) deployment. The primary purpose is to study the carbon cycle and greenhouse gases. The HIPPO objectives can only be met with a platform that has the performance characteristics of the GV.

In FY07, the HIAPER successfully made the transition into nominal operations. The Research Aircraft Facility of the National Center for Atmospheric Research (NCAR), a Federally Funded Research and Development Center of the NSF, operates and maintains the HIAPER. The NCAR also operates and maintains the NSF's C-130Q research aircraft. The GV's expected lifetime is 10–25 years, during which new instrumentation innovations will be continually integrated onto the airframe, as appropriate.

Upper Atmospheric Research Section

The Upper Atmospheric Research Section (UARS) in the NSF's Division of Atmospheric Sciences supported a wide variety of research programs in space science during 2007. 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. The 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 education and outreach activities. An effective knowledge transfer program also ensured that CISM models were transferred for use in operational space weather forecasting centers. The CISM submitted a successful renewal proposal in FY06, and an additional five years of NSF support began in FY07.

Research facilities have always been a key component of UARS efforts. The major goal of the UAF program in FY07 continued to be the promotion of basic research on the structure and dynamics of Earth's upper atmosphere. Research efforts using these facilities were linked strongly to the CEDAR and GEM programs. The UARS completed the first deployment of the Advanced Modular Incoherent-Scatter Radar (AMISR) at Poker Flat, Alaska, with routine operations starting in January 2007. The AMISR conducted initial experiments in support of a series of NASA sounding rockets launched from Poker Flat. Observations throughout 2007 demonstrated the unique AMISR capabilities, including the ability to image the ionospheric effects of auroral precipitation in three dimensions. The NSF incoherent scatter radars, including the AMISR, operated extended hours since March 2007 as part of International Polar Year activities. These routine observations are providing a wealth of measurements particularly useful to modelers interested in validating space weather models using long-duration data sets.

In addition, the UARS continued to support the study of magnetospheric physics in the international Super Dual Auroral Radar Network (SuperDARN)

consortium. In FY07, the NSF funded a new SuperDARN radar at Wallops Island, Virginia (operated by The Johns Hopkins University Applied Physics Laboratory), and assisted its international partners in deploying new radars in Hokkaido, Japan (operated by the University of Nagoya), and at Rankin Inlet and Inuvik, Canada (both operated by the University of Saskatchewan). The UARS community also continues to benefit from the NSF's astronomy efforts to develop the proposed ATST, described previously in this document. In addition, the NSF allocated UARS funding in FY07 for the design and development of the proposed Frequency Agile Solar Radiotelescope (FASR), as well as funding to support the NSF's astronomy efforts to build a radiotelescope testbed in Western Australia (known as the Murchison Widefield Array [MWA]).

The NSWP is a multiagency Federal program whose goal is to mitigate the adverse effects of space weather on the Nation's technological infrastructure by providing timely, accurate, and reliable space environment observations, specifications, and forecasts. The NSWP Strategic Plan and Implementation Plan contains NSWP information and is available online through the Office of the Federal Coordinator for Meteorology (OFCM). During 2007, the UARS worked with the OFCM to develop a strategic plan for space weather activities in response to a request by the National Science and Technology Council's Subcommittee on Disaster Reduction. In 2007, the UARS also contributed to an OFCM-led assessment of the impacts resulting from the descoping of space sensors planned for the NPOESS.

Late in 2006, a panel of eight scientists, including Dr. Louis Lanzerotti, a member of the National Science Board, completed its assessment of the NSWP and presented its report to the OFCM. In response to a key recommendation from the panel, the UARS sponsored a community workshop, held at George Mason University in Arlington, Virginia, on May 15–17, 2007, to explore the possibilities and benefits of utilizing small satellite missions to provide essential measurements for space weather and atmospheric research. About 150 participants from academia, Government, and the aerospace industry attended the workshop, which was highly successful in gathering the information needed to develop plans for a future NSF program to support such an activity.

During the week of November 5–8, 2007, the Community Coordinated Modeling Center (CCMC) for space weather research, which is cosponsored by the NSF and NASA, held its biennial workshop at the Arecibo Observatory in Puerto Rico. More than 50 scientists attended, and community outreach and service programs were laid out for the next several years. Throughout 2007, the CCMC continued to provide the research community with access to state-of-the-art space weather models and conducted important validation activities necessary for the transition of research models to operational use.

Office of Polar Programs

In FY07, the Office of Polar Programs in ground-based space science and astronomy completed the ten-meter, off-axis radio telescope at the U.S. Amundsen-Scott South Pole Station to survey galaxy clusters and continued construction of the IceCube Neutrino Observatory.

While the South Pole Telescope's (SPT) ground shield has not yet been erected, the SPT saw its first light on February 16, 2007, and by the end of October 2007 successfully completed its first winter survey-observing period. The IceCube South Pole Neutrino Observatory also began its observational phase. While only a third of 80 planned ice boreholes were equipped with strings of optical photo detectors, data collection began including advance filtering and reconstruction of neutrino events recorded at the South Pole. Scientific topics under study include searches for weakly interacting massive particles (WIMPs), neutrino point sources, and magnetic monopoles. A number of muon neutrino candidates were detected from the 22 detector strings that are currently in place.

Department of State

DOS

The Department of State (DOS) supports U.S. space activities through the negotiation of bilateral and multilateral agreements of scientific and technical cooperation with partner countries. The DOS also maintains outreach programs to advance U.S. foreign and space policy objectives. FY07 saw extensive integration of space issues into Presidential diplomacy.

As part of the Presidential initiative to transform the U.S. relationship with India into a "strategic partnership," the DOS developed and began implementation of an ambitious plan to foster space cooperation between the two countries, in particular, through the establishment of a Joint Working Group (JWG) on Civil Space Cooperation. The JWG met for the second time in Washington, DC, from February 27–28, 2007, resulting in new agreements for cooperation on satellite navigation systems, Earth observation programs, and space exploration initiatives such as the placement of U.S. instruments on the Chandrayaan-1 lunar orbiter (scheduled for launch in 2008). The DOS, together with other U.S. agencies, is also in the process of negotiating with India various space cooperation agreements and cooperative projects, including a Technology Security Agreement and a Commercial Space Launch Agreement.

Similarly, based on an agreement at the U.S.-European Union Summit of June 2005, the two countries agreed to establish a U.S.-European Union civil space policy dialogue to further join efforts between both sides. The civil space dialogue working group met for the second time in Washington, DC, from April 19–20, 2007, resulting in agreements to expand collaborative work on Earth observation, Earth and space science, and space exploration. The two sides also agreed to coordinate with multilateral organizations such as the Committee on Earth Observing

Satellites (COES) and the GEO, with the ultimate goal of creating a GEOSS. The DOE reached other bilateral agreements, including a framework agreement on civil space cooperation between the United States and France, which was signed in January 2007.

The DOS led vigorous efforts in FY07 to promote the GPS and its augmentation in accordance with the President's 2004 Policy on Space-Based Positioning, Navigation, and Timing (PNT). The DOS led consultations with Japan in May 2007 in Washington, DC, to review and discuss ongoing cooperation on the civilian use of GPS. Among the topics discussed were Japan's plans to construct a regional satellite positioning system, known as the Quasi-Zenith Satellite System (QZSS), which would be compatible and interoperable with the GPS. The QZSS is also expected to provide new economic and public transportation safety benefits to Japan and its neighbors, as well as contribute to the peaceful development of the Asia-Pacific region. The U.S. is assisting Japan in installing QZSS monitoring stations in Hawaii and Guam. The U.S. also conducted GPS consultation with Australia in April 2007, resulting in a Joint Statement on GPS Cooperation.

The DOS coordinated meetings of working groups established under the 2004 U.S.-European Union Agreement on Cooperation between the GPS and Europe's planned Galileo satellite navigation system. Fruitful collaboration in the radio frequency compatibility and interoperability working group led to an agreement in June 2007 between the U.S. and the European Union to adopt jointly a new modulation, known as the Multiplexed Binary Offset Carrier (MBOC), for use in the Galileo Open Service and the new civil signal for GPS III. A working group on trade issues met in January 2007 and began work on ensuring nondiscrimination in trade practices in satellite navigation goods and services. In addition, the DOS pursued negotiations with Russia on cooperation between the GPS and its Russian counterpart, the Global Navigation Satellite System (GLONASS). The DOS coordinated progress between the working groups on radio frequency compatibility and interoperability and our common interest in satellite-based search and rescue capabilities.

The DOS worked to establish the United Nations International Committee on Global Navigation Satellite Systems (ICG) in late 2006. The ICG will help promote use of GNSS applications, especially for developing countries. The ICG met

for the second time in India on September 4–7, 2007, and more than 140 GNSS experts from around the world participated. At that meeting, the U.S. led a movement to start a related Providers Forum where GNSS providers (U.S., European Union, Russia, China, Japan, and India) could meet to work on issues of common interest. The U.S. plans to hold the ICG-3 in California during December 2008. During FY07, the DOS also provided funding for regional GNSS workshops and experts' meetings held under the auspices of the United Nations and the United States, bringing together regional experts and decision makers to advance awareness and support of GNSS applications for sustainable growth, transportation safety, and environmental management.

The DOS began working extensively with foreign governments to coordinate the use of the communications spectrum in support of various Presidential Initiatives. As part of the Vision for Space Exploration, the DOS established the Lunar and Planetary Spectrum Initiative to ensure international cooperation on communications bandwidth.

Exploiting similar U.S. advantages in another area, the DOS worked extensively with foreign governments and private industry to promote U.S. satellite imagery exports. For example, the DOS negotiated within the Administration and then with Latin American countries to redeploy a GOES meteorological satellite to cover the Caribbean. The DOS joined the Geographic Information for Sustainable Development (GISD) program—an international effort to meld maps, remote sensing data from satellites, and cutting-edge software. The DOS space imagery export efforts not only provided commercial advantage to the U.S., but they also enhanced foreign capabilities to pursue other U.S. interests in natural resources management, disaster mitigation, and economic development. The DOS sponsored or cosponsored workshops in Africa on the distribution and use of Landsat data. Another DOS-supported effort produced a cooperative telemedicine project, which involved the use of space and communications technologies and the Indian Space Research Organization (ISRO) at the Indira Gandhi Hospital in Kabul, Afghanistan.

The DOS continued to represent the U.S. on the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). With so many countries now engaged in space activities, the DOS considers promoting the safe use of space as an important goal. At UNCOPUOS, the DOS led U.S. efforts on the problem of

orbital space debris, meteorology, astronomy and astrophysics, space transportation, nuclear power sources in space, and legal issues related to international liability and responsibility of the launching nations.

Department of Energy

DOE

During FY07, the DOE 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 the DOE signed by the NASA Administrator and the DOE Secretary in 1992. The DOE's Office of Nuclear Energy continued to support NASA's space science and exploration programs by pursuing the development of space radioisotope and reactor power system technologies for future space missions and by maintaining the necessary nuclear facilities infrastructure.

The SC continued to work on the Alpha Magnetic Spectrometer (AMS). In FY07, 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 to use the unique environment of space to search for and measure, with a much greater sensitivity than previously possible, various unusual types of matter. The AMS would 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. The DOE provided funding in FY07 to support the research group at the Massachusetts Institute of Technology (MIT) that is leading the AMS program.

The SC and NASA's 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 as well as the Instrument Science Operations Center (ISOC), which will process the data during operations. Fabrication of the LAT was completed in early FY06. The LAT then underwent commissioning and began integration on the spacecraft. The DOE provided funding in FY07 in conjunction with NASA and international partners for GLAST commissioning and preoperations activities for the LAT and the ISOC.

The DOE and NASA both have a high-priority science objective to determine the nature of dark energy, which may cause the acceleration of the expansion of the universe. The Joint Dark Energy Mission (JDEM) is a plan for a space-based mission endorsed by both the DOE and NASA for the study of dark energy. In this plan, both the DOE and NASA are responsible for the success of the mission, with NASA leading the space mission management. In FY07, the DOE supported R&D activities for the Supernova Acceleration Probe (SNAP) collaboration, led by the Lawrence Berkeley National Laboratory (LBNL), and began R&D funding for two other collaborations—Advanced Dark Energy Physics Telescope (ADEPT) and Dark Energy Space Telescope (Destiny). NASA awarded grants starting in FY07 to the same three collaborations to begin mission concept studies for the JDEM. In FY07, the DOE and NASA jointly funded a National Research Council study, the Beyond Einstein Program Assessment Committee (BEPAC), to recommend which of the five missions in NASA's Beyond Einstein program should be developed and launched first. In September 2007, the BEPAC submitted their report to the agencies with the recommendation that the JDEM be developed and launched first.

The Office of Nuclear Physics within the 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. The AGS allows for NASA-funded radiobiology

experiments 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, the DOE and NASA supported the design and fabrication of the Electron Beam Ion Source (EBIS) at BNL in FY07. NASA is contributing approximately 25 percent of the EBIS project cost 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 FY07, the Office of Nuclear Physics continued to support astrophysicists who used approximately 400,000 processor hours at the National Energy Research Scientific-computing Center (NERSC), which is funded by the 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. The 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., the National Reconnaissance Office and the U.S. Air Force), 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 beam time to NASA, DOE-applied laboratories, European and Japanese space agencies, and private companies.

In FY07, 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 on the spherical torus and plasma-jet-driven magneto-inertial fusion. The 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. The OFES also investigated plasma-jet-driven magneto-inertial fusion at General

Atomics; Lawrence Livermore National Laboratory; Hyper V Technologies Corporation; Far-Tech Inc.; Voss Scientific, Inc.; the University of Washington; the University of Wisconsin; the University of New Mexico; the Air Force Research Laboratory; and Los Alamos National Laboratory as part of its high-energy density physics program. The two fusion rocket concepts based on 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 ten. The advanced plasma jet research has the potential to be a very high-power plasma thruster as well. HyperV Technologies Corporation in Virginia demonstrated the launch of a plasma jet of 157 μg to 70 km/s. The plasma jet also has potential for laboratory studies of astrophysical jets, a class of astrophysical objects of interest to NASA. The 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.

Agency interaction with NASA also included the working of the interagency Task Force on High Energy Density Physics under the guidance of the Interagency Working Group on the Physics of the Universe of the Committee on Science of the National Science and Technology Council. Two offices of the DOE chaired the task force, and NASA was one of the member agencies. The task force released its report in September 2007. The report covered activities that require coordination and collaboration between the DOE and NASA.

In addition, the 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 space-related plasma physics and astrophysics topics. The Magnetic Reconnection Experiment investigates the coupling between microscale reconnection layers and global forcing and plasma topology evolution. This cross-discipline research has made recent significant progress in understanding the effects of two-fluid physics.

The SC and NASA worked together to calculate the daily primary productivity of terrestrial ecosystems at diverse sites in Northern and Central States. The 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 approximately 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 provide critical baseline data to calibrate existing and planned NASA satellite data streams.

The SC's Atmospheric Radiation Measurement (ARM) provided ground-validation support for NASA's Atmospheric Infrared Sounder (AIRS) instrument. The AIRS is a high spectral resolution infrared sounder on the EOS Aqua platform. 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. During FY07, the ARM continued support of NASA's solar-viewing Bruker 125 HR 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. During the summer of 2007, NASA participated in the SC's Cloud and Land Surface Interaction Campaign (CLASIC) field experiment conducted at the Southern Great Plains (SGP) site. The focus of this cross-disciplinary interagency research effort was to advance the understanding of how land surface processes influence cumulus convection.

NASA, NOAA, and the DOE jointly sponsored a series of workshops on the use of Uninhabited Aerial Systems (UAS) for weather and climate change research. The focus of these workshops was to identify the key scientific questions that could be addressed using the current capabilities of UASs and to identify aircraft or instrument technology gaps that would require future development of UAS capabilities and their applications. The workshops brought together distinguished scientists

from the agencies, universities, and private industry. Signed in November 2006, the MOU facilitated a collaborative, cost-sharing partnership between NASA's SMD, NOAA's Office of Oceanic and Marine Operations (NMAO), and the DOE's SC. One of their goals is to define how UASs may extend climate and weather-related measurements over regions of Earth that are currently under-sampled.

The SC, NSF, NOAA, and NASA continued their collaborative effort to develop and employ climate models. All four agencies supported a variety of activities associated with high-end climate models, e.g., the Community Climate System Model. The SC's Scientific Discovery through Advanced Scientific Computing project (SciDAC) continued to develop and increase the level of sophistication in complex climate models.

The SC's SciDAC program supports researchers at NASA ARC in the development of numerical methods and computational tools to investigate turbulent flows with strong shocks and density variations. The current ability to predict these flow phenomena is strongly limited by the models of turbulence and computational algorithms in use. The collaborative work could lead to stable and accurate treatment of interface boundaries, grid refinement, and accurate solvers for a wide spectrum of flow types.

During FY07, under the guidance of U.S. Climate Variability and Predictability (CLIVAR), NASA, the DOE, NOAA, and the NSF participated in the interagency Drought in Coupled Models Project (DRICOMP) that focuses on the evaluation of a variety of existing model products to address issues such as the roles of the oceans and the seasonal cycle of drought, the impacts of drought on water availability, and distinctions between drought and drying. The DRICOMP objective is to increase community-wide diagnostic research into the physical mechanisms of drought and to evaluate its simulation in current models. The DRICOMP will lead to more robust evaluations of model projections of drought risk and severity, thus leading to a better quantification of the uncertainty in climate model projections.

With NASA funding, the DOE and NASA principal investigators (PI) are collaborating in a study of the effects of meteorological variability on atmospheric carbon species distributions. The DOE and NASA study uses the NASA Goddard Data Assimilation System with NASA satellite data and computing resources at

the National Leadership Computing Facility (NLCF) at the Oak Ridge National Laboratory (ORNL).

The SC's Low Dose Radiation Research Program continued to interact with the Space Radiation Project within NASA's Human Research Program. The DOE's 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 assessed. Both research programs are recognizing the importance of delineating mechanisms of action of biological responses induced in the low-dose region. In FY01, NASA and the 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. Sixteen jointly funded projects were ongoing in FY07, and these include two NASA Specialized Center of Research (NSCOR) projects.

The DOE's Energy Sciences Network (ESnet) and NASA's Research and Education Network (NREN) continued their close working relationship. The ESnet has one of its major peering points (points where it connects to other networks) at NASA ARC. Additionally, NASA ARC has been an active participant in the DOE-sponsored Optical Network Technologies workshops.

NASA and the DOE also continued their collaboration 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 and Argonne National Laboratories, and the SLAC.

The DOE's Office of Nuclear Energy continued to support NASA's space science and exploration programs 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 FY07, the DOE continued development and testing of a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) for first use on the Mars Science Laboratory mission, which is to be launched in 2009, and development of the Advanced Stirling Radioisotope Generator (ASRG) now under consideration for Discovery or Scout class missions in the 2012–2013 timeframe. Both of these new radioisotope

power systems are designed for use in multiple mission environments, including planetary surfaces and deep space. The MMRTG and ASRG systems will each provide greater than 100-watts electric for more than 14 years. The Office of Nuclear Energy and DOE National Laboratories are also supporting technology development that could lead to a fission surface power system for deployment by NASA on the Moon around the year 2020. During FY07, the DOE supported NASA studies of surface reactor power and nuclear thermal propulsion technologies and systems and participated in technology development activities related to the design of a fission surface power. As part of maintaining the required infrastructure, the DOE continued operation of facilities at ORNL, Idaho National Laboratory, and Los Alamos National Laboratory.

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 engaged in a broad program of research in astronomy, astrophysics, and science education. The Smithsonian National Air and Space Museum (NASM) in Washington, DC, also contributed to national aerospace goals through its research and education activities.

In FY07, SAO astronomers measured the fastest-spinning black hole known to exist, which whirls around 950 times per second. Such a fast spin approaches the theoretical speed limit set by Einstein's General Theory of Relativity. Astronomers also spotted evidence of a galactic hit-and-run, using the Spitzer Space Telescope to show that the dwarf galaxy Messier 32 collided with the Andromeda spiral galaxy about 200 million years ago. In a second discovery, Spitzer spied a monster galaxy pileup, photographing four galaxies that are colliding into each other. The quadruple merger eventually will form one of the biggest galaxies in the universe.

The SAO theoretical findings included the discovery that some "super-Earths" (planets 5 to 15 times the mass of Earth that orbit distant stars) form in cosmic snowstorms, accumulating icy material from a protoplanetary disk during the course of millions of years.

FY07 marked the fourth year of operations for NASA's Spitzer Space Telescope —operated by the JPL—whose Infrared Array Camera (IRAC) was developed at the SAO. The Spitzer Space Telescope studies the universe at infrared wavelengths of light, enabling the telescope to peer into nearby dust-obscured regions, as well as to spot distant, highly redshifted galaxies. The IRAC logged a total of more than 9,600 hours of operation in flight.

Spitzer Space Telescope and IRAC team member findings included the following:

- The first crude day-night temperature map of the atmosphere of an extrasolar planet, giving astronomers their first detailed look at an alien world.
- The first infrared spectrum of the atmosphere of an extrasolar planet, which let astronomers get their first "sniffs of alien air."
- A new mid-infrared view of the Andromeda galaxy and evidence that an almost head-on collision with a neighboring galaxy created two off-center rings in Andromeda.
- Evidence for a new population of highly redshifted galaxies detectable only at infrared and submillimeter wavelengths.
- New insights into galaxy birth and evolution by measurements of the stellar mass and star formation history of highly redshifted galaxies.
- New insights into the structure and evolution of young stellar clusters in our galaxy.
- A new view of the structure of planetary nebulae.
- Large-scale, mid-infrared maps of the entire Large Magellanic Cloud, a satellite of the Milky Way, which distinguished contributions from stars and dust and yielded new insights into its structure.
- First mid-infrared photometry of cool, dim M, L, and T dwarf stars and the discovery of two T dwarf companions to nearby stars.

FY07 marked the first full year of operation of the Hinode satellite, which provides continuous viewing of the Sun from space. The SAO's X-Ray Telescope (XRT) on board Hinode is the highest-resolution telescope of its type ever flown for solar studies. The XRT observes x-rays from the solar corona (a million-degree-hot outer layer of the Sun's atmosphere). The XRT provided groundbreaking observations of 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 the SAO served as the focal point from which both satellite operations and scientific studies are coordinated.

Initial findings from Hinode were reported at a NASA Space Science update in March 2007. The XRT provided the first clear view of the possible energy source for the corona. It observed twisted and tangled magnetic fields that store huge

amounts of energy. When those complicated magnetic structures relax to simpler configurations, a huge amount of energy is released. That energy heats the corona and powers solar eruptions like flares and coronal mass ejections. The XRT also uncovered new details in active regions (areas of strong magnetic fields), including gigantic arcing magnetic structures that dwarf the underlying sunspots.

The SOHO Ultraviolet Coronagraph Spectrometer (UVCS) investigation made major progress in understanding both the solar wind and eruptions called CMEs through the use of innovative spectroscopic diagnostics of the extended solar corona. These observations, combined with theoretical studies, provided a powerful means of understanding the underlying physics of solar wind acceleration, CME evolution, and the production of solar energetic particles from CME shock fronts.

Some recent results from the UVCS group included a paper that confirms the existence of intense preferential heating of solar wind oxygen ions high in the Sun's corona or extended atmosphere (a previous UVCS result). The new result showed that the heating of ions in the corona is 10 to 100 times greater in the direction across the coronal magnetic field than it is in the direction along the magnetic field. This result provided strong evidence that the energy that drives the solar wind comes from magnetic waves produced in the region of the corona where the heating occurs.

UVCS observations led to significant progress in understanding CMEs and their relationship to solar energetic particles, which are a known hazard to astronauts. Scientists knew that the fastest CMEs produce shock waves when they collide with the slower background solar wind, and they believed that these shocks potentially produce the fastest and most dangerous solar energetic particles. UVCS research provided measurements of the physical quantities involved in producing the shocks, which allowed the means of testing and guiding theoretical models aimed at understanding how solar energetic particles are produced. Such models could ultimately produce the capability to predict the occurrence and severity of solar energetic particle-producing events.

During FY07, the Chandra X-ray Observatory continued its scientific pursuits and successful operations under SAO control. Since its launch in 1999, Chandra served as an indispensable tool for astronomers around the world in their attempt to learn more about the universe.

One of the biggest results from Chandra in FY07, along with ground-based telescopes, was the discovery of the brightest supernova ever recorded. This result indicated that violent explosions of extremely massive stars were relatively common in the early universe and that a similar explosion may be ready to go off in our own galaxy.

In other areas of astrophysics, Chandra continued its unprecedented work in studying black holes. Astronomers used Chandra to capture a rare eclipse of a black hole at the center of a distant galaxy, allowing key predictions of black holes to be tested. Chandra also added more information about how and when black holes formed when the universe was much younger.

Cosmology, the study of the origin and the evolution of the universe as a whole, remained an important area of inquiry for scientists using Chandra. One result was the discovery of a cosmic "train wreck" between giant galaxy clusters. Chandra once again was teamed with optical telescopes to unravel the details of this collision. This result may pose problems for some of the current theories of dark matter, the mysterious, unknown substance believed to constitute a majority of the matter in the universe.

The Smithsonian's Submillimeter Array (SMA), the world's first and only interferometric imaging telescope for submillimeter wavelengths, continued forefront research on a wide range of astrophysical topics, from nearby star-forming regions and evolved star envelopes, to the supermassive black hole in the center of the Milky Way, and to galaxies more than 12 billion light-years from Earth. Ongoing upgrades continued to improve SMA's performance, sensitivity, and observing efficiency. Competition for SMA observing time remained very high; less than one of four requests for the SMA's unique capabilities could be accommodated. As more (and longer-term) projects are completed, the publication rate of scientific results from the SMA in peer-reviewed journals increased to approximately one article per week, a testament to the impact of this unrivaled telescope facility.

A major focus for the SMA continued to be the study of star and planet formation, as submillimeter wavelengths provide distinct diagnostics of physical and chemical conditions of cool, dense gas and dust. SMA imaging of regions where stars form that are more massive than the Sun have revealed intriguing clusters whose gas motions have stimulated debate over whether these stars form by

processes similar to their Sun-like counterparts. With the growing number of planetary systems found around other stars, attention was also focused on the origin of our solar system and others like it. The SMA recently completed the largest interferometric survey to date of disks surrounding young stars. Such disks are reservoirs of planet-building material and serve as analogs of the young solar system. SMA observations provided direct views of the internal properties of disks and enabled astronomers to constrain the initial conditions for planet formation. Astronomers also saw exciting images of inner holes in some of the disks, most likely resulting from the gravitational influence of giant protoplanets.

In FY07, astronomers using the SMA made remarkable discoveries about galaxies beyond the Milky Way. For example, SMA imaging of molecular gas at unprecedented angular resolution in the galaxy cluster Perseus A gave new insights into the "cooling flow" phenomenon, an effect that was long predicted but never clearly seen. The SMA showed that cool molecular gas is confined to a few infalling "filaments" that feed a central black hole. Jets of hot plasma from the vicinity of the black hole reheat the surrounding gas and serve to limit the extent of the cooling flow within the cluster. In another study, the SMA made long-exposure observations to pinpoint the positions of a sample of faint dusty galaxies in areas of the sky studied extensively by the Cosmic Evolution Survey (COSMOS) and the Great Observatories Origins Deep Survey (GOODS). With the new SMA information, it became possible, for the first time, to examine possible counterparts of these dusty galaxies at a wide range of wavelengths, and then to deduce their distances and investigate their physical nature. Remarkably, most of these galaxies cannot be detected at all at visible wavelengths, even with the Hubble Space Telescope, because surrounding dust hides nearly all of their light. These galaxies represented a previously unrecognized population of massive, luminous galaxies existing when the universe was less than two billion years old, producing stars at a rate 1,000 times faster than the Milky Way.

In public outreach, the SAO continued to offer its popular monthly Observatory Night lectures and telescope observing sessions, as well as new Family Friendly Nights aimed at younger children. The SAO also held occasional Author's Night programs and Sci-fi Movie Nights that explored the theme, "Everything I learned about science, I learned at the movies."

In FY07, the Smithsonian NASM continued to educate and inspire the public through exhibits and educational programs, including discovery stations, lecture series, and intern programs. A major effort involved the construction of "America by Air," a brand new permanent exhibition scheduled to open in mid-November 2007. "America by Air" tells the story of passenger air travel in the United States with dramatic displays, including a life-size interactive cockpit simulation of an Airbus A320 taking off and landing at Ronald Reagan Washington National Airport. Visitors also will be able to cross a 30-foot-high pedestrian bridge and step inside the forward fuselage of a retired Northwest Boeing 747, getting a close-up look at the cockpit along with the view from the upper deck of the wide-body airliner.

The NASM celebrated the 50th anniversary of space flight with the publication of *After Sputnik: 50 Years of the Space Age*. This book tells the story of space exploration through examination of key artifacts in the NASM collection.

In June, the NASM's Steven F. Udvar-Hazy Center hosted a spectacular educational event, "Become a Pilot Family Day and Aviation Display." More than 50 aircraft, ranging from a huge U.S. Air Force KC-135 tanker to a 1940s WACO biplane, flew in to participate in the event, and more than 17,500 people viewed the aircraft and interacted with the pilots.

Staff members in the NASM's Center for Earth and Planetary Studies (CEPS) continued to participate on the science teams of several spacecraft missions. Dr. John Grant works as a participating scientist in the MER mission that is currently operating on Mars. Also a chair of the MER Science Operations Working Group, he directs the science team to consensus on targets and operations for the long-lived rovers. Dr. Grant conducts real-time mission planning from a control station installed on site at the CEPS. CEPS staff worked on the science teams for the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) radar instrument on Mars Express; the HiRISE and Shallow Subsurface Radar (SHARAD) instruments on the MRO; and the Messenger mission to Mercury, which will make its first flyby of that planet in January 2008. During this encounter, a large portion of the hemisphere unseen by the Mariner 10 spacecraft in the 1970s will be imaged.

The 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 the Moon, Mars, Earth, Titan, and Venus, resulting in 23 peer-reviewed publications. Research topics included MER and HiRISE results; Martian fluvial, aeolian, and volcanic processes; volcanic features of Venus; Martian hemispheric dichotomy; terrestrial analogs of Martian features; and Martian geologic and climate history using radar sounding data. 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), the CEPS continued to house a collection of more than 300,000 images of the planets and their satellites as a reference library for science researchers and the public, serving the mid-Atlantic and Southeastern United States. The CEPS RPIF holds the most complete collection of lunar images of any RPIF in the world. In FY07, support from the Smithsonian Collections Care and Preservation Fund allowed improved storage for archive preservation.

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	20[d]	0	2	0
2007 (through September 30, 2007)	9	2	2	0
TOTAL	1,599	153	106	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 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		
2007 (through September 30, 2007)	18	23			3	11			5	3	1
Total	1,351	2,791	10	8	70	102	1	1	172	21	5

a. This includes commercial expendable launches and launches of the Space Shuttle, as well as launches to useless orbits.

b. Launches from U.S.-Russia joint platform included in U.S. totals.

c. Since 1979, all launches for ESA member countries have been joint and are listed under ESA.

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2006–September 30, 2007

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
October 26, 2006 STEREO A and B 2006-047A-B Delta 2	Solar and space physics	Twin spacecraft mission with STEREO A orbiting ahead of the Sun (period of 345 days) and STEREO B behind the Sun (period of 385 days)	Study of the sun and CMEs
October 30, 2006 XM 4 2006-049A Zenit 3SL rocket	Communications	Geosynchronous	Sea Launch from Odyssey in the Pacific Ocean at 154° W longitude Carried a 18 kW transponder to provide S-band Digital Audio Radio Service (DARS)
November 4, 2006 DMSP 5D-3/F17 2006-050A Delta 4	Surveillance and other military Weather satellite	855 km 841 km 102 min 98.8°	DOD/NOAA
November 17, 2006 Navstar 59 2006-052A Delta 2	Navigational satellite (GPS)	20,367 km 20,206 km 722 min 51.7°	Plane B, Slot 4 position Replaced GPS 2A-22
December 10, 2006 STS 116/*Discovery* 2006-055A Shuttle	ISS assembly	338 km 315 km 91 min	Installed P5 truss
December 10, 2006 Space Test Program-H2 (STP-H2)	Communications, Earth science, and technology application	Altitude 350 km	The Atmospheric Neutral Density Experiment (ANDE) consisted of two microsatellites to measure the density and composition of the low Earth orbit atmosphere while being tracked from the ground: ANDE Fence Calibration (FCal) (2006-055J) and
Multiple			Mock ANDE Active (MAA) (2006-055F) Microelectromechanical System-Based Picosat Inspector (MEPSI) (2006-055B) included a low-power inspection satellite demonstration Radar Fence Transponder (RAFT) 1 (2006-055C) included a U.S. Naval Academy student experiment
Military Affiliate Radio System Communications (MARScom) 2006-055D	Communications		U.S. Navy/Marine Corps

Appendix B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2006–September 30, 2007

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
December 14, 2006 USA 193 2006-057A Unknown	Classified military satellite	Unknown	National Reconnaissance Office
December 16, 2006 GeneSat 1 2006-058C Minotaur	Life science	420 km 413 km 92.9 min 40°	NASA nanosatellite "Astrobionics" experiment
TacSat 2 2006-058A	Engineering, earth observing, and technology application	424 km 413 km 92.9 min 40°	DOD/Air Force and NASA New Millenium Program Carried 50 cm aperture telescope First in a series of satellites to demonstrate objectives of the joint warfighting space (JWS) initiative
February 17, 2007 THEMIS 1-5 2007-004A-E Delta 2	Space physics	87,330 km 470 km 1,870 min 16.0°	NASA Explorer Mission THEMIS will study geomagnetic substorms to better understand and predict space weather, including examining auroras
March 9, 2007 CFESat 2007-006F Atlas V	Surveillance and military	563 km 558 km 95.9 min 35.4°	Defense Advanced Research Projects Agency microsatellite
OE-ASTRO 2007-006A	Surveillance and military	499 km 491 km 94.5 min 46.03°	Defense Advanced Research Projects Agency satellite
MidSTAR 1 2007-006B	Surveillance and military	499 km 494 km 94.5 min 46.03°	Defense Advanced Research Projects Agency microsatellite NSBRI
OE-NEXTSAT 2007-006C	Surveillance and military	449 km 491 km 95.9 min 46.03°	Defense Advanced Research Projects Agency minisatellite
STPSat 1 2007-006D	Surveillance and military	561 km 558 km 95.8 min 35.4°	Defense Advanced Research Projects Agency microsatellite
FalconSat 3 2007-006E	Surveillance and military	560 km 558 km 95.8 min 35.4°	Defense Advanced Research Projects Agency picosatellite

Appendix B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 2006–September 30, 2007

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
April 24, 2007 AIM 2007-015A Pegasus XL	Space physics	600 km 586 km 96.5 min 97.8°	NASA study of Polar Mesospheric Clouds (PMCs) Pegasus was dropped and launched from a Lockheed L-1011 TriStar
Near Field InfraRed Experiment (NFIRE) 2007-014A Minotaur	Surveillance and military	464 km 255 km 91.7 min 48.2°	
June 8, 2007 STS 117/*Atlantis* 2007-024A Space Shuttle	ISS assembly	International Space Station 354 km 334 km 91.4 min 51.6°	Installed S3/S4 trusses and additional solar panels
COSMO-SkyMed 1 2007-023A Delta 2	Earth imaging	623 km 622 km 97 min 97.9°	Geosynchronous Italian spacecraft Constellation of Small Satellites for Mediterranean Basin Observation (COSMO) Civilian and military
June 15, 2007 USA 194 2007-027A Atlas V	Surveillance and military	Unknown	Classified
August 4, 2007 Phoenix Mars Lander 2007-034A Delta 2	Planetary science	N/A	Martian Arctic at a site 68.35°N and 233°E
August 8, 2007 STS 118/*Endeavour* 2007-035A Space Shuttle	ISS assembly	International Space Station 348 km 337 km 91.4 min 51.6°	Installed S5 truss
September 18, 2007 WorldView 1 2007-041A Delta 2	Commercial imaging Earth Science	495 km 493 km 94.5 min 97.5°	
September 27, 2007 Dawn 2007-043A Delta 2	Planetary science	N/A	Visiting asteroids: Vesta and Ceres

* U.N. Committee on Space Research

Appendix C

HUMAN SPACE FLIGHTS

October 1, 2006–September 30, 2007

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Space Shuttle *Discovery* (STS 116)	December 10, 2006	Mark L. Polansky William A. Oefelein Nicholas J.M. Patrick Robert L. Curbeam Christer Fuglesang Joan E. Higginbotham	12:20:45	Carried Sunita Williams and returned Thomas Reiter Installed P5 truss Expanded electrical system First nighttime launch in more than 4 years Record set by Curbeam for the most spacewalks performed by one astronaut during a single mission
Soyuz TMA 10 (Expedition 15)	April 7, 2007	Sunita L. Williams Fyodor Nikolayevich Yurchikhin Oleg Valeriyevich Kotov Charles Simonyi	196:17:05	Carried fifth space tourist Charles Simonyi, who returned on Soyuz TMA-9 Returned Sheikh Muzaphar Shukor, who arrived on Soyuz TMA-11
Space Shuttle *Atlantis* (STS 117)	June 8, 2007	Frederick Sturckow Lee Archambault James Reilly II Patrick Forrester Steven Swanson John D. Olivas Clayton C. Anderson Sunita L. Williams	13:20:12	Carried Clayton C. Anderson and returned Sunita Williams Installed S3/S4 trusses and additional solar panels
Space Shuttle *Endeavour* (STS 118)	August 8, 2007	Scott J. Kelly Charles O. Hobaugh Tracy E. Caldwell Richard A. Mastracchio Dafydd Williams Barbara R. Morgan Benjamin Alvin Drew	12:17:55	Installed S5 truss

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	0		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
2007	16,285	15,568	22,418	1,680	200	912	87	65	404	12	39,666

* Transition Quarter

Appendix D-1B

Space Activities of the U.S. Government

HISTORICAL TABLE OF BUDGET AUTHORITY
(in millions of inflation-adjusted FY 2007 dollars)

FY	Inflation Factors	NASA Total	NASA Space	DOD	Other	DOE	DOC	Interior	USDA	NSF	DOT	Total Space
1959	5.699	1,886	1,487	2,792	194	194	0	0	0	0	0	4,474
1960	5.611	2,940	2,592	3,148	241	241	0	0	0	0	0	5,981
1961	5.544	5,345	5,134	4,513	377	377	0	0	0	0	0	10,024
1962	5.466	9,976	9,823	7,095	1,088	809	279	0	0	0	0	18,006
1963	5.405	19,854	19,600	8,378	1,389	1,157	232	0	0	0	0	29,367
1964	5.338	27,226	26,777	8,536	1,137	1,121	16	0	0	0	0	36,450
1965	5.275	27,696	27,105	8,304	1,271	1,208	63	0	0	0	0	36,680
1966	5.186	26,839	26,268	8,759	1,110	970	140	0	0	0	0	36,137
1967	5.078	25,215	24,525	8,449	1,082	934	147	0	0	0	0	34,056
1968	4.919	22,563	21,791	9,454	857	713	138	1	5	0	0	32,102
1969	4.750	18,958	18,156	9,562	809	561	95	1	5	148	0	28,527
1970	4.543	17,017	16,113	7,623	641	468	36	5	5	127	0	24,376
1971	4.307	14,262	13,357	6,513	698	409	116	9	4	159	0	20,568
1972	4.103	13,567	12,599	5,772	547	226	127	25	8	162	0	18,918
1973	3.916	13,339	12,113	6,356	577	211	157	39	8	162	0	19,046
1974	3.752	11,395	10,352	6,626	593	158	225	34	11	165	0	17,572
1975	3.500	11,300	10,201	6,621	552	105	224	28	7	188	0	17,374
1976	3.170	11,253	10,223	6,286	534	73	228	32	13	188	0	17,042
TQ*	2.957	2,756	2,510	1,360	127	15	65	9	3	35	0	3,997
1977	2.866	10,941	9,858	6,912	555	63	261	29	17	185	0	17,324
1978	2.751	11,167	9,965	7,531	622	94	283	28	22	195	0	18,118
1979	2.577	11,844	10,385	7,824	639	152	253	26	21	188	0	18,848
1980	2.385	12,497	11,161	9,177	551	95	222	29	33	172	0	20,889
1981	2.193	12,099	10,946	10,586	514	90	191	26	35	172	0	22,046
1982	1.997	12,070	11,040	13,339	625	122	290	24	30	159	0	25,003
1983	1.869	12,850	11,828	16,858	611	73	333	9	37	159	0	29,297
1984	1.790	13,351	12,277	18,250	707	61	422	5	34	184	0	31,234
1985	1.726	13,074	11,955	22,043	1,008	59	730	3	26	189	0	35,006
1986	1.672	13,054	11,981	23,620	797	59	517	3	38	180	0	36,398
1987	1.634	17,849	16,029	26,615	761	78	454	13	31	183	2	43,405
1988	1.593	14,432	13,253	28,154	1,180	384	561	22	29	183	2	42,588
1989	1.544	16,936	15,589	27,646	865	150	465	26	32	187	5	44,100
1990	1.486	18,316	17,032	23,209	752	117	361	46	37	184	6	40,992
1991	1.433	20,085	18,695	20,321	1,107	360	360	42	37	303	6	40,122
1992	1.381	19,774	18,230	20,749	1,102	308	452	47	40	250	6	40,080
1993	1.347	19,279	17,601	19,004	985	222	437	44	34	242	5	37,590
1994	1.317	19,194	17,155	17,345	833	97	411	41	41	236	7	35,333
1995	1.290	17,867	16,176	13,727	978	77	454	40	41	358	8	30,882
1996	1.263	17,536	15,876	14,543	1,046	58	596	45	47	291	8	31,464
1997	1.239	16,989	15,438	14,533	978	43	555	52	48	272	7	30,949
1998	1.218	16,623	15,007	15,053	1,023	125	530	52	48	260	7	31,083
1999	1.203	16,430	14,993	15,889	1,182	126	692	71	45	241	7	32,064
2000	1.188	16,156	14,873	15,372	1,254	195	683	71	52	245	7	31,498
2001	1.164	16,568	15,490	16,680	1,236	169	672	70	42	270	14	33,406
2002	1.137	16,912	15,778	17,904	1,342	189	733	73	32	303	14	35,023
2003	1.116	17,148	16,027	21,639	1,456	213	724	83	47	376	13	39,122
2004	1.094	16,824	15,668	20,911	1,602	229	815	78	67	400	13	38,180
2005	1.066	17,270	16,243	20,994	1,654	244	860	75	78	384	13	38,890
2006	1.033	17,173	16,287	22,846	1,702	253	888	85	87	376	12	40,834
2007	1.000	16,285	15,568	22,418	1,680	200	912	87	65	404	12	39,666

* Transition Quarter

Appendix D-2

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority				Budget Outlays	
	2006 actual	2007 actual	2008 est.	2009 est.	2006 actual	2007 actual
NASA [1,2]	15,765	15,568	16,502	17,167	14,403	15,247
DOD	22,114	22,418	25,949	26,528	19,959	22,060
DOE [3]	245	200	195	203	243	188
DOC	860	912	862	1089	780	820
DOI	82	87	90	91	80	87
USDA	84	65	59	56	71	47
DOT	12	12	13	14	12	11
NSF	364	404	464	504	298	370

1. The 2008 Consolidated Appropriations Act rescinded $192.5 million in NASA prior-year unobligated balances, effectively reducing NASA's total FY 2008 budget authority by this amount.
2. Beginning in 2009, NASA program budgets reflect only direct program costs. Indirect costs are budgeted within the Cross-Agency Support Programs account (captured within the Federal Space Activities Budget table).
3. Beginning in 2007, DOE budget figures do not include any physics research and operations funding for ground-based experiments managed in the High Energy Physics program.

Appendix D-3

Federal Aeronautics Activities Budget

(in millions of dollars by fiscal year)

	Budget Authority				Budget Outlays	
	2006 actual	2007 actual	2008 est.	2009 est.	2006 actual	2007 actual
NASA [1, 2]	893	717	615	447	722	614
DOD	9,295	11,614	10,873	12,556	9,346	10,640
DOT	2,636	2,632	2,646	2,879	2,632	2,426

1. The 2008 Consolidated Appropriations Act rescinded $192.5 million in NASA prior-year unobligated balances, effectively reducing NASA's total FY 2008 budget authority by this amount.

2. Beginning in 2009, NASA program budgets will reflect only direct program costs. Indirect costs are budgeted within the Cross-Agency Support Programs account (captured within the Federal Space Activities Budget table).

ACRONYMS

1

1 SPCS	Space Control Squadron

A

AAD	Aircraft Aging and Durability
AASI	Alcatel Alenia Space-Italia
ACC	Analysis Center Coordinator
ACD	Advanced Capabilities Division
ADEPT	Advanced Dark Energy Physics Telescope
AEHF	Advance Extremely High Frequency Satellite Communications System
AFRL	Air Force Research Lab
AFS	Alaska Fire Service
AGRHYMET	Agricultural-Hydrological-Meteorological
AGS	Alternating Gradient Synchrotron
AHAB	Advanced Hyperspectral Autonomous Buoy
AIAA	American Institute of Aeronautics and Astronautics
AIM	Aeronomy of Ice in the Mesosphere
AIRS	Atmospheric Infrared Sounder
AirSTAR	Airborne Subscale Transport Aircraft Research
ALMA	Atacama Large Millimeter Array
AMISR	Advanced Modular Incoherent-Scatter Radar
AMS	Alpha Magnetic Spectrometer
AOD	Aerosol Optical Depth
AP	Associated Press
APHIS	Animal and Plant Health Inspection Service
APLCs	Aerospace Products Literature Centers
ARC	Ames Research Center
ARM	Atmospheric Radiation Measurement
ARMD	Aeronautics Research Mission Directorate
ARS	Agricultural Research Service
ASIAS	Aviation Safety Information and Analysis Sharing
ASIC	Achieving Satellite Instrument Calibration for Climate Change
ASRG	Advanced Stirling Radioisotope Generator
ATK	Alliant Techsystems Incorporated
ATP	Aeronautics Test Program
ATST	Advanced Technology Solar Telescope
AWACS	Airborne Early Warning and Control
AWiFS	Advanced Wide Field Sensor

B

BA	"Big Airspace"
BEPAC	Beyond Einstein Program Assessment Committee
BIS	Bureau of Industry and Security
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory
BWB	Blended Wing-Body

C

C3PO	Commercial Crew & Cargo Program Office
CAEP	Committee on Aviation Environmental Protection
CAST	Commercial Aviation Safety Team
CAVP	Cryptographic Algorithm Validation Program
CAWL	Corrected Allowable Weight Loss
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
CIR	Color-Infrared
CISM	Center for Integrated Space Weather Modeling
CLASIC	Cloud and Land Surface Interaction Campaign
CLIVAR	Climate Variability and Predictability
CLU	Common Land Unit
CME	Coronal Mass Ejection
CMVP	Cryptographic Module Validation Program
CNES	Centre National d'Études Spatiales
CNN	Cable News Network
COES	Committee on Earth Observing Satellites
ConOps	Concept of Operations
CONUS	Continental United States
CORS	Continuously Operating Reference Station
COSMO	Constellation of Small Satellites for Mediterranean Basin Observation
COSMOS	Cosmic Evolution Survey
COTS	Commercial Orbital Transportation Services
CPHST	Center for Plant Health Science and Technology
CRISP	Central Region Integrated Science Partnership Funds
CS	Commercial Services
CSLAA	Commercial Space Launch Amendments Act
CSPRs	Closely Spaced Parallel Runways
CSREES	Cooperative State Research, Education, and Extension Service

D

DARPA	Defense Advanced Research Projects Agency
DCMM	Discrete Classification Mapping Methodology
DES	Dark Energy Survey
Destiny	Dark Energy Space Telescope
DFRC	Drysden Flight Research Center
DLR	German Aerospace Center
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DRICOMP	Drought in Coupled Models Project
DSCS	Defense Communications System
DSP	Defense Support Program
DSR	Display System Replacement

E

EARD	Exploration Architecture Requirements Document
EAS	Early Ammonia Servicer
EBIS	Electron Beam Ion Source
EDL	Entry/Descent/Landing
EELV	Evolved Expendable Launch Vehicle
ELV	Expendable Launch Vehicle
EMA	Electro-Mechanical Actuators
ENVI	Environment for Visualizing Images
EO	Executive Order
EOS	Earth Observing System
ERAM	En Route Automation Motorization
ERS	Economic Research Service
ESAS	Exploration Systems Architecture Study
ESMD	Exploration Systems Mission Directorate
ESnet	Energy Sciences Network
ESPA	EELV Secondary Payload Adapter
ETDP	Exploration Technology Development Program
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EVA	Extravehicular Activity Systems
EVO	Equivalent Visual Operations

F

FAA	Federal Aviation Administration
FAS	Foreign Agricultural Service
FASR	Frequency Agile Solar Radiotelescope
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FEWS	Future En Route Workstation
FIPS	Federal Information Processing Standard
FS	Forest Service
FSA	Farm Service Agency
FTS	Fourier Transform Spectrometer
FWI	Fire Weather Index
FWS	Fish and Wildlife Service

G

GA-ASI	General Atomics
GEM	Geospace Environment Modeling
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GINA	Geographic Information Network of Alaska
GIS	Geographic Information Systems
GISD	Geographic Information for Sustainable Development
GLAM	Global Agriculture Monitoring
GLAST	Gamma-ray Large Area Space Telescope
GLC	Global Land Cover
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite Systems
GOES	Geostationary Operational Environmental Satellite
GOODS	Great Observatories Origins Deep Survey
GPS	Global Positioning System

GSFC	Goddard Space Flight Center
GV	Gulfstream V
GWAT	Global War on Terrorism

H

HABs	Harmful Algal Blooms
HIAPER	High-Performance Instrumented Airborne Platform for Environmental Research
HIPPO	HIAPER Pole to Pole Observations
HiRise	High Resolution Imaging Science Experiment
HITL	Human-In-The-Loop
HRP	Human Research Program
HyBoLT	Hypersonics Boundary Layer Transition
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory

I

IAH	George Bush Intercontinental Airport
ICAO	International Civil Aviation Organization
ICBM	Intercontinental Ballistic Missile
ICG	International Committee on Global Navigation Satellite Systems
IGN	Institut Géographique National
IGS	International Global Navigation Satellite Systems Service
IIFD	Integrated Intelligent Flight Deck
IOOS	Integrated Ocean Observing System
IPCC	Intergovernmental Panel on Climate Change
IRAC	Integrated Resilient Aircraft Control
IRAC	Infrared Array Camera
ISOC	Instrument Science Operations Center
ISRO	Indian Space Research Organization
ISS	International Space Station
ITA	International Trade Administration
IVHM	Integrated Vehicle Health Management
IWP	Integrated Work Plan

J

JAXA	Japan Aerospace and Exploration Agency
JDEM	Joint Dark Energy Mission
JEM-PM	Japanese Experiment Module – Pressurized Module
JEM-PS	Japanese Experiment Module – Pressurized Section
JPDO	Joint Planning and Development Office
JSC	Johnson Space Center
JWG	Joint Working Group

K

KSC	Kennedy Space Center

L

LAS	Launch Abort System
LAT	Lunar Architecture Team
LAT	Large Area Telescope
LBNL	Lawrence Berkeley National Laboratory
LCROSS	Lunar Crater Observation and Sensing Satellite
LEO	Low-Earth Orbit

LIDAR	Light Detection and Ranging
LPRP	Lunar Precursor Robotic Program
LRC	Langley Research Center
LRO	Lunar Reconnaissance Orbiter
LSP	Launch Services Program
LSST	Large Synoptic Survey Telescope
LULC	Land Use and Land Cover

M

MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MBOC	Multiplexed Binary Offset Carrier
MCC	Millennium Challenge Corporation
MDA	Missile Defense Agency
MEP	Manufacturing Extension Partnership
MER	Mars Exploration Rover
MIT	Massachusetts Institute of Technology
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
MOA	Memorandum of Agreement
MOBY	Marine Optical Buoy
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MRLC	Multi-Resolution Land Characteristics Consortium
MRO	Mars Reconnaissance Orbiter
MSFC	Marshall Space Flight Center
MWA	Murchison Widefield Array

N

NAIC	National Astronomy and Ionosphere Center
NAIP	National Aerial Imagery Program
NANOOS	Northwest Association of Networked Ocean Observing Systems
NASM	National Air and Space Museum
NASS	National Agricultural Statistic Service
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NCVA	National Ceiling and Visibility Analysis
NDGD	National Digital Guidance Database
NERSC	National Energy Research Scientific-Computing Center
NESDIS	National Environmental Satellite Data and Information Service
NextGen	Next Generation Air Transportation System
NGATS	Next Generation Air Transportation System
NGDC	National Geophysical Data Center
NIDIS	National Integrated Drought Information System
NISN	NASA Integrated Services Network
NIST	National Institute of Standards and Technology
NLCD	National Land Cover Database
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
NOS	National Ocean Service
NPAT	National Partnership for Aeronautical Testing
NPD	NASA Policy Directive
NPOESS	National Polar-Orbiting Operational Environmental Satellite System

NPP	NPOESS Preparatory Project
NPR	NASA Procedural Requirement
NPS	National Park Service
NRA	NASA Research Announcement
NRAO	National Radio Astronomy Observatory
NRCS	National Resource Conservation Service
NREN	NASA's Research and Education Network
NRI	National Resources Inventory
NSAS	National Strategy for Aviation Security
NSBRI	National Space Biomedical Research Institute
NSCOR	NASA Specialized Center of Research
NSF	National Science Foundation
NSO	National Solar Observatory
NSRL	NASA Space Radiation Laboratory
NSRS	National Spatial Reference System
NSSO	National Security Space Office
NSWP	National Space Weather Program
NTIA	National Telecommunications and Information Administration
NWLON	National Water Level Observation Network
NWR	National Wildlife Refuge
NWS	National Weather Service

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
OGA	Office of Global Analysis
ORNL	Oak Ridge National Laboratory
ORS	Operationally Responsive Space
ORZS	Optimization of Root Zone Substrates
OSC	Office of Space Commercialization
OSTM	Ocean Surface Topography Mission

P

PACDEX	Pacific Dust Experiment
PBS	Program Baseline Synchronization Review
PCC	Policy Coordinating Committee
PI	Principal Investigators
PNT	Positioning, Navigation, and Timing
POES	Polar-Orbiting Operational Environmental Satellites
PPGD	Portable Programmable Guidance Display
PPPL	Princeton Plasma Physics Laboratory
PRF	Pasture, Rangeland, and Forage

Q

QZSS	Quasi-Zenith Satellite System

R

R&D	Research and Development
RAWS	Remote Automatic Weather Station
RDT&E	Research, Development, Test, and Evaluation
RFP	Request for Proposal

RHIC	Relativistic Heavy Ion Collider
RLV	Reusable Launch Vehicle
RMS	Remote Manipulator System
RPIF	Regional Planetary Image Facility
RpK	Rocketplane Kistler
RPT	Rocket Propulsion Test
RSAC	Remote Sensing Applications Center
RTK	Real-Time Kinematic

S

SAAs	Space Act Agreements
SAME	Smoke and Aerosol Measurement Experiment
SAO	Smithsonian Astrophysical Observatory
SBIRS	Space Based Infra-Red System
SC	Office of Science
SCaN	Space Communications and Navigation
SciDAC	Scientific Discovery through Advanced Scientific Computing project
SDRs	Systems Design Reviews
SGP	Southern Great Plains
SHARAD	Shallow Subsurface Radar
SHINE	Solar, Heliosphere, and Interplanetary Environment
SIA	Satellite Imagery Archive
SIBC	Space Industrial Base Council
SiC	Silicon Carbide
SLAC	Stanford Linear Accelerator Center
SMA	Submillimeter Array
SMD	Science Mission Directorate
SNAP	Supernova Acceleration Probe
SOAREX	Sub-Orbital Aerodynamics Re-Entry Experiment
SOHO	Solar and Heliospheric Observatory
SOMD	Space Operations Missions Directorate
SpaceX	Space Exploration Technologies
SpacePCC	Space Policy Coordination Committee
SPT	South Pole Telescope
SQUIDs	Superconducting Quantum Interference Devices
SRR	Systems Requirements Review
SSA	Space Situational Awareness
SSPTS	Station-Shuttle Power Transfer System
SSRMS	Space Station Remote Manipulator System
SSTL	Survey Satellite Technology Limited
STaR	Shuttle Transition and Retirement
STEREO	Solar Terrestrial Relations Observatory
STL	Lambert-St. Louis International Airport
STP	Space Test Program
SuperDARN	Super Dual Auroral Radar Network
SWAB	Surface, Water, and Air Biocharacterization

T

t/Space	Transformational Space
TC4	Tropical Composition, Cloud and Climate Coupling
TDRS	Tracking and Data Relay Satellite
TES	Transition-Edge Sensor
THEMIS	Time History of Events and Macroscale Interactions during Substorms
TIM	Technical Interchange Meeting

TM	Thematic Mapper
TRaP	Tropical Rainfall Potential
T-REX	Terrain Induced Rotor Experiment
TSAT	Transformational Satellite Communications System
TWP	Tropical Western Pacific

U

UAF	Upper Atmospheric Facilities
UARS	Upper Atmospheric Research System
UAS	Uninhabited Aerial Systems
UAV	Unpiloted Aerial Vehicle
UAVS	Unmanned Aerial Vehicle Systems
ULA	United Launch Alliance
UMESC	USGS/Upper Midwest Environmental Sciences Center
UMRS	Upper Mississippi River System
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
US&FCS	U.S. and Foreign Commercial Service
USAID	U.S. Agency for International Development
USDA	Department of Agriculture
USGS	U.S. Geological Survey
USGS EROS	USGS Center for Earth Resources Observation and Science
USMCC	U.S. Mission Control Center
US-TEC	U.S. Total Electron Content
USTR	U.S. Trade Representative
UVCS	Ultraviolet Coronagraph Spectrometer

V

VEE	Venezuelan equine encephalomyelitis
VMP	Vegetation Mapping Program

W

WARP	Web-Based Access and Retrieval Portal
WGIPP	Waterton-Glacier International Peace Park
WGS	Wideband Global System
WIMPs	Weakly Interactive Massive Particles
WRP	Wetland Reserve Program
WTMD	Wake Turbulence Mitigation for Departures
W-VAAC	Washington Volcanic Advisory Center

X

XRT	X-Ray Telescope

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