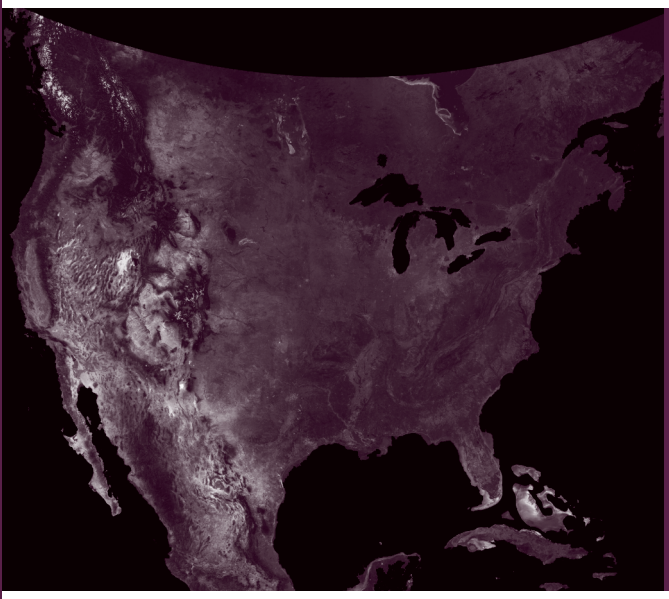
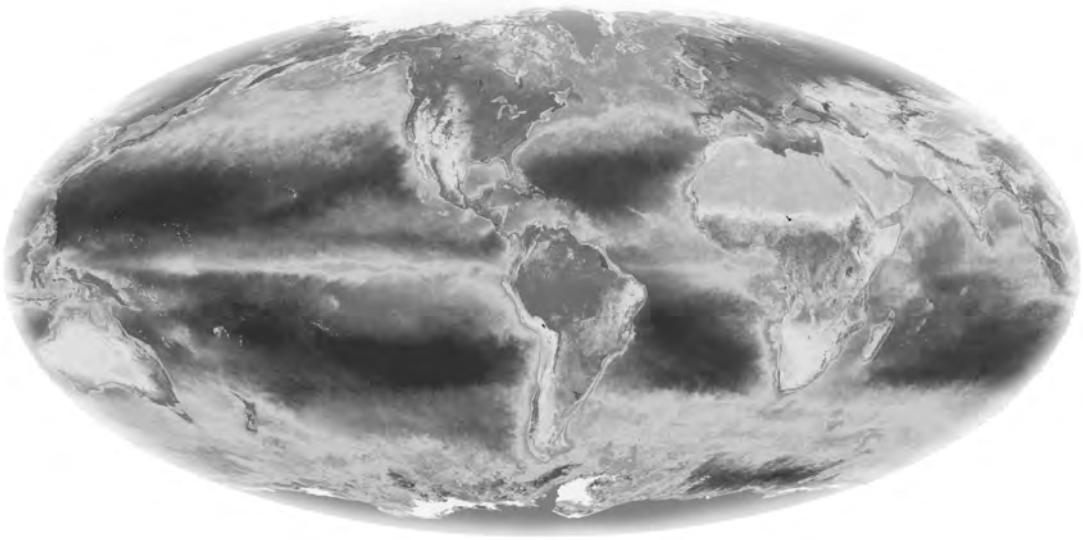
Aeronautics and Space Report of the President



Fiscal Year 2008 Activities

Aeronautics and Space Report of the President



Fiscal Year 2008 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, 2007, through September 30, 2008.

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National Aeronautics and Space Administration

NASA

Exploration Systems Mission Directorate

The National Aeronautics and Space Administration's (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 to the Moon, 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 fiscal year (FY) 2008 (FY08), 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.

Constellation Systems Division

Constellation Program

In 2008, the Constellation Program and its projects made significant progress well beyond artists' concepts and PowerPoint presentations. Since its initiation in 2005, the Constellation Program reached the end of formulation and entered into the development phase. The "Season of System Definition Reviews (SDRs)" for the

Constellation Program and its near-term projects (Orion, Ares I, Extravehicular Activities Systems, Mission Operations, and Ground Operations) supporting initial capability to the ISS successfully concluded during 2008. The Ares I Project completed its integrated launch vehicle Preliminary Design Review (PDR) in September 2008; also, the upper stage engine (J2X) successfully completed the Critical Design Review (CDR), which marks a major milestone of entering into manufacturing.

Constellation also planned the next steps in preparing for lunar missions. The Constellation Program completed a milestone review in 2008 that will help determine the systems needed to return humans to the Moon and establish a lunar outpost. The 3-day Lunar Capability Concept Review capped a 9-month study that looked at possible lunar mission scenarios and compared them to the capabilities of the emerging lunar transportation system design concepts. This review established all the technical parameters that will be needed to begin the initial design phase in preparing vehicle requirements for the Ares V Heavy Lift Cargo Launch Vehicle and the Altair Lunar Lander.

Contracts have been let for the Orion Crew Exploration Vehicle and the Ares I Crew Launch Vehicle. The Constellation Program also moved beyond initial concepts and into hardware fabrication and testing. Engineers at NASA's Marshall Space Flight Center in Huntsville, Alabama, continued to conduct tests on the J2X power pack and gas generator to support the development of the upper stage engine for NASA's Ares I crew launch vehicle and the Earth Departure Stage of the Ares V cargo launch vehicle. Both the Orion and the Ares projects continued to conduct parachute drop tests in Yuma, Arizona, to better understand the reefing performance of the pilot and main chutes. The Orion project initiated component testing of the new Launch Abort System (LAS). NASA and Aerojet successfully fired the abort system jettison motor at the Aerojet facility in Sacramento, California. Engineers will use the test firing to verify that the motor meets specification requirements and to help define induced acoustic, vibration, and shock loads caused by the motor. Orion's first Pad Abort test (PA-1) progressed with hardware manufacturing on schedule towards meeting its launch date in 2009. The Ares I-X, the first test demonstration flight, made significant progress toward its launch date in late 2009. Fabrication of Ares I-X elements was completed, and

hardware delivery to Kennedy Space Center (KSC) for the stacking of the upper stage simulator elements has begun.

Construction of major facilities to support the Constellation Program continued. In mid-2008, KSC renovated the Launch Control Center Firing Room 1 to support the Constellation Program. Construction began on a new test stand to support the Ares I upper stage engine (J2X) that will enable the critical testing needed to verify the engine performance at altitude conditions. The estimated completion year for the new test stand is 2010. In addition, the Ares I project began renovations to the Dynamic Test Stand for use in performing the ground vibration test of the Ares I launch vehicle. This test stand tested and validated hardware for both the Apollo and the Shuttle missions.

Commercial Crew & Cargo Program Office (C3PO) FY08 Highlights

Administered out of the C3PO, the Commercial Orbital Transportation Services (COTS) project progressed toward the goal of demonstrating an orbital capability to service the ISS and encouraging a commercial market for ISS resupply. During FY08, NASA maintained two unfunded Space Act Agreements (SAAs) with PlanetSpace and SpaceDev. Space Exploration Technologies (SpaceX) continued to make significant progress under their funded SAA, including a full-mission-length test firing of the Falcon 9 first-stage configuration, integration of the Falcon 9 launch vehicle, construction of their Cape Canaveral launch facility, and completing the final demonstration mission-level CDR. SpaceX also experienced delays common within the aerospace community that resulted in the renegotiation of milestones. In planning for multiple companies to develop ISS resupply capability, NASA signed a second funded SAA with Orbital Sciences Corporation (Orbital) of Dulles, Virginia, in 2008. Orbital also continued to make significant progress completing major element design reviews, including a groundbreaking at their Wallops Flight Facility launch site. Both SpaceX and Orbital plan for ISS demonstration missions in 2010.

Advanced Capabilities

The ESMD's Advanced Capabilities Division (ACD) develops and provides the types of critical products that reduce operational and technical risks for the Constellation System's projects. These products support high-priority technology

requirements for lunar exploration; risk mitigation related to astronaut health and performance using the ISS, free-flyers (self-contained experimental modules) that typically get launched into space to conduct microgravity experiments and feature a retrievable module for analyses of the experiments, and ground-based laboratories; and lunar robotic missions to gather data relevant to future human lunar 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 surface temperature and composition characterization. Data from LPRP missions remain critical to the Constellation System's efforts to return humans to the Moon and will support astronaut safety, landing site selection, and engineering requirements for lunar surface hardware.

The first lunar robotic mission consists of the Lunar Reconnaissance Orbiter (LRO), which will provide detailed mapping for human landing site selection, as well as valuable information about the lunar radiation and thermal environments and the identification of lunar resource availability. A secondary payload, the Lunar CRater Observation and Sensing Satellite (LCROSS), will provide additional data on lunar resources by impacting a permanently shadowed crater on the lunar surface to investigate the possible presence of water and other volatiles.

During FY08, LRO completed its Systems Integration Readiness Review (SIRR) and Pre-Environmental Review (PER), as well as the spacecraft integration and environmental tests up to thermal vacuum testing. LRO also established a Mission Operations Center and completed simulations of launch and lunar orbit insertion. LCROSS completed integration and testing of the space vehicle through a Systems Acceptance Review (SAR). LCROSS also established a Mission Operations Center and completed simulations of launch, lunar flyby, impactor separation, and lunar impact.

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 FY08, the HRP completed renal stone countermeasure experiments on the ISS as a part of operational evaluation. These experiments will lead to a strategy to mitigate the buildup of calcium in the urine that results in the development of renal stones during long-term exposure to microgravity. Data will be provided to the NASA Chief Health and Medical Officer's Transition to Medical Practice process for evaluating new countermeasures. At the joint NASA and National Institutes of Health bed-rest facility, the HRP also completed a study of the ability of low-amplitude vibration, delivered through the feet, to preserve bone density and strength. Scientists conducted two 90-day human bed-rest campaigns with 18 subjects for 2 different intensities of vibration. The results of this study found no statistically significant difference between subjects who received the treatment and subjects who did not. Other accomplishments in the HRP include characterizing lunar dust size distribution in the inhalable size range and initiating toxicity testing with simulated lunar dust, as well as initiating intratracheal instillation studies in collaboration with the National Institute of Occupational Safety and Health (NIOSH). Dermal studies showed the ability of larger grains to abrade skin, and chemical activation studies demonstrated that lunar dust remains reactive for several hours, depending on environmental conditions. NIOSH also continued studies to determine the stability of a controlled set of kits of food/nutritional items and common medications, representative of the types and classes typically provided on space missions, after prolonged exposure to the space flight environment. Kits that have been exposed to space for a period of up to 19 months have been returned to Earth 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 include 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 PDR of a

target flight system. The ETDP matures near-term technologies to enable the first flight of Orion and develops long-lead technologies needed for the lunar exploration missions.

During FY08, at Moses Lake, Washington, the ETDP conducted field tests of the Chariot rover, the All-Terrain Hex-Legged Extra-Terrestrial Explorer (ATHLETE) rover, and the payload-handling crane to simulate lunar outpost assembly activities. The ETDP also conducted human-in-the-loop testing of the Carbon Dioxide and Moisture Removal Amine Swingbed (CAMRAS) system for Orion. It initiated a contract with Aerojet to develop a 5,500-pound-thrust liquid oxygen-methane engine for the Altair lunar lander ascent stage. The program conducted a helicopter flight test of a flash-LIght Detection And Ranging (LIDAR) sensor for the Altair lunar lander autonomous landing and hazard avoidance system and demonstrated a sampling drill integrated with the Scarab rover for lunar ice prospecting. It also demonstrated the Small Pressurized Rover and suit-port concept for enabling exploration far beyond the lunar outpost. The ETDP developed two prototype In Situ Resource Utilization (ISRU) systems to produce oxygen for the lunar outpost. The ETDP also delivered an Electronic Nose (E-Nose) instrument and a Combustion Integrated Rack for launch to the ISS, where they were used in investigations on the Shear History Extensional Rheology Experiment (SHERE), the Structure of Paramagnetic Aggregates from Colloidal Emulsions-2 (InSPACE-2), and the Coarsening in Solid-Liquid Mixtures-2 (CSLM-2).

Crosscutting Program Support Analogs

The ESMD made great strides in FY08 in analog tests and demonstrations. To accurately develop operational concepts for lunar exploration and effectively design the hardware necessary to live and work on the lunar surface, the ESMD successfully used analogs to refine the exploration architecture in FY08.

Antarctica Engineering Evaluation Field Test: ESMD design personnel led the NASA team and supported the National Science Foundation's effort to deploy an inflatable habitat in Antarctica during the months of January and February 2008. This Antarctic testing proved the durability of an inflatable habitat while operating in an extreme environment, including the challenge of dealing with the packing, transport, and deployment of a large, inflatable habitat system. The field

test also generated data on the use of best in situ materials for radiation shielding and improving lunar dust mitigation practices.

Mobility Field Tests—Phase 1: The Moses Lake Field Test analogs took place in Moses Lake, Washington, during June 2008 and provided the opportunity for 1- to 2-kilometer-range expeditions on dry lava soils that are not available at NASA Field Centers. Testing robotic rovers and extravehicular activity (EVA) suits on the varied slopes and soil types provided scientists and engineers with accurate timelines, surveying data, and other operational design considerations essential to establishing a baseline for operational concepts and hardware systems for the lunar architecture.

Space Shuttle to Constellation Transition Activity

NASA defines "transition" as the crosscutting activities associated with completing the Space Shuttle Program and beginning future 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 remains critical to the future of the exploration programs' success. Both the Space Operations Mission Directorate (SOMD) and ESMD approach transition tasks in a measured and disciplined manner as a team. The team established a baseline in a NASA Transition Management Plan that provided the strategic foundation for the management and execution of transition efforts. This plan contained the Agency-level goals, objectives, roles, and responsibilities necessary to execute NASA transition efforts. It tracked major transition milestone planning and execution events through the Multi-Program Integrated Milestones schedule that captures all major NASA developmental and operational milestones through 2020. It also continued work on major integrated transition plans through previously defined board and governance structures, such as the Transition Control Board and the Joint Integrated Control Board. It developed an initial draft of exploration institutional capability (e.g., facilities and equipment) needs through the Exploration Requirements for Institution Capabilities Study. The team submitted to Congress the first of two reports regarding the status of NASA's Shuttle to Constellation workforce transition plans. It continued to work with the Office of Human Capital Management on the Shuttle to Constellation

workforce mapping initiative to identify critical skills existing in the current program and the predicted level and need for those skills in future programs. The team continued Web-based transition communications through updates to the NASA transition Web site, which includes policy documents, points of contact for transition-related inquiries, and links to most of the Agency's transition activities. The team also initiated collaboration with Government agencies and industry to discuss potential long-term Space Industrial Base policies and issues affecting NASA's exploration program.

Space Operations Mission Directorate

For the past 11 years, NASA has applied the full capabilities of the Space Shuttle to the mission for which this unique vehicle was originally conceived—the assembly of a large, advanced research station in LEO, one that can serve as a critical international way station for further missions to the Moon, Mars, and beyond. In FY08, the assembly of this facility, the ISS, entered a pivotal stage. The last of the Station's pressurized laboratories arrived, as did hardware critical for expanding the Station's crew complement to six in FY09—a total of nearly 117,000 pounds of hardware integrated over four highly successful Space Shuttle missions and 22 spacewalks, or EVAs (20 U.S., 2 Russian). By the end of FY08, the ISS massed over 611,000 pounds, approximately 71 percent of its final size. But even as work continues on the world's highest and fastest-moving construction site, the ISS supports a robust scientific research program, with over 78 experiments conducted in FY08 alone.

On November 2, 2007, NASA celebrated 7 years of continuous, onboard human presence on the ISS. During FY08, the ISS saw the addition of the European and Japanese laboratories, which was the culmination of years of effort on the part of all the partners. The knowledge gained and still yet to be gained from the ISS will result in a dramatic expansion of humanity's understanding of numerous fields, including human life and medical sciences, materials and microgravity sciences, Earth observations, plant growth, and technology development. During the first 7 years of continuous presence, 167 people from 15 countries visited the ISS.

On October 10, 2007, Soyuz TMA-11 launched from Baikonur Cosmodrome, Kazakhstan, carrying Expedition 16 crewmembers Peggy Whitson and Yuri Malenchenko, as well as space flight participant Sheikh Muszaphar Shukor, the

first Malaysian in space. Soyuz TMA-10 left the ISS on October 21, 2007, carrying returning Expedition 15 crewmembers Oleg Kotov and Fyodor Yurchikhin and space flight participant Shukor. During reentry, TMA-10 transitioned to ballistic reentry mode, which was later traced to a damaged control panel cable. Crewmembers repaired the same cable on TMA-11, already on orbit, while it was docked to the ISS.

Space Shuttle *Discovery* carried out the first Shuttle mission of the fiscal year, STS-120, and launched on October 23, 2007. The mission was notable in many respects, not least because it marked the first time female commanders served on both the Space Shuttle (Pamela Melroy) and the ISS (Peggy Whitson). The primary objective of this mission, the 23rd Space Shuttle flight to the ISS, consisted of the delivery and installation of the Node 2 module. This module (whose name, Harmony, was selected through an educational outreach program to the Nation's schoolchildren) serves as the primary interface between the European and Japanese laboratory modules and the rest of the Station. STS-120 rotated the crew, bringing astronaut Dan Tani to the ISS to join Expedition 16 crewmembers Peggy Whitson and Yuri Malenchenko and returning astronaut Clay Anderson to Earth after 152 days aboard the Station. The mission twice demonstrated the value of onsite crew to address unforeseen events. During the redeployment of the solar array assembly on the P6 truss (which had been retracted for relocation on a previous mission), one of the arrays developed a tear. However, the ISS and Space Shuttle crews, along with mission controllers in Houston, Texas, improvised a repair, which astronaut Scott Parazynski successfully carried out during the mission's fourth spacewalk. The first indications of excessively high current draw from the starboard Solar Alpha Rotary Joint (SARJ), a mechanism that keeps the solar arrays on that side of the ISS pointed toward the Sun while the Station orbits Earth, became of greater concern. Inspections during the second EVA revealed damage to the SARJ "race ring" that made rotating the starboard array increasingly difficult; at the time, the root cause of this damage remained unknown. Crewmembers performed additional inspections and minor repairs during the fourth EVA and locked the starboard array in position to avoid further damage until a mitigation plan could be developed: this action led to minimal operations and science impact. The solar array tear repair and SARJ inspection proved once

again that a well-trained, prepared, and adaptable team of astronaut crews and ground controllers provide the ultimate capability in space—a lesson that will serve the United States and its international partners well as NASA continues to explore outward to the Moon, Mars, and beyond.

The Expedition 16 crew conducted five ISS standalone EVAs between November 2007 and January 2008. Peggy Whitson and Yuri Malenchenko performed the first EVA, which prepared Pressurized Mating Adapter-2 (PMA-2) for relocation to Node 2, along with assorted other minor tasks. Peggy Whitson and Dan Tani conducted the next four EVAs, which focused on completing the installation of Node 2 and PMA-2 and inspecting and testing the port and starboard SARJs. The work done during these EVAs will be invaluable to the planning for the final repairs that will be conducted on STS-126.

Despite two delays due to intermittent issues with fuel sensors in the External Tank (ET), Space Shuttle *Atlantis* launched flawlessly on mission STS-122 on February 7, 2008. Once on orbit, the Space Shuttle and the ISS began an extensive series of installation and checkout activities to integrate the European Space Agency's (ESA's) new Columbus research module. Columbus is Europe's first Station research module, commanded through an independent facility in Oberpfaffenhofen, Germany. German Chancellor Angela Merkel and ESA Director General Jean-Jacques Dordain called the crews to congratulate them upon the successful activation of the new laboratory and to commemorate the on-orbit arrival of a founding member of the ISS partnership. STS-122 also saw another crew rotation, with Léopold Eyharts (the first European member of an ISS Expedition crew) relieving U.S. astronaut Dan Tani after a 120-day tour.

Space Shuttle *Endeavour* launched on mission STS-123 on March 11, 2008, less than 3 weeks after STS-122 landed just a few miles away from Launch Complex 39A (LC-39A) at KSC in Florida. The longest Space Shuttle mission to the ISS to date, STS-123, delivered the first Japanese element to the ISS, the Japanese Experiment Logistics Module, Pressurized Section (or ELM-PS, the first of three major elements of Japan's Kibo, or "Hope," complex on the ISS), and the Canadian Special Purpose Dexterous Manipulator, or Dextre. STS-123 marked the first time that all the ISS partners—the United States, Russia, European nations, Canada, and Japan—had operational hardware in orbit that was commanded

through four mission control centers on three continents. During the fifth EVA, crewmembers carried out additional inspections on the damaged, and still locked, starboard SARJ as root-cause analysis and repair plans continued to be developed. Finally, as with most previous missions, STS-123 also became a ferry flight for the ISS crew, with Garrett Reisman taking Léopold Eyharts' place as flight engineer on the Expedition 16 crew alongside Peggy Whitson and Yuri Malenchenko.

On March 9, 2008, the ESA launched its first Automated Transfer Vehicle (ATV), named Jules Verne. The ATV performed several weeks of tests on orbit before flawlessly docking with the ISS on April 3, 2008, with food, water, cargo, and propellant. During its 5-month stay at the ISS, the ATV performed Station reboosts and provided the crew with additional living space. The ATV undocked from the ISS on September 5, 2008, and reentered over the Pacific Ocean several weeks later.

On April 8, 2008, Soyuz TMA-12 launched from Kazakhstan carrying Expedition 17 crewmembers Sergei Volkov and Oleg Kononenko, as well as space flight participant Yi So-yeon of South Korea. Soyuz TMA-11 returned to Earth on April 19, 2008, carrying Expedition 16 crewmembers Peggy Whitson and Yuri Malenchenko and space flight participant Yi So-yeon. As with Soyuz TMA-10, TMA-11 experienced a transition to a ballistic trajectory during reentry. Analysis later showed that the Propulsion Module failed to separate nominally from the Descent Module, triggering the ballistic reentry. Investigators traced the cause of the failed separation to a failed pyrotechnic separation bolt, the duplicate of which was removed from TMA-12 during a Russian EVA on July 10, 2008. TMA-12 reentered nominally without the pyrotechnic bolt on October 24, 2008. Analysis of the root cause of the failed bolt remains ongoing.

Space Shuttle *Discovery*'s STS-124 came next in the lineup. Nearly filling *Discovery*'s 15-by-60-foot cargo bay for launch on May 31, 2008, the Japanese Experiment Module, Pressurized Module (JEM-PM), featured the largest pressurized laboratory destined for the ISS. Once docked, *Discovery* and her crew extracted the Kibo module from the cargo bay and deftly maneuvered it around the large and increasingly busy exterior of the ISS with the Station's robotic arm before mooring it across from Columbus on Node 2. After initial quality checks of the module's systems and environmental controls, Expedition 16 and STS-124 astronauts began outfitting the module and its 10 racks of experiment space. Crewmembers

also relocated the ELM-PS to its permanent location above the JEM-PM. Once again, the Space Shuttle helped to rotate the ISS' permanent crew, taking Gregory Chamitoff to the Station and bringing Garrett Reisman safely home after 3 months in space.

NASA planned an additional mission, STS-125, for FY08. This would have been the fifth and final servicing mission to the Hubble Space Telescope (HST) and the only mission not going to the ISS until the Space Shuttle's retirement. In preparation for the mission by September 2008, NASA placed two Space Shuttles prepped and ready on the pad at the same time—*Atlantis* on LC-39A, as the primary STS-125 vehicle, and *Endeavour* on LC-39B. The rare joint processing of two vehicles allowed *Endeavour* to be ready to launch a rescue mission (designated STS-401) to *Atlantis*, whose crew would not have the usual option of falling back on the resources of the ISS should any contingencies develop during the HST servicing mission. The mission, however, was postponed due to issues with HST's prime science package communications payload on orbit and the need to qualify replacement hardware to fly on STS-125. NASA rolled back *Atlantis* to the Vehicle Assembly Building to demate the orbiter and to allow preparations for supporting STS-119 to begin, while *Endeavour* rolled to LC-39A in preparation for STS-126 in November 2008.

Overall, the Space Shuttle team safely and successfully conducted 4 missions, supported 15 spacewalks, spent over 57 days in space, and flew almost 24 million miles in FY08.

Activities continued in FY08 to fly out the remaining missions on the manifest safely while preparing for the planned retirement of the Shuttle in FY10. NASA phased activities in a way designed to maintain production and sustain engineering and operational capabilities for as long as possible. Production neared completion on the last scheduled Space Shuttle Main Engine (SSME) scheduled for flight, SSME-2061. Workers assembled an additional engine, SSME-2062, and major ET elements (liquid oxygen, liquid hydrogen, and intertank segments) both as a skills-retention activity and to provide additional manifest robustness. Production on the last Space Shuttle ET, ET-138, continued at the Michoud Assembly Facility (MAF) in Mississippi. Meanwhile, the Space Shuttle Program continues to work closely with the Constellation Program to ensure a smooth transition of materials,

tooling, critical skills, and shop floor space at the MAF, from ET production to Orion and Ares I development. Although NASA remains on schedule to complete the assembly of the ISS by September 2010, the Agency will take no actions before April 2009 that would preclude flying the Space Shuttle beyond FY10. Other activities related to the transition and retirement of the Space Shuttle included the release of the "Final Space Shuttle Programmatic Environmental Assessment" in February 2008, along with continued work to identify and dispose of property and facilities no longer needed for safe flyout using joint management processes to coordinate activities and promote efficiencies in operations and development.

As NASA prepares to retire the Space Shuttle, the Agency also continues to transition the workforce, technology, facilities, and operational experience from this remarkable vehicle to a new generation of safer, even more capable systems. These activities accelerated in FY08. Preparations progressed throughout the year for the first full-scale test flight in the Constellation Program, Ares I-X: Space Shuttle personnel and facilities played a critical role in these activities. Through new systems like Ares I, Orion, and Ares V, the legacy of the Space Shuttle will live on in future missions of exploration—missions that will also be essential for maintaining U.S. leadership in critical areas of advanced technology well into the 21st century. In addition, NASA continued to focus on the critical role played by the Agency's highly skilled contractor and civil service workforce. Efforts included sharing a skilled workforce among the Space Shuttle, Constellation, and ISS programs; working with the Space Shuttle prime contractors on retention issues; performing regular surveys of the Space Shuttle civil servant workforce and line management to identify and address emerging workforce issues; and publishing "NASA's Transition Workforce Strategy" every 2 years.

In FY08, NASA's Space Communications and Navigation (SCaN) Program Office continued to provide the highly reliable space communications capability that is critical to all of NASA's space missions. The three networks SCaN operated and managed—the Near Earth Network, the Space Network (the Tracking and Data Relay Satellite System), and the Deep Space Network—met the communications needs, such as Earth monitoring and support of deep space exploration missions, of a wide range of customers, both internal and external to NASA. During this period, SCaN transferred the management and operations of the NASA

Integrated Services Network to NASA's Chief Information Officer (CIO); SCaN worked closely in FY08 with the CIO on all coordination issues.

A core team of systems engineers representing each of NASA's relevant Centers made a focused effort in FY08 to develop a space communications architecture that included the Goddard Space Flight Center (GSFC), the Glenn Research Center (GRC), and the Jet Propulsion Laboratory (JPL). The resulting Architecture Definition Document will drive the integration of SCaN's three networks while providing the flexibility required for all of NASA's science and exploration missions for the next 20 to 25 years, as directed in the NASA Authorization Act of 2005.

In FY08, looking into the future to determine Moon and Mars space communications requirements, SCaN continued its strong interagency cooperation on spectrum-related issues to ensure that sufficient spectrum will continue to be available for all of NASA's space missions. NASA achieved excellent results in its World Radiocommunication Conference 2007 negotiations, with success in each agenda item it pursued on behalf of NASA's science and exploration missions.

The Launch Services Program (LSP) successfully managed the launch of two missions on expendable launch vehicles (ELVs) during FY08. On June 11, 2008, the Gamma-ray Large Area Space Telescope (GLAST) launched from Cape Canaveral Air Force Station, Florida, on a two-stage Delta II Heavy. On June 20, 2008, the Ocean Surface Topography Mission (OSTM)/Jason-2 launched on a Delta II from Vandenberg Air Force Base (VAFB), California. Both missions launched within 9 days of each other, one from the East Coast and one from the West, and continue to perform successfully. For each mission, NASA competitively procured launch services from domestic commercial companies. To find out more about these and other NASA science missions, see the Science Mission Directorate section in this report.

In a continuing effort to open the bidding process to a larger number of launch providers, LSP established the NASA Launch Services (NLS) Follow-on Procurement Development Team (PDT). In 2008, the PDT released a Request for Information to the launch service provider community with a small- and medium-class mission model. The PDT received and evaluated the responses and proposed a philosophy for the follow-on contract mechanism to the NLS contract together with input from current contracted launch service providers and LSP customers.

LSP placed SpaceX onto the NLS contract to include Falcon 1 and Falcon 9 launch vehicles. LSP also entered into unfunded Space Act Agreements with companies that are actively funding new launch vehicles.

In 2008, the Rocket Propulsion Test (RPT) Program continued to develop and coordinate RPT activities in support of the safe operation of the Space Shuttle and implementation of the U.S. Space Exploration Policy, as well as activities for use by other Department of Defense (DOD) and commercial programs. Assets include rocket propulsion test facilities, associated infrastructure and systems, and the core skilled workforce necessary to operate and maintain these resources. The RPT Program also made significant strides toward establishing and implementing the internal program agreements and strategies necessary to prioritize and execute facility maintenance and modernization projects that will ensure the continued safe and reliable operation of test facilities and associated infrastructure and systems.

Science Mission Directorate

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

NASA and university scientists announced in November 2007 that they had developed a promising new technique for estimating the intensity of tropical cyclones from space. The method could one day supplement existing techniques, assist in designing future tropical cyclone satellite observing systems, and improve disaster preparedness and recovery efforts. The technique uses NASA satellite data, including simultaneous, accurate measurements of cloud-top temperatures from the Aqua satellite, as well as cloud-top height and cloud profiling information from the CloudSat satellite. Both satellites fly in formation as part of NASA's "A-Train" of Earth-observing satellites. The Afternoon Train, or A-Train, is the nickname given to a group of satellites that fly close together, pass over the Equator in the early afternoon, and provide coordinated science observations of Earth and its atmosphere. Members of the A-Train so far include NASA missions Aqua, Aura, and CloudSat; a NASA-Centre National d'Études Spatiales (CNES) mission called Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO);

and a CNES mission called Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations with a Lidar (PARASOL). Each satellite has a unique set of Earth observation capabilities, but this becomes a case where the whole is greater than the sum of the parts. Together, these diverse tools give humankind the most comprehensive set of observations of Earth's atmosphere ever obtained.

This new method of estimating intensity requires cloud profiling information from over or near a storm's eye. The team analyzed data from nine tropical cyclones observed by CloudSat and calculated their peak winds; then they compared the estimates with available weather data, including data from aircraft. Initial results show that the technique's estimates agreed with available weather data. The technique appeared to work better for stronger storms.

The International Polar Year (IPY) is a large scientific program focused on the Arctic and the Antarctic from March 2007 to March 2009, which provides the opportunity for scientists to conduct two annual observing cycles or visit both polar regions. As part of the IPY, a team of researchers from NASA, the U.S. Geological Survey (USGS), the National Science Foundation (NSF), and the British Antarctic Survey unveiled the best-ever map of Antarctica, which comprised about 1,100 satellite images from the NASA-U.S. Geological Survey Landsat-7 mission in November 2007. The map will revolutionize scientific research about the continent's frozen landscape. The map is a realistic, nearly cloudless satellite view of the continent at a resolution 10 times greater than ever before, with images captured by Landsat-7. With the unprecedented ability to see features half the size of a basketball court, the mosaic offers the most geographically accurate, high-resolution views of Antarctica, with the truest colors, to date.

As another activity for IPY, NASA sponsored the Polar Palooza. The Polar Palooza featured multimedia public presentations entitled "Stories from a Changing Planet" told by NASA scientists and researchers sponsored by the NSF. It also provided workshops for K–12 and museum educators, briefings for local news media and business leaders, and camp-ins for Girl Scouts and Boys and Girls Clubs. Polar Palooza provided the public with a valuable opportunity to interact personally with the scientists who bring polar research to life and to share in the wonder of an

ice core 2,000 years old that scientists are using to better understand how Earth's climate has changed over time.

On March 18, 2008, the Two Wide-angle Imaging Neutral-atom Spectrometers Mission B (TWINS-B) launched. TWINS-B works with TWINS-A to provide the second half of the stereo-imaging of Earth's magnetosphere, the region surrounding the planet controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. TWINS-B enabled three-dimensional (3-D) global visualization of this region, which led to a greatly enhanced understanding of the connections between different regions of the magnetosphere and their relation to the solar wind. TWINS-A and TWINS-B will enable the 3-D visualization and the resolution of large-scale structures and dynamics within the magnetosphere for the first time. TWINS-B belongs to the Heliophysics Division of SMD, which aims to understand the Sun and its effects on Earth.

On March 19, 2008, NASA's Swift satellite detected a powerful stellar explosion called a gamma-ray burst that shattered the record for the most distant object that could be seen with the naked eye. Although the explosion occurred in a galaxy 7.5 billion light-years away (more than halfway across the visible universe), it briefly became bright enough to be visible to the unaided eye. The observations gave astronomers the most detailed portrait of a gamma-ray burst ever recorded. The Swift satellite belongs to the Astrophysics Division of SMD, which aims to discover and understand the origin, structure, and evolution of the universe.

On April 16, 2008, the Coupled Ion-Neutral Dynamics Investigation (CINDI) mission launched. CINDI discovered the role of ion-neutral interactions in the generation of small- and large-scale electric fields in Earth's upper atmosphere. Ion-neutral interactions are a key process in controlling the dynamics of all planetary atmospheres, and understanding them appears to be important to describing the electrodynamic connections between the Sun and the upper atmosphere. In addition, the CINDI instruments provided measurements of the 3-D neutral winds and ion drifts. CINDI belongs to the Heliophysics Division.

Another Heliophysics Division mission, Ulysses, helped SMD obtain valuable science data. The venerable Ulysses mission, after more than 17 years in space, or almost four times its expected lifetime, is finally succumbing to the harsh environment of space. As the first mission to study the region of space above and below

the poles of the Sun, Ulysses returned reams of data that forever changed the way scientists view the Sun and its effects.

Key results from Ulysses to date included the first detailed measurements of the solar wind from the Sun's polar regions at solar minimum and solar maximum, the discovery that the magnetic flux leaving the Sun is the same at all latitudes, the discovery of energetic particle "reservoirs" surrounding the Sun, the discovery of interstellar dust in the solar system, and the first direct measurements of interstellar helium atoms in the solar system. Data from the spacecraft showed that the Sun has reduced its output of solar wind to the lowest levels since accurate readings became available. The Sun's current state could reduce the natural shielding that envelops our solar system.

Another noteworthy mission in the Heliophysics Division is the Time History of Events and Macroscale Interactions during Substorms (THEMIS). Researchers using a network of 20 ground observations and a fleet of 5 NASA satellites from THEMIS discovered in 2008 that explosions of magnetic energy occurring a third of the way to the Moon power substorms that cause sudden brightening and rapid movement of the aurora borealis, or northern lights. The cause is magnetic reconnection, a common process that occurs throughout the universe when stressed magnetic field lines suddenly snap to a new shape, like a rubber band that has been stretched too far. These substorms often accompany intense space storms that can cause power outages and disrupt radio communications and Global Positioning System signals.

On May 25, 2008, NASA's Phoenix Mars Lander safely touched down on Mars at a site farther north than where any previous spacecraft had landed. Phoenix used thrusters to land on the surface of Mars, a technique not used since the Viking missions in 1976. Cameras on Phoenix sent more than 25,000 images back to Earth. Science data proved that there was water ice on Mars; detected snow falling from Martian clouds; documented a mildly alkaline soil environment unlike any found by earlier missions; discovered small concentrations of salts that could be nutrients for life; located calcium carbonate (a marker of effects of liquid water); revealed at least two distinct types of ice deposits; provided a mission-long weather record, with data on temperature, pressure, humidity, and wind; and detected perchlorate salt. The findings also advanced the goal of documenting the history of water on

Mars. Phoenix exceeded its planned operational life of 3 months. Phoenix Mars Lander officially ended its mission on November 10, 2008, after successfully returning unprecedented science data to Earth. Phoenix belongs to the Planetary Division of SMD, which aims to advance scientific knowledge of the origin and history of the solar system and the hazards and resources present as humans explore space.

Another Planetary Division mission, the NASA Mars Reconnaissance Orbiter, revealed vast Martian glaciers of water ice under protective blankets of rocky debris at much lower latitudes than those of any ice previously identified on the planet. Scientists analyzed data from the spacecraft's ground-penetrating radar and reported that buried glaciers extended for dozens of miles from the edges of mountains or cliffs. A layer of rocky debris blanketing the ice may have preserved the underground glaciers as remnants from an ice sheet that covered middle latitudes during a past ice age. This discovery is similar to that of massive ice glaciers that have been detected under rocky coverings in Antarctica.

On June 11, 2008, NASA's GLAST launched. Scientists spent 2 months testing and calibrating the spacecraft's two main instruments, the Large Area Telescope (LAT) and the GLAST Burst Monitor. After combining 95 hours of instrument observations, the LAT team unveiled an all-sky image showing the glowing gas of the Milky Way, blinking pulsars, and a flaring galaxy billions of light-years away. The spacecraft has since been renamed the Fermi Gamma-ray Space Telescope (FGST). Fermi is now exploring the most extreme environments in the universe and searching for signs of how black holes accelerate immense jets of material to nearly light speed, clues to help crack the mysteries behind powerful explosions known as gamma-ray bursts, and answers to questions about the composition of the universe's mysterious "dark matter." Fermi belongs to the Astrophysics Division.

Another important mission in the Astrophysics Division is the Hubble Space Telescope (HST). Astronomers announced in 2008 that Hubble had taken the first visible-light snapshot of a planet circling another star. Observations taken 21 months apart by the coronagraph on Hubble's Advanced Camera for Surveys showed an object orbiting around a star named Fomalhaut. Astronomers identified the object as a planet, now called Fomalhaut b, which measures approximately 10 times as far from Fomalhaut as the distance of Saturn from our Sun. Estimated to be as much as three times Jupiter's mass, Fomalhaut b is located 25 light-years away

from Earth in the constellation Piscis Australis, or the "Southern Fish." Fomalhaut has been a candidate for planet hunting since NASA's Infrared Astronomy Satellite discovered an excess of dust around the star in the early 1980s. The planet appears brighter than expected for an object of three Jupiter masses. One possible explanation is that the planet has a Saturn-like ring of ice and dust reflecting starlight. Scientists theorize that the ring might eventually coalesce to form moons.

Also, in commemoration of Hubble's completion of its 100,000th orbit during its 18th year of exploration and discovery, scientists aimed Hubble to take a snapshot of a dazzling region of celestial birth and renewal. Hubble peered into a small portion of the Tarantula nebula near the star cluster NGC 2074. The region is a firestorm of raw stellar creation, perhaps triggered by a nearby supernova explosion. It lies about 170,000 light-years away and is one of the most active star-forming regions in our local group of galaxies. The image reveals dramatic ridges and valleys of dust, serpent-head "pillars of creation," and gaseous filaments glowing fiercely under torrential ultraviolet radiation.

Further, Hubble and other powerful, space-based telescopes (i.e., Chandra and Spitzer) that complement each other in their observations spanning the electromagnetic spectrum participated in an SMD outreach activity for the blind. At a ceremony in January 2008 at the National Federation of the Blind, NASA unveiled a new book that brings majestic images taken by its Great Observatories to the fingertips of the blind. NASA's new Braille book "Touch the Invisible Sky" presented the first printed introduction to modern, multiwavelength astronomy studies to the sight-disabled community.

"Touch the Invisible Sky" is a 60-page book with color images of nebulae, stars, galaxies, and some of the telescopes that captured the original pictures. Each image is embossed with lines, bumps, and other textures. These raised patterns translate colors, shapes, and other intricate details of the cosmic objects, allowing visually impaired people to experience them. Braille and large-print descriptions accompany each of the book's 28 photographs, making the book's design accessible to readers of all visual abilities.

On June 20, 2008, the OSTM/Jason-2 mission launched. OSTM is the next-generation ocean altimetry mission to extend the time series of sea surface topography measurements begun by TOPography EXperiment (TOPEX)/Poseidon

(1992–2005) and continued by Jason-1 (2001–present). Generally, OSTM included the following science objectives: (a) improve the knowledge of the ocean circulation that does not change with time, (b) measure global sea level change, and (c) improve coast ocean tide models.

While NASA partnered with CNES for the TOPEX/Poseidon and Jason-1 missions, OSTM featured four partners including NASA, CNES, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and the National Oceanic and Atmospheric Administration (NOAA). The OSTM satellite carries the next-generation instruments including CNES' Poseidon-3 dual-frequency radar altimeter to measure sea surface height and NASA JPL's Advanced Microwave Radiometer to remove the effects of water vapor from the altimetry measurement. With these and other technological improvements, OSTM will maintain or surpass Jason-1's measurement accuracy of 3.3 centimeters. This precise measurement will help scientists better understand ocean circulation and its effect on global climate. OSTM belongs to the Earth Sciences Division of SMD, which aims to study Earth from space to advance scientific understanding and meet societal needs.

On October 19, 2008, the Interstellar Boundary Explorer (IBEX) mission launched. IBEX will detect the edge of the solar system for the first time and study galactic cosmic rays and energetic particles from beyond the solar system that pose health and safety hazards for humans exploring beyond Earth's orbit. As the solar wind from the Sun flows out beyond Pluto, it collides with the material between the stars, forming a shock front. IBEX contains two neutral atom imagers that are designed to detect particles from the termination shock at the boundary between the solar system and interstellar space. IBEX will make these observations from a highly elliptical orbit that takes it beyond the interference of Earth's magnetosphere. IBEX belongs to the Heliophysics Division.

On November 8, 2008, India's first lunar explorer, Chandrayaan-1, entered lunar orbit. NASA partnered with India to fly two science instruments aboard Chandrayaan-1. The NASA instruments included the Moon Mineralogy Mapper to survey the mineral resources of the Moon and the Miniature Synthetic Aperture Radar (Mini-SAR) to map the Moon's polar regions and look for ice deposits in the permanently shadowed craters. Recently, scientists using NASA's Mini-SAR

on Chandrayaan-1 looked inside two of the Moon's coldest, darkest craters at its north and south poles. The floors of the craters—Seares near the Moon's north pole and Haworth at the south pole—are not visible from Earth. However, by using the Mini-SAR radar on the Chandrayaan-1 spacecraft, scientists can map and search the insides of the craters for water ice. More analysis will assist scientists to determine whether buried ice deposits exist in the permanently shadowed craters near the Moon's poles. The instruments on Chandrayaan-1 belong to the Planetary Division.

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft is another noteworthy mission in the Planetary Division; it has traveled 3 billion miles since its launch in August 2004. The planet Mercury orbits deep within the Sun's gravity well. Although the planet can be as close as 51 million miles from Earth, getting the spacecraft into orbit around Mercury depends on an innovative trajectory using the gravity of Earth, Venus, and Mercury itself to slow and shape the spacecraft's descent into the inner solar system. On its 4.9-billion-mile journey to become the first probe to orbit the planet Mercury, MESSENGER flew by Earth once, Venus twice, and Mercury twice.

During the two Mercury flybys, MESSENGER's cameras captured more than 1,200 high-resolution and color images of the planet, unveiling another 30 percent of Mercury's surface that had never before been seen by spacecraft and gathering essential data for planning the overall mission after orbit insertion in 2011. The second flyby provided an opportunity for several of the MESSENGER Educator Fellows, master science educators, to share the experience and excitement felt by the scientists and engineers. Besides being present for the closest approach, the Fellows also listened to the discussions of the data from the flyby. With the use of Web 2.0 and social media networking, the Fellows reported in real time to their school districts and students about their experiences.

The Planetary Division also featured the significant results from the Cassini mission. Before the Cassini spacecraft reached Saturn, scientists thought Saturn's moon Titan would have global oceans of methane, ethane, and other light hydrocarbons. More than 40 close flybys of Titan by Cassini showed that no such global oceans exist but did show hundreds of what appear to be dark, lakelike features

that might contain liquid or simply dark solid material. NASA scientists concluded that at least one of the large lakes observed on Titan contains liquid hydrocarbons and positively identified the presence of ethane. This makes Titan the only body in our solar system beyond Earth known to have liquid on its surface. Scientists made the discovery using data from one of Cassini's instruments, which identified chemically different materials based on the way they absorb and reflect infrared light.

Aeronautics Research Mission Directorate

NASA's Aeronautics Research Mission Directorate (ARMD) continued its commitment to conducting long-term, cutting-edge research for the benefit of the broad aeronautics community and in support of NASA's goals for both human and robotic space exploration. In addition, ARMD remains committed to supporting the aeronautics test infrastructure that enables the performance of the research. In FY08, this cutting-edge research included the following:

- Foundational research across a number of core competencies that supports aeronautics and space exploration activities.
- Research in key areas related to the development of advanced aircraft technologies and systems, including those related to aircraft safety, environmental compatibility, and fuel efficiency.
- Research that supports the Next Generation Air Transportation System (NextGen) in partnership with the Joint Planning and Development Office (JPDO).

ARMD's research plans directly supported the goals and objectives of the National Aeronautics Research and Development (R&D) Policy established by Presidential Executive Order 13419 in December 2006. 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) Openly disseminate the results of all research to the widest practical and appropriate extent, consistent with national security and foreign policy, through archival publications (such as books, technical papers,

technical memoranda, and peer-reviewed journal articles) and conference proceedings, as well as NASA publications.

(3) Pursue a coordinated approach to managing the Nation's research, development, test, and evaluation (RDT&E) infrastructure. ARMD's continued cooperation with DOD through the National Partnership for Aeronautical Testing resulted in the development of guiding principles for determining priorities and consistent pricing.

(4) Foster intellectual partnerships with industry and academia by means of cooperative Space Act Agreements (SAAs) and full and open competitive research awards that emphasize true collaborations among all partners by means of the NASA Research Announcement (NRA). In FY08, ARMD received 145 proposals through the NRA process and selected 50 for the negotiation of an award. ARMD has 68 SAAs in place across all programs.

(5) Continue strong partnerships with other Government agencies and organizations, especially the Federal Aviation Administration (FAA), DOD, and the JPDO. The FAA and NASA have established Research Transition Teams (RTTs) organized around the NextGen Concept of Operations framework. These teams are currently under way with both FAA and NASA participation. 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, continued its contributions to developing technical solutions that will mitigate the forecasted increase in air traffic demand during the next two decades. The current air transportation system faces limitations in its ability to handle growing demand and develop energy-efficient and environmentally friendly technologies.[1] With increased numbers of flights, the JPDO has predicted that noise and emissions will become a bigger problem at airports, factors that already constrain the growth of the air transportation system. The JPDO anticipates that emissions will also become a problem in en route airspace.[2]

1. "JPDO Progress Report," 2007, *http://www.jpdo.gov/library.asp*; NextGen, *http://www.jpdo.gov/Nextgen_Topics.asp*.
2. NextGen Integrated Work Plan, v1.0, September 2008, *http://www.jpdo.gov/library.asp*.

In FY08, ARMD executed a robust research portfolio that addressed challenges of the future air transportation system, including expanding capacity needs, environmental issues, efficiency, safety, and mobility challenges. As a major highlight illustrating this progress, NASA researchers, in collaboration with San Jose State University, Perot Systems, and the FAA, successfully completed a series of human-in-the-loop experiments that explored advanced concepts and technology for separation assurance. Such technology remains critical to relieving air traffic controller workload, a key constraint on airspace capacity.

These experiments, which involved 6 professional controllers and 20 professional pilots, examined the performance of controllers, pilots, and separation-assurance automation in the face of nominal and dramatically increased (doubled and tripled) traffic demand through a complex airspace sector in the FAA's Indianapolis Air Route Traffic Control Center. Researchers provided varying levels of automation support to the controller and pilot subjects, including automated conflict detection, automated strategic conflict resolution, and automated tactical conflict resolution. The test scenarios included routine operations and off-nominal situations such as data communication failures and aircraft blunders toward proximate traffic.

NASA's research into separation-assurance automation addresses a key research need for the NextGen. By automating fundamental air traffic control functions such as conflict detection and conflict resolution, researchers believe that automation could be made to accept responsibility for separation from human controllers. Initial results showed that even under conditions of heavier-than-normal simulated air traffic, using automated separation-assurance technology resolved more than 99 percent of potential traffic conflicts without substantially increasing controller workloads. While further investigation will validate the underlying technology and procedures, such concepts hold the promise of dramatically increasing the capacity of our air transportation system, thereby facilitating the economic growth that comes with improved mobility of people and goods about the country. In addition, the following items describe and represent the technical accomplishments of the ARMD programs during FY08.

Fundamental Aeronautics Program

The goal of the Fundamental Aeronautics Program consists of conducting cutting-edge research that will produce innovative concepts, tools, and technologies

to enable revolutionary changes for vehicles that fly in all speed regimes. The program focuses on creating innovative solutions and technologies for addressing the main problems of modern air transportation, which include public concerns over noise and emissions, the sustainability of affordable air travel with the increasing cost and decreasing availability of jet fuel, providing for mobility to meet an increasing demand for air transportation, and a lack of progress toward a faster means of transportation. The program also pursued innovative concepts 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 developed technological capabilities that range from basic knowledge of underlying physical phenomena to the understanding of system-level interactions. The program also emphasized the development of tools for advanced multidisciplinary design and analysis capabilities to realize integrated technology advances in future aircraft and to guide its research and technology investments.

Researchers structured the program by flight regime and encompassed the four thrust areas of Subsonic Fixed Wing, Subsonic Rotary Wing, Supersonics, and Hypersonics. The Subsonic Fixed Wing project addressed the challenge of making future aircraft quieter and cleaner to meet stringent noise and emissions requirements 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 reduced fuel burn. The Subsonic Rotary Wing project addressed the technical barriers that constrain rotorcraft from reaching widespread use in civil aviation. To overcome these barriers, NASA is conducting research that enables improved range, speed, payload capacity, fuel efficiency, and environmental acceptance. The unique ability of rotorcraft to operate independently 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 cruising over land, as well as the technical challenges related to supersonic deceleration to enable safe, precision planetary entry/descent/landing (EDL) of human and large science missions in planetary atmospheres. Because all access to space and all entry from space through any planetary atmosphere require hypersonic flight, the Hypersonics project addressed long-term challenges and key fundamental research issues related

to ascent and flight through Earth's atmosphere and entry and descent in planetary atmospheres. 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 the hypersonic entry and descent of very heavy payloads into planetary atmospheres to enable a high-mass Mars entry system. In FY08, each project contributed to the goals of the Fundamental Aeronautics Program. The following examples illustrate significant accomplishments of each project.

The Subsonic Fixed Wing project, in partnership with Pratt & Whitney Rocketdyne, completed ground testing of a geared turbofan concept and demonstrated design confidence for the integration of the advanced turbofan concept with the wing structure. The geared turbofan will reduce noise and fuel burn for the next generation of tube-and-wing aircraft configuration. Through wind tunnel testing of scaled models of cruise efficient short takeoff and landing (CESTOL) configuration concepts, the project identified component technology concepts that will permit aircraft to take off and land with runways of less than 3,000 feet. In addition, the project, in partnership with Williams International, completed engine testing to demonstrate an advanced technology concept, called the over-the-rotor foam metal liner concept, to reduce engine noise.

The Subsonic Rotary Wing project, in partnership with the Defense Advanced Research Projects Agency (DARPA), the Boeing Company, and the U.S. Army, demonstrated through large-scale wind tunnel testing the effectiveness of Smart Material Actuated Rotor Technology (SMART) in controlling noise and vibration in rotorcraft. This technology will enable the reduction of interior cabin noise for passenger comfort and the quiet operation of rotorcraft over populated areas. The project completed conceptual studies of drive configuration concepts capable of providing a 50-percent reduction in main rotor rotational speed from hover to forward flight without adversely affecting propulsion efficiency and vehicle weight. Further development of these concepts will enable rotorcraft with higher cruise speeds capable of providing point-to-point service using the metroplex airport concept, i.e., multiple airports within the same metropolitan region.

The Supersonics project completed flight experiments at NASA's Dryden Flight Research Center to validate high-fidelity computational tools to predict the effect of jet plumes on shock waves that cause sonic booms in supersonic aircraft. The

high-fidelity computational tools will enable future designs of supersonic aircraft with reduced sonic boom signatures. The project successfully demonstrated the structural performance of an advanced composite fan containment concept that researchers predict could be more than 20 percent lighter than state-of-the-art engine containment systems. The lightweight engine will increase the cruise efficiency of low-boom supersonic aircraft.

The Hypersonics project completed flight clearance testing of the X-51 X-2 hydrocarbon-fueled, flight-weight scramjet engines in the NASA Langley 8-Foot High Temperature Tunnel simulating Mach 5 flight conditions as part of a collaborative effort between Pratt & Whitney Rocketdyne, the Air Force Research Laboratory, DARPA, and the Boeing Company. The successful ground testing of the engine qualified the engine for X-51 flight-testing in 2009, which will demonstrate the operation of a scramjet-powered hypersonic system and lay the foundation for future hypersonic applications, including access to space.

Participation in professional forums and other networking opportunities allowed Fundamental Aeronautics Program researchers to disseminate their research efforts to the widest audience possible. They presented over 309 conference papers this year. In addition, they published 75 peer-reviewed journal papers and 53 technical reports.

Aviation Safety Program

The Aviation Safety Program built upon the unique safety-related research capabilities of NASA to develop innovative algorithms, tools, concepts, and technologies that will improve the intrinsic safety attributes of current and future aircraft operating in the national airspace system and overcome aircraft safety technological barriers that would otherwise constrain the full realization of NextGen.

The Aviation Safety Program consisted of four projects. 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 sought to prevent loss-of-control incidents through better modeling of upset flight conditions due to a variety of causes, including icing and structural

degradation, and through adaptive control methods. 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.

During FY08, researchers in the AAD project developed an analysis framework that integrated the detection, prediction, and mitigation technologies using a goal-oriented systems structure. The framework coupled specific issues related to the diverse applications of these technologies in airframes, propulsion, and wiring systems with end-user requirements for aircraft design, operations, and sustainment. The AAD project will use the framework as a tool to guide ongoing research to maximize aging and durability performance.

The IIFD project conducted an experiment in a high-fidelity flight simulator to evaluate multiple display concepts during approach, landing, surface operations, and takeoff operations. Twenty-four airline transport-rated pilots participated to assess the feasibility of the concepts for active operator assistance. Pilot awareness and reactions to failure scenarios and other abnormal events proved to be critical determinants in the underlying safety of all-weather terminal area operations.

Through simulation and flight-testing, the IRAC project defined the control architectures capable of adapting to degradations in aircraft dynamics. Researchers developed three direct, adaptive neural-network-based flight control systems and subjected them to an in-flight simulation of a destabilizing failure on the NASA NF-15B Intelligent Flight Control System airplane. Results of the flight evaluation with the simulated destabilizing failure and adaptation engaged showed improvement in the vehicle stability margins. Adaptive flight control systems hold the potential to be more resilient to extreme changes in airplane behavior.

The IVHM project developed and validated fault detection and isolation methods on a current-generation aircraft electromechanical actuator test stand with realistic nominal and fault scenarios. Researchers used a feed forward neural network as a fault detector and classifier by fusing the information from the temperature and accelerometer sensors to provide input to the neural network for classification. Results showed false positive rates of less than 1 percent and false negative rates of less than 10 percent. Improved robustness of the diagnostic

systems in distinguishing and classifying faults, as in these simulations, remains critical to enabling future integrated vehicle health management systems.

Researchers for the Aviation Safety Program presented over 150 conference papers this year and published 25 peer-reviewed journal papers and 2 books. In addition, program researchers received one patent award and filed six invention disclosures. Work done under the program resulted in the Agency's signing 10 software licenses and usage agreements.

Airspace Systems Program

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 consists of two projects, NextGen-Airspace and NextGen-Airportal, and the goal of each project is 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.

In FY08, the NextGen-Airspace project conducted a number of simulations, demonstrations, and analyses to examine concepts and technologies aimed at enhancing air traffic operations in the en route and approach airspace. Researchers successfully conducted an experiment to examine air/ground trajectory negotiation feasibility. The results showed that the trajectory negotiation appears feasible using the current Flight Management System (FMS) with advanced datalink capabilities. A human-in-the-loop simulation study examined the feasibility of mixed equipage operations within the same airspace. The results showed that mixed equipage operations appear feasible even with higher traffic densities. Researchers completed an initial study to explore the impact of reduced capacity due to weather using a fast-time modeling technique showing that the traffic flow management optimization algorithms seemed helpful in significantly reducing delays for New York airspace traffic flows. Researchers examined the feasibility of closely spaced parallel approach procedures for triple runways by conducting an additional human-in-the-loop simulation study. This study used wake and blunder scenarios and identified flight deck information needs and the feasibility of these procedures. In another separation-assurance-related human-in-the-loop simulation, researchers successfully

examined the initial feasibility of strategic and tactical ground-based conflict detection automation and flight deck conflict detection automation. Demonstrations of four-dimensional (4-D) FMS (i.e., current FMS with three spatial dimensions plus time constraints) and Flight Deck Merging and Spacing (FDMS) technologies examined capabilities for precision merging and spacing on continuous descent arrivals. In addition, the Airspace project conducted a workshop to discuss nonconvective weather information translation for traffic flow management.

Whereas the Airspace project targets 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 will not increase equally at each airport as the system grows, the project will develop and evaluate a suite of capacity-increasing concepts and the system-analysis capability to aid in tailoring solutions to specific needs. During FY08, the project further identified airport capacity constraint factors at key airports and ranked them according to airport demand forecasts as a basis for future research and study to accomplish this long-term goal. The project completed the development of an initial simulation environment that will enable the evaluation of surface traffic optimization algorithms and concepts. The project also completed the development of an initial set of tools to analyze surface operations data. In an effort to gain an understanding of metroplex operations, researchers conducted an initial characterization of metroplex operations to understand current performance. Additionally, the Airspace and Airportal projects identified and developed joint milestones between the two projects, which will begin to ensure technical and operational integration between their developed concepts and technologies.

NASA and the FAA also initiated four Research Transition Teams (RTTs) to accelerate concepts and technology for further maturity. These RTTs include Efficient Flow into Congested Airspace, Dynamic Airspace Configuration, Multi-Sector Planner, and Integrated Arrivals/Departures/Surface Management. The RTTs will ensure that research and development needed for NextGen implementation are identified and conducted and that the results are effectively transitioned to the implementing agency.

Researchers for the Airspace Systems Program published over a hundred conference papers this year, four of which received Best Paper awards at American Institute of Aeronautics and Astronautics (AIAA) conferences. The Smithsonian Institution's National Air and Space Museum (NASM) showcased the Future Air Traffic Management Concepts Evaluation Tool (FACET), an acclaimed research tool developed by the program. NASA became one of the recipients of the Robert J. Collier Trophy for its sustained contributions to applications of Airborne Dependent Surveillance Broadcast (ADS-B) technology.

Aeronautics Test Program

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

From FY06 to FY08, the ATP invested approximately $48 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 NASA's deferred maintenance liability for these national assets by an estimated 20 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 FY08, the ATP extended this initiative and collaborated with the Dryden Flight Research Center to establish a clear pricing structure and charging policy for flight-test and research operations support.

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 had severely eroded. The ARMD reviewed several recommendations for FY08 and began the implementation of the National Force

Measurement Technology Capability (NFMTC), a multiyear project to address gaps and deficiencies in the Government and industry's state-of-the-art strain gage balance technology capability.

In FY08, the ATP partnered with the Air Force to begin a series of tests using a shared model and test team in several national transonic wind tunnels, including the Air Force's Arnold Engineering and Development Center 16T transonic wind tunnel. The tests will compare the results from each facility using an agreed-upon test matrix and enable consistent practices among the national facilities through shared test processes, techniques, and data reduction methods. This will be the first national transonic wind tunnel comparison conducted in 30 years.

Also in FY08, the ATP completed a comprehensive assessment of the current condition and reliability of ATP facilities and their ability to meet current and future (5-year horizon) ground-test requirements. The assessment identified a set of facility projects that would ensure availability and operational status; from this set, a 5-year investment project schedule for each facility was developed. The ATP will immediately start the implementation of these recommended recapitalization and maintenance projects.

In its first 3 years (FY06–FY08), the ATP intentionally focused its efforts at the tactical level and invested primarily in stabilizing aeronautics test facility conditions, charge rates, and workforce competency. In FY08, the ATP started the development of a new strategic plan that will have three main thrusts: (1) provide vision and leadership for the use of ATP assets in meeting national goals; (2) provide sustained financial support for workforce, capability improvements, test technology development, maintenance, mothballing, and divestiture; and (3) provide strategic planning, management, and coordination within NASA and between NASA and other Government and industry stakeholders. This strategic plan will also guide the recapitalization and maintenance investments identified through the comprehensive facility assessment. For FY08, in collaboration with the National Partnership for Aeronautical Testing (NPAT), the ATP completed an assessment of the Nation's transonic wind tunnel capabilities. This assessment identified wind tunnels in the transonic speed regime that remain critical to the Nation and will therefore require continued investment; it also identified wind tunnels that appear to be noncritical and will become candidates for consolidation.

The ATP involved the Air Force's Arnold Engineering Development Center in its quarterly aeronautics test facility meetings with the NASA Centers. This collaboration included the sharing of information on charge rate structure and content, maintenance and capital investment activities, and test facility schedules and long-range planning. By collaborating with the Air Force 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 the exchange of staff and experiences among NASA Centers and between NASA and DOD. In addition, the ATP furthered the NPAT relationship by conducting two meetings of the NPAT Council.

National Aeronautics R&D Plan

During FY07, the Aeronautics Science and Technology Subcommittee of the National Science and Technology Council, cochaired by the ARMD Associate Administrator, developed a national aeronautics R&D plan in response to the National Aeronautics R&D Policy, as enacted by the President in December 2006 under Executive Order 13419, National Aeronautics Research and Development. President George W. Bush approved the plan on December 21, 2007, and, in concert with the policy, the plan will guide the conduct of U.S. aeronautics R&D activities through 2020. The plan established high-priority national aeronautics R&D challenges, goals, and supporting objectives along with timelines to achieve those objectives. In FY08, the subcommittee worked to develop an appendix to the plan, which contained additional technical content on aeronautics R&D goals and objectives and a preliminary assessment of current relevant Federal aeronautics R&D activities. The subcommittee completed this appendix in December 2008.

Partnerships with Government and Industry

NASA seeks to be in the leadership position for the conduct of fundamental research required to solve aeronautics challenges. In part, NASA accomplished this goal through close and strong partnerships with industry, academia, and other Government agencies in order to maximize the research capabilities of the Nation.

Because these partnerships are so important, NASA put many mechanisms in place to engage academia and industry, including industry working groups and

technical interchange meetings at the program and project levels, SAAs for cooperative partnerships with industry, and the NRA process that provides full and open competition for the best and most promising research ideas. Cooperative partnerships with industry consortia can result in a significant leveraging of resources for all partners and can provide opportunities to test the value of component-technology advances in full system-level contexts.

Currently, ARMD has in place over 68 SAAs with different members of the aerospace industry and, in some situations, with consortia of industrial participants. These collaborative opportunities have produced very significant research results at the system level, where the expertise of industry and NASA come together to integrate technologies that can, one day, be incorporated into the Nation's aircraft fleet. In addition, ARMD selected 50 proposals through the FY08 NRA process for the negotiation of an award.

Finally, NASA recognizes the importance of close coordination, not just with industry and academia, but with its partners in other Government agencies as well. For example, ARMD, the FAA, and the JPDO established a new process to help ensure that NASA's fundamental research translates into implementation in NextGen systems and concepts. They continue to work collaboratively to establish this process, which ensures that research is sufficient and appropriate to enable NextGen. The new process has top-level commitment from the ARMD Associate Administrator and the FAA Senior Vice President of NextGen and Operations Planning. The collaboration resulted in four RTTs, co-led by representatives from the FAA and NASA, established and organized around the NextGen Concept of Operations framework. The teams worked to plan near-term R&D transition in areas such as surface management and long-term transition in areas such as dynamic airspace allocation. With regards to the initial collaborative RTT activity, more than 35 participants from FAA service units, NASA, the MITRE Center for Advanced Aviation System Development (CAASD), and industry attended a workshop in Washington, DC, in February 2008 to focus on the integration of NASA and FAA research plans, schedules, roadmaps, and coordinated simulations for near-term NextGen Trajectory Management objectives. Since February 2008, the RTTs have held 10 workshops to synchronize research roadmaps and clearly define the handoff states.

Aeronautics Research Relevance and Benefits to the Public

NASA's aeronautics program ensures long-term focus on 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.

Department of Defense

DOD

Space Activities

FY08 proved to be a historic and dynamic year for the Department of Defense (DOD). DOD remained involved in a wide variety of exciting and challenging space activities, including continuing the successful string of the Evolved Expendable Launch Vehicle (EELV) launches and supporting our Nation's military operations and combat activities in Iraq, Afghanistan, and around the world. DOD reached out to international and interagency partners in support of national policy objectives and continues its close relationship with NASA to further our Nation's civil space programs. DOD supported four Space Shuttle launches and four NASA robotic spacecraft launches in FY08. All eight missions successfully launched from Air Force-operated space launch ranges.

U.S. national space policy directs the U.S. Government to pursue international cooperation on space activities of mutual benefit that advance U.S. interests. DOD collaborates with the Department of State, NASA, and other departments and agencies to expand space cooperation with selected nations to further national foreign policy objectives. Key initiatives within this effort include improving international space cooperation governance, expanding and formalizing cooperative relationships with key allies, supporting foreign space surveillance needs for space flight safety, and promoting efforts to develop voluntary guidelines for safe space operations.

A prime example of interagency space cooperation involved the successful interception of a nonfunctioning National Reconnaissance Office (NRO) satellite on February 20, 2008. The President made the decision to intercept the NRO satellite based on recommendations from his national security advisers in the interest of mitigating the risk to human life. The U.S. Strategic Command ran the intercept

and commanded the forces, which included the Joint Space Operations Center at Vandenberg Air Force Base (AFB).

The world-class EELV program continued to place satellites into orbit successfully during FY08, extending its record to 21 out of 21 successful launches. United Launch Alliance (ULA) conducted four EELV launches—three Government and one commercial.

Early in FY08 (November 11, 2007), the final Defense Support Program (DSP) missile warning satellite (DSP-23) launched from Cape Canaveral on the first operational Delta IV heavy vehicle. The NRO followed this success on December 10 with the NROL-24 mission on an Atlas V from the Cape. Another first occurred on March 13, 2008, when the NRO launched NROL-28 from Vandenberg AFB—the first operational Atlas V West Coast launch. The final EELV launch occurred on April 14, when ULA launched a commercial communications satellite from the Cape on an Atlas V booster.

In addition to the EELV launches, ULA launched four Delta II rockets in 2008. The Air Force launched a Global Positioning System (GPS) satellite (GPSIIRM-19) on March 15 from Cape Canaveral. NASA launched the GLAST gamma-ray telescope science mission from the Cape on June 11 and the Jason-2 ocean topography mission from Vandenberg AFB on June 20. Lastly, a Commercial Delta II launched the GeoEye-1 commercial imaging satellite on September 6, while Italy's COSMOS-Skymed-3 synthetic aperture radar satellite was simultaneously prepared for launch later in calendar year 2008, both from Vandenberg AFB.

DOD also supported the historic first successful launch of SpaceX Corporation's Falcon 1 (the first privately funded, liquid-fueled rocket to reach orbit successfully) from Kwajalein Atoll with Reagan Test Range tracking assets providing range safety during the launch. This successful launch occurred on September 28, 2008, and became the fourth launch attempt with the Falcon 1.

DOD space professionals and the space systems they operate continued to provide world-class support for military forces conducting operations in Iraq, Afghanistan, and other locations around the globe. These space professionals continue to ensure that space assets remain responsive to the operational forces and to drive the requirements to better provide communications, increased bandwidth, more precise navigation support, and earlier warning of threats.

As the first full year of operation, 2008 saw the Operationally Responsive Space (ORS) Office make significant progress towards the objectives identified by DOD and approved by Congress less than 1 year previously. Addressing the ability to respond to Joint Force Commander (JFC) needs, the ORS Office demonstrated unparalleled acquisition agility by surveying alternatives, identifying a solution, and negotiating a contract in response to the Commander's identified needs, all in less than 3 weeks, a feat that historically took months, if not years. Known as ORS-1, this 24-month satellite development effort will provide needed capability to the warfighter while advancing significant technical, logistic, and launch objectives and abilities for the ORS Office. Launched in August 2008, the ORS Jumpstart mission provided a preview of how revolutionary ORS payloads will be developed, launched, and demonstrated. The Jumpstart mission realized a record 15-day timeline from final payload selection to launch, including shipping to launch site, environmental testing, and integration to the launch vehicle. Though both the ORS-1 and the Jumpstart missions address the JFC needs, the ORS Office has not wavered in its commitment to achieving the desired goal in 2015 by developing the necessary technology enablers. Realizing that these enablers remain critical to the success of the ORS mission, the ORS Office invested nearly 20 percent of its FY08 budget in 22 key technology enabler contracts that will provide a solid foundation for ORS to move forward in the next several years. The ORS Office also continued to pioneer new interagency agreements within the Federal Government. As an example, the ORS Office adopted the Goddard Mission Systems Evolution Center (GMSEC) as the core infrastructure for its Ground System Enterprise, heavily leveraging the pioneering work done by NASA in this area. Led by the vision of the new ORS Director and bolstered by the key staff positions provided by the approved Unit Manning Document for the ORS Office, the ORS Office made accelerated progress towards realizing the technical, programmatic, and logistical objectives.

Space protection remained a high priority for DOD. Both piloted and robotic spacecraft become more at risk each year as the number of objects in space increases. The Commander of Air Force Space Command and the NRO Director established the Space Protection Program (SPP) on March 31, 2008, as a joint USAF-NRO program focused on providing recommendations on how best to

protect the Nation's space systems and stay ahead of threats. The SPP continues to develop protection strategies, comprehensive vulnerability assessments, roadmaps and alternatives, and capstone requirements to ensure that capabilities are available to protect U.S. national security space assets.

In conclusion, DOD remains focused on supplying our Nation with the world's best space capabilities. From providing civil and commercial programs with launch facilities and range support to providing critical support to operating forces involved in vital missions around the world, DOD remains committed to providing first-class space professionals and assets for the national security space mission. From sharing the advanced technologies of GPS at no cost to all users to developing the next generation of meteorological satellites with our civil partners, DOD remains fully committed to keeping the United States as the world's premier spacefaring nation.

Aeronautics Research Activities

DOD continues to advance the state of the art in aeronautics for our Nation's military. Aeronautics research is conducted in collaboration with other U.S. Government agencies (e.g., NASA) and with industrial, academic, and international partners. DOD aeronautics research and development activities are conducted primarily by the military services and DARPA.

During 2008, DOD made significant progress towards goals and objectives laid out by the National Plan for Aeronautics Research and Development and Related Infrastructure. This plan was developed in response to Executive Order 13419, which implemented the National Aeronautics R&D Policy. The following goals are from the National Security and Homeland Defense Section of the National Plan:

- Demonstrate increased cruise lift-to-drag and innovative airframe structural concepts for highly efficient high-altitude flight and for mobility aircraft.
- Develop improved lift, range, and mission capability for rotorcraft.
- Demonstrate reduced gas turbine specific fuel consumption.
- Demonstrate increased power generation and thermal management capacity for aircraft.
- Demonstrate sustained, controlled, hypersonic flight.

DOD aeronautics research supports our Nation's military operations and combat activities around the world. Research that has a short response time and generates technology fixes to deficiencies identified in combat theater remains a priority. However, the emphasis in what follows is on longer-term aeronautics development. Significant DOD accomplishments in 2008, corresponding to the goals listed above, are outlined below.

Fixed Wing Vehicles

Alternate aircraft configurations can improve energy efficiency and mobility by increasing lift over drag and reducing aircraft weight. A joint Air Force, NASA, and Boeing Phantom Works X-48B effort is the Blended Wing Body. Blended wing body concepts, such as the dynamically scaled and remotely piloted aircraft X-48B, offer the promise of improved flight efficiency, reduced noise, and larger internal volume for payload compared to conventional tube-and-wing designs. Flight tests of the X-48B started in 2007 at NASA's Dryden Flight Research Center and continued through 2008. The flight testing focused on expanding understanding of low-speed handling qualities, stall performance, and one-engine-out flight control. In addition to flight control and handling, other technology areas for further research include lightweight, noncircular composite structures; increased areas of laminar flow; and engine integration.

Researchers at the Air Force Research Laboratory (AFRL) worked with Lockheed Martin on the flight-testing of the Advanced Composite Cargo Aircraft (ACCA, which has now been designated the X-55A by the Air Force). The composite structure fuselage is built in two halves from sandwich structures and joined together along the longitudinal seam with adhesive and ply overlays. It was joined with an existing Dornier 328J cockpit, wing, engines, and horizontal tail. The vertical tail was replaced using tailored stiffness technology. The resulting composite sections reduced the number of structural parts and the number of mechanical fasteners by approximately an order of magnitude under a metal design.

DOD invested in lighter-than-air technology. The DARPA Control of Static Heaviness (COSH) Program successfully demonstrated airship ballast-less flight in July 2008 with the Aeros 40D Sky Dragon airship. COSH works by compressing, storing, and then decompressing helium to adjust the vehicle's buoyancy. COSH

was designed to control lift in all stages of air or ground operations and includes the ability to offload payload without taking ballast on board.

Rotorcraft

To address vibration and noise issues, a rotor test was performed at the National Full-Scale Aerodynamics Complex (NFAC). The test demonstrated the effectiveness of active flap control for controlling noise and vibration. The Smart Material Actuated Rotor Technology (SMART) helicopter rotor test was jointly conducted from February to May 2008 by NASA, the U.S. Army, DARPA, the U.S. Air Force, and the Boeing Company. It used on-blade piezoelectric actuators and demonstrated dramatic reductions in certain acoustic noise and hub loads during simulated flight conditions. The acoustic noise data obtained were used to validate helicopter aeroacoustic analysis codes developed under the DARPA Helicopter Quieting Program (HQP). The goal of the HQP was to identify, develop, and demonstrate advanced rotor technologies that dramatically improve the survivability of military rotor systems; a crucial element of the effort was demonstrating a physics-based design tool set. This tool set enables the analytical design of novel rotor systems and rotorcraft for reduced acoustic susceptibility (detection and recognition).

The A160 program, a DARPA collaboration with the U.S. Army, exploited a hingeless, rigid rotor concept operating at the optimum rotational speed and offers the potential for significant increases in the Vertical Take-Off and Landing (VTOL) UAV range (>2,000 nanometers) and/or endurance (>20 hours). In 2008, flight tests demonstrated an 18-hour endurance without refueling, a world record for UAVs in the aircraft's weight class, and hovering at over 16,000 feet altitude. These tests demonstrated significant increases in VTOL system performance, in both hovering efficiency and forward flight efficiency.

Handling qualities describe the ability of the pilot to control the aircraft. Recent efforts are paving the way for the expansion of handling quality criteria expressed in current standards such as the Army Aeronautical Design Standard-33 (ADS-33). An Army-NASA collaborative piloted-simulation study used the NASA Ames Research Center (ARC) Vertical Motion Simulator to investigate control system stability criteria for large rotorcraft. The experiment concentrated on hover and low-speed tasks and requirements. Four aircraft configurations were

investigated, and 10 pilots flew over 2,000 data runs with evaluation comments and objective performance data recorded.

Turbine Engines

The Versatile Affordable Advanced Turbine Engine (VAATE) program leads strategic planning for turbine engine research across the Federal Government. The AFRL Adaptive Versatile Engine Technology (ADVENT) program developed detailed designs for two variable cycle engine concepts, and the variable fan for one of these concepts was successfully tested. The AFRL Highly Efficient Embedded Turbine Engine (HEETE) program will improve the thermal efficiency of turbine engines via high-pressure compressors to enable high-overall-pressure-ratio engine concepts. The program developed designs and started the fabrication of two high-pressure-ratio compressors. Both the ADVENT and the HEETE programs are targeting 25-percent reductions in specific fuel consumption by separately addressing variable cycle concepts and thermal efficiency; the intent is to combine these approaches to enable even greater efficiency improvements.

Also within the VAATE framework, the Army initiated the Advanced Affordable Turbine Engine (AATE) program to develop high-power, fuel-efficient turboshaft engines for helicopters. The AATE program is targeting similar improvements in fuel efficiency for this class of engine by increasing the overall pressure ratio of the engine cycle and by improving component efficiency. The program produced two engines: a single-stage turboprop engine and a two-stage Very Small Heavy Fuel Engine (VSHFE) engine. The single-stage turboprop engine, in the 35–60 horsepower range, may have set a new world record for endurance run time on a VSHFE, having amassed over 250 hours in total, with four runs in excess of 24 hours each. The two-stage VSHFE engine has an estimated capability for reducing fuel consumption by 50 percent while doubling the power output.

AFRL's Alternative Fuels program supports an Air Force goal that all weapons systems be certified by early 2011 to use a 50/50 blend of Fischer-Tropsch (F-T), a synthetic fuel, and Jet Propellant 8 (JP-8). Every time the price of fuel goes up by $10 a barrel, it costs the Air Force an additional $600 million per year. AFRL supported the Air Force Alternative Fuels Certification Office's certification of the C-17 and B-1 aircraft to use a 50/50 blend of F-T synthetic fuel and conventional JP-8, a military jet fuel.

Power and Thermal Management

AFRL developed and transitioned a flight-critical electro-hydrostatic actuator, with applications to the F-35 Joint Strike Fighter, to help reduce heat loads associated with the control system. In addition, AFRL demonstrated a turbogenerator-based supplemental cooling and power system providing a fivefold increase in cooling capacity. Finally, AFRL developed a hybrid fuel cell and lithium-ion battery propulsion system and demonstrated this technology on a small Unmanned Aircraft System (UAS), with a dramatic improvement in aircraft endurance. Aspects of this technology also transitioned to produce lightweight portable power sources for aircrew.

AFRL initiated the Integrated Vehicle Energy Technology (INVENT) program to develop a research framework, modeling and simulation capabilities, and hardware-in-the-loop simulation to address power and thermal management from an integrated system perspective. The goal of INVENT is to facilitate energy-optimized aircraft, enabling future aircraft with a much broader range of capabilities.

Hypersonics

The hydrocarbon-fuel-cooled scramjet for the DARPA and Air Force X-51A program was successfully ground-tested to Mach 4.6, Mach 5, and Mach 6 over a span of more than 20 test cycles. Work continued on the Navy and DARPA Hypersonic Flight (HyFly) effort, expected to achieve Mach 6 flight. Ground tests were performed for high-Mach turbine engines under the Navy's Revolutionary Approach To Time-critical Long Range Strike (RATTLRS) and the Air Force and DARPA High-Speed Turbine Engine Demonstration (HiSTED) program.

The DARPA Falcon Hypersonic Technology Vehicle (HTV-2) program developed and demonstrated manufacturing techniques for the production of a carbon-carbon aeroshell for its flight-test vehicle, including thermal protection systems and advanced guidance and control. A related Army effort, the Advanced Hypersonic Weapon (AHW), also made progress toward the development of advanced thermal protection systems. Finally, AFRL is addressing high-temperature materials and structures, advanced thermal protection systems, and guidance and control for hypersonic flight. AFRL's Air Force Office of Scientific Research teamed with

NASA and Sandia National Laboratories to develop the National Hypersonic Foundational Research Plan, establishing an integrated portfolio of efforts to advance the state of the art in hypersonic research.

Unmanned Aircraft Systems

Demand for capabilities providing Unmanned Aircraft Systems (UASes) is increasing dramatically as the DOD components are realizing the benefits provided by these systems. Aeronautics R&D in this area is delivering increased capabilities of existing systems and improving the abilities of future systems. UASes have proven their worth as remote persistent surveillance and strike platforms and show promise for cargo movement. Within DOD, the Unmanned Aircraft Systems Task Force coordinates work in DOD components and other Government organizations.

Integration of UAS within the NAS was identified as a fundamental challenge in the 2007 National Plan for Aeronautics Research and Development and Related Infrastructure. Significant progress has been made in understanding the fundamental R&D issues associated with UAS airspace integration in the NAS. AFRL continued the development of a Sense and Avoid (SAA) capability for High Altitude Long Endurance unpiloted aircraft as part of a Global Hawk-sponsored Advanced Technology Demonstration (ATD) program. The goal of the SAA ATD is to develop and demonstrate the ability to autonomously detect other aircraft and execute appropriate avoidance maneuvers.

Army research addressed operational challenges of UAS operation in urban environments. Research efforts investigated UAS navigation; precision hovering; landing on an unprepared surface; maneuvering in close proximity to obstacles; and sensing and avoiding small yet lethal hazards such as wires, poles, and antennas.

DARPA's Wasp UAV is a small (approximately 14-inch wingspan, approximately ½ pound), portable (i.e., back-packable), reliable, and rugged uncrewed air platform designed for frontline reconnaissance and surveillance over land or sea. Wasp serves as a reconnaissance platform for the company level. The air vehicle is capable of loitering in excess of 1 hour at 35 miles per hour and provides unobtrusive, real-time imagery from low altitudes. Wasp prototypes have been deployed for user evaluation by the U.S. military in theater. The Wasp family of vehicles embodies a number of variants.

Federal Aviation Administration

FAA

The tremendous benefits derived from a highly mobile citizenry and rapid cargo transport dictate that America's air transportation system remain the best in the world. Being the best requires the constant introduction of new technologies and procedures, innovative policies, and advanced management practices into the aviation system, as well as sustained investments in advanced research and technology development.

As a result, the FAA continued to perform a comprehensive system upgrade that will allow fundamental change to air traffic management. The Next Generation Air Transportation System, or NextGen, will help the FAA meet that challenge. NextGen will enable critical transitions: from ground-based to satellite-based navigation and surveillance; from voice communications to digital data exchange; from a disparate and fragmented weather forecast delivery system to a system that uses a single, authoritative source; and from operations limited by visibility to operations that can sustain their pace even when impacted by adverse weather or difficult terrain. NextGen means flying more passengers, more cargo, and more types of aircraft more safely, more precisely, and more efficiently using less fuel, making less noise, and creating less environmental impact.

In FY08, FAA research and development addressed current needs of the system, developing technologies that will enable those NextGen transitions. The FAA developed a NextGen Towers concept of operations, for both staffed and automated towers, that will improve operational efficiency and enable the cost-effective expansion of air traffic services to a significantly larger number of airports than

would be possible with traditional methods of service delivery. Additionally, the agency completed a technology assessment for staffed towers and alternatives.

The FAA completed the development of the Forecast Icing Product (FIP-Severity). This icing forecasting product will alert users to areas of forecasted in-flight icing by graphically displaying the probability that icing will occur along their planned flightpath. These capabilities will allow users to plan more effective flight routes that will avoid hazardous icing areas. In-flight icing causes more than 25 accidents annually, with over half of these resulting in fatalities and destroyed aircraft. In monetary terms, the results of these accidents equate to $100 million in injuries, fatalities, and aircraft damage annually.

The FAA developed hydrocarbon emissions profiles known as Aircraft Emissions Inventories for aircraft equipped with turbofan, turbojet, and turboprop engines. This inventory of aircraft emissions is the first time that aircraft hydrocarbon emissions have been characterized based on commercial engines. The agency developed a Recommended Best Practice document and incorporated the new data into the Emissions and Dispersion Model System (EDMS version 5.1) to support requirements for aircraft emissions inventories required under the National Environmental Policy Act. This updated system will streamline and improve airport environmental assessments and compliance activities, saving millions of dollars and reducing implementation time for capacity enhancements.

The Future Terminal Workstation effort continued in FY08 with the identification of the requirements platform that will serve as the basis for future human-in-the-loop simulations. The prototype workstation will be used to conduct human factors research on NextGen operational concepts and procedures to determine their effect on controller performance, decision making, and workload and how the information needed by NextGen in the terminal domain can be best presented and integrated into the controller workstation.

The FAA's Oceanic Trajectory-Based Operations Proof of Concept Demonstration showed that four-dimensional oceanic trajectory-based air traffic management can provide more efficient aircraft-centric oceanic routes and reduce fuel burn and environmental footprint. The initial demonstration resulted in approximately 330 gallons of fuel savings and a reduction of approximately

6,700 pounds of carbon emissions. This effort will assist the FAA in meeting its goal to promote environmental stewardship.

In July, more than a decade's worth of research and innovation reached fruition when the FAA announced the final rule making that will significantly enhance fuel tank safety. The rule requires the operators and manufacturers of more than 5,000 passenger jets to reduce the flammability levels of fuel tank vapors. Publication of the rule in the Federal Register came 1 day before the 12th anniversary of the TWA 800 explosion that killed 230 people, an accident that was attributed to the ignition of fuel vapors in the center wing fuel tank of the aircraft shortly after the plane took off from John F. Kennedy International Airport.

The FAA installed and evaluated trapezoidal grooving, an alternative pavement grooving technique, at both the Chicago O'Hare International Airport and the Quantico Marine Corps Facility. This innovatively shaped groove's ability to resist damage from sweeping, snowplowing, and aircraft traffic could potentially save millions of dollars in repairs and runway downtime at airports. The standard (rectangular) shape remains susceptible to damage and is typically replaced after only a few years.

The FAA's work in licensing commercial space transportation saw great success in 2008. The agency licensed 11 orbital commercial space launches, including the first successful launch of the Falcon 1, operated by Space Exploration Technologies (SpaceX). The launch took place in September 2008 from the Ronald Reagan Ballistic Missile Defense Test Site on Kwajalein Atoll in the Marshall Islands.

The remaining commercial launches included five by the Sea Launch multinational partnership from a mobile platform in the Pacific Ocean, two by the Boeing Company using the Delta II launch vehicle from Vandenberg AFB in California, one launch of Falcon 1 by SpaceX from Kwajalein that failed, one by Lockheed Martin Launch Services of an Atlas V from Cape Canaveral Air Force Station in Florida, and one of Orbital Sciences Corporation's Pegasus XL from Kwajalein.

In addition, Armadillo Aerospace operated five permitted launches in FY08, all low-altitude flights by the MOD-1 vehicle. Four of these permitted flights occurred at Holloman AFB in New Mexico as part of the Northrop Grumman Lunar Lander Challenge competition, and one flight originated at Oklahoma Spaceport.

During FY08, the FAA conducted approximately 40 safety inspections on over 17 different types of licensed and permitted activities. The goal of every safety inspection is to ensure public safety by verifying FAA licensee and permittee compliance with FAA regulations and license/permit terms and conditions. Inspectors traveled to various locations including Cape Canaveral, Florida; Vandenberg AFB, California; Mojave, California; Kodiak, Alaska; Wallops Flight Facility, Virginia; the Republic of the Marshall Islands; and a point on the equator in the Pacific Ocean for Sea Launch operations.

Additionally, as part of its licensing responsibilities, the FAA developed the Draft Environmental Impact Statement for the Spaceport America Commercial Launch Site in Sierra County, New Mexico. Six public hearings were held last August to get public comments on the proposed site to be developed and operated by the New Mexico Spaceport Authority (NMSA). NMSA proposes to operate the site for horizontal and vertical launches of suborbital launch vehicles. The vehicles may carry space flight participants, scientific experiments, or other payloads.

The FAA completed two research and development projects in FY08: the "Study of Informed Consent for Space Flight Participants" provided industry with insight into what they will need to do to satisfy the regulatory requirements for informing space flight participants of the hazards and risks of commercial human space flight operations, and the "Historical Database of Failures and Reliability of Rocket-powered Vehicles" described which components of rocket-powered vehicles fail and why they fail.

The FAA also released a space transportation annex to the NextGen Concept of Operations. The annex outlines a common national vision for conducting space flight operations in the future and integrating space and air traffic. Further, the annex will be used by the FAA's JPDO to inform long-term NextGen planning investment decisions.

The FAA completed the Shuttle Hazard Area to Aircraft Calculator (SHAAC) tool in FY08. This tool predicts and identifies the extent of the airspace that could contain falling debris hazardous to aircraft in the event of a Space Shuttle orbiter failure on reentry, such as the failure of *Columbia* in 2003. This tool serves as the prototype for a tool under development by the FAA's Air Traffic Organization that

will predict and identify aircraft hazard areas during commercial space launches and reentries.

In partnership with NASA, the FAA supported the selection process of a Commercial Resupply Services (CRS) contract that will supply launch and return services for the ISS. These commercial space launches and reentries will be licensed by the FAA. The FAA also supported NASA in the recompetition for the Commercial Orbital Transportation Services (COTS) contract that was won by Orbital Sciences Corporation.

In partnership with the U.S. Air Force, the FAA cohosted a Commercial Space Entrepreneurial Reusable Launch Vehicle Summit. The summit allowed commercial operators to discuss capabilities with senior Air Force leadership and determine potential ways to meet future Air Force requirements, including responsive space.

More information about the Office of Commercial Space Transportation, regulations, reports, and other documents can be found at *http://www.faa.gov/about/office_org/headquarters_offices/ast/*.

Department of Commerce

DOC

In FY08, the Department of Commerce (DOC) engaged in a wide variety of activities that furthered U.S. interests in aeronautics and space, including national policy implementation, satellite operations, technology development, measurement and calibration, international cooperation, trade promotion, and spectrum management.

Office of Space Commercialization (OSC)

OSC continued to play a key role in the national management of the Global Positioning System (GPS) by hosting the meetings and offices of the National Executive Committee for Space-Based Positioning, Navigation, and Timing. The Deputy Secretary of Commerce continued to participate in the activities of the National Executive Committee, along with members from the Departments of Defense, Transportation, State, Interior, Agriculture, and Homeland Security; the Joint Chiefs of Staff; and NASA. Such activities included interagency coordination of GPS-related programs and budgets, guiding international cooperation with other providers of Global Navigation Satellite Systems (GNSS), protecting the spectrum used by GPS, and outreach and education.

OSC orchestrated an agreement between the National Oceanic and Atmospheric Administration (NOAA) and the Japan Aerospace Exploration Agency (JAXA) related to Japan's Quasi-Zenith Satellite System (QZSS), a regional subconstellation designed to be fully compatible and interoperable with GPS. The agreement allows JAXA to install a QZSS monitoring station at a NOAA facility in Guam, providing satellite observations that enhance GPS-QZSS interoperability.

OSC conducted a study and collected public comments on the Government's plan to phase out civil use of so-called "semicodeless" GPS equipment, which

leverages military GPS signals to enable high-precision positioning. The collected information contributed to the Department of Defense's final decision to continue supporting semicodeless access to military GPS signals through December 31, 2020, by which time the modernized civil GPS signals will be fully available. The final decision appeared in the Federal Register on September 23, 2008.

In July 2008, OSC organized the second meeting of the GPS Galileo Working Group "B" on Trade and Civil Applications, continuing to encourage equal access to information and markets related to Europe's emerging Galileo satellite navigation system. In June 2008, OSC participated in a Latin American regional workshop in Colombia to promote the use of GPS for precision agriculture, landscape epidemiology, and other fields.

National Oceanic and Atmospheric Administration (NOAA)

Within NOAA, space-related activities occurred across the entire organization. During the 2008 Atlantic hurricane season, NOAA's Geostationary Operational Environmental Satellite (GOES) system provided a continuous flow of imagery that contributed significantly to the development of storm forecasts. These forecasts helped minimize the loss of life in the United States from major hurricanes Gustav and Ike. GOES satellites continued to provide space weather monitoring for the NOAA Space Weather Prediction Center to issue forecasts and warnings that protected spacecraft and power grids.

NOAA's GOES and Polar-orbiting Operational Environmental Satellite (POES) system continued to provide an uninterrupted flow of global environmental information to support weather, ocean, and space environmental modeling, as well as tropical storm analysis and forecasting, local weather forecasting, and ecosystem and climate monitoring. NOAA's weather and climate prediction numerical models used the global data from these satellites extensively.

NOAA provided forecast support for NASA Space Shuttle missions before launching, during flight, and during landing. NOAA led the multiagency effort with the FAA and DOD to build a four-dimensional database of weather elements of interest to aviation, such as thunderstorms, icing, turbulence, ceiling, visibility, and winds. NOAA's lead was specified in the JPDO's NextGen Integrated Work Plan (2008) and has research roots in Executive Order 13419, National Aeronautics Research and Development (2006), which assigned the responsibility

for foundational weather research affecting aviation to DOC. NOAA led the efforts to develop a coordinated information technology infrastructure with common data standards and data exchange protocols and to identify data that will satisfy FAA Air Traffic Management requirements for a common weather picture for use in the NAS.

NOAA's National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO) completed several key tasks toward the launch of the NPOESS Preparatory Project (NPP) expected for 2011. The Ozone Mapping and Profiler Suite for NPP successfully completed environmental testing in August 2008. This sensor suite will protect the public by monitoring the depletion of ozone in the stratosphere. Reduced ozone levels could lead to a higher incidence of skin cancer. The IPO's Ground Systems Division achieved four key milestones: it successfully tested ground systems for NPP spacecraft communication and data gathering; upgraded ahead of schedule the satellite communications at McMurdo Base, Antarctica; installed Integrated Data Processing System hardware and software; and broke ground for a tracking station in Torrejon, Spain. Two sensors were added to the NPOESS program: the Total Solar Irradiance Sensor (TSIS) and the Clouds and the Earth's Radiant Energy System (CERES). TSIS measurements address long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and UV-B radiation, while CERES will provide data for studying the ways in which clouds affect Earth's climate.

On June 20, 2008, the OSTM/Jason-2 spacecraft, an international effort between NOAA, NASA, France's CNES, and EUMETSAT, launched from Vandenberg AFB. This satellite monitors the rate of sea-level rise and helps measure ocean conditions that contribute to the strength of hurricanes. Data from this satellite and its predecessors show that sea level is rising at a rate of 3.4 millimeters per year—nearly twice as fast as in the previous 100 years. If this rate of sea-level rise continues, it will have a large impact on coastal regions, causing more erosion and flooding. OSTM/Jason-2 also helps scientists predict short-term, severe weather events such as hurricanes and tropical storms fueled by heat energy stored in the upper layer of the ocean.

In August 2008, NOAA's Center for Satellite Applications and Research (STAR) developed the first operational greenhouse gas products based on data

from the Infrared Atmospheric Sounding Interferometer aboard the European Metop-A satellite. Measurements include carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4). Information on the seasonal and geographic distribution of greenhouse gases will provide critical data on the sources of these gases and how best to mitigate the risks.

Since April 2008, NOAA's ground stations in Fairbanks, Alaska; Wallops, Virginia; and Tromso, Norway, have received occultation satellite data from the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) satellites. In order to accomplish this data collection and dispersal, NOAA installed a 5-meter antenna in the Fairbanks Command and Data Acquisition station in only 2 months during unfavorable weather conditions and modified an existing antenna at Wallops. COSMIC is a collaborative effort with NSF, NASA, the University Corporation for Atmospheric Research, and the Norwegian Space Center. The COSMIC system provides useful data for meteorological, climate, and space weather monitoring, research, and forecasting applications.

NOAA installed the last 9 of the 114 stations that compose the U.S. Climate Reference Network (USCRN). These stations monitor weather trends across the country. NOAA's geostationary satellites relay the data from these ground-based stations to NOAA's National Climatic Data Center, which posts the observations online. The operation of this network will help improve weather forecasts.

NOAA continued to help prepare coastal communities for tsunamis through improved forecasts, warnings, and mitigation capabilities. NOAA satellites collected and transmitted data from Deep-ocean Assessment and Reporting of Tsunami (DART) buoys to the NOAA Tsunami Warning Centers and the NOAA National Data Buoy Center in real time, enabling early detection, measurement, and real-time reporting of tsunamis in the open ocean.

In FY08, the international Search and Rescue Satellite-Aided Tracking (SARSAT) System assisted in the rescue of 308 people throughout the United States and its surrounding waters. This high-tech system used a network of international satellites—including NOAA's geostationary and polar-orbiting satellites—and ground stations to quickly detect and locate distress signals from emergency beacons aboard boats and planes and from handheld personal locator devices. Also in FY08, NOAA reached a milestone with the 200,000th emergency beacon

registered in the National 406 Megahertz (MHz) Beacon Registration Database. The database provides user contact information and vehicle descriptions to search and rescue authorities in order to expedite rescues and cancel false alerts.

On May 22, 2008, the Solar Backscatter Ultraviolet Spectral Radiometer instrument on the NOAA-18 satellite malfunctioned, rendering it unable to take measurements. The instrument maps total concentrations and vertical distribution of ozone—an important greenhouse gas—in Earth's atmosphere on a global scale. These data are essential to scientists and forecasters, especially during the critical period for ozone monitoring from late August through September. NOAA, NASA, and contract engineers developed an innovative solution to correct the malfunction and restore the instrument's data collection operations. After followup testing, normal daily operational ozone measurements and product processing resumed on July 29, 2008.

GEONETCast is part of a global effort of the intergovernmental Group on Earth Observations (GEO), which collects Earth observational data and distributes them to a variety of end users. GEONETCast Americas started operations in April 2008. This system, operated by NOAA, disseminates weather and environmental data throughout the Western Hemisphere. With a real-time, 24/7 data stream, GEONETCast Americas provides information critical to a wide array of efforts, including disaster mitigation, high-impact weather forecasting, agriculture management, and professional training. NOAA has been instrumental in facilitating coordination and contributions from GEONETCast's many international partners.

NOAA's Coral Reef Watch (CRW) uses satellite data to monitor coral reefs worldwide. In FY08, CRW launched a new experimental Seasonal Coral Bleaching Thermal Stress Outlook product and expanded the number of virtual stations for monitoring coral bleaching conditions. This launch included 20 new experimental sites in the Greater Caribbean region, the Philippines, and Tanzania. CRW also trained coral reef managers to address coral bleaching and the impacts of climate change on coral reefs. Coral bleaching is one of the top three threats to coral reefs. This phenomenon, caused by climate change, is a response to environmental stress whereby the colored algae that live in the coral are expelled, leaving the coral looking bleached. This expulsion kills corals and threatens reefs around the world.

To meet the continuing demand by weather forecasters for ocean surface vector wind (OSVW) data, NOAA's STAR created a new procedure to capture and process data from the Advanced Scatterometer (ASCAT) aboard the European Metop-A satellite. Currently, NASA's Quick Scatterometer (QuikSCAT) satellite provides OSVW data used for weather forecasting and warnings. In preparation for the eventual degradation of QuikSCAT, STAR designed the ASCAT processing system to ensure continuity of OSVW information.

Improved marine weather forecasting and warnings benefit the marine transportation system, recreational boating and fishing activities, and coastal regions and islands impacted by marine storms. Global OSVW data improve our knowledge of how the ocean and atmosphere interact. This knowledge is important for understanding the longer-term (climate) and shorter-term (weather) changes to the global environment.

Responding to thousands of requests per day for water temperatures in U.S. coastal areas, including the Great Lakes, NOAA's National Oceanographic Data Center (NODC) enhanced its most popular Web application: the Coastal Water Temperature Guide (CWTG). CWTG provides comprehensive coastal water temperature data, which are widely used by the oceanographic research community, coastal resource managers and decision makers, fishermen, beach users, vacationers, and academics. Since the Google Map-enabled CWTG Web site went public in May of 2008, it has quickly become the primary Internet gateway to useful information for planning beach activities such as swimming or fishing.

NESDIS provided significant support for the creation of the National Museum of Natural History's Sant Ocean Hall, the largest museum exhibit dedicated to ocean science. Visitors can learn how oceans circulate and transport heat, how the atmosphere interacts with the ocean to form hurricanes, and how phytoplankton blooms across the planet. Videos developed for the hall will be shared with aquariums across the country, reaching a potential audience of 30 million people who can learn about the importance of protecting the oceans.

On July 16, 2008, the GOES biomass burning (agricultural and forest fires) emissions product for air quality modeling applications became operational. To accomplish this, STAR worked with EPA and NOAA's Air Resource Lab. Biomass burning releases trace gases and aerosols into the atmosphere, which pollute the air

and pose risks to human health. Since most biomass burning events occur with no advance warning, satellite observations are the best way to monitor them.

STAR scientists and operations personnel, collaborating with domestic and international academic partners, developed and implemented a new class of sea surface temperature (SST) analysis. These new operational ocean remote sensing products blend SST measurements from NOAA's polar-orbiting and geostationary satellites and are available via NOAA CoastWatch. Under development for a number of years, these new products bring improved geographic measurements of the world's oceans and better temporal coverage. Better SST measurements throughout the world's oceans will improve numerical weather predictions, marine transportation, climate variability, and ecosystem management efforts.

Sally Ride, the first American woman in space, joined NOAA scientists in Silver Spring, Maryland, from July 23 to 24 to teach K–12 educators how to integrate the science of Earth's changing climate into their classroom lesson plans. During "Earth Then, Earth Now: Our Changing Climate," 250 participants investigated the basic science of climate change, as well as global impacts on the atmosphere, ocean, and every continent and ecosystem around the world.

Land cover maps made from remotely sensed data document how much of a region is covered by forests, wetlands, impervious surfaces, and other land and water types. By comparing land cover maps over a specific time, users can also document land use trends and changes. Land cover data (*http://www.csc.noaa.gov/landcover/*) are available for nearly all of the developed areas of the Nation's coasts and are updated every 5 years. Land cover data collected for Hawaii mark the first maps in this series developed from high-resolution satellite imagery. These data assess human impacts on coral reef environments and identify at-risk populations and resources during events such as tsunamis.

LIDAR is a remote sensing technology used to collect topographic and bathymetric data. Coastal LIDAR data (*http://www.csc.noaa.gov/lidar*) are available for portions of the Great Lakes, Florida, South Carolina, Mississippi, Oregon, and Southern California. The sensors—typically mounted on an aircraft—represent important savings of time and money for states that traditionally have used ground surveys to get this information. Through partnerships, the NOAA Coastal Services Center gathered significant coastal coverage for the United States.

In July, NOAA began testing the incorporation of surface currents data into its Harmful Algal Bloom Forecasting System (HAB-FS). NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) and the National Data Buoy Center (NDBC) use satellite data as well as in situ measurements to monitor the development of harmful algal blooms that could affect coastal areas.

In 2008, NOAA's National Geodetic Survey (NGS) began test flights of its recently acquired airborne gravimeter. Test flights occurred in Montgomery, Alabama, and Kachemak Bay, Alaska, supporting the Gravity for the Redefinition of the American Vertical Datum (GRAV-D) program. GRAV-D is an effort to use gravity data to redefine the vertical datum of the United States by 2017. NGS flew about 100 hours over Alabama and 400 hours over Alaska to determine optimum flight levels, spacing, and various other procedures required to collect good airborne gravity data. The program will lead to greater accuracy of data, giving users the ability to use GPS to determine elevations relative to sea level. NOAA's NGS released a new version of its popular Online Positioning User Service (OPUS) in February 2008. The OPUS-Rapid Static (OPUS-RS) system, designed in partnership with Ohio State University, saves time and money compared to standard OPUS. NGS expects that OPUS-RS usage will exceed OPUS usage by a factor of 10. Each OPUS solution could save the user an estimated $600 over traditional positioning methods. In total, the service has processed over 500,000 OPUS solutions.

For the next 4 years, NOAA's NGS will lead an international effort to pinpoint the locations of more than 40 global positioning satellites in Earth's orbit, which will ensure the accuracy of GPS data. NGS acquired nearly 23,000 high-resolution color and near-infrared aerial images and topographic LIDAR data in a project area extending from Cape Henry, Virginia, to Ocracoke Island, North Carolina. NGS also supplied LIDAR data and aerial imagery for inclusion in the "Shallow Survey 2008" Common Dataset (*http://shallowsurvey2008.org/*). Researchers from around the world will be able to use these high-resolution coastal surveying and mapping data.

NOAA's NGS released version 3.0 of the Horizontal Time-Dependent Positioning (HTDP3.0) software. Users may now apply HTDP3.0 to predict how

points on Earth's surface have moved due to plate tectonics, earthquakes, and volcanic activity.

NOAA's NGS developed new Airport Data Logger (ADL) software, which will help standardize the process of airport and aeronautical surveys. NGS trained private contractors on the use of the ADL software at the NGS Field Operations Branch in Norfolk, Virginia. This software replaced the outdated Automatic Collection Exchange System (ACES) software. Data collected and analyzed using ADL software will help develop runway approach procedures and obstruction charts.

NOAA's NGS provided technical assistance to Iraq for installing a Continuously Operating Reference Station (CORS) to be installed by the Iraqi Government. This station enables users to determine highly accurate GPS positions, which will improve the quality, accuracy, and cost of airfield and boundary surveys and other precise positioning activities in the country.

NOAA's NGS is in the final stages of creating an Absolute Antenna Calibration Facility in Corbin, Virginia. The facility will allow scientists to determine the phase center of geodetic antennas, in particular the phase centers or precise point from which satellite signals originate for satellites launched to modernize the GPS constellation. Once operational, this facility will improve the accuracy of GPS-derived elevations. Accurate elevations remain critical to monitoring changes in environmentally sensitive regions, as well as for industrial and civil engineering projects.

NOAA's NGS, with funding from USAID, continued to assist Ethiopia in building a network of GPS CORSes and making the data from these stations available to the public through the NGS Web site.

Famed ocean explorer Robert Ballard led an expedition in the Monterey Bay National Marine Sanctuary during March 2–7, 2008. NOAA's Office of National Marine Sanctuaries, in partnership with Immersion Presents (Dr. Ballard's interactive educational program), used telepresence technology—a combination of satellite and Internet connections—to transport young people "live" to the research cruise. The students "visited" the deep sea in the NOAA research vessel *Fulmar*, viewed kelp forests reaching 100 feet tall, and observed endangered and threatened marine mammals such as the gray whale, blue whale, and California sea otter.

Daily live broadcasts, including a 20-minute segment in Spanish, brought the oceans into the classrooms and living rooms of thousands of people nationwide.

The high-resolution IKONOS color satellite imagery used in 2008 produced a shallow-water benthic habitat map of approximately 200 square kilometers of the Florida Keys, part of a NOAA effort to map all U.S. coral reefs.

A National Centers for Coastal Ocean Science (NCCOS) researcher collaborated with scientists at the NASA facility at Wallops Island, Virginia, to create a Harmful Algal Bloom (HAB) lesson plan for national distribution at high schools and placement on agency education Web sites. The lesson plan explains how various species of single-celled algae multiply and develop into toxic blooms and explores the possible effects on humans and marine resources.

Scientists from NOAA's Environmental Cooperative Sciences Center developed regression models using satellite data to monitor chlorophyll-*a* and total suspended solids (TSS) in Apalachicola Bay, Florida.

Dr. Rita Colwell from the University of Maryland, one of two NOAA Oceans and Human Health Initiative Distinguished Scholars, wrote a paper on how to use satellites to predict outbreaks of cholera. Ocean and climate patterns can be useful predictors of cholera endemics.

Using satellite data, NOAA's CRW monitors ocean acidification in the Greater Caribbean region and examines the changes that have transpired over the past two decades. Regional maps and time-series studies of ocean acidification are available online.

In 2008, NOAA trained 60 reef managers from the Pacific and Caribbean to improve their ability to anticipate and respond to coral bleaching events and to build resilience into management plans. To date, NOAA has trained over 150 coral reef experts and managers from 18 countries around the world. In 2009, additional workshops will take place in Bonaire and Guam.

NOAA's CRW developed a new training module for Bilko—a system operated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO)—that teaches users how to predict coral bleaching from satellite sea surface temperature data. The step-by-step training module provides users with an in-depth knowledge of how CRW data are produced, as well as how to use the data to predict coral bleaching. This lesson plan is available on both the CRW

(*http://coralreefwatch.noaa.gov/satellite/education/bilko_lesson.html*) and Bilko (*http://www.noc.soton.ac.uk/bilko/noaa_crw.php*) Web sites.

NOAA's CRW participated in the 2008 Satellites and Education Conference at California State University, Los Angeles, held August 7–9. CRW presented a session entitled "NOAA Coral Reef Watch: Teaching About Coral Reefs with Satellite Data." Many teachers indicated that they were going to attempt to develop a coral reef information module in their classrooms.

NOAA's Oceanic and Atmospheric Research (OAR) scientists in the Global Systems Division of the Earth System Research Laboratory in Boulder, Colorado, performed real-time research with GOES products. Scientists used GOES cloud drift wind product data for wind analysis. Scientists used GOES infrared and visible imagery for cloud and atmospheric moisture analysis and for local and high-resolution hurricane model initialization. Additionally, Global Systems Division scientists developed and tested algorithms for sounder retrieval quality related to atmospheric moisture measurements in an effort to shorten the learning curve for using GOES R-Series satellite data in the near future.

DOC continued to participate in an interagency initiative to develop an Integrated Weather Plan for NextGen. NOAA contributed to the formation of the interagency JPDO. Various technical working teams benefit from NOAA's leadership and participation. These include the NextGen 4-Dimensional (4-D) Weather Data Cube Management Team for coordinating the tasks of building a 4-D Weather Cube for initial operational capability in 2013; the Policy Team, which addresses regulations, governance, and agency roles and responsibilities; the Environmental Information Team, which develops 4-D cube contents; and the Information Technology/Enterprise Services Team, which determines standards and protocols.

Researchers at the Global Systems Division of the Earth System Research Laboratory (ESRL) and the National Center for Environmental Prediction (NCEP) collaborated on the development and implementation of a major Rapid Update Cycle (RUC) model upgrade. RUC is used extensively for aviation and severe weather forecasting support on an hourly update cycle. The RUC upgrade included assimilation of radar reflectivity—the first model at NCEP to do so—and Tropospheric Airborne Meteorological Data Reporting (TAMDAR) aircraft

observations. Development of the model included observation impact studies for TAMDAR and all mesoscale data sources over the RUC domain and extensive retrospective experiments using RUC. Real-time testing of the High-Resolution Rapid Refresh (HRRR) model at 3-kilometer resolution, updating hourly, including radar assimilation, was conducted as well. The Weather Research and Forecasting with Chemistry (WRF-Chem), a version of the WRF model using inline atmospheric chemistry, is currently under development. The outcome of coupling atmospheric chemistry in this forecast model will be important for future aviation activities to improve visibility and cloud forecasts.

Development and real-time testing of the Flow-following Finite-volume Icosahedral Model (FIM), a new global model using isentropic coordinates, will include finite-volume numerics and an icosahedral horizontal grid. Development of FIM is occurring at ESRL and coordinated with NCEP. FIM will be part of the future NCEP global model ensemble and will be a candidate for global aviation forecasting.

NASA and NOAA's partnership in developing joint expertise in civilian applications of Unmanned Aerial Systems (UASes) successfully continued after the signing of a Memorandum of Understanding (MOU) in 2006 between NASA, NOAA, and DOE concerning "Unmanned Aircraft Systems for Global Observing System Science Research."

The radio-frequency spectrum is a limited natural resource that has to be shared among nations on a regional and global basis. For that reason, under the auspices of the United Nations, the World Radiocommunication Conference (WRC) convenes every 4 years to consider the regulatory framework to manage the international use of radio-frequency spectrum in a rational and equitable manner.

WRC-07 established a preliminary agenda for WRC-11. One of the preliminary agenda items will "consider spectrum requirements and possible regulatory action, including allocations, to support the safe operation of unmanned aircraft systems" such as seamless integration into segregated airspaces, including "Sense and Avoid" functions and "Command and Control" communications, as well as payload radio communication applications (i.e., "Data Transfer"). NASA, NOAA, and other Federal agencies will continue to address UAS frequency issues through the WRC-11 forum.

Satellite products continued to be an integral part of the long-term climate record and of national efforts to determine what has happened to the climate system and why these changes have occurred. In 2008, the interagency Climate Change Science Program (CCSP) released a number of Syntheses and Assessment Products aimed at these issues. NOAA led the report "Reanalysis and Attribution: Understanding How and Why Recent Climate Has Varied and Changed," which made extensive use of historical satellite measurements to describe atmospheric temperature changes over North America. Satellite observations continued to be critical in monitoring ozone depletion and recovery, as described in the NOAA-led CCSP report "The Ozone Layer Ozone Depletion, Recovery in a Changing Climate, and the 'World Avoided.'" The measurement of climate variability and change from both operational and research satellites remains prominent throughout the CCSP report series.

The Great Lakes Environmental Research Laboratory (GLERL) obtains, produces, and delivers environmental data and derived products for near-real-time observation of the Great Lakes to support environmental science, ecosystem forecasting, decision making, and research. Clients included Federal, state, and local agencies; academic institutions; and the public. CoastWatch uses data from POES and GOES satellites.

NASA and NOAA plan to utilize both crewed aircraft and Unmanned Aerial Vehicles (UAVs) to monitor HABs in the western basin of Lake Erie. These blooms remain a concern for human, fish, and wildlife health because they can contain a toxic alga, microcystin. In the Great Lakes, Microcystin-LR is common and highly toxic. Because of this toxicity, the blooms require continual monitoring.

GLERL, in collaboration with the National Ocean Service (NOS), developed and issued a prototype HAB warning bulletin for Lake Erie. Derived from MERIS satellite imagery, the bulletin depicts areas of HAB development. Increasing in frequency, potentially toxic Microcystis blooms can pose a health hazard to humans, wildlife, and fish.

NOAA's GLERL, in collaboration with JPL, developed an algorithm for the classification and mapping of Great Lakes ice cover using satellite Synthetic Aperture Radar (SAR). Validation continues with icebreaker support from the

U.S. Coast Guard. Users include the U.S. Coast Guard, the National Weather Service (NWS), and the National Ice Center.

Scientists know that the algorithms for estimating chlorophyll in the ocean using satellite data do not work well in time or space for the Great Lakes. In collaboration with researchers from the Michigan Tech Research Institute (formerly of Altarum/Environmental Research Institute of Michigan [ERIM]) and the Nansen International Environmental and Remote Sensing Center (NIERSC) of St. Petersburg, Russia, NOAA scientists are developing and testing a fundamentally different algorithm for the retrieval of color-producing agents from satellite data.

National Institute of Standards and Technology (NIST)

In FY08, NIST continued to provide Federal agencies and the aerospace industry with the research, guidance, standards, products, and services needed to advance the President's space agenda. These wide-ranging outputs fall into four main categories: (1) validation, measurement, and calibration; (2) manufacturing technology; (3) observation and sensing; and (4) spacecraft and living environments. NIST supported accurate and compatible measurements made by the aerospace industry by providing Standard Reference Materials (SRMs) and calibration services. Customers used these SRMs and services to ensure the accuracy of their own instrument calibrations and the validity of their measurement methods. In 2008, aerospace companies purchased 89 units of SRMs, including ferrous and nonferrous metals certified for chemical composition and for hardness, and artifacts certified for nanoscale dimensional properties. In addition, these companies submitted over 300 instruments or artifacts to NIST for calibration. NIST performed nearly 2,400 separate tests on these items, spanning dimensional, force, vibration, and electrical measurements, providing the companies with a source of metrological traceability for their primary measurement standards.

NIST administers the National Voluntary Laboratory Accreditation Program (NVLAP), which accredited two aerospace and aeronautic facilities in 2008. NVLAP accreditation ensures that the laboratories are following best practices for quality in testing and measurements as established by standards organizations such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Ensuring the security of communications and data remains crucial to aerospace applications. NIST helped

NASA Langley Research Center with information technology security through the NIST Cryptographic Module Validation Program and the Cryptographic Algorithm Validation Program to ensure proper use of Federal Information Processing Standards. NASA works with many vendors and other Government space agencies such as JAXA, which must comply with Federal Information Processing Standards (FIPS).

Carbon nanotubes are lightweight materials with potentially great strength and unique electrical properties, plus other attributes that make them very interesting for potential aerospace applications. NIST collaborated with NASA Johnson Space Center to promote the standardization of test techniques for single-wall carbon nanotubes. Following a third joint workshop that brought together over 70 leading experts, NIST developed and published a recommended practice guide, "Measurement Issues in Carbon Nanotubes," in 2008. In addition, documentary standards advanced through the International Organization for Standardization's Technical Committee on Nanotechnology, and in-house research led to the development of prototype reference materials for interlaboratory comparison and environmental health and safety studies. Precise time synchronization is needed in military aerospace applications, navigation, and positioning, as well as for applications in industries such as automation and control, power and utility, and telecommunications. Previously, NIST initiated and coordinated standards activity leading to the release of the first version of the Institute of Electrical and Electronics Engineers' (IEEE's) standard for precision clock synchronization for networked measurement and control (IEEE 1588). Scientists used NIST's SURF III Synchrotron Ultraviolet Radiation Facility as a source of soft x rays and vacuum ultraviolet light to calibrate mirrors, detectors, and spectrometers used in NASA spacecraft. These included the extreme ultraviolet (EUV) Variability Experiment (EVE), which will be launched on the Solar Dynamics Observatory (SDO), and the calibration rocket experiment for the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. Both of these satellites study EUV solar irradiance and its variability over minutes (flares) to years (11-year solar cycle). These measurements remained important to the National Space Weather Program (NSWP), which tracks solar storms that impact space-based communications and navigation technologies. In addition, SURF III provided the calibration standard

for experimental determination of atomic radiation intensities that are required for the interpretation of data from Hubble Space Telescope (HST) experiments.

With funding from NASA and its partner, ESA, NIST developed special lamps for wavelength calibrations of instruments used to make astronomical observations in the near-infrared region. These lamps came from the same batch as those used for in-flight calibration of the Cosmic Origins Spectrograph (COS), to be installed on HST during the 2009 Hubble servicing mission. NIST carried out accelerated aging experiments to predict the lifetimes and possible indicators of failure of the calibration lamps for use on COS.

NIST collaborated with Utah State University's Space Dynamics Laboratory (SDL) to advance the development and calibration of optical sensors. The collaboration emphasized the calibration and characterization of satellite imagers and sensors important for defense and climate-change research.

NIST provided support to the Laboratory for Atmospheric and Space Physics (LASP) facility at the University of Colorado to calibrate a cryogenic radiometer built to measure top-of-the-atmosphere solar flux levels. Scientists designed the cryogenic radiometer to calibrate the Total Irradiance Monitor (TIM) instrument for measuring total solar irradiance.

NIST used its Low Background Infrared (LBIR) Facility to provide calibrations of infrared sources and test chambers for quality assurance for the Missile Defense Agency's (MDA's) testing of Exoatmospheric Kill Vehicle (EKV) units prior to deployment. The LBIR Facility also supported calibrations of the antiballistic missile defense hardware simulation test chamber being developed by MDA at the Arnold Engineering Development Center in Tennessee.

NIST supported the testing of calibrators for the near-infrared spectrograph (NIRSpec) being built by ESA and its contractors for the James Webb Space Telescope (JWST). NIRSpec will enable scientists to understand better the formation of stars, stellar clusters, and galaxies.

NIST hosted the Global Earth Observations (GEO) Committee on Earth Observation Satellites (CEOS) workshop for Quality Assurance of Calibration and Validation Processes. Nearly 70 scientists from around the world attended, and together they developed the guidelines for Quality Assurance for Earth Observations (QA4EO) for satellite sensors. The guidelines were submitted to

NASA, ESA, and NOAA for implementation. The effort will help advance the goals of the Global Space-Based Inter Calibration System (GSICS), led by NOAA.

NIST continued to collaborate with NASA, the U.S. Geological Survey (USGS), the University of Arizona, and Ball Aerospace on the calibration and validation of the Landsat Data Continuity Mission (LDCM). This collaboration helped ensure that measurements provided by the Operational Land Imager (OLI) are traceable to international standards.

In 2008, NIST's Manufacturing Extension Partnership (MEP) network of centers completed process improvement, waste reduction, environmental improvement, energy efficiency, and quality system implementation projects with 142 aerospace manufacturing companies. MEP Centers worked with aerospace prime companies, including United Technologies (Sikorsky Helicopter, Hamilton, and Pratt & Whitney Rocketdyne), Rockwell-Collins, and the Boeing Company, as well as the Aerospace Industries Association (AIA), to establish a better understanding of their future needs and serve their supply base effectively. Working through these prime companies and with partner agencies, MEP centers conducted projects that resulted in reduced supplier lead times and improved quality and on-time delivery.

NIST collaborated with members of NASA in FY08 on their Six Degrees of Freedom (6DOF) project in the areas of metrology and standards. The 6DOF project gives researchers a means to evaluate the performance of a real-time Vision Based Robot Control, a technique that uses feedback information extracted from a vision sensor to control the motion of a robot.

NIST, along with researchers from Boeing and Acumence, collaborated with the Organization for Machine Automation and Control (OMAC) on a demonstration of the implementation of the International Society of Automation standard ISA-88 to show how machine tools used in the discrete manufacturing industries could benefit from software that is easily adapted for machine tool analysis. The demonstration showed software technology suitable both for monitoring continuous/discrete manufacturing and for providing real-time manufacturing business intelligence.

MTConnect is a new low-cost machine tool integration standard sponsored by the Association for Manufacturing Technology. Spurred by demonstrations at the September 2008 International Manufacturing Technology Show, factory managers

at the Boeing plant in Auburn, Oregon, asked NIST to help bring this technology to their plant. NIST and Boeing worked together to integrate MTConnect into their plant using NIST-developed computer numerical control (CNC) data servers. They integrated the MTConnect technology with the Boeing Dashboard Web Service to allow easy monitoring of progress and delays in plant production for different original equipment manufacturer machine tools.

NIST leads the effort to promote the Quality Measurement Data (QMD) Specification to enable the seamless exchange of quality measurement information between disparate and proprietary gauges and reporting tools. This effort solves data integration problems by reducing as many as 1,500 data formats to one single, open reporting format. In FY08, NIST briefed members of the NASA Goddard Space Flight Center/Northrop Grumman manufacturing facility's metrology/inspection department on QMD and the role of interoperability in manufacturing quality.

Many of NASA's next-generation satellite observatories require new detectors with improved sensitivity and scalability. With funding from NASA, NIST developed new detectors that use a transition-edge sensor (TES). The TES improves the detection of electromagnetic signals from millimeter waves through x rays. NIST continued work in the development of Superconducting Quantum Interference Devices (SQUIDs) and SQUID-based multiplexers used to read out large arrays of detectors. In FY08, NIST provided SQUID systems to many researchers, both at NASA Centers (GSFC and JPL) and in academia (including California Polytechnic Institute; Stanford University; Massachusetts Institute of Technology; the University of California, Berkeley; Princeton University; and the University of Wisconsin), working on NASA-funded projects.

Over the last several years, with funding from NASA, NIST took several critical steps toward fielding even larger detector arrays (>10,000 pixels) in NASA missions. These included the development of dissipationless microwave SQUID multiplexers and code-division multiplexers. In combination, these steps will make it possible to read out many thousands of detector channels in a single coaxial cable. In FY08, NIST worked to optimize these devices and transfer this technology to its collaborators at NASA Centers and universities.

In FY08, NIST collaborated with NASA Goddard Space Flight Center to develop photo detectors for space applications. The current program focuses on

testing gallium nitride nanowires as the active photoemitter material for high-sensitivity imaging systems in the ultraviolet spectrum. A breakthrough in this detector technology will enable new experiments in ultraviolet space telemetry, including searching for Earth-like planets and testing theories of phenomena in the early universe.

NIST developed a test plan in conjunction with NASA to measure standards that support the Aquarius satellite program. Aquarius is a focused satellite mission to measure global Sea Surface Salinity (SSS). In addition, NIST measured a set of thermal noise standards used to calibrate some of the instruments aboard Aquarius. NIST initiated research in 2006 to study the feasibility of using temperature gradient focusing (TGF) and other chemical analysis methods developed at NIST to improve the performance of the Mars Organic Analyzer (MOA) currently in development at the University of California, Berkeley, and JPL. In 2008, the NIST team addressed the issue of sample complexity. To address this problem, the team developed a method to improve the MOA's ability to detect organic material.

To support the Orbiting Carbon Observatory (OCO) and Remote Sensing Applications, NIST provided NASA with high-accuracy reference spectra. The NASA OCO mission is an Earth-orbiting satellite designed to monitor contributions to the greenhouse effect by tracking sources and sinks of atmospheric CO_2 throughout the world. The measurement strategy employed by the OCO utilizes the oxygen A-band spectra to indicate the presence of clouds and optically thick aerosols that preclude full atmospheric column measurements of CO_2. Observations from this band also help scientists infer the total atmospheric pressure, as well as to measure the length of the path of solar radiation as it passes through Earth's atmosphere. Using its state-of-the-art capabilities in frequency-stabilized cavity ring-down spectroscopy, NIST provided the OCO project team with newly determined, high-accuracy spectral profile and intensity information for both oxygen and CO_2. These high-accuracy spectral line intensity and profile data will enable NASA scientists to achieve the required accuracy.

The presence of water on planetary bodies such as the Moon and Mars can be inferred from satellite-based measurements of high-energy neutrons that are created by the action of cosmic rays striking the planetary surface. The use of neutron optics can substantially increase the accuracy of these planetary neutron mapping

measurements. However, the high degree of polishing required for the various optical elements greatly increases fabrication costs. Scientists from the NIST Center for Neutron Research, working in collaboration with researchers from NASA Marshall Space Flight Center, completed neutron reflectivity measurements on a series of nickel-coated optical elements with varying degrees of surface smoothness in order to determine the minimum level of smoothness that is required for this application.

With strong NASA support, NIST continued the production of atomic spectroscopic data needed by space astronomers. To support NASA's space observatories for the vacuum ultraviolet (VUV), x-ray, and infrared spectral regions, NIST atomic data activities focused on the spectra of hydrogen, helium, sodium, magnesium, aluminum, silicon, argon, potassium, cesium, barium, boron, and other elements with relatively high cosmic abundance.

With NASA funding, NIST continued to expand the existing online numerical and bibliographic databases: Atomic Spectra Database (version 3.1.5), bibliographic databases on transition probabilities, spectral line broadening, atomic energy levels and wavelengths, and plasma kinetics databases containing benchmark computational results. These online databases and calculation tools facilitate the interpretation of observations carried out with NASA space observatories, including HST, the Chandra X-ray Observatory (CXO), the Far Ultraviolet Spectroscopic Explorer, and the Spitzer Infrared Observatory.

With funding from NASA, NIST renewed collaboration between the NIST Electron Beam Ion Trap team and the Harvard-Smithsonian Center for Astrophysics (CfA) Microcalorimeter team. NIST used instruments on the ground to create and observe exotic states of matter similar to those observed from space by orbiting observatories. This practice improves the scientific return from the multi-billion-dollar CXO, operated in orbit for NASA out of CfA, and helps design improved observational hardware for future x-ray astronomy missions. Spectra from highly charged states of iron, among the most prevalent and brightest observed from space, are produced under known and well-controlled conditions and studied using a combination of instruments from NIST and Harvard University. Analysis is under way to resolve discrepancies that have persisted for years between experiments from various groups, as well as between theory and experiments.

NIST initiated a new program called "NIST Stars" to improve the accuracy of spectral irradiance measurements of stars for applications in satellite remote sensing, nighttime aerosol monitoring, and dark-energy research. Collaborators include Harvard University (Panoramic Survey Telescope and Rapid Response System [Pan-STARRS] and Large Synoptic Survey Telescope [LSST]), California Institute of Technology (Cosmic Infrared Background Experiment [CIBER]), and Harvard-Smithsonian (Mount Hopkins Multi Mirror Telescope [MMT]).

NIST collaborated with NASA, NOAA, and San Jose State University in the construction of a prototype buoy for the next-generation marine optical system, which will eventually replace the Marine Optical Buoy (MOBY). MOBY helps calibrate ocean-color measurements performed by on-orbit sensors, including SeaWiFS and MODIS instruments. The next-generation buoy will use state-of-the-art technology to allow for simultaneous measurements of downwelling irradiance and upwelling radiance at various water depths, with hyperspectral capability. This capability will greatly improve the quality of ocean-color measurements from satellites by reducing sampling-time delays.

NIST supported the NASA Space Shuttle Program with electromagnetic shielding measurements. The current Shuttles are scheduled for retirement around 2010. NASA intended to replace the Shuttles with crewed Orion exploration vehicles in a program named Constellation. NASA and NIST worked together to develop a comprehensive test plan for the Constellation Program, and a key first step in the plan was to determine whether the Space Power Facility (SPF) Vacuum Chamber located at NASA Glenn Research Center (GRC) could be used as a reverberation chamber for testing the Orion vehicle. In FY08, NIST developed a test plan for the FY09 testing of the SPF chamber.

NIST worked with the Air Force, as well as industry and NASA, in fuels research geared toward developing alternative fuels and generating an understanding upon which to base innovative designs for jet and rocket propulsion systems. Two of the major foci of the work involved combustion kinetics and thermophysical properties. In particular, NIST evaluated properties of synthetic Fischer-Tropsch fuels and rocket/jet fuels.

To address the critical issue of the stability of thermal barrier coatings used to extend the high-temperature behavior of nickel-based superalloy turbine blades and

improve engine efficiency, NIST developed diffusion mobility descriptions for two ordered phases in the nickel-aluminum-chromium alloy system. These descriptions enabled improved modeling of the interdiffusion between bond coats and superalloys. In addition, NIST provided revised diffusion mobility descriptions for the nickel-based systems to support collaborators at QuesTek Innovations and GRC. Scientists used these results to model, validate, and predict the microstructural evolution of third-generation nickel-based disk superalloys, used in gas turbine manufacture, during heat treating and service conditions.

In 2008, NIST provided consultation to the Ground and Flight Systems Divisions on a NASA GSFC mission entitled Global Precipitation Measurement (GPM) for infusing certified algorithms (FIPS 140-1, 140-2 SHA) into their command authentication for their ground systems and flight software. NIST provided guidance for key management schemes for ground systems and for the Command Ingest subsystem for flight software. For the first time, NASA will be incorporating NIST-approved hash algorithms and key infrastructure schemes within a given mission.

NIST is currently working with GRC on spacecraft fire-detection research. Scientists designed ISS and Shuttle smoke detectors based upon Earth gravity test data and experience due to the lack of experimental data for spacecraft fires. The absence of or reduction in gravity has a significant impact on the smoke properties from a spacecraft fire. NASA and NIST developed the Smoke Aerosol Measurement Experiment (SAME) to characterize smoke properties from overheated spacecraft materials using a suite of aerosol measurement instruments and smoke-collection devices.

NIST collaborated with NASA, which sponsored research to examine material flammability. Scientists used numerical simulations of standard ground-based test methods to examine how test results may change if gravity, pressure, and oxygen levels are changed to simulate those characteristic of habitats on the Moon, Mars, or spacecraft. A NIST scientist went on a Shuttle mission to conduct, compare, and contrast the suppression of flames in normal gravity and microgravity. A better understanding of smoke characteristics in space will help improve fire detection in spacecraft.

With longer-duration human exploration missions to Mars, to the Moon, or on the ISS, the chances for an accidental fire increase. Despite excellent and useful

research designed to increase understanding of the behavior of laboratory flames in microgravity, virtually no work has been conducted to understand larger fires in space habitats. This lack undoubtedly results from the danger and difficulty in conducting such experiments. Work at NIST uses detailed numerical modeling to understand large fires in reduced-gravity conditions. In FY08, NIST made progress in five distinct areas: (1) discovering limitations to fire growth in reduced-gravity environments due to lower oxygen transport rates, (2) improving fire code predictive capability for solid material burning rates in normal and reduced gravity, (3) learning more about overall fire behavior in space habitation modules, (4) studying extinction in co-flow diffusion flames, and (5) using flame size as a method to determine the heat release rate from a flame.

NIST and DOD worked to improve the accuracy of optical signature measurements on ground and aerospace vehicles. NIST provides optical standards, measurement comparisons, and sensor characterizations to help assess and improve measurement accuracy. As part of this effort, NIST collaborated with the Signature Measurement Standards Group of DOD's Range Commanders Council to advance measurement quality and cosponsored a workshop with Utah State University's SDL on "Electro-optical and Infrared Calibration and Characterization."

International Trade Administration (ITA)

ITA's Office of Aerospace and Automotive Industries (OAAI) participated in the development of Administration policies on aeronautical research and development through the National Science and Technology Council's Aeronautics Science and Technology (AS&T) Subcommittee. In the beginning of FY08, the AS&T Subcommittee completed work on the "National Plan on Aeronautics Research and Development," which establishes research goals and objectives for Federal aeronautics research and development investments in priority areas. After President Bush signed the plan in December 2007, the AS&T Subcommittee initiated work on the associated "Technical Appendix to the National Plan for Aeronautics Research and Development." The technical appendix identifies Federal department and agency research investments related to the national goals and objectives and includes a preliminary assessment of current Federal R&D activities to identify areas of opportunity for potential increased emphasis, as well as potential areas of unnecessary redundancy. OAAI coordinated DOC

subject-matter expert contributions to the plan and technical appendix and supported outreach to non-Federal stakeholders on AS&T Subcommittee activities and progress.

ITA OAAI participated in the planning and implementation process for NextGen under the JPDO's management. OAAI staff continued to represent DOC on both the Global Harmonization Working Group (GHWG) and the Aviation Security Working Group. As part of the GHWG, OAAI staff participated in the drafting of the GHWG FY09 work plan to implement elements of the JPDO Integrated Work Plan. Also, OAAI staff supported the GHWG Executive Committee and cochaired the Liaison Standing Committee (which is charged with collaborating with the other working groups on technological and procedural developments with global implications). Further, OAAI staff coordinated the review of various JPDO documents, including the Avionics Roadmap and the Aviation Safety Information Analysis and Sharing (ASIAS) system proposal.

OAAI hosted a meeting and workshop for the Commercial Aviation Alternative Fuels Initiative (CAAFI). CAAFI is a public/private group sponsored by the FAA, the Air Transport Association of America, the Aerospace Industries Association, and Airports Council International-North America. The meeting facilitated interaction between airlines and energy companies so the two groups can plan for the development of alternative fuels for aviation. Attendees participated in a series of panel discussions with speakers from Government and industry and created roadmaps of the technical and commercial benchmarks for fuel development. One hundred thirty people participated in the meeting, including representatives from airlines, aircraft manufacturers, energy companies, pipeline companies, and the U.S. Government, as well as financiers. Though a majority of the companies participating came from the United States, some representatives also came from European, African, and South American firms.

In FY08, OAAI developed updated market and policy assessments for civil-use UASes. OAAI continued public outreach on UAS issues, including providing briefings to UAS companies about Government policies affecting domestic and international UAS markets.

OAAI continued its participation in aviation security activities, including work on the JPDO Aviation Security Working Group and on various aspects of the

implementation of the National Strategy for Aviation Security (NSAS [pursuant to NSPD-47/HSPD-16]). The JPDO nominated OAAI staff members to take part in the Standing Interagency Aviation Security Committee (SIASC), which was established to meet the requirements set forth by the NSAS. The JPDO has charged the SIASC with coordinating U.S. Government activities encompassing national aviation security, including the identification of conflicting procedures, the investigation of vulnerabilities and consequences, and the coordination of corresponding interagency solutions. Furthermore, OAAI participation in both the JPDO and NSAS-related activities reduced the likelihood that these interagency efforts will work at cross-purposes. Moreover, OAAI staff supported ITA participation in an interagency aviation security tabletop exercise to determine possible responses to (as well as the economic costs of) a man-portable air defense system (MANPADS) attack on a commercial airliner.

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

ITA OAAI continued to participate in the group on Sector Understanding on Export Credits for Civil Aircraft (the "Aircraft Sector Understanding") at the Organization for Economic Cooperation and Development (OECD). The governments of most countries with major aircraft manufacturers signed the OECD Arrangement on Officially Supported Export Credits, which establishes rules for export credit agencies. In combination with the annexed Aircraft Sector Understanding, the arrangement tries to ensure that government-provided export financing is not a competitive factor in civil aircraft sales competitions. The governments also reached a new Aircraft Sector Understanding in 2007. As a member of the U.S. delegation, ITA supported U.S. efforts to ensure the successful implementation of the new agreement. DOC hosted over 12 meetings and teleconfer-

ences with industry on this topic and will continue to consult with industry while the new understanding is implemented.

ITA OAAI continued its active participation in the implementation of the National Space Policy and other Federal space policies recently signed by President Bush. ITA ensures that U.S. industry's commercial interests continue to be adequately addressed during policy implementation actions and helps to create an environment to enhance the global competitiveness of U.S. industry.

OAAI continued to represent commercial remote sensing satellite industry interests within the Remote Sensing Interagency Working Group (RSIWG), led by DOS. The RSIWG coordinates policy for the export of commercial remote sensing satellite systems and negotiates government-to-government agreements that address the safeguarding of those systems' technologies. The RSIWG consulted with several foreign countries on satellite cooperation and met with industry representatives to understand the impact on industry.

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

In July 2008, ITA organized and supported DOC's participation in the Farnborough International Air Show and arranged senior-level meetings for the Deputy Assistant Secretary for Manufacturing with foreign government and industry officials, as well as U.S. industry executives. ITA OAAI met with numerous U.S. and foreign government and industry officials to discuss ongoing policy issues affecting the competitiveness of U.S. industry.

The OAAI Aerospace Team also participated in the sixth meeting of the U.S.-India High Technology Cooperation Group (HTCG) in New Delhi, India, on February 28, 2008. At the request of U.S. aerospace industry and trade association officials, the OAAI Aerospace Team Leader represented the interests of U.S. civil aviation manufacturers before senior members of the Government of India's Ministries of External Affairs and Science, Technology, and Earth Sciences, as well as Indian high-technology industry officials. During the meeting, the OAAI

Team Leader proposed the creation of a "civil aviation" committee to the group. The creation of a civil aviation-focused committee would allow the HTCG to address more effectively the improvement of bilateral trade in civil aviation goods through the identification and elimination of tariff and nontariff barriers to trade, as well as identifying and exploiting common U.S.-Indian strategic interests. The Government of India and industry representatives took under consideration the inclusion of a civil aviation committee in future HTCG meetings. They decided to schedule further discussion and a decision on the inclusion of a civil aviation committee for a future meeting of the HTCG.

In FY08, OAAI initiated an expansion of the collaboration between DOC and the Association of Unmanned Vehicle Systems International (AUVSI) to expand global sales by small and medium-sized UAS manufacturers. DOC experts provided export control regulation and "how to export" briefings to attendees of the AUVSI Annual Conference and Trade Show in June 2008 and also provided one-on-one counseling to attendees. Additionally, DOC assisted foreign attendees participating in the conference, leading a trade delegation from South Korea, and provided marketing assistance for the conference through DOC's global network of field offices.

The ITA U.S. and Foreign Commercial Service (US&FCS) recorded 169 export successes valued at over $5 billion in FY08. An export success is an activity in which DOC personnel effectively assist a U.S. company with identifying new international sales channels or resolving an issue that is hindering an export sale. Commercial Service (CS) personnel influenced deals with small and medium-sized companies, as well as larger corporations such as the Boeing Company, Lockheed Martin, Raytheon, and Northrop Grumman. The CS held over 800 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 CS participated in 38 domestic and international aerospace trade events at which CS Aerospace Team members supported U.S. industry with one-on-one counseling sessions, arranged individualized business-to-business meetings with international business partners, and provided additional export counseling services. ITA also sponsored Aerospace Products Literature Centers (APLCs) at several air shows, which offered low-cost, efficient venues for U.S. small to

medium-sized aerospace companies to explore international and niche aerospace markets. This ITA trade show support generated hundreds of trade leads for participating companies, allowing them to enter or expand their exports to international markets. These international trade events included the Dubai Air Show, Singapore Air Show, Farnborough International Air Show, and Africa Aerospace & Defence, among others.

Bureau of Industry and Security (BIS)

DOC's BIS provided greater regulatory certainty and predictability for exporters and reexporters of U.S.-origin aircraft and parts by revising and clarifying the regulatory interpretation of section 17(c) of the Export Administration Act. Section 17(c) sets certain criteria for determining whether an aircraft part or component is subject to the export control jurisdiction of DOS, which generally regulates exports of military items, or of DOC, which generally regulates exports of items having primarily commercial uses.

Department of the Interior

DOI

Remotely sensed data are important to the success of activities within the Department of the Interior (DOI) agencies. From traditional aerial photography to moderate-resolution Landsat satellite data and more specialized data collection systems, DOI personnel find remotely sensed data systems useful in evaluating land surface conditions over the vast areas for which DOI has responsibility. Access and applications of the data are often built on the longstanding partnership with NASA.

The various agencies within DOI and NASA frequently cooperate when remotely sensed data resources can be efficiently applied to problem solving. For example, active range and forest fires have caused damage to large areas of the country. DOI agencies have applied their combined talents and technical resources, especially remotely sensed data applications systems, to evaluate the impact of fires.

When individual fires have been identified and measured, a burn severity interagency team reviews the impact, extent, vegetation species affected, and critical habitat changed, and postfire recovery plans are developed from the evaluations.

The USGS, long known as an authoritative source of aerial photography and satellite-based imagery, has initiated new Earth observation work using Unmanned Aircraft Systems (UASes). In dangerous and remote areas, such as polar regions, volcanic islands, and expansive deserts, remote-controlled UAS technology provides more detailed and timely data about the status of natural resources and environmental conditions than would be feasible by any other means. In many cases, UAS technology proves to be a cost-effective way to gather Earth observation data for a wide variety of applications: managing Federal lands, investigating climate change, mapping and charting, conducting environmental risk assessments, and responding to and recovering from natural and human-induced disasters. UAS

technology is an effective alternative to piloted aircraft flights that may not be feasible at times due to long flight durations, hazardous weather conditions, and associated operations cost. Satellite-based observations can be hindered by coarse image resolution, limited sensor capabilities, and repeat orbiting cycles of days or weeks. The use of UAS technology allows flexibility in delivering timely data to support informed decision making. Furthermore, data collection by UAS can be specifically tailored to the required resolution and radiometric parameters of individual investigations. An important focus of this activity, working in partnership with many other Federal agencies, academia, and industry groups, leverages the commitment that the defense and intelligence communities have made in supporting UAS research.

During 2008, the USGS' Rocky Mountain Geographic Science Center responded to numerous requests to support the U.S. Forest Service's (USFS') Rapid Assessment of Values at Risk (RAVAR) project. RAVAR is a modeling effort that provides dollar estimates of values (structures, infrastructure, etc.) as well as assessments of nonmonetary values such as critical habitats that are threatened by a wildfire. When county-level parcel data are not available, the USFS' Missoula Fire Lab requests the USGS to examine existing imagery for the existence and location of structures. The National Agricultural Imagery Program's (NAIP's) photography served as the primary source of imagery. The USGS provided the locations of over 124,000 structures for over 275 1:24,000 scale 7.5-minute quadrangles to the USFS for analysis and use by the fire science community. The response time from request to data provision was normally around 5 hours, with anywhere from two to nine people working on a given request.

In the past 10 years, the average number of acres of forest and rangeland impacted yearly by wild land fire grew to over 7 million acres. The Geospatial Multi Agency Coordination (GeoMAC) application team integrates the following data: fire locations, provided by the National Interagency Fire Center in Boise, Idaho; wild land fire perimeters, collected by Geographic Information System (GIS) specialists at the fire; and daily input from the Moderate Resolution Imaging Spectroradiometer (MODIS) acquired from the USFS' Remote Sensing Applications Center (RSAC) in Salt Lake City, Utah. In addition to the fire data, GeoMAC also displays the Remote Access Weather Station data for hourly weather information. These data

layers are displayed interactively with traditional base mapping layers. Users are able to get the latest wild land fire information across the Nation in a consistent manner. Users are able to view an active wild land fire on a map in relation to where they are or where their property is located. MODIS data give the users a sense of where the fire is going. MODIS collects heat signatures from the fires; when these are displayed daily with the field-collected perimeters, the direction of the fire starts to emerge. GeoMAC averages 50 million user requests yearly. In 2008, researchers loaded nearly 6,000 fire perimeters into the application and made it available for downloading from a Web connection.

In the past decade, conifer forests in Colorado and many western states experienced widespread mortality from epidemic population outbreaks of insects such as the Mountain Pine Beetle. This condition may increase the risk of wildfire and other associated hazards and affect many key ecosystem services and social/economic values. The USGS used advanced remote sensing techniques at several scales to quantify forest mortality in Grand County—the epicenter of Colorado's outbreak and the source of much of the state's water supply. A preliminary classification employed the Civil Air Patrol's hyperspectral high-resolution (1-meter resolution) sensor to delineate several distinct stages of conifer mortality in a 3.5-square-kilometer study area around several major reservoirs. Additionally, QuickBird imagery (2.4-meter resolution) assisted in producing a fine-scale 5-meter vegetation cover and conifer condition assessment spanning Central-Eastern Grand County. This information, along with the locations of structures and critical infrastructure, updated the eight traditional USGS 1:24,000 topographic maps covering the area, which are widely used by emergency response personnel during events such as wildfires. Finally, the USGS utilized 30-meter Landsat data to produce a moderate-resolution conifer condition assessment spanning Grand County and is developing a statewide assessment using the same methods. Remote sensing specialists, forest ecologists, and entomologists from both the USGS and the USFS continue to collaborate in calibrating these assessments with forest and fuels data collected in the field and with the traditional aerial surveys conducted by state and Federal forest services. The use of remote sensing technology enabled analysts to quantify forest conditions and associated fire hazards—critical information for resource managers, emergency responders, and scientists alike—in a

more objective and repeatable manner and at a greater spatial scale than previous methods allowed.

The Office of Surface Mining Reclamation and Enforcement, Mid-Continent Region, Indiana Department of Natural Resources, and the Western Region Technology Innovation and Professional Services Program partnered with Southern Illinois University on the first phase of a pilot study to evaluate the feasibility of using remote sensing technology to develop a habitat assessment protocol for the endangered Indiana bat (*Myotis sodalis*). Phase one of this assessment technique used high-resolution satellite imagery along with geospatial applications to determine summer habitat quality in areas proposed for coal mining and areas reclaimed to forest. Combining this information with that collected through conventional ground-monitoring studies creates new opportunities to help ensure that regulatory decisions provide protection for endangered species while still meeting the demands of energy development.

The Astrogeology Team of the USGS is a national resource for the integration of planetary geoscience, cartography, and remote sensing. A major source of funding support for the Astrogeology Team's work comes from reimbursable projects funded by NASA, including continued involvement in the Mars Exploration Rovers (MER) mission whose twin rovers, Spirit and Opportunity, both surpassed 1,650 sols (Martian days) of surface operations in 2008. Since the rovers' landings in January 2004, USGS Astrogeology Team members led efforts to plan, acquire, archive, and interpret data from the rovers' cameras, principally the Microscopic Imager on the instrument arm, along with analysis of color Panoramic Camera data from rocks, soils, and active processes on the surface of Mars. The USGS also led the Science Operations Working Group to plan each day of rover operations alongside science team members throughout the world and engineers at the Jet Propulsion Laboratory. The Opportunity rover spent most of the year navigating inside the western rim of the 800-meter-diameter Victoria impact crater. While there, it analyzed the sulfate-rich, layered sandstones and extensively imaged the exposed, cross-bedded cliff faces. By the end of the year, Opportunity left Victoria to begin a 2-year trek to the southeast towards the 22-kilometer-diameter crater Endeavour. Spirit began the year driving across the 80-meter-diameter volcanic plateau known as Home Plate to reach its "winter haven" location. There, it spent the

Martian winter parked at a 30° northerly tilt to generate sufficient power through its solar panels to survive the winter. While parked, it completed a systematic observing campaign of the surrounding terrain in preparation for driving south once Martian spring arrived.

The USGS Astrogeology Team directly supported the testing, calibration, operation, and analysis of images acquired by the High Resolution Imaging Science Experiment (HiRISE) camera aboard the MRO. This camera provides the highest resolution images of Mars from orbit (approximately 30 centimeters per pixel) and is being used to certify future spacecraft landing sites for the Mars Science Laboratory rover, as well as to support numerous Mars science investigations. The USGS supported a major portion of HiRISE image processing and analysis software development in 2008. The USGS and the University of Arizona used this software to process high-resolution monochrome and color images acquired by HiRISE and to construct the highest resolution digital elevation models (DEMs) of Mars ever made. These DEMs have been the subject of many recently published studies of Mars. In addition, images of the terrain explored by the MERs (along with the rovers themselves!) served to guide the MER team in its journey.

USGS Astrogeology Team members continued their participation as Science Team Members on the NASA Cassini-Huygens Mission to Saturn and its moon Titan, including in the following ways: (1) continuing the investigation of lakes and larger seas of hydrocarbons around Titan's north pole; (2) following up 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, with more detailed studies of the time-evolution of the rotation to verify this theory; (3) beginning to systematically generate digital elevation models of Titan from stereo pairs of radar images to provide quantitative information about liquid transport, ice volcanism, and other processes; and (4) beginning the systematic production of Titan map products that will be archived in the NASA Planetary Data System in 2009, including image mosaics, topographic models, and maps of microwave emission and scattering properties relevant to understanding surface composition.

In 2008, DOI established a working group designed to foster and encourage the use of remote sensing data and technology and data applications within DOI. Among the group's responsibilities are providing operational and scientific

requirements for DOI and performing research, development, and training to promote and expand the range of uses of remote sensing and related products to meet DOI user needs.

In 2008, the USGS released the entire 36-year USGS Landsat archive. These data are of high quality, with limited cloud cover. The Web-based distribution system provided the user community with easier access to satellite images with acquisition dates ranging from 1972 to the day of the request. This Web-based distribution reflects a new paradigm of free Landsat data that will be expanded with the launch of the Landsat Data Continuity Mission (LDCM). LDCM launch is scheduled for December 2012. On March 1, 2008, Landsat 5 began its 25th year of operation, collecting data over the North American land mass. On April 15, Landsat 7 completed its 9th year of operation. The two Landsats, each designed to provide data for up to 5 years, continue to expand the 36+ year Landsat series of global observations. Landsat data remain a vital component used for monitoring wildfire mapping, crop identification, timber harvesting, and natural and anthropocentric changes to the land surface of the planet.

The USGS completed an initiative to improve access to the vast and diverse USGS aerial photography film collections stored within the USGS archives. Beginning in October 2004, the USGS systematically digitized its film collections using high-performance digital camera systems to create 400-dot-per-inch (dpi) medium-resolution imagery. Technicians digitized and stored over 6 million frames and then provided them to the public over the Internet. The medium-resolution digital imagery extends the digital record back to 1940, providing scientists with ready access to important land data. Combining this historical digital photography with Landsat and other satellite and aerial collections results in a powerful tool for understanding changes to Earth's land surface. Medium-resolution digitized imagery and the Landsat archive data are available online for free downloading through Earth Explorer (*http://earthexplorer.usgs.gov*) and the Global Visualization Viewer (GloVis) (*http://glovis.usgs.gov/*).

The USGS Mineral Resources Program developed a new remote sensing method using the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data for regional mapping of minerals typically associated with copper, gold, and silver deposits. Researchers used the data to create regional mineral

maps that cover over 1,500,000 square kilometers of Iran, southern Kazakhstan, and western Mexico. These maps contributed to an ongoing global mineral resource assessment.

USGS scientists and their counterparts in west African countries completed land use and land cover (LULC) maps of 12 countries, including LULC trends from 1972 to 2000. The national teams collaborated with the Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center in Niger, with support from the U.S. Agency for International Development (USAID), and used Landsat data to complete the two periods of maps of the Republic of Senegal, The Gambia, Guinea-Bissau, Guinea, Mauritania, Mali, Burkina Faso, Ghana, Benin, Togo, Niger, and Chad. Scientists produced a new tool, the Rapid Land Cover Mapper, to facilitate the land cover change analyses across large spatial areas and frequent time periods. For most countries, this is the first definitive effort to visualize and quantify LULC changes at national levels. The maps and the trends remain vitally important for showing the rapid pace of environmental change, especially in this region where the human population growth rate is among the highest in the world and where drought has an impact on both human and natural ecosystems. The maps and trends show many kinds of land cover change. Major agricultural encroachment into the region's savannas, woodlands, and forests results in the most common driver of change.

USGS scientists initiated a new activity in Guinea, Sierra Leone, and Liberia to monitor the threatened and highly biodiverse remaining forests in each country. Working with their African counterparts, USGS scientists are using a combination of historical and recent Landsat and high-resolution imagery to establish forest baselines, including extent and canopy cover conditions. Surrounding land uses and natural resource management practices are being mapped as well. The project helps USAID and other national Government agencies monitor quantitative changes in forest resources, biodiversity, land use practices, and successes in natural resource management.

USGS scientists collaborated with NASA, the United Nations Environment Programme (UNEP), the World Conservation Monitoring Center, the Joint Research Centre of the European Commission, the Food and Agriculture Organization of the United Nations, Arizona State University, and Global Observation of Forest and Land Cover Dynamics to map and monitor the

distribution and dynamics of the mangrove forests of the world from 1990 to 2005. This research is the first application of multitemporal Landsat data to assess and monitor global mangrove forest dynamics. For the first time, researchers will be able to prepare a wall-to-wall map of the remaining mangrove forests of the world using Landsat data. It is the first experiment to quantify the historical mangrove forest cover change and to identify major deforestation fronts, causes, and consequences worldwide.

The Bureau of Indian Affairs (BIA) accessed Landsat data from the USGS for many activities. The BIA processed and created a mosaic of the Fort Berthold Reservation to be used as the base layer for the Division of Energy and Minerals Resources. Mosaics created of reservations assisted in hybrid GIS products for land boundary use. High-resolution commercial imagery obtained from the USGS gave GIS programs the ability to create hybrid products. These hybrid products provide greater accuracy and a picture of what is actually on the ground versus a GIS product of perceived ground cover. Remote sensing data delineated natural resources providing acreages of various types of ground cover.

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. The technologies ranged from simple digital cameras to USGS-NASA satellites (e.g., MODIS, Landsat). During 2008, BLM's remote sensing efforts were concentrated in four primary areas: (1) fire mapping and rehabilitation monitoring, (2) rangeland monitoring, (3) vegetation and habitat mapping, and (4) surface disturbance mapping.

Aerial photography and orthoimagery remained the largest source of remote sensing data used at the BLM. Researchers used historical aerial photography to assist in determining the existence of roads prior to 1976 in an ongoing right-of-way legal issue in Utah. The BLM acquired and interpreted all existing dates of aerial photography to determine whether or not key roads and routes existed during certain time periods in the past. The BLM then submitted the data to the Office of the Solicitor General to be used as expert witness information in court.

The BLM undertook multiple photogrammetric projects in 2008. The Judith River and Arrow Creek projects highlighted the continued vital role photogrammetry plays in supporting the BLM's mission. The Judith River and Arrow Creek

projects produced very detailed terrain data covering a several-mile stretch of each tributary to the Missouri River. BLM hydrologists used these data to model stream flows, which ultimately enabled the BLM to quantify Federal reserved water rights for the Upper Missouri Breaks National Monument. The BLM used newly acquired digital aerial imagery at 3-inch resolution and image autocorrelation software to produce the digital terrain maps (DTMs) and digital stereo compilation environment to manually collect planimetric features and edit the DTM files.

Traditionally, and for 2008, fire-related activities remained the widest use of remote sensing data in the BLM. Most of the activities centered on infrared interpretation of active fires, postfire perimeter delineation, and vegetation classification for fire/fuel risk modeling and disturbance mapping. One example that highlights this traditional use included a collaboration between BLM Oregon State Office, USFS Region 6, and the Pacific Northwest National Lab (PNNL). Researchers used Landsat data to map annual forest disturbance intensity and type (e.g., harvest, fire, and insect outbreaks) throughout western Oregon and Washington between 1984 and 2007. These data will provide a foundation for future management actions.

Remote sensing remained a component of all assessment efforts and continued to play a major role in the implementation and monitoring phases of this project. Burned Area Reflectance Classification maps assisted in deriving detailed burn perimeters and the identification of interior unburned islands, mapping soil burn severity classes, and serving as a surrogate for vegetation mortality. Additional assessment information derived from Landsat data included a map of prefire annual grasses and an analysis of recovery patterns on how previously treated and untreated fires compared to the current fire. The combination of these derived datasets, plus some other inputs, enabled the creation of more accurate reseeding plans for contractors than are typically available to the BLM. This availability resulted in more accurate Government cost estimates and allowed the placement of the "burned-not seeded controls" required by the monitoring plan. Remote sensing also became a valuable tool for the implementation and monitoring phases of the project. Access to remote sensing imagery and analyses enhanced the selection of both seeding locations and sampling locations. Monitoring support was four-fold:

- Determining short-term vegetation recovery and seedling effectiveness for the burn area.
- Estimating annual grasses and perennial plant recovery.
- "Extending" the value of ground-truth data and displaying patterns.
- Laying the foundation for long-term mapping in the burn area.

In conjunction with the USGS, under the Central Region Integrated Science Partnership Funds (CRISP), the BLM participated in projects using high-resolution imagery (QuickBird) and moderate-resolution imagery (Landsat and the Advanced Wide Field Sensor [AWiFS]) to develop methodologies to identify and map species, cover, and height classes of sagebrush at multiple scales. The USGS has since applied these continuous field models to cover the entire state of Wyoming. These models represent continuous estimates (from 1 to 100 percent) of percentage of bare ground, percentage of herbaceousness (grass and forb), percentage of shrubs, and percentage of litter, which provide key inputs to allow better understanding of sage grouse habitat dynamics and the influences anthropogenic forces have on those habitats. The success of this new USGS mapping technique in Wyoming led the BLM to expand into other regions, not just to support habitat mapping, but to address a host of needs related to resource management planning.

The huge expansion of oil and gas development on public lands places extreme pressures on field offices within the BLM to track the impacts on the landscape. In response, the BLM attempts to better capture, quantify, and thus manage surface disturbance activities in order to understand how this development is affecting the landscape. Single projects by the USGS and the BLM in 2006 and 2007 developed protocols for delineating surface disturbance activities in oil and gas development regions using orthophotography and high-resolution satellite data. In 2008, the BLM implemented the procedures in field offices for doing this mapping. At least seven field offices (Rock Springs, Buffalo, White River, Glenwood Springs, Farmington, Pinedale, and Grand Junction) now employ or plan to employ imagery (aerial or satellite) and variations on the protocols developed by the USGS and the BLM to map and monitor these surface disturbance activities. The White River Field Office represents a prime example of how remote sensing and planning are being integrated to address a pressing management question.

LIDAR is an increasingly valuable tool that supports natural resource management activities. The BLM's Oregon and Idaho State Office actively pursued LIDAR projects to support multiple management needs. The Oregon/Washington BLM Office works as a partner in the Oregon LIDAR Consortium to acquire LIDAR data cooperatively within the state of Oregon. The BLM used these data for a variety of ongoing projects, including a silviculture program that used Landsat and previous LIDAR data covering the Panther Creek watershed as a test to create a process to capture timber stands for inventory purposes. The Landsat images provide species information and, combined with the LIDAR, will also provide density and timber volume information.

The National Park Service (NPS) has a long history and standing investment in remote sensing and GPS technologies. Today, a wide range of projects and programs have business requirements that utilize aerial and spaceborne platforms ranging from acquisition to applications and the use of imagery in reports and related products.

The NPS' Inventory and Monitoring (I&M) Program, Southwest Alaska Network, used a combination of high-resolution IKONOS imagery, Landsat data, and historic aerial photographs to quantify decadal changes in glacier ice cover (1973–2002) and to document land cover change (1955–2005) in three national park units. In addition, MODIS data assisted in documenting seasonal variation in lake ice and in calculating growing season metrics across the study region.

The Southwest Alaska Network, in cooperation with NASA, used Landsat data to quantify current glacial extent and changes in ice cover over a roughly 30-year period in Kenai Fjords, Katmai, and Lake Clark National Park and Preserve. Scientists used automated classification techniques and manual interpretation to delineate ice boundaries. In addition, the NPS and the USGS developed a baseline DEM for the Bear and Exit Glaciers using LIDAR data acquired through a partnership grant.

Under an Interagency Agreement with the USFS-Pacific Northwest Research Station, the Southwest Alaska Network developed methods for using Landsat data to detect changes in land cover in Lake Clark National Park and Preserve (1987–2005), including loss of tree cover due to fire or insect outbreaks, shrub establishment on glacial outwash and/or abandoned river channels, and pond drying.

The new analytical approach resulted in more stable and thematically consistent labels for changes occurring on the landscape and better integration of information from the existing land cover maps. Additional funding from NASA supported the analysis of scenes from Katmai National Park and Preserve.

Evaluating approximately 423,952 acres of parklands, researchers generated wild land fire burn severity products from Landsat data for 18 fires that occurred between 2005 and 2007 within Alaska national parks. Resulting data products included burn severity datasets and detailed fire perimeters, which NPS distributed to park staff and public users.

A University of Colorado research team, in coordination with the Alaska Arctic Inventory and Monitoring Network, continued to assess rates of coastal erosion and accretion along the shores of Bering Land Bridge National Preserve and Cape Krusenstern National Monument. The team used repeat aerial photography with time series from the 1950s, 1980s, and 2003, as well as IKONOS satellite imagery, to determine coastline changes. The project will assist NPS in developing protocols to continue acquiring aerial photographs and satellite imagery for long-term monitoring of the coastline. Significant changes to the 450 kilometers of coastline along the park shorelines became evident by comparing the imagery. These changes affect animal habitat, water, soil, permafrost, and other aspects of coastal ecosystems, cultural resources, and local communities.

NPS Yellowstone National Park staff used a temporal series of high-resolution (1-meter resolution or less) imagery and Landsat-derived Normalized Burn Ratio products to delineate stand-replacing fire effects from 1988 to the present in Yellowstone National Park. The park purchased 1,600 square kilometers of QuickBird 2-foot-resolution imagery along road corridors and developed areas. This imagery will be used for multiple park projects, including updating buildings, roads, utilities, vegetation, and trails in GIS data layers. Since high-resolution imagery became the de facto background base map for park operations maps, the QuickBird imagery will also be used as background imagery for cartographic products.

Starting in 2005, the NPS became DOI's sponsoring agency for the Monitoring Trends in Burn Severity (MTBS) project as a joint venture between DOI and USFS with the USGS and the USFS Remote Sensing Application Center (RSAC) responsible for the project. MTBS maps all wild land and prescribed fires greater

than 1,000 acres in the West and 500 acres in the East from the present back to the early 1980s.

The NPS continued a longstanding use and demand for imagery-derived products to support the vegetation inventories on 270 national parks. The list of ongoing projects can be viewed at the collaborative project Web site: *http://biology.usgs.gov/npsveg/*.

During 2008, the USGS completed two studies documenting historic and contemporary coastal erosion rates along a portion of the Beaufort Sea Arctic coastline. To conduct this study, researchers combined high-resolution imagery collected from aircraft and satellites with Differential Global Positioning System (DGPS) data collection along the coastline at numerous times during 2007 and 2008. The combination of these high-resolution spatial and temporal data sources allowed staff to characterize trends in coastal erosion from 1955 to the present. Between 1955 and 1979, erosion rates along this portion of the Beaufort Sea coast averaged 22 feet per year. Between 1979 and 2002, erosion rates increased to 28 feet per year. Since 2002, erosion rates accelerated, averaging nearly 45 feet per year. During this most recent 6-year period, erosion rates also became more uniform across the study coastline, partially accounting for the rapid increase. Between mid-July 2007 and the end of August 2008, scientists measured local erosion as high as 60 meters through repeat DGPS surveys of the bluff line. Changing arctic conditions resulted in substantial increases to the erosion of this northern coastline. Concurrent arctic changes potentially responsible for this shift in the rate and pattern of land loss include declining sea ice extent, increasing summertime sea surface temperature, rising sea level, and increases in storm power and corresponding wave action. Taken together, these factors may lead to a new regime of ocean-land interactions that are repositioning and reshaping the Arctic coastline. Implications associated with these recent trends towards accelerated coastal erosion seem numerous. As large portions of the Arctic become targeted for additional hydrocarbon development, it will be very important to maintain this monitoring program as more knowledge of the changes in the patterns and rates of coastline erosion will be needed to develop appropriate strategies and structures for onshore and offshore development.

Studies indicated that shrub cover may be increasing across the Arctic, and this activity likely holds important implications for hydrology and habitat at the

local to regional scales and might impact global climate by decreasing albedo across the Arctic. The primary aim of an additional study will determine which remotely sensed datasets are most effective for mapping shrub cover in the Arctic at a moderate spatial resolution (approximately 250 meters). During the summer of 2008, researchers collected shrub canopy density measurements along 61 transects covering a 90- by 12-kilometer swath of IKONOS imagery extending from the northern Brooks Range foothills to the southern edge of the Arctic Coastal Plain. Preliminary results indicated that Landsat and Multiangle Imaging SpectroRadiometer (MISR) datasets seem most useful for mapping shrub canopy in the Arctic. Finer spatial resolution appeared to be more important for accurately mapping shrub cover than additional spectral, angular, or temporal information, even for coarse resolution mapping applications. Multispectral data seemed substantially more useful for mapping shrub cover than multiangular or multitemporal data, though combining the multispectral and multiangular data from MISR does boost accuracy slightly above that obtained by using MISR multispectral data alone.

For several years now, the USGS Upper Midwest Environmental Science Center has used a combination of Next Generation Weather Radar (NEXRAD) data, land cover data, ground-based surveys, and bird-banding projects to compare movement patterns, species composition, and habitat associations of migratory birds in the Upper Mississippi River floodplain and adjacent uplands. These results help resource managers optimize locations for energy projects, telephone towers, and habitat restoration projects.

The Bureau of Reclamation's (BOR's) Water Conservation Group within the Lower Colorado Region used high-resolution aerial imagery to update digital agricultural field boundary databases and to map vegetation crown closures in phreatophyte communities along the Lower Colorado River. Medium-resolution Landsat data contributed to mapping crop types and open water surfaces in the same area. All data went into computing consumptive water use along the Lower Colorado River.

The Remote Sensing and Geographic Information Group (RSGIG) with BOR's Denver Office mapped agricultural evapotranspiration in western Colorado using an energy balance approach that utilized a time series of Landsat satellite imagery acquired over a growing season. The resulting evapotranspiration map will be an

input used to estimate total consumptive water use within the Upper Colorado River Basin.

RSGIG personnel also used high-definition video and digital multispectral still images acquired from a helicopter to map in-stream habitats and invasive vegetation species along the Yampa, Green, Colorado, Gunnison, and San Juan Rivers within the Upper Colorado River Basin. Maps of in-stream habitats obtained from imagery acquired at different river discharges are used to identify river flow regimes that favor the survival of endangered fish species, and maps of invasive vegetation species are used to monitor their spread and plan control efforts.

The U.S. Fish and Wildlife Service (FWS) uses a diverse set of remotely sensed data, from traditional aerial images to satellite radar, and GPS technology to support a wide variety of mission activities including wetland inventory and mapping, habitat and vegetation mapping, fish and wildlife population monitoring, habitat assessments, data and map verification and updating, trend analysis and other models, climate change mapping, strategic habitat conservation (SHC), and management plans. The Multi-Resolution Land Characteristics (MRLC), which include the Landsat dataset and National Land Cover Dataset (NLCD), and NAIP remain widely used in the FWS to support many of these activities. As one example of the diversity of remotely sensed data applications, this year marks the 50th anniversary of using aerial observers for waterfowl surveys. The following examples of current applications using remote sensing and GPS do not include the enormous amount of time and effort spent on processing and analyzing these geospatial image datasets.

The FWS serves as the lead Federal agency for the Office of Management and Budget's (OMB's) Circular A-16: "National Spatial Data Infrastructure (NSDI)," wetland data theme section. NWI began over 30 years ago by mapping wetland types using USGS spring, leaf-off, high-altitude, black-and-white/color infrared (CIR) aerial photographs using the Cowardin classification system. Currently, NWI uses a variety of state or local government-acquired spring, leaf-off, CIR aerial digital imagery to inventory and update wetland maps. NWI also uses U.S. Department of Agriculture (USDA) NAIP imagery in some update projects; however, NAIP imagery is not ideal because the images are taken in midsummer (leaf-on). For the upcoming 2010 national wetlands status and trends report, NWI acquired aerial imagery and some high-resolution satellite imagery for this past

year to map wetland changes on plots scattered across America. The National Geospatial-Intelligence Agency (NGA) also supplied high-resolution commercial imagery in scattered project areas throughout the country where current commercial-ready sources were not available. The 2008 Intergovernmental Panel on Climate Change's (IPCC's) "Climate Change and Water Technical Paper" considers wetlands to be the most vulnerable habitat subject to climate change. As a result, the need to map and monitor wetland habitats has substantially increased, not only for habitat and landscape planning, but also for assessing climate change impacts on fish, wildlife, and human resources.

The FWS Midwest Region started work using Phased Array type L-band Synthetic Aperture Radar (PALSAR) and RADARSAT imagery for improved wetland extent delineation and water elevation change mapping in collaboration with the Canada Centre for Remote Sensing (CCRS) and the Michigan Tech Research Institute (MTRI). The Midwest Region also worked with the City of St. Paul and with Airborne Data Systems to demonstrate near-real-time, 1-foot, multispectral imagery and three-dimensional (3-D) images for city land use planning. The FWS Midwest Region used aerial photography, GPS, and aerial surveillance to support wildlife counts (e.g., waterfowl, deer, bald eagles), law enforcement, land use surveys, fire assessments, easement violations, and fisheries and wildlife habitat management, as well as for radio telemetry tracking of wildlife and fish. The Midwest Region Aviation Program acquired aerial photographs for 17 National Wildlife Refuges (NWRs) and the Northern Prairie Pothole Region. Using this information, the Midwest Region developed terrestrial and aquatic vegetation maps and analytical reports for refuges for use in Comprehensive Conservation Plans. With support from the USFS, the Midwest Region also mapped Oak Wilt disease areas at Sherburne NWR from 2008 CIR aerial photographs. The Midwest Region collected historical aerial photograph film stored for over 50 years at FWS field offices, scanned and georeferenced the scans, and sent the film to the USGS for permanent archiving. The scope of aerial photograph and surveillance missions will continue to expand (including the purchase of a medium-format airborne digital camera system) in the Midwest Region with missions on the Upper Mississippi River for the development of land use/land cover data for the navigable portions of the Upper Mississippi River Basin.

The Gulf Coast Joint Venture (GCJV) used a combination of aerial photography and satellite imagery for developing habitat models for priority bird species along the western Gulf Coast. The GCJV used both USGS digital orthophotographs and USDA NAIP orthophotographs for estimating the amount of available foraging habitat for wintering waterfowl in emergent coastal marshes. Landsat data helped model redhead ducks for protection and enhancement ponds based on available shallow shoal grass, distance to freshwater basins from foraging sites, and degree of isolation and permanence. The GCJV also used Landsat data to develop estimates of seasonal surface water on agricultural landscapes for wintering waterfowl and fall migrating shorebirds.

Federal Communications Commission

FCC

The Federal Communications Commission (FCC) formulates rules to facilitate the provision of commercial satellite services in the United States. It also issues licenses for the launch and operation of all nongovernmental U.S. satellites. Internationally, the FCC coordinates satellite radio-frequency usage with other countries. The FCC's activities in FY08 related primarily to commercial communications satellites and Earth observation satellites.

The FCC took two significant actions in rule-making proceedings in FY08. In one proceeding, the FCC modified the rules concerning the use of radio-frequency spectrum in the 1.6- through 2.4-gigahertz frequency range to provide for an equitable distribution of frequencies between the two currently operating systems. For one of the two systems, the FCC also increased the amount of 1.6- through 2.4-gigahertz radio-frequency spectrum available for services provided using terrestrial stations integrated into the satellite service offered to consumers. The FCC also modified the licenses for the two systems to implement both decisions.

On February 21, 2008, the FCC modified licenses held by the satellite operator Intelsat. The modifications added certain conditions to Intelsat's space station licenses, as requested by the U.S. Department of State, in consultation with the National Telecommunications and Information Administration. The U.S. Department of State requested that the FCC design the conditions in order to promote the fulfillment of U.S. obligations under an international agreement and to promote the fulfillment of U.S. foreign policy objectives.

The FCC's second Annual Report to Congress on the state of competition in the communications satellite services industry examined information from

calendar year 2007. The FCC found effective competition in the six wholesale and two retail satellite services markets addressed, despite increasing concentration in some market segments. The FCC concluded that the consumers of communications satellite services continue to realize significant benefits in terms of service choice, innovations fostered by technological change, and improvements in both space and ground segments, as well as improvements in service quality.

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

- October 4, 2007: To DG Consents for a nongeostationary remote sensing satellite.
- October 18, 2007: To PanAmSat for a geostationary satellite planned for the longitude 123° west orbit location.
- January 11, 2008: To EchoStar for a geostationary satellite planned for the longitude 110° west orbit location.
- March 12, 2008: To EchoStar for a geostationary satellite planned for the longitude 61.5° west orbit location.
- March 21, 2008: To Orbcomm to construct, launch, and operate 24 new satellites to replenish and enhance its nongeostationary mobile satellite system. The satellites include equipment for monitoring Automatic Identification System (AIS) channels. AIS is a shipboard broadcast system that transmits a marine vessel's identification and position to aid in navigation and maritime safety.

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

- October 31, 2007: The FCC granted Intelsat authority to transfer control of the Intelsat 601 satellite to a German subsidiary, which would operate the satellite at the longitude 47.5° east orbit location under a German authorization.

- March 28, 2008: The FCC granted PanAmSat authority to operate the SBS-6 satellite at the longitude 80.9° west orbit location, consistent with satellite coordination arrangements with Argentina.

The FCC added two non-U.S.-licensed space stations to the Commission's permitted space station list in order to allow these space stations to provide domestic and international satellite service to U.S. Earth stations that have routine technical parameters. Specifically, on August 6, 2008, the FCC added the United Kingdom's AMC-21 space station to its permitted list for Ku-band frequencies. On February 7, 2008, the FCC added the Brazilian Star One C5 space station 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 as listed below:

- March 27, 2008: Satamatics, Skywave Mobile, Stratos, and Vizada received permanent authorization to use multiple terminals in L-band frequencies to access the United Kingdom's Inmarsat 4F2 satellite at the longitude 52.75° west orbit location.
- July 28, 2008: EchoStar received authorization to deploy terminals to receive direct-to-home service from the EchoStar 6 satellite, licensed by Canada to operate at the longitude 72.7° west orbit location.

The FCC also remained active in international satellite coordination. In the first quarter of FY08, the FCC reached a total of 43 Administration-to-Administration Coordination Agreements for U.S. networks with the United Kingdom, Pakistan, South Korea, and Luxembourg. In the second quarter of FY08, the FCC reached a total of 32 Administration-to-Administration Coordination Agreements for U.S. networks with the Netherlands. In the third quarter of FY08, the FCC reached a total of five Administration-to-Administration Coordination Agreements for U.S. networks with Malaysia.

U.S. Department of Agriculture

USDA

As the primary research agency for the U.S. Department of Agriculture (USDA), the Agricultural Research Service (ARS) conducts research to solve problems affecting food and fiber production, including water, air, and soil quality issues. ARS collaborates with NASA in partnership with other USDA agencies (Natural Resources Conservation Service [NRCS], Risk Management Agency [RMA], World Agricultural Outlook Board [WAOB], Foreign Agricultural Service [FAS], National Agricultural Statistics Service [NASS], and Animal and Plant Health Inspection Service [APHIS]) to develop technologies that will help the agencies carry out their missions. Partnerships with other Federal agencies, universities, industry, and state governments also remain important to ARS research.

ARS conducted remote sensing research to develop technologies for the management of water and soil resources, crop production, and rangeland resources, as well as for understanding the impact of changing climate on managed and natural ecosystems. The sensor systems included satellite systems, airborne systems including UAVs, on-the-go sensors mounted on field equipment, and other ground-based systems.

Water quality and quantity management continued to be the largest area of emphasis for ARS remote sensing activities. Researchers demonstrated that thermal infrared (TIR) data could be used to map evapotranspiration and plant moisture stress from scales ranging from within-field to continental. ARS scientists have also shown that TIR and multispectral visible, near-infrared, and shortwave infrared data could be used to schedule irrigation, perform spatially variable irrigation, map drought, estimate soil moisture, and estimate vegetation canopy water content.

Further research into more efficient fertilizer applications using remote sensing of crop nitrogen status will reduce excess fertilizer losses to the environment, thus leading to improved water quality and better economic returns to farmers.

ARS also researched the remote sensing of invasive weeds as a tool for managing rangeland and understanding the impacts of changing climate. Researchers developed a prototype rangeland decision support tool for public land management incorporating remote sensing for access via the Internet.

Scientists researched the management of soil resources using remotely sensed information via projects to map crop tillage practices, crop residue cover, and soil carbon. These applications remain important for conserving soil and water, sustaining soil quality, and sequestering carbon. Soil moisture retrieval research continued through the development of algorithms for the retrieval of soil moisture from aircraft and satellite sensors. Wetland assessment using radar remote sensing is being developed as a tool to better understand and manage the fate of agrochemicals and sediment.

ARS developed a data assimilation system for merging land surface information from models and remote sensing into a single enhanced estimate of land surface variables including root-zone soil moisture, stream flow, and evapotranspiration. The data assimilation technique can enhance the value of remote sensing retrievals for monitoring key environmental variables, as well as improved precipitation estimates from numerical weather prediction models.

ARS continued to work with Utah State University to develop a LIDAR system for measuring particulate matter emissions to the atmosphere from agricultural sources. The system enables whole-facility mapping of emissions from animal, crop, and postprocessing facilities. As a tool, airborne LIDAR allows researchers to map riparian vegetation species and provide estimates of plant canopy characteristics that can be used to estimate the water use of semiarid riparian systems.

ARS scientists also contributed to the development of the next generation of satellite remote sensing systems through LDCM and the Soil Moisture Active-Passive (SMAP) mission.

As the extramural research arm of the USDA, the Cooperative State Research, Education, and Extension Service (CSREES) primarily provides financial assistance, in the form of grants, to conduct high-priority agricultural research and

education. The CSREES awarded many grants that used NASA data products to solve complex, environmentally related problems on topics such as water use, forest carbon management, air quality, and invasive species. A few examples of these topics supported by CSREES that used NASA data products include the following:

- Validated estimates of evapotranspiration from satellite imagery to develop subsurface drainage technologies for improved crop production.
- Provided information for making decisions about which options for managing carbon sources and sinks are observable and quantifiable with remote sensing data in northeastern U.S. forests.
- Developed a method for determining the extent, timing, and total combusted biomass of rangeland burns in the Flint Hills of Kansas (used MODIS remote sensing data).
- Examined how biochemical differences among invasive and native species may explain invasive species' success across environmental gradients and how this biochemical information can be used to identify invasive species' distribution and spread using remote sensing techniques.

The CSREES also funded long-term studies in Mississippi, Kentucky, Alabama, and Wisconsin that utilized 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 several geospatial extension programs at land-grant, sea-grant, and space-grant institutions with NASA's SMD. These geospatial outreach programs have continued to operate after the funding terminated to help train local and regional technologists in the use of NASA data products and geospatial technologies. By leveraging the ongoing coordination in these state geospatial programs in the realm of geospatial technologies (e.g., interoperability, standards, metadata, and architecture), 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 and shared more broadly with the public.

The Farm Service Agency (FSA) administers and manages farm commodity, credit, conservation, disaster, and loan programs as laid out by Congress through a network of Federal, state, and county offices. Geospatial data play a fundamental role in the management of FSA's programs. The agency maintains a nationally

consistent geospatial dataset representing farm and field boundaries known as Common Land Units (CLUs). FSA uses CLUs, digital soil surveys, 1-meter imagery, and other datasets for program implementation, management, and monitoring, as well as for response and recovery efforts during natural disasters. For example, FSA used remotely sensed data to determine the agricultural impacts of the 2008 Midwest floods and to support allocations of over $45 million of Emergency Conservation Program funds to restore agricultural lands damaged by the flooding. FSA also used remotely sensed data in ongoing reforestation efforts associated with the aftermath of Hurricane Katrina and other Gulf Coast hurricanes. In South Dakota, FSA used imagery and other datasets to identify land use conversion of rangeland/pastureland to cropland. Record high prices for corn and other agricultural commodities precipitated this land conversion.

As the primary source of aerial imagery for the USDA, FSA administers the National Agriculture Imagery Program (NAIP), leveraging partnership funds from other Federal, state, and local entities to acquire imagery during the agricultural growing season over the continental United States. In 2008, FSA acquired imagery over 20 states across the Nation. This imagery, as well as a large imagery archive, remains available to the public through the USDA Geospatial Data Gateway.

The Foreign Agricultural Service's (FAS') Office of Global Analysis (OGA) 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 Satellite Imagery Archive (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 satellite remote sensing program remained a critical element in the 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 in regions such as Central Asia and the Middle East.

The FAS exploited many global imagery datasets, including vegetation health products from the University of Maryland and NASA, while continuing to purchase most of its satellite data from the commercial industry. The FAS continued

to rely on Earth observations from the commercial sector and the international community while supporting the U.S. Government space agencies and DOD through cooperative agreements in which FAS 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.*

The U.S. Forest Service (USFS) 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 wild land fire mapping products daily for the Continental United States (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 USFS posted these products on the Internet at *http://activefiremaps.fs.fed.us*, where they were accessible to national fire managers and the general public.

More than 2 million users accessed the MODIS Active Fire Maps Web site during 2008. The MODIS fire mapping products provided the interagency fire community with a synoptic view of the wild land fire situation; this view aided in the strategic allocation of firefighting resources and assets throughout the country. A collaborative effort with NASA Goddard Space Flight Center (GSFC) and the University of Maryland has 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 USFS also continued to work with NASA 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 datalinks, UAV development, and mission profiling for tactical wild land fire mapping.

The USFS and ARC collaborated on significant flight demonstrations in 2008. In July and August, a General Atomics Reaper-class aircraft (named *Ikhana*) flew several scheduled missions covering California and Oregon. The missions 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 6 to 10 hours. These flights resulted from a collaborative effort between RSAC, ARC, NASA Dryden Flight Research Center, and the National Interagency Fire Center. Due to the success of this partnership, the USFS is actively incorporating many of the technologies demonstrated on board the *Ikhana* aircraft.

During FY08, 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 as inputs for GIS. NASS uses remote sensing data and techniques to improve the accuracy of its statistics. For example, NASS used Landsat imagery, digital NAIP orthophoto quadrangles, and other remotely sensed inputs for CONUS and Puerto Rico to select the yearly area-based samples for the June Agricultural Survey. In addition, NASS constructed new area-based sampling frames in Louisiana and Oklahoma and converted Montana and Wyoming data from paper to digital format. All area sampling frames in the conterminous states have now been converted to digital GIS format.

The remote sensing acreage estimation project used Resourcesat-1's Advanced Wide Field Sensor (AWiFS) and NASA MODIS data to produce crop acreage estimates for major crops at the state and county levels for 19 Midwestern and Mississippi Delta states for the 2008 crop year. The FAS SIA provided the AWiFS imagery through a cooperative partnership. Researchers derived remote sensing-based acreage estimates from a crop-specific land cover categorization called the Cropland Data Layer (CDL). The ground truth for building the CDL came from the FSA CLU program over the agricultural domain, while the U.S. Geological Survey's National Land Cover Dataset, circa 2001, provided the nonagricultural ground truth. NASS provided acreage estimates in season during the 2008 crop year for select winter wheat states in the June Agricultural Survey and for the

major corn- and soybean-producing states in the official August and October Crop Production Reports. Because of the improved timeliness, the NASS Agricultural Statistics Board used the remote sensing estimates when setting the official estimates. In addition, NASS distributed the CDL for each of the completed states to users for the previous 2007 crop season on DVD and via the USDA Geospatial Data Gateway Web site.

NASS utilized MODIS, Landsat, and AWiFS satellites to help mitigate the flooding impacts in the Midwest during June 2008. The satellite data assisted in determining areas affected by the flooding while the June Agricultural Survey remained ongoing. NASS identified the flooded areas and selected a subsample of farm operations for re-interview. The satellite imagery plotted the physical locations of respondents and nonrespondents to show no geographic difference between respondents and nonrespondents. This result allowed the Agricultural Statistics Board to incorporate major natural disaster effects in the June Acreage Report released on June 30.

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 Illinois, Indiana, Iowa, Minnesota, and Nebraska. The Agricultural Statistics Board utilized estimates from this algorithm when setting the official September and October yield estimates for these states.

The Economic Research Service (ERS) used a host of derived datasets, such as the USGS National Land Cover and Global Land Cover datasets, to quantify domestic and international agricultural efficiency and to track environmental responses to changes in agricultural markets and policies. These activities included assessing land use change in response to the rapid rise in ethanol production and commodity prices. The ERS also used USDA imagery-derived products, such as the FSA Common Land Unit and Conservation Reserve Program boundaries, the NRCS detailed soils database, and NASS survey area frames and cropland datasets, to support a host of research projects informing natural resource agricultural policy decisions. Through the ERS farm- and field-level survey program, the ERS collected and tabulated information on farmer usage of remote sensing and GPS technologies.

National Science Foundation

NSF

The National Science Foundation (NSF) continued to serve as the lead Federal agency for the support of ground-based astronomy. Through the Divisions of Astronomical Sciences, Atmospheric Sciences, and Physics, as well as through the Office of Polar Programs, 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 Sun and planetary system, as well as Earth's atmosphere and space environment.

Division of Astronomical Sciences (AST)

AST 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 remain accessible to the community on the basis of scientific merit. 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). 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—and provided the United States' share of support for the program.

In partnership with Europe, Canada, Japan, and Taiwan, construction continued on the Atacama Large Millimeter/submillimeter Array (ALMA), an interferometer located near San Pedro de Atacama, Chile. FY08 saw the arrival of further antennas at the mid-level (9,000-foot elevation) site in Chile, now comprising a total of 11: 7 from the United States and 4 from Japan. Acceptance testing of the first two antennas by the ALMA Project is close to completion. The two antenna transporters arrived at the Atacama site to move antennas around the mid-level site. Workers installed the first quadrant of the digital correlator inside the high-site (17,000-foot) technical building. The first two cryostats containing preproduction receivers arrived in Chile, and workers installed one unit, along with the photonic and digital electronics systems, in an antenna.

AST continued support for the development of the Advanced Technology Solar Telescope (ATST), the next-generation U.S. ground-based solar telescope. The ATST, a collaboration of scientists from 22 institutions representing a broad segment of the U.S. solar physics community, previously recommended as a moderate-sized project by the National Research Council of the National Academy of Sciences. In FY08, the ATST passed a comprehensive Preliminary Design Review and was deemed ready by the National Science Board for inclusion in a future budget in NSF's Major Research Equipment Facilities Construction queue. The ATST project, with oversight by NSF, will conduct a Final Design Review in the spring of 2009 and will publish the final Environmental Impact Statement in the summer of 2009.

In FY08, AST continued to fund a 4-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 3°. In addition, the LSST would use a 3-gigapixel camera to image the entire accessible sky repeatedly, producing approximately 20 terabytes of data nightly. The science goals of the LSST project span the fields of cosmology, galactic structure, and solar system astronomy. The LSST would undertake both a census of distant (trans-Neptunian) solar system objects and surveys of near-Earth and potentially hazardous asteroids. Over a 10-year lifetime, the LSST would provide a 90-percent-complete sample of potentially hazardous objects with diameters greater than 250 meters and an 80-percent-complete sample of those with diameters down to

140 meters. The University of Arizona's Steward Observatory Mirror Lab is fabricating the 8.4-meter-diameter primary/tertiary mirror using funds donated from private sources.

AST continued its support for the construction and commissioning of the Atacama Cosmology Telescope (ACT), a new 6-meter-diameter millimeter-wave telescope located at 5,200 meters (17,000 feet) on Cerro Toco in the Atacama Desert of northern Chile, near the ALMA site. It is designed to measure minute variations in intensity of the cosmic microwave background (the radiation at microwave wavelengths that is a remnant of the Big Bang) to study how the universe began, what it is made of, and how it evolved to its current state. ACT is a dedicated special-purpose telescope and is equipped with a state-of-the-art customized camera with over 2,500 detectors cooled to a third of a degree above absolute zero. During FY08, scientists completed, debugged, installed, and operated the millimeter-wavelength camera at the telescope. ACT became fully operational in August 2008 and obtained measurements that span size scales on the sky two to three times finer than those of any previous experiment. When analyzed completely, the data will provide new insights into the early history and structure of the universe.

Division of Atmospheric Sciences (ATM)

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) midsize jet aircraft. The GV is FAA-certified to operate at 51,000 feet. Its ability to fly for a long duration (over 12 hours), its range (over 6,000 kilometers), and its scientific payload capacity (6,000 pounds) enabled scientific research heretofore not possible with existing U.S. research platforms. The GV is the most advanced airborne research platform in the U.S. civilian fleet. The German Aerospace Center (DLR) recently completed modifications to and instrumentation of a Gulfstream 550 that can "partner" with NSF GV. In FY08, the GV performed the first of several long-duration flights for the HIAPER Pole to Pole Observations (HIPPO) deployment to study the carbon cycle and greenhouse gases. HIPPO conducted flights from Colorado, Alaska, Tahiti, Fiji, Easter Island, New Zealand, and Costa Rica. The Research Aircraft Facility at the National Center for Atmospheric Research

(NCAR), a Federally Funded Research and Development Center of NSF, continues to operate and maintain HIAPER. NCAR also operates and maintains NSF's C-130Q research aircraft. During the GV's expected lifetime of 10 to 25 years, new instrumentation innovations will be continually integrated onto the airframe as appropriate.

The Upper Atmospheric Research Section (UARS) supported a wide variety of research programs in space science in FY08. These included the funding of advanced radar systems to study the ionosphere and magnetosphere, ground-based optical equipment to study the aurora and airglow, partial support to ground-based solar telescopes and instruments, and a wide-ranging portfolio of basic research in space physics. Major UARS-funded activities included the Upper Atmospheric Facilities (UAF); the National Space Weather Program (NSWP); the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) program; the Geospace Environment Modeling (GEM) program; and the Solar, Heliosphere, and INterplanetary Environment (SHINE) program.

In addition, a formal NSF Science and Technology Center called the Center for Integrated Space Weather Modeling (CISM) continued to develop and test an end-to-end computer simulation for space physics research and applications. CISM's coupled models simulated the processes by which energy from the Sun and solar wind propagates to Earth, as well as the resulting effects on Earth's magnetosphere, ionosphere, and thermosphere. CISM researchers integrated these results with education and outreach activities. An effective knowledge transfer program also ensured that CISM shared the models for use in operational space weather forecasting centers of the United States Air Force and NOAA.

Throughout FY08, the Community Coordinated Modeling Center (CCMC) for space weather research, cosponsored by NSF and NASA and located at GSFC, continued to provide the research community with access to state-of-the-art space weather models and conducted important model validation activities necessary for the transition of research models to operational use.

Research facilities remained as the key component of UARS efforts. The UAF program in FY08 continued to promote basic research on the structure and dynamics of Earth's upper atmosphere. In particular, the CEDAR and GEM programs conducted research efforts utilizing these facilities. Observations made by the

Advanced Modular Incoherent-Scatter Radar (AMISR) at Poker Flat, Alaska, throughout FY08 demonstrated the unique capabilities of this new instrument, including the ability to image the ionospheric effects of auroral precipitation in three dimensions. These observations provided a wealth of data particularly useful to modelers interested in validating space weather models.

In early 2008, UARS started a new program to support CubeSat-based small satellite science missions for atmospheric and space weather research. The first NSF CubeSat competition in May 2008 received proposals for 29 missions, and all proposals presented extraordinarily high quality. NSF competitively selected two of these missions, which received funding in September 2008. The first NSF-sponsored CubeSat proposal awarded, entitled "CubeSat-Based Ground-to-Space Bistatic Radar Experiment—Radio Aurora Explorer," will operate in coordination with the ground-based AMISR incoherent-scatter radar to investigate Earth's radio aurora from field-aligned irregularities in the high-latitude ionosphere. The experiment will launch as a secondary payload on a DOD Space Test Program launch scheduled for December 2009. The "Firefly" mission won the second award, aimed at investigating terrestrial gamma-ray flashes in the atmosphere. A launch date has not yet been set for the Firefly mission, but it is targeted for mid- to late 2010.

UARS continued to support the study of magnetospheric physics within the international Super Dual Auroral Radar Network (SuperDARN) consortium by contributing a new radar installation in southern Virginia to a chain of midlatitude SuperDARN radars designed to study geomagnetic storm electric fields. UARS also started the satellite-based Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) in FY08. AMPERE utilized the 66 networked satellites of the existing Iridium constellation to create a new facility for collecting geomagnetic field data. The AMPERE facility will yield the first-ever real-time observations of the electric currents that link Earth's magnetosphere and ionosphere and will provide the first-ever continuous, global observations for tracking geomagnetic storm-time dynamics. Geomagnetic storms occur when charged particles emitted by solar flares interact with Earth's magnetosphere. Such storms can cause major disruptions of power and communications systems on the ground.

The UARS community also continues to benefit from the Division of Astronomical Sciences' efforts in FY08 to develop and manage the Advanced

Technology Solar Telescope, described earlier. In addition, UARS funding supported the continuing design and development of the proposed Frequency Agile Solar Radiotelescope (FASR), as well as the completion of NSF Astronomy's support of a radiotelescope test bed in Western Australia known as the Murchison Widefield Array (MWA).

Office of Polar Programs (OPP)

For FY08, the primary activities of the OPP in ground-based space science and astronomy included full-scale observations with the 10-meter off-axis radio telescope at the U.S. Amundsen-Scott South Pole Station to survey deep space galaxy clusters, as well as the continued construction of the IceCube Neutrino Observatory.

The South Pole Telescope successfully completed its second winter survey-observing period (northern summer 2008) with the discovery of three new galaxy clusters via the Sunayev-Zeldovich Effect, a decrement in the strength of the Cosmic Microwave Background Radiation as it is scattered by electrons in galaxy clusters. This discovery confirms the power of this new method of distant galaxy cluster mass detection.

The South Pole IceCube Neutrino Observatory gained a total of 18 strings of new optical photodetectors, making half of the total detector volume available for science observations. The observatory expects the completion of all 80 strings in 2011. Data collection continued with the advance filtering and reconstruction of neutrino events. Scientific topics under study included searches for weakly interacting massive particles (WIMPs), neutrino point sources, and magnetic monopoles.

Department of State

DOS

The Department of State (DOS) carries out diplomatic efforts to support U.S. space policies and programs internationally. The DOS supports U.S. civil space activities through the negotiation of bilateral and multilateral agreements with partner countries and leads U.S. participation in numerous international space and technological venues and international organizations. The DOS also maintains outreach programs to advance U.S. space and foreign policy objectives.

The DOS continued to represent the United States on the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and its Legal and Science and Technology Subcommittees. With so many countries now engaged in space activities, the DOS considers promoting the safe and responsible use of space by all current and future spacefaring nations as a vital 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 launching nations. The DOS also launched a new U.S. effort, building on the results of the International Heliophysical Year, to improve international cooperation in understanding the impact of space weather on satellites and the Earth environment in general.

The DOS participated in the third meeting of the U.S.-European Union Civil Space Policy Dialogue, established at the June 2005 U.S.-EU Summit and held in Brussels, Belgium, in May 2008. The two sides agreed to expand collaborative work on Earth observation and space science and to coordinate closely on space policy issues in the UNCOPUOS, the Group on Earth Observations, and other multilateral bodies. In support of the dialogue, a workshop of U.S. and EU experts

on space situational awareness (SSA) was held in Washington, DC, in June 2008. The DOS signed a Government-to-Government framework agreement on civil space cooperation in March 2008 with Ukraine, which will facilitate cooperation between NASA and other U.S. agencies and their Ukrainian counterparts. The DOS completed the text of a similar framework agreement with Canada in December 2008. Work also continued in 2008 to implement joint Earth observation and space exploration programs with India as agreed at the February 2007 meeting of the U.S.-India Joint Working Group on Civil Space Cooperation.

The DOS led vigorous efforts in FY08 to promote GPS and its augmentation in accordance with the President's 2004 Policy on Space-Based Positioning, Navigation, and Timing. In 2008, the DOS signed a joint statement in Washington, DC, at the first U.S.-EU GPS Plenary to explore coordination on issues of mutual interest. GPS public diplomacy efforts in Europe in 2008 included support and attendance at European-based GNSS conferences, including the Munich Satellite Summit, the Berlin GNSS Symposium, the XVI International Scientific and Technical Conference for the Role of Navigation in Support of Human Activity at Sea, the Swedish Navigation Radio Board Conference, the first GNSS Vulnerabilities and Solutions Conference, the European Navigation Conference, and the International Subcommittee of the Civil GPS Service Interface Committee meeting.

The DOS held consultations with Japan in November 2008 in Tokyo to coordinate U.S. interagency efforts to conclude and sign agreements with Japan on the placement of Quasi-Zenith Satellite System monitoring sites in Hawaii and Guam. Bilateral discussions on compatibility and interoperability with GPS also took place with Russia and India in 2008. With Russia, the focus remained on the potential for new Global Navigation Satellite System (GLONASS) signals that would be interoperable with GPS. With India, the DOS discussed signal plans for the proposed Indian Regional Navigation Satellite System. In 2008, the DOS chaired the third United Nations International Committee on Global Navigation Satellite Systems (ICG) meeting held in California. This meeting paved the way for collaborative efforts to move beyond interoperability to interchangeability. The DOS formally launched the ICG in late 2006 to help promote the use of GNSS applications, especially for developing countries, and met for the second

time in India on September 4–7, 2007. More than 140 GNSS experts from around the world participated at that meeting, where the United States led a movement to start a related Providers Forum for GNSS providers (United States, European Union, Russia, China, Japan, and India) to work on issues of common interest. In FY08, 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.

With regard to space issues in Africa, the DOS implemented a related initiative under its Global Dialogue on Emerging Science and Technology program focused on "Geospatial Sciences for Sustainable Development in Africa." The project brought a team of U.S. experts to nine different countries in Africa to look at challenges and opportunities for collaboration in geospatial science and technology. Following these visits, the University of Capetown hosted a conference during March 17–19, 2008, where over 100 geospatial experts from over 15 countries presented papers about geoinformation research and activities in Africa. In a similar effort, the DOS facilitated the participation of 20 African scientists in the June 26–21, 2008, AfricaArray Conference, hosted by the University of Witswatersrand, South Africa, which promoted the unification of African Reference Frames using modern space geodetic technologies, including GPS.

Department of Energy

DOE

During FY08, the Department of Energy (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 occurred 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 facility infrastructure.

The SC continued to work on the Alpha Magnetic Spectrometer (AMS) instrument, designed and built to be carried aboard a Space Shuttle for installation on the International Space Station (ISS). With a much greater sensitivity than previously possible, the international AMS scientific collaboration will use the unique environment of space to study the origin and structure of the universe, search for antimatter and dark matter, and collect information from cosmic sources emanating from stars and galaxies millions of light-years beyond the Milky Way. In FY08, this work focused on the integration of the instrument at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland. The SC provided funding in FY08 to support the research group at the Massachusetts Institute of Technology (MIT) that leads the AMS program. NASA plans to deliver AMS to the ISS aboard the Space Shuttle in 2010.

The SC and NASA's Science Mission Directorate (SMD), along with international partners, have collaborated since FY00 on the design and fabrication of the Large Area Telescope (LAT), the primary instrument for NASA's Fermi Gamma-ray Space Telescope (FGST). Previously called the Gamma-ray Large Area Space Telescope (GLAST), FGST was renamed after launch in June 2008. The LAT instrument, using the techniques of experimental particle physics research, detects and studies gamma rays emitted by the most energetic objects and phenomena in the universe. In FY08, the Stanford Linear Accelerator Center (SLAC), the National Accelerator Laboratory, and SC-funded university groups led the international collaboration that performed the final testing prior to launch and commissioning, as well as the start of data-taking operations after launch. SLAC runs the LAT Instrument Science Operations Center (ISOC), which processes the data during operations.

Determining the nature of dark energy and how it may cause the acceleration of the expansion of the universe remains a high-priority science objective for both SC and NASA. The National Academies of Science "Beyond Einstein Program Advisory Committee" (BEPAC) study, released in September 2007, recommended that SC and NASA proceed together on a Joint Dark Energy Mission (JDEM). In FY08, SC provided funding to the Lawrence Berkeley National Laboratory (LBNL) and other labs and universities for JDEM R&D activities. NASA and the DOE set up a Science Working Group and a Science Coordination Group to help guide the scientific requirements for the mission.

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 operates at BNL 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 FY08. NASA contributes 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 FY08, the Office of Nuclear Physics continued to support astrophysicists who used approximately 18,283,737 XT4-equivalent processor hours at the National Energy Research Scientific Computing Center (NERSC), which is funded by the DOE's Office of Advanced Scientific Computing Research (OASCR). Simulations of supernova explosions, such as those observed by the Hubble Space Telescope, used most of these processor hours. Scientists also used the NERSC computer capabilities for studies on galaxy formation and black holes.

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

In FY08, the SC Office of Fusion Energy Sciences (OFES) continued to provide support to NASA on fusion and plasma propulsion. The fusion propulsion concepts included potential use of the spherical torus and magneto-inertial fusion by means of the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory (PPPL) and the basic research in magneto-inertial fusion at various locations. These two fusion concepts hold the potential for reducing traveling times to the planets in our solar system by more than a factor of 10. In addition, the plasma jet research may provide a very high-thrust electric propulsion system, which could be powered by a fission reactor, solar panels, or, eventually, a fusion reactor.

In response to the FY07 interagency Task Force on High Energy Density Physics report, prepared under the guidance of the National Science and Technology Council, OFES and the National Nuclear Security Administration (NNSA) issued a Joint Solicitation in FY08. This solicitation resulted in the receipt of proposals in the field of laboratory astrophysics; i.e., the physical simulations of astrophysical phenomena in the laboratory using such devices as high-power lasers. In addition,

in FY08, the council continued to receive proposals in space-related plasma physics in response to their annual request for proposals.

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 scientists 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 occurred 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 Earth Observing System (EOS) Aqua platform. ARM conducted additional measurements 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 FY08, the ARM continued support of NASA's solar-viewing Bruker 125 HR Fourier Transform Spectrometer (FTS) at the TWP facility, which validates space-based column CO_2 retrievals and ensures the accuracy of CO_2 source and sink information. During the winter of 2008, NASA participated in the SC's Indirect and Semi-Direct Aerosol Campaign (ISDAC). The focus of this cross-disciplinary interagency research effort was to advance the understanding of how aerosols impact climate in the Arctic.

NASA, NOAA, and the DOE met recently and agreed to renew their MOU addressing the use of Uninhabited Aerial Systems (UASes) for weather and climate

change research. The MOU, signed in November 2006, facilitates a collaborative, cost-sharing partnership between NASA's SMD, NOAA's Office of Oceanic and Marine Operations (NMAO), and the DOE's SC in utilizing UASes.

The SC's Scientific Discovery through Advanced Scientific Computing (SciDAC) program, jointly with NNSA, 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 models of turbulence and computational algorithms in use strongly limit the current ability to predict these flow phenomena. The collaborative work may lead to stable and accurate treatment of interface boundaries, grid refinement, and accurate solvers for a wide spectrum of flow types.

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 measured at or below current workplace exposure limits. NASA's Space Radiation Project seeks to understand the biological effects of space radiation so that radiation risks may be accurately assessed. Both research programs recognize 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. In FY08 there were 10 jointly funded projects, including two NASA Specialized Center of Research (NSCOR) program projects. A new program research solicitation offered in FY08 is expected to yield an additional number of projects jointly supported by the DOE and NASA.

The DOE's Office of Nuclear Energy continued to support NASA's space science and exploration programs by pursuing the development of specific technologies for future space missions and by maintaining the necessary program and nuclear facility infrastructure capabilities to provide radioisotope power systems and heater units. In FY08, the DOE continued the development and testing of a Multi-Mission Radioisotope Thermoelectric Generator for first use on the Mars Science Laboratory mission, which is to be launched in 2011, and the development of the Advanced Stirling Radioisotope Generator now under consideration for Discovery- or Scout-class missions in the 2014 timeframe. Designed for use in multiple mission

environments, including planetary surfaces and deep space, these new radioisotope power systems, which convert the decay heat of plutonium-238 into electricity, will each provide greater than 100 watts of electricity for more than 14 years.

Maintaining a reliable supply of plutonium-238 for future missions that depend on these unique power systems has been a key challenge since domestic production of plutonium-238 ceased in 1988. The FY10 congressional budget request for funds to restart domestic production of plutonium-238 is not supported in the conference report language. The Office of Nuclear Energy augments the Nation's limited inventory of plutonium-238 through purchases from Russia. However, Russia recently suspended its agreement to sell plutonium-238 to the DOE, and a new agreement could delay future deliveries by 3 to 5 years. The Office of Nuclear Energy is continuing its efforts to resolve these supply issues.

The Office of Nuclear Energy and DOE national laboratories also supported technology development that could lead to a fission surface power system for deployment by NASA on the Moon around the year 2020. During FY08, the DOE supported test component and reactor design, as well as lander integration concepts for a candidate fission surface power system. As part of maintaining the required infrastructure capabilities, the DOE continued the maintenance and operation of equipment and facilities at Oak Ridge National Laboratory (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 (CfA). Through this organization, more than 300 scientists engaged in a broad program of research in astronomy, astrophysics, Earth and space sciences, and science education. The Smithsonian's NASM in Washington, DC, also contributed to national aerospace goals through its research and education activities.

FY08 marked the fifth year of operations for NASA's Spitzer Space Telescope—operated by JPL—which carries the Infrared Array Camera (IRAC) developed at SAO and constructed at NASA Goddard Space Flight Center. Spitzer studies the universe using infrared wavelengths of light, so it can peer into nearby dust-obscured regions to study stellar birth and evolution, observe the atmospheres of alien worlds (exoplanets), and spot distant galaxies. IRAC has logged a total of over 12,400 hours of operation in flight.

Using Spitzer, astronomers found evidence that rocky, terrestrial planets might orbit many, if not most, of the nearby Sun-like stars in the disk of our galaxy. They discovered that at least one-fifth, and possibly as many as three-fifths, of stars similar to the Sun are candidates for forming rocky planets. These new results suggest that worlds with potential for life are more common that we thought.

Other FY08 findings made by the Spitzer Space Telescope with IRAC team members include the following:

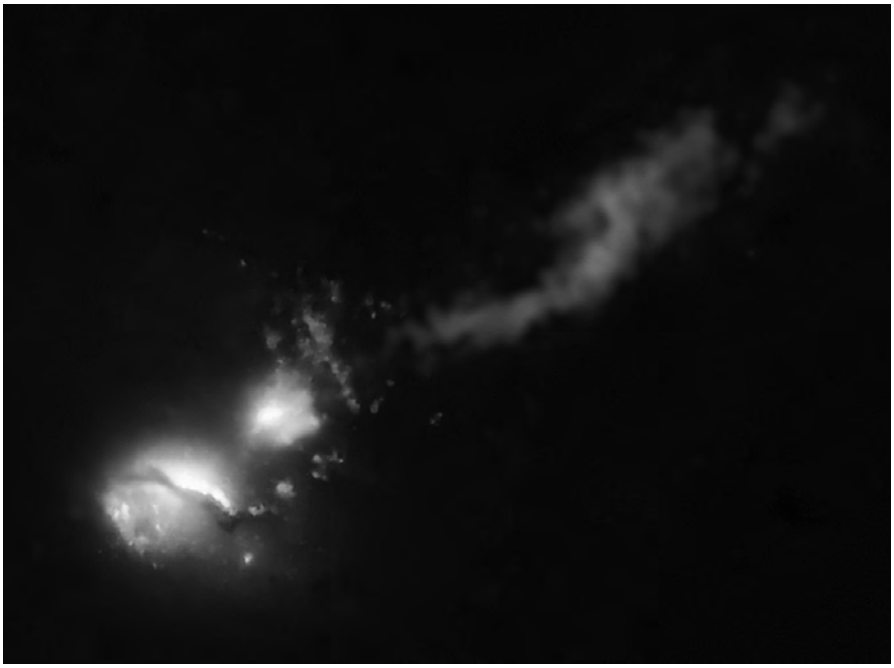
- The discovery that the closest exoplanet system hosts two asteroid belts. Our own solar system just has one.
- Dramatic new evidence that massive stars—through their fierce winds and radiation—can trigger the birth of stellar newborns.

- The discovery of an extreme stellar machine—a galaxy in the very distant, and hence young, universe pumping out stars at a surprising rate of up to 4,000 per year. In comparison, our own Milky Way galaxy turns out an average of just 10 stars per year.
- The determination of the diameters and albedos (reflectivities) of three small (<1 kilometer in diameter) Near-Earth Objects.
- Evidence of a new population of distant galaxies emitting submillimeter radiation.
- A map of the day-night contrast of the distant planet HD 189733b.
- The structure and evolution of the massive star-forming complex S254-S258.
- The determination of distant protogalaxy candidates in the Bootes field.
- The determination of the structure of an active system of merging galaxies.
- An infrared point source survey of the Andromeda galaxy.

NASA's Chandra X-ray Observatory, which is run from an SAO-operated control center, is having a widespread, profound impact on 21st-century astrophysics. With its unrivaled ability to create highly detailed x-ray images and spatially resolved spectra, Chandra enables astronomers to investigate phenomena from comets to cosmology. These discoveries accumulate at a rapid rate as Chandra makes observations of hundreds of objects each year. Highlights from the past year include the detection of the most recent supernova in our Milky Way galaxy, the discovery of the most massive stellar black hole known, and images that show how supermassive black holes can affect entire galaxies.

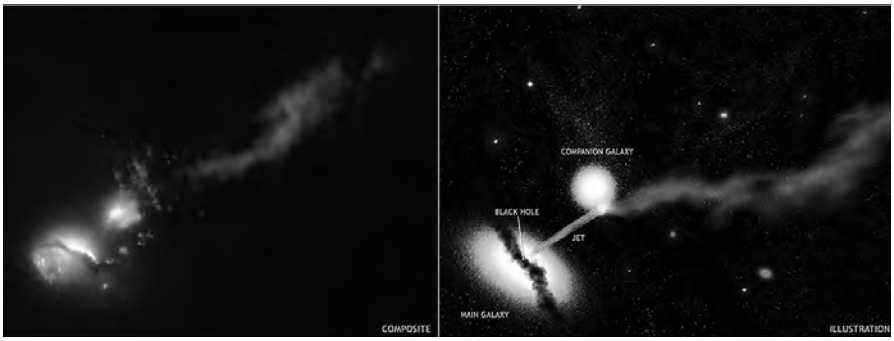
Astronomers discovered the most recent supernova in the Milky Way during FY08 by tracking the rapid expansion of its remains in x rays with Chandra and in radio emission with the NRAO's Very Large Array (VLA). The supernova explosion occurred about 140 years ago, making it the most recent supernova in the Milky Way as measured in Earth's timeframe. The last known previous galactic supernova occurred around 1680.

When an extremely massive star reaches the end of its life, theory predicts that its core will collapse to form a stellar black hole. Knowing how massive these black holes are is important for understanding the process by which they are formed. By



This composite image shows the jet from a black hole at the center of a galaxy striking the edge of another galaxy, the first time such an interaction has been found. In the image, data from several wavelengths have been combined. The jet impacts the companion galaxy at its edge and is then disrupted and deflected, much like how a stream of water from a hose will splay out after hitting a wall at an angle.

Credit: X ray: NASA/Chandra X-ray Center/CfA/D. Evans et al.; Optical/ultraviolet: NASA/Space Telescope Science Institute; Radio: NSF/VLA/CfA/D. Evans et al., Science and Technology Facilities Council (STFC)/JBO/MERLIN. To see in color, visit http://chandra.harvard.edu/photo/2007/3c321/more.html.



This image compares the composite image of 3C321 to an artist's illustration of the system, showing the main galaxy and the companion galaxy. A jet of particles generated by a supermassive black hole at the center of the main galaxy is striking the companion galaxy. The jet is disrupted and deflected by the impact. The labels identify key features of this system in the second panel.

Credit: Image: X ray: NASA/CXC/CfA/D. Evans et al.; Optical/ultraviolet: NASA/STScI; Radio: NSF/VLA/CfA/D. Evans et al., STFC/JBO/MERLIN; Illustration: NASA/CXC/M. Weiss. To see in color, visit http://chandra.harvard.edu/photo/2007/3c321/more.html.

combining x-ray observations from Chandra and data from optical telescopes about stellar black holes in nearby galaxies, astronomers discovered the two most massive

black holes known of this class (16 and 25 times the mass of the Sun) during this past year.

On a larger scale, a dramatic new Chandra image of the nearby galaxy Centaurus A revealed the effect on an entire galaxy of energy produced by a spinning supermassive black hole. This image provides one of the best views to date of the effects of an active supermassive black hole. Opposing jets of high-energy particles can be seen extending to the outer reaches of the galaxy, and numerous smaller black holes in binary star systems are also visible.

Astronomers think that jets produced by black holes are important vehicles for transporting energy from the black hole to the outer reaches of a galaxy and beyond. Observations of the double galaxy system called 3C321, made by x-ray, optical, infrared, and radio telescopes, revealed a spectacular example of the "reach" of black holes where a powerful jet from a supermassive black hole blasts a neighboring galaxy. This galactic violence could have a profound effect on any planets in the path of the jet and trigger a burst of star formation in the wake of its destruction, thereby altering the evolution of the galaxy.

FY08 marked the second full year of operation of the Hinode satellite, which provided continuous viewing of the Sun from space. SAO's X-Ray Telescope (XRT) aboard Hinode is the highest resolution telescope of its type ever flown for solar studies. The XRT observed x rays from the solar corona—the Sun's million-degree hot outer atmosphere. The XRT provided groundbreaking new 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 SAO served as the focal point from which both satellite operations and scientific studies were coordinated.

Scientists reported the results from Hinode at a dedicated international conference in Boulder, Colorado, in fall 2008, titled "Beyond Discovery—Toward Understanding." The XRT demonstrated the ways in which magnetic disturbances travel through the corona and identified the ways in which magnetic energy is stored in S-shaped "sigmoids" that subsequently erupt into huge mass ejections. Far smaller jetlike events in the corona have been found to be so numerous that they may be a major source of energy and particles for the solar wind, which travels outward from the Sun at nearly 1,000,000 miles per hour and blows past Earth.

The XRT has proven to be a highly versatile instrument, appearing in 70 of the 90 refereed Hinode publications in 2008.

SAO's Ultraviolet Coronagraph Spectrometer (UVCS) Group continued to make major progress in understanding coronal mass ejections (CMEs)—explosive events on the Sun that modify the interplanetary environment. Some FY08 highlights from this research included the following:

- For the first time, UVCS observed the evolution of a hot, 6-million-degree CME current sheet from its initial onset. Current sheets are swept-back regions behind CMEs where magnetic lines of force are stretched and compressed. The release of magnetic energy in these current sheets, through a process called magnetic reconnection, is believed to provide the energy that heats and accelerates the CME. UVCS measurements, along with data from other instruments, provided strong evidence that the thickness of the observed current sheet was larger than expected.
- UVCS researchers performed a comparison of current sheets formed in two extremely different environments: Earth's magnetosphere and the Sun's outer atmosphere. The study showed that the magnetic wave speeds (Alfven speeds) in the two regions were similar, although the density and magnetic field strengths differed by orders of magnitude. This is of interest because the Alfven speed is strongly related to the energy release rate of the magnetic reconnection process. Since magnetic reconnection powers solar eruptions, understanding this process may lead to the ability to predict upcoming eruptions and the resulting "space weather," which can damage satellites.
- Researchers developed a numerical model using UVCS observations, which can help predict the ultraviolet emissions of plasmas heated by CME shock waves. The model indicated that the observed ultraviolet emissions in CMEs showed the presence of shock waves and could be used to determine the shock wave characteristics.

The Smithsonian's Submillimeter Array (SMA), the world's first and, currently, only interferometric imaging telescope for submillimeter wavelengths, continued forefront research on a wide range of astrophysical topics, including planetary science, star formation, envelopes around evolved stars, distant and nearby galaxies,

and the supermassive black hole in the center of the Milky Way. Ongoing upgrades continued to improve SMA performance in terms of both sensitivity and observing efficiency. Test science observations made during the daytime, not possible with other submillimeter interferometers, showed promising results. Competition for SMA observing time remained very high, especially in the areas where the SMA is unique. The publication rate of scientific results from the SMA in peer-reviewed journals continued to increase and now surpasses that of comparable facilities at longer wavelengths, further testament to the technical performance and scientific impact of this unrivaled telescope facility. Since submillimeter wavelengths provide detailed information regarding the physical and chemical conditions of cool, dense gas and dust, a major focus for the SMA continued to be star formation, including the study of gaseous envelopes around evolved stars.

Another major focus of the SMA included a systematic study of CW-Leo, which emits most of its radiation in the infrared and is the brightest infrared object in the northern sky. Barely visible at optical wavelengths, CW-Leo has already burned much of its hydrogen and helium fuel and produced shells of dust that are remarkably rich in molecules in the process. CW-Leo, which ejects about one Earth-mass of material per year, represents the class of evolved stars in our galaxy that astronomers believe responsible for making and dispersing most of the dust and organic molecules in space. This research is being carried out in collaboration with the CfA's spectroscopy laboratory, which conducts precise measurements of the frequencies of the spectral lines of interstellar molecules.

The first phase of the SMA study of CW-Leo has detected about a hundred types of molecules thus far. Roughly half of these included new detections, of which 20 remain unassigned and could reveal the first detections of new molecular types. Amongst these new detections, the SMA found a whole class of narrow spectral lines very close to the central star and kinematically quite distinct from the lines seen in earlier surveys. Astronomers are still trying to figure out exactly how the star makes and blows away all this material.

Also in FY08, the SMA participated as a receiving element in a three-station Very Long Baseline Interferometry (VLBI) experiment, which combines several telescopes separated by large distances to achieve very high resolution, equivalent to that of an Earth-sized telescope. This experiment, which peered into the galactic

center, showed that the size of the emitting region around the black hole in the center of our galaxy (known as SgrA*) was 37 micro-arcseconds in diameter, the equivalent of the size of a baseball seen from the Moon. More importantly, the emitting region appeared to be only about twice the Schwarzschild diameter (a.k.a. the event horizon) of the black hole. Being able to probe that close to the event horizon of a black hole is unprecedented. Astronomers viewed these observations at a wavelength of 1.3 millimeters, the shortest wavelength ever attempted for VLBI, with antenna separations up to 4,500 kilometers. The success of this experiment opens the way to understanding how matter behaves in the strong-field limit of general relativity and also to understanding how general relativity itself works. Future experiments are planned at 0.86 millimeter and will include new telescopes, just coming online, that will allow astronomers to image the immediate region around the black hole.

Astronomers now believe that every galaxy contains a supermassive black hole in its center. The issue of whether the black holes form before or after the galaxies assemble remains a major concern of modern cosmology. The black hole in our galaxy is the nearest one to us; therefore, we can study it in the most detail. One of the mysteries of SgrA* includes its very quiet state. If SgrA* accreted matter at its current rate (as determined recently by SMA polarization observations), then it would have taken much longer than the age of the universe to reach its present mass of 4 million solar masses. Hence it must have been more "active" in the past.

In the laboratory, SAO researchers developed a new laser technology that can be used to locate Earth-like planets orbiting distant stars. Known as an astro-comb, the novel device uses ultrashort, femtosecond (1 millionth of 1 billionth of 1 second) pulses of laser light, linked to an atomic clock, to provide a precise standard against which light from a star can be measured. The astro-comb makes measurements accurate to one part in a trillion. This may increase the resolution of one planet-hunting technique by about 100 times, which would allow astronomers to detect Earth-sized planets in Earth-like orbits. This technology is now being tested at the Smithsonian's MMT Observatory in Arizona.

In public outreach, SAO continued to offer its popular monthly Observatory Night lectures and telescope observing sessions, including a special lecture, "50 Years of the Space Age," in honor of the 50th anniversary of NASA. SAO also held Family Friendly Nights aimed at younger children, occasional Author's Night

programs, and Sci-fi Movie Nights that explored the theme "Everything I Learned About Science, I Learned at the Movies." Dedicated telescope viewing opportunities included a lunar eclipse open house and an offsite trip to a state park, each drawing hundreds of visitors.

In FY08, NASM continued to educate and inspire the public through exhibits and education programs, including discovery stations, lecture series, family educational events, and intern programs. The "America by Air" exhibition, which opened in November 2007, tells the story of passenger air travel in the United States. The exhibit "Space: A Journey to Our Future," which opened in June 2008, presents numerous interactive activities to educate and engage visitors on the topics of current and future space exploration. In addition, the museum initiated an early childhood education program through a generous gift from the Conrad N. Hilton Foundation.

At NASM's Steven F. Udvar-Hazy Center, which welcomed its 5 millionth visitor this year, plans continue for Phase Two construction. Phase Two will accommodate NASM's archives and the facilities for the restoration and preservation of the Nation's collection of air and space artifacts.

Staff members in NASM's Center for Earth and Planetary Studies (CEPS) continued to participate on the science teams of several spacecraft missions. Dr. John Grant is a Participating Scientist for the MER mission that currently operates on Mars. As one of multiple Chairs of the MER Science Operations Working Group, he leads the science team in reaching consensus on targets and operations for the long-lived rovers. He conducts real-time mission planning from a control station installed onsite at CEPS. CEPS staff work on the science teams for the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument on Mars Express; both the HiRISE and Shallow Subsurface Radar (SHARAD) instruments on the MRO; and the MESSENGER mission to Mercury, which made its first flyby of that planet in January 2008. During this encounter, MESSENGER imaged a large portion of the planet that had never been seen before.

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, Mercury, and Saturn's moons, resulting

in 21 peer-reviewed publications. Research topics included MER, HiRISE, and MESSENGER results; Earth-based radar observations of the Saturn system; studies of Martian subsurface and composition; geophysical mapping with ground-penetrating radar; and investigations of Martian polar deposits. In addition, CEPS scientists used new capabilities in focused Earth-based radar imaging to study the surface and deep deposits of the Moon at resolutions comparable to those of photos taken from lunar orbit. This work has great importance for understanding potential mineral resources and landing hazards for future human exploration.

As a NASA Regional Planetary Image Facility (RPIF), CEPS continued to house a collection of over 300,000 images of the planets and their satellites as a reference library for science researchers and the public, serving the mid-Atlantic and south-eastern United States. The CEPS RPIF holds the most complete collection of lunar images of any RPIF in the world.

Appendices

Appendix A-1

U.S. Government Spacecraft Record

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

Calendar Year	Earth Orbit[a]		Earth Escape[b]	
	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	16	2	2	0
2008 (through September 30, 2008)	19[f]	0	0	0
TOTAL	1,625	155	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 Small Spacecraft Technology Initiative (SSTI) Lewis spacecraft that began spinning out of control shortly after it achieved Earth orbit.

f. This includes American spacecraft not launched in the U.S.

Appendix A-2

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

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

Calendar Year	United States[b]	USSR/ CIS	France[c]	Italy[c]	Japan	People's Republic of China	Australia	United Kingdom[c]	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	25	33			3	13			8	3	1
2008 (through September 30, 2008)	16	19			1	5			5	2	
TOTAL	1,374	2,820	10	8	71	109	1	1	180	23	5

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

b. Launches from U.S.-Russia joint platform 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. Vehicles

October 1, 2007–September 30, 2008

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
October 11, 2007 WGS F1 (USA 195) 2007-046A Atlas 5	Geostationary military communications	Unavailable	Wideband Global SATCOM F1 (WGS F1) Also known as USA 195
October 17, 2007 GPS 2R-17 2007-047A Delta 2	Navigational	20,369 km 192 km 356.6 min 40°	Also known as Navstar 60 and as USA 196 Replaced GPS 2A-14 in Plane F and Slot 2
October 23, 2007 STS-120/*Discovery* 2007-050A Space Shuttle	International Space Station	344 km 340 km 91.4 min 51.6°	Installed Harmony Node 2 module. Relocated P6 truss Repaired torn solar array Station crew exchange
November 11, 2007 USA 197 2007-054A Delta 4	Geostationary military	Unavailable	Also known as DSP 23 Carried infrared detectors to warn of rocket launches
December 9, 2007 Skymed 2 2007-059A Delta 2	Earth imaging	624 km 622 km 97.2 min 97.9°	Italian (military-civilian) dual use. Carried a synthetic aperture radar (SAR) operating in X-band
December 10, 2007 USA 198 2007-060A Atlas 5	Military	Unavailable	Also known as NROL 24 Reported as a data-relaying craft for other military satellites. National Reconnaissance Office
December 20, 2007 GPS 2R-18 2007-062A Delta 2	Navigational	20,310 km 20,150 km 720 min 55°	Also known as GPS 2R-M, Navstar 61, and USA 199 Moved to Slot 1 in Plane C to replace GPS 2A-24. GPS 2A-24 moved to replace GPS 2A-20
January 15, 2008 Thuraya 3 2008-001A Zenit 3SL	Geostationary military	98.5° E longitude	United Arab Emirates (UAE) satellite launched from Odyssey, a floating platform on the equatorial Pacific Ocean at 154° W longitude Enabled communications from mobile phones
February 7, 2008 STS-122/*Atlantis* 2008-005A Space Shuttle	International Space Station	343 km 329 km 91.25 min 51.64°	Installed ESA's Columbus laboratory Station crew exchange
March 11, 2008 STS-123/*Endeavour* 2008-009A Space Shuttle	International Space Station	343 km 340 km 91.4 min 51.6°	Delivered the Japanese Kibo ("Hope") experiment logistics module and the Canadian Dextre robotic arm Station crew exchange

Appendix B

(Continued)

Successful Launches to Orbit on U.S. Vehicles

October 1, 2007–September 30, 2008

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
March 13, 2008 USA 200 2008-010A Atlas 5	Military reconnaissance	Unavailable	National Reconnaissance Office
March 15, 2008 Navstar 62 2008-012A Delta 2	Navigational	20,218 km 20,147 km 718 min 55.1°	Also known as USA 201 and as GPS 2R-19(M) Standby GPS replacement satellite
March 19, 2008 DirecTV 11 2008-013A Zenit 3SL	Geostationary communications	35,796.2 km 35,791.8 km 1,436.1 min 0.0°	Launched from the floating Odyssey platform located at equatorial 154° W longitude Provides High-Definition Television (HDTV) throughout North America through 55 spot-beam transponders in the Ka-band 99.2° W longitude
April 14, 2008 ICO G1 2008-016A Atlas 5	Geostationary communications	35,805.8 km 35,782.3 km 1,436.1 min 5.5°	Carried an unfurlable 39-ft (12-m) diameter S-band mesh reflector antenna and solar wings. Utilizes a Ground-Based Beam Forming (GBBF) system, which allows 250 transmitting and 250 receiving independent S-band beams for television and navigation services 92.9° W longitude
April 16, 2008 C/NOFS 2008-017A Pegasus	Military	853 km 405 km 97.3 min 13°	Communication/Navigation Outage Forecasting System (C/NOFS). Launched by a Pegasus rocket released from an L-1011 aircraft flying out of Reagan Test Site at Kwajalein in the Marshall Islands Will monitor the conditions that lead to the generation of irregularities/bubbles that produce radio scintillations in the equatorial ionosphere and will warn against imminent disruption/degradation of military communications NASA sponsored the Coupled Ion Neutral Dynamic Investigation (CINDI) consisting of an Ion Velocity Meter (IVM), a Neutral Wind Monitor (NWM), and a Vector Electric Field Instrument (VEFI)

Appendix B

(Continued)

Successful Launches to Orbit on U.S. Vehicles

October 1, 2007–September 30, 2008

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
May 21, 2008 Galaxy 18 2008-024A Zenit 3SL	Geostationary communications	35,805.2 km 35,782.6 km 1,436.1 min 0.0°	Launched from the Odyssey platform Provides advanced cable television and data through 24 Ku-band and 24 C-band transponders 123° W longitude
May 31, 2008 STS-124/*Discovery* 2008-027A Space Shuttle	International Space Station	315 km 303 km 91 min 51.6°	Delivered the Japanese Kibo pressurized module and robotic arms Station crew exchange
June 11, 2008 GLAST 2008-029A Delta 2	Astrophysics	562 km 542 km 95.7 min 25.6°	NASA Gamma-ray Large Area Space Telescope (GLAST) will research dark matter, black holes, gamma-ray bursts, and other open questions about the universe Renamed Fermi Gamma-ray Telescope
June 20, 2008 Jason 2 2008-032A Delta 2	Ocean monitoring	1,335 km 1,324 km 112 min 66°	Ocean surface topography mission extends continuous climate record of sea surface height measurements Collaborative effort between NASA, the National Oceanic and Atmospheric Administration (NOAA), Centre National d'Études Spatiales (CNES), and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
July 16, 2008 Echostar 11 2008-035A Zenit 3SL	Geostationary communications	35,806.8 km 35,780.8 km 1,436.1 min 0.0°	Launched from the Odyssey platform DISH Network satellite television 110° W longitude
September 6, 2008 GeoEye 1 2008-042A Delta 2	Remote sensing	687 km 671 km 98.3 min 98.1°	Provides 0.4-m-resolution panchromatic and 1.6-m multicolor images
September 24, 2008 Galaxy 19 2008-045A Zenit 3SL	Geostationary communications	35,805.5 km 35,782.6 km 1,436.1 min 0.0°	Launched from the Odyssey platform Carried 24 C-band and 28 Ku-band transponders to provide video and Internet services Replaces Galaxy 25 (also known as Telstar 5) 97° W longitude

Appendix B

(Continued)

Successful Launches to Orbit on U.S. Vehicles

October 1, 2007–September 30, 2008

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
September 28, 2008 Demosat/Falcon 1 2008-048A Falcon 1	Launch vehicle development	643 km 622 km 97.4 min 9.35°	First successful launch of the Falcon 1 rocket from Omelek Island in Kwajalein Atoll in the Pacific Ocean Demosat (also named Ratsat) failed to separate from the second stage

*U.N. Committee on Space Research

Appendix C

Human Space Flights

October 1, 2007–September 30, 2008

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TMA-11 (Expedition 16)	October 10, 2007	Peggy A. Whitson Yuri I. Malenchenko Sheikh Muszaphar Shukor	191:19:08	First female commander for ISS (Peggy A. Whitson) Returned Peggy A. Whitson, Yuri I. Malenchenko, and So-yeon Yi
Space Shuttle *Discovery* (STS-120)	October 23, 2007	Pamela A. Melroy George D. Zamka Scott E. Parazynski Douglas H. Wheelock Stephanie D. Wilson Paolo Nespoli Daniel M. Tani Clayton Anderson	15:2:24	Installed Harmony Node 2 module Relocated P6 truss Repaired torn solar array Carried Daniel M. Tani and returned Clayton Anderson
Space Shuttle *Atlantis* (STS-122)	February 7, 2008	Stephen N. Frick Alan G. Poindexter Leland D. Melvin Rex J. Walheim Stanley G. Love Hans Schlegel Léopold Eyharts Daniel M. Tani	12:18:21	Installed ESA's Columbus laboratory, along with a European solar monitor (SOLAR) and the European Technology Exposure Facility (EuTEF) Carried Léopold Eyharts and returned Daniel M. Tani
Space Shuttle *Endeavour* (STS-123)	March 11, 2008	Dominic Gorie Gregory H. Johnson Robert L. Behnken Mike Foreman Rick Linnehan Takao Doi Garrett Reisman Léopold Eyharts	15:18:11	Delivered the Japanese Kibo ("Hope") experiment logistics module and the Canadian Dextre robotics system Carried Garrett Reisman and returned Léopold Eyharts

Appendix C

(Continued)

Human Space Flights

October 1, 2007–September 30, 2008

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TMA-12 (Expedition 17)	April 8, 2008	Sergei Volkov Oleg Kononenko So-yeon Yi	198:16:21	First South Korean astronaut (So-yeon Yi) First second-generation cosmonaut (Sergei Volkov) Returned Sergei Volkov, Oleg Kononenko, and Richard Garriott
Space Shuttle *Discovery* (STS-124)	May 31, 2008	Mark Kelly Ken Ham Karen Nyberg Ron Garan Mike Fossum Akihiko Hoshide Greg Chamitoff Garrett Reisman	13:18:13	Delivered the Japanese Kibo pressurized module and robotic arm Carried Greg Chamitoff and returned Garrett Reisman
Shenzhou 7	September 25, 2008	Liu Boming Jing Haipeng Zhai Zhigang	2:20:28	First crew of three men in a Chinese spacecraft First Chinese spacewalk

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[a]	DOE[b]	DOC	DOI	USDA	NSF[c]	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
2008	17,117	16,502	24,795	1,698	195	862	90	59	479	13	42,995

a. The Other column is the total of the non-NASA and non-DOD budget authority figures that appear in the succeeding columns. The total is sometimes different from the sum of the individual figures because of rounding. The Total Space column does not include the NASA Total column because the latter includes budget authority for aeronautics as well as in space. For the years 1989–1997, this Other column also includes small figures for the Environmental Protection Agency (EPA). Also includes $2.1 billion for replacement of Space Shuttle *Challenger* in 1987.

b. The DOE has recalculated its space expenditures since 1998.

c. The NSF has recalculated its space expenditures since 1980, making them significantly higher than reported in previous years.

* Transition Quarter

Appendix D-1B

Space Activities of the U.S. Government

HISTORICAL TABLE OF BUDGET AUTHORITY
(in millions of inflation-adjusted FY 2008 dollars)

FY	Inflation Factors	NASA Total	NASA Space	DOD	Other[a]	DOE[b]	DOC	DOI	USDA	NSF[c]	DOT	Total Space
1959	5.860	1,940	1,529	2,871	199	199	0	0	0	0	0	4,600
1960	5.769	3,023	2,665	3,236	248	248	0	0	0	0	0	6,150
1961	5.700	5,495	5,279	4,640	388	388	0	0	0	0	0	10,306
1962	5.620	10,257	10,099	7,295	1,118	832	287	0	0	0	0	18,513
1963	5.558	20,413	20,152	8,614	1,428	1,189	239	0	0	0	0	30,194
1964	5.489	27,993	27,532	8,777	1,169	1,153	16	0	0	0	0	37,477
1965	5.424	28,477	27,869	8,538	1,307	1,242	65	0	0	0	0	37,714
1966	5.332	27,595	27,008	9,006	1,141	997	144	0	0	0	0	37,155
1967	5.221	25,926	25,216	8,687	1,112	961	151	0	0	0	0	35,015
1968	5.057	23,199	22,405	9,720	881	733	142	1	5	0	0	33,006
1969	4.884	19,493	18,667	9,832	832	576	98	1	5	152	0	29,331
1970	4.671	17,496	16,567	7,837	659	481	37	5	5	131	0	25,063
1971	4.429	14,664	13,734	6,696	717	421	120	9	4	164	0	21,147
1972	4.218	13,949	12,954	5,935	563	232	131	25	8	166	0	19,451
1973	4.028	13,719	12,458	6,537	594	218	161	40	8	167	0	19,589
1974	3.858	11,716	10,644	6,813	610	162	231	35	12	170	0	18,067
1975	3.598	11,618	10,489	6,808	568	108	230	29	7	193	0	17,864
1976	3.259	11,570	10,511	6,463	549	75	235	33	13	193	0	17,522
TQ*	3.040	2,833	2,581	1,398	131	15	67	9	3	36	0	4,110
1977	2.946	11,249	10,135	7,107	570	65	268	29	18	190	0	17,812
1978	2.828	11,482	10,246	7,743	639	96	291	28	23	201	0	18,628
1979	2.650	12,178	10,678	8,044	657	156	260	26	21	193	0	19,379
1980	2.452	12,849	11,476	9,436	567	98	228	29	34	177	0	21,478
1981	2.254	12,440	11,254	10,884	528	92	196	27	36	176	0	22,667
1982	2.053	12,410	11,351	13,714	642	125	298	25	31	164	0	25,707
1983	1.922	13,212	12,161	17,333	629	75	342	10	38	163	0	30,123
1984	1.841	13,727	12,623	18,765	727	63	434	6	35	189	0	32,114
1985	1.775	13,443	12,292	22,664	1,036	60	751	4	27	195	0	35,992
1986	1.719	13,422	12,318	24,286	820	60	531	3	40	185	0	37,424
1987	1.680	18,352	16,480	27,364	783	81	467	13	32	188	2	44,628
1988	1.637	14,838	13,626	28,948	1,213	395	576	23	29	188	2	43,787
1989	1.587	17,413	16,029	28,425	889	154	478	27	33	192	5	45,343
1990	1.528	18,832	17,512	23,863	773	121	371	47	38	189	6	42,147
1991	1.473	20,651	19,221	20,894	1,138	370	370	43	38	311	6	41,253
1992	1.420	20,331	18,743	21,333	1,133	317	464	48	41	257	6	41,209
1993	1.385	19,822	18,096	19,540	1,012	229	449	46	35	249	6	38,649
1994	1.354	19,735	17,638	17,833	857	100	423	42	42	243	7	36,328
1995	1.326	18,370	16,632	14,114	1,006	79	467	41	42	369	8	31,752
1996	1.299	18,031	16,323	14,953	1,075	60	613	47	48	300	8	32,351
1997	1.274	17,468	15,873	14,942	1,006	45	571	54	50	280	8	31,821
1998	1.252	17,092	15,430	15,478	1,051	129	545	54	49	267	8	31,959
1999	1.237	16,893	15,416	16,336	1,215	130	711	73	46	247	7	32,967
2000	1.221	16,611	15,292	15,805	1,289	200	702	73	54	252	7	32,386
2001	1.197	17,035	15,926	17,150	1,271	174	691	72	43	278	14	34,347
2002	1.169	17,388	16,222	18,408	1,380	194	753	75	33	311	14	36,010
2003	1.148	17,631	16,478	22,248	1,498	219	745	85	48	387	14	40,224
2004	1.125	17,298	16,109	21,500	1,647	235	838	80	69	412	13	39,256
2005	1.096	17,757	16,700	21,585	1,700	251	885	77	80	395	13	39,986
2006	1.062	17,657	16,746	23,490	1,749	260	913	87	89	387	13	41,985
2007	1.027	16,731	15,994	23,032	1,726	205	937	89	67	415	12	40,752
2008	1.000	17,117	16,502	24,795	1,698	195	862	90	59	479	13	42,995

a. The Other column is the total of the non-NASA and non-DOD budget authority figures that appear in the succeeding columns. The total is sometimes different from the sum of the individual figures because of rounding. The Total Space column does not include the NASA Total column because the latter includes budget authority for aeronautics as well as in space. For the years 1989–1997, this Other column also includes small figures for the Environmental Protection Agency (EPA). Also includes $2.1 billion for replacement of Space Shuttle *Challenger* in 1987.

b. The DOE has recalculated its space expenditures since 1998.

c. The NSF has recalculated its space expenditures since 1980, making them significantly higher than reported in previous years.

* Transition Quarter

Appendix D-2

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority					Budget Outlays	
	2007 actual	2008 actual	2009 enacted	Recovery enacted	2010 est.	2007 actual	2008 actual
NASA[1, 2]	15,568	16,502	17,282	852	18,179	15,247	17,231
DOD	22,487	24,795	25,595	0	26,463	22,060	24,080
DOE[3]	200	195	191	5	234	188	192
DOC	912	862	1,074	74	1,350	803	603
DOI	87	90	87	15	88	87	86
USDA	65	59	68	0	57	46	46
DOT	12	13	14	0	15	11	12
NSF	404	479	499	291	481	370	361

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 that 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)

Federal Agencies	Budget Authority					Budget Outlays	
	2007 actual	2008 actual	2009 enacted	Recovery enacted	2010 est.	2007 actual	2008 actual
NASA[1, 2]	717	615	500	150	507	614	603
DOD	11,614	10,873	14,253	52	14,664	10,640	10,994
DOT	2,632	2,646	2,879	200	3,089	2,426	2,562

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).

Acronyms

3-D	three-dimensional
4-D	four-dimensional (three spatial dimensions plus time constraints); 4-Dimension (as part of 4-D Weather Data Cube Management Team)
6DOF	Six Degrees of Freedom

A

AAD	Aircraft Aging and Durability
AATE	Advanced Affordable Turbine Engine
ACCA	Advanced Composite Cargo Aircraft
ACD	Advanced Capabilities Division
ACES	Automatic Collection Exchange System
ACT	Atacama Cosmology Telescope
ADL	Airport Data Logger
ADS-33	Aeronautical Design Standard-33
ADS-B	Airborne Dependent Surveillance Broadcast
ADVENT	Adaptive Versatile Engine Technology
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AGRHYMET	Agricultural-Hydrological-Meteorological
AGS	Alternating Gradient Synchrotron
AHW	Advanced Hypersonic Weapon
AIA	Aerospace Industries Association
AIAA	American Institute of Aeronautics and Astronautics
AIRS	Atmospheric Infrared Sounder
AIS	Automatic Identification System
ALMA	Atacama Large Millimeter/submillimeter Array
AMISR	Advanced Modular Incoherent-Scatter Radar
AMPERE	Active Magnetosphere and Planetary Electrodynamics Response Experiment
AMS	Alpha Magnetic Spectrometer
AP	Associated Press
APHIS	Animal and Plant Health Inspection Service
APLC	Aerospace Products Literature Center
ARC	Ames Research Center
ARM	Atmospheric Radiation Measurement
ARMD	Aeronautics Research Mission Directorate
ARS	Agricultural Research Service
AS&T	Aeronautics Science and Technology
ASCAT	Advanced Scatterometer
ASI	Infrared Atmospheric Sounding Interferometer
ASIAS	Aviation Safety Information Analysis and Sharing
AST	Division of Astronomical Sciences
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATD	Advanced Technology Demonstration
ATHLETE	All-Terrain Hex-Legged Extra-Terrestrial Explorer
ATI	Airborne Technologies, Inc.
ATM	Division of Atmospheric Sciences
ATP	Aeronautics Test Program
ATST	Advanced Technology Solar Telescope
ATV	Automated Transfer Vehicle
AUVSI	Association of Unmanned Vehicle Systems International

AVHRR	Advanced Very High Resolution Radiometer
AWiFS	Advanced Wide Field Sensor

B

BEPAC	Beyond Einstein Program Advisory Committee
BIA	Bureau of Indian Affairs
BIS	Bureau of Industry and Security
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory
BOR	Bureau of Reclamation

C

C3PO	Commercial Crew & Cargo Program Office
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAASD	Center for Advanced Aviation System Development
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAMRAS	Carbon Dioxide and Moisture Removal Amine Swingbed
CATHALAC	Water Center for the Humid Tropics of Latin America and the Caribbean
CCMC	Community Coordinated Modeling Center
CCRS	Canada Centre for Remote Sensing
CCSP	Climate Change Science Program
CDA	Command and Data Acquisition
CDL	Cropland Data Layer
CDR	Critical Design Review
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions
CEOS	Committee on Earth Observation Satellites
CEPS	Center for Earth and Planetary Studies
CERES	Clouds and the Earth's Radiant Energy System
CERN	European Organization for Nuclear Research
CESTOL	cruise efficient short takeoff and landing
CfA	Center for Astrophysics
CH_4	methane
chl	chlorophyll
CIBER	Cosmic Infrared Background Experiment
CINDI	Coupled Ion-Neutral Dynamics Investigation
CIO	Chief Information Officer
CIR	color infrared
CISM	Center for Integrated Space Weather Modeling
CLU	Common Land Unit
CME	coronal mass ejection
CNC	computer numerical control
CNES	Centre National d'Études Spatiales
CNN	Cable News Network
CO	carbon monoxide
CO-OPS	Center for Operational Oceanographic Products and Services
CO_2	carbon dioxide
COASTAL	Coastal Oceanographic Applications and Services for Tides and Lakes
CONUS	Continental United States
CORS	Continuously Operating Reference Station
COS	Cosmic Origins Spectrograph
COSH	Control of Static Heaviness
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
COTS	Commercial Orbital Transportation Services

CPA	color-producing agent
CRISP	Central Region Integrated Science Partnership Funds
CRS	Commercial Resupply Services
CRW	Coral Reef Watch
CS	Commercial Service
CSLM-2	Coarsening in Solid-Liquid Mixtures-2
CSREES	Cooperative State Research, Education, and Extension Service
CWTG	Coastal Water Temperature Guide
CXO	Chandra X-ray Observatory

D

DARPA	Defense Advanced Research Projects Agency
DART	Deep-ocean Assessment and Reporting of Tsunami
DEM	digital elevation model
Dextre	Canadian Special Purpose Dexterous Manipulator
DGPS	differential global positioning system
DIO	Directorate Integration Office
DLR	German Aerospace Center
DOC	Department of Commerce
doc	dissolved organic carbon
DOD	Department of Defense
DOE	Department of Energy
DOS	Department of State
dpi	dots per inch
DSP	Defense Support Program
DTM	digital terrain map

E

E-Nose	Electronic Nose
EBIS	Electron Beam Ion Source
ECOHAB	Ecology and Oceanography of Harmful Algal Blooms
EDL	entry/descent/landing
EDMS	Emissions and Dispersion Model System
EELV	Evolved Expendable Launch Vehicle
EKV	Exoatmospheric Kill Vehicle
ELM-PS	Experiment Logistics Module, Pressurized Section (part of Kibo)
ELV	expendable launch vehicle
EMA	Ethiopian Mapping Authority
EOS	Earth Observing System
EPA	Environmental Protection Agency
ERIM	Environmental Research Institute of Michigan
ERS	Economic Research Service
ESA	European Space Agency
ESMD	Exploration Systems Mission Directorate
ESRL	Earth System Research Laboratory
ET	External Tank
ETDP	Exploration Technology Development Program
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUV	extreme ultraviolet
EVA	extravehicular activity
EVE	EUV Variability Experiment

F

F-T	Fischer-Tropsch fuel
FAA	Federal Aviation Administration
FACET	Future Air Traffic Management Concepts Evaluation Tool
FAS	Foreign Agricultural Service
FASR	Frequency Agile Solar Radiotelescope
FCC	Federal Communications Commission
FDMS	Flight Deck Merging and Spacing
FGST	Fermi Gamma-ray Space Telescope (previously GLAST)
FIM	Flow-following Finite-volume Icosahedral Model
FIP	Forecast Icing Product
FIPS	Federal Information Processing Standards
FMS	Flight Management System
FSA	Farm Service Agency
FTS	Fourier Transform Spectrometer
FWS	Fish and Wildlife Service
FY	fiscal year

G

GCJV	Gulf Coast Joint Venture
GEM	Geospace Environment Modeling
GEO	Group on Earth Observations; Global Earth Observations
GeoMAC	Geospatial Multi Agency Coordination
GHWG	Global Harmonization Working Group
GIS	Geographic Information System
GLAM	Global Agriculture Monitoring
GLAST	Gamma-ray Large Area Space Telescope
GLERL	Great Lakes Environmental Research Laboratory
GLONASS	Global Navigation Satellite System
GloVis	Global Visualization Viewer
GMSEC	Goddard Mission Systems Evolution Center
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GPSIIRM-19	specific GPS satellite
GPSRO	Global Positioning System Radio Occultation
GRAV-D	Gravity for the Redefinition of the American Vertical Datum
GRC	Glenn Research Center
GSD	Ground Systems Division
GSFC	Goddard Space Flight Center
GSICS	Global Space-Based Inter Calibration System
GV	Gulfstream V

H

HAB	Harmful Algal Bloom
HAB-FS	Harmful Algal Bloom Forecasting System
HEETE	Highly Efficient Embedded Turbine Engine
HIAPER	High-performance Instrumented Airborne Platform for Environmental Research
HIPPO	HIAPER Pole to Pole Observations
HiRISE	High Resolution Imaging Science Experiment
HiSTED	High-Speed Turbine Engine Demonstration
HQP	Helicopter Quieting Program

HRP	Human Research Program
HRRR	High-Resolution Rapid Refresh
HST	Hubble Space Telescope
HTCG	High Technology Cooperation Group
HTDP3.0	Horizontal Time-Dependent Positioning software, version 3.0
HTV-2	Hypersonic Technology Vehicle
HyFly	Hypersonic Flight

I

I&M	Inventory and Monitoring
IBEX	Interstellar Boundary Explorer
ICG	International Committee on Global Navigation Satellite Systems
IDPS	Integrated Data Processing System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGRS	Iraqi Geospatial Reference System
IGS	International GNSS Service
IIFD	Integrated Intelligent Flight Deck
InSPACE-2	Structure of Paramagnetic Aggregates from Colloidal Emulsions-2
INVENT	Integrated Vehicle Energy Technology
IOCM	Integrated Ocean and Coastal Mapping
IPCC	Intergovernmental Panel on Climate Change
IPO	Integrated Program Office
IPY	International Polar Year
IRAC	Integrated Resilient Aircraft Control; Infrared Array Camera
ISDAC	Indirect and Semi-Direct Aerosol Campaign
ISO	International Organization for Standardization
ISOC	Instrument Science Operations Center
ISRE	International Symposium on Remote Sensing of Environment
ISRU	In Situ Resource Utilization
ISS	International Space Station
ITA	International Trade Administration
IVHM	Integrated Vehicle Health Management

J

J2X	upper stage engine (relating to Ares I)
JAXA	Japan Aerospace Exploration Agency
JDEM	Joint Dark Energy Mission
JEM-PM	Japanese Experiment Module, Pressurized Module
JFC	Joint Force Commander
JP-8	Jet Propellant 8
JPDO	Joint Planning and Development Office
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope

K

KSC	Kennedy Space Center

L

LAS	Launch Abort System
LASP	Laboratory for Atmospheric and Space Physics
LAT	Large Area Telescope

LBIR	Low Background Infrared
LBNL	Lawrence Berkeley National Laboratory
LC	Launch Complex (e.g., LC-39A)
LCROSS	Lunar CRater Observation and Sensing Satellite
LDCM	Landsat Data Continuity Mission
LEO	low-Earth orbit
LIDAR	LIght Detection And Ranging
LPRP	Lunar Precursor Robotic Program
LRO	Lunar Reconnaissance Orbiter
LSP	Launch Services Program
LSST	Large Synoptic Survey Telescope
LULC	land use and land cover

M

M.Y.S.P.A.C.E.	Multinational Youth Studying Practical Applications of Climatic Events
MAF	Michoud Assembly Facility
MANPADS	man-portable air defense system
MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MDA	Missile Defense Agency
MEP	Manufacturing Extension Partnership
MER	Mars Exploration Rovers
MERIS	Medium Resolution Imaging Spectrometer
MESSENGER	MErcury Surface, Space ENvironment, GEochemistry, and Ranging
MHz	megahertz
Mini-SAR	Miniature Synthetic Aperture Radar
MISR	Multiangle Imaging SpectroRadiometer
MIT	Massachusetts Institute of Technology
MMT	Multi Mirror Telescope
MOA	Mars Organic Analyzer; Memorandum of Agreement
MOBY	Marine Optical Buoy
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MRLC	Multi-Resolution Land Characteristics
MRO	Mars Reconnaissance Orbiter
MTBS	Monitoring Trends in Burn Severity
MTRI	Michigan Tech Research Institute
MWA	Murchison Widefield Array

N

NAIC	National Astronomy and Ionosphere Center
NAIP	National Agricultural Imagery Program
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum
NASS	National Agricultural Statistics Service
NCAR	National Center for Atmospheric Research
NCCOS	National Centers for Coastal Ocean Science
NCEP	National Center for Environmental Prediction
NDBC	National Data Buoy Center
NERSC	National Energy Research Scientific-Computing Center
NESDIS	National Environmental Satellite, Data, and Information Service
NextGen	Next Generation Air Transportation System
NEXRAD	Next Generation Weather Radar
NFAC	National Full-Scale Aerodynamics Complex

NFMTC	National Force Measurement Technology Capability
NGA	National Geospatial-Intelligence Agency
NGDC	National Geophysical Data Center
NGS	National Geodetic Survey
NIERSC	Nansen International Environmental and Remote Sensing Center
NIOSH	National Institute of Occupational Safety and Health
NIRSpec	near-infrared spectrograph
NIST	National Institute of Standards and Technology
NLCD	National Land Cover Dataset
NLS	NASA Launch Services
NMSA	New Mexico Spaceport Authority
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NODC	National Oceanographic Data Center
NOS	National Ocean Service
NPAT	National Partnership for Aeronautical Testing
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NPS	National Park Service
NRA	NASA Research Announcement
NRAO	National Radio Astronomy Observatory
NRCS	Natural Resources Conservation Service
NRO	National Reconnaissance Office
NSAS	National Strategy for Aviation Security
NSCOR	NASA Specialized Center of Research
NSDI	National Spatial Data Infrastructure
NSF	National Science Foundation
NSO	National Solar Observatory
NSRL	NASA Space Radiation Laboratory
NSWP	National Space Weather Program
NVLAP	National Voluntary Laboratory Accreditation Program
NWI	National Wetland Inventory
NWR	National Wildlife Refuge
NWS	National Weather Service

O

OAAI	Office of Aerospace and Automotive Industries
OAR	Oceanic and Atmospheric Research
OASCR	Office of Advanced Scientific Computing Research
OCO	Orbiting Carbon Observatory
OECD	Organization for Economic Cooperation and Development
OFES	Office of Fusion Energy Sciences
OGA	Office of Global Analysis
OLI	Operational Land Imager
OMAC	Organization for Machine Automation and Control
OMB	Office of Management and Budget
OMPS	Ozone Mapping and Profiler Suite
OPP	Office of Polar Programs
OPUS	Online Positioning User Service
OPUS-RS	OPUS-Rapid Static
Orbital	Orbital Sciences Corporation
ORNL	Oak Ridge National Laboratory
ORS	Operationally Responsive Space
OSC	Office of Space Commercialization

OSTM	Ocean Surface Topography Mission
OSVW	ocean surface vector wind

P

PA	Pad Abort test for Orion (e.g., PA-1)
PALSAR	Phased Array type L-band Synthetic Aperture Radar
Pan-STARRS	Panoramic Survey Telescope and Rapid Response System
PARASOL	Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations with a Lidar
PDR	Preliminary Design Review
PDT	Procurement Development Team
PER	Pre-Environmental Review
PISCES	Pacific International Space Center for Exploration Systems
PMA	Pressurized Mating Adapter (e.g., PMA-2)
PNAS	"Proceedings of the National Academies of Science"
PNNL	Pacific Northwest National Lab
POES	Polar-orbiting Operational Environmental Satellite
PPPL	Princeton Plasma Physics Laboratory

Q

QA4EO	Quality Assurance for Earth Observations
QMD	Quality Measurement Data
QuikSCAT	Quick Scatterometer
QZSS	Quasi-Zenith Satellite System

R

R&D	research and development
RATTLRS	Revolutionary Approach To Time-critical Long Range Strike
RAVAR	Rapid Assessment of Values at Risk
RDT&E	research, development, test, and evaluation
RHIC	Relativistic Heavy Ion Collider
RMA	Risk Management Agency
RPIF	Regional Planetary Image Facility
RPT	Rocket Propulsion Test
RSAC	Remote Sensing Applications Center
RSGIG	Remote Sensing and Geographic Information Group
RSIWG	Remote Sensing Interagency Working Group
RTK	real-time kinematic
RTT	Research Transition Team
RUC	Rapid Update Cycle

S

SAA	Space Act Agreement; Sense and Avoid
SAME	Smoke Aerosol Measurement Experiment
SAO	Smithsonian Astrophysical Observatory
SAR	Systems Acceptance Review; Search and Rescue; Synthetic Aperture Radar
SARJ	Solar Alpha Rotary Joint
SARSAT	Search and Rescue Satellite-Aided Tracking
SBUV/2	Solar Backscatter Ultraviolet Spectral Radiometer
SC	Office of Science
SCaN	Space Communications and Navigation
SciDAC	Scientific Discovery through Advanced Scientific Computing

SDL	Space Dynamics Laboratory
SDO	Solar Dynamics Observatory
SDR	System Definition Review
SEA	Satellite Educators Association
SeaWiFS	Sea-viewing Wide Field-of-view
SHAAC	Shuttle Hazard Area to Aircraft Calculator
SHARAD	Shallow Subsurface Radar
SHC	strategic habitat conservation
SHERE	Shear History Extensional Rheology Experiment
SHINE	Solar, Heliosphere, and INterplanetary Environment
SIA	Satellite Imagery Archive
SIASC	Standing Interagency Aviation Security Committee
SIRR	Systems Integration Readiness Review
SLAC	Stanford Linear Accelerator Center
sm	suspended minerals
SMA	Submillimeter Array
SMAP	Soil Moisture Active-Passive
SMART	Smart Material Actuated Rotor Technology
SMD	Science Mission Directorate
SOMD	Space Operations Mission Directorate
SOS	Science on a Sphere
SpaceX	Space Exploration Technologies
SPF	Space Power Facility
SPP	Space Protection Program
SQUID	Superconducting Quantum Interference Device
SRM	Standard Reference Material
SSA	space situational awareness
SSME	Space Shuttle Main Engine
SSS	Sea Surface Salinity
SST	sea surface temperature
STAR	Center for Satellite Applications and Research; Science to Achieve Results
STFC	Science and Technology Facilities Council
SuperDARN	Super Dual Auroral Radar Network
SURF III	Synchrotron Ultraviolet Radiation Facility

T

TAMDAR	Tropospheric Airborne Meteorological Data Reporting
TES	transition-edge sensor
TGF	temperature gradient focusing
THEMIS	Time History of Events and Macroscale Interactions during Substorms
TIM	Total Irradiance Monitor
TIMED	Thermosphere Ionosphere Mesosphere Energetics and Dynamics
TIR	thermal infrared
TOPEX	TOPography EXperiment
TSIS	Total Solar Irradiance Sensor
TSS	total suspended solids
TWINS	Two Wide-angle Imaging Neutral-atom Spectrometers (with mission designation, TWINS-A or TWINS-B)
TWP	Tropical Western Pacific

U

UAF	Upper Atmospheric Facilities
UARS	Upper Atmospheric Research Section
UAS	Unmanned Aerial System; Unmanned Aircraft System; Uninhabited Aerial System

UAV	Unmanned Aerial Vehicle
ULA	United Launch Alliance
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
US&FCS	U.S. and Foreign Commercial Service
USAID	United States Agency for International Development
USCRN	U.S. Climate Reference Network
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USTR	U.S. Trade Representative
UVCS	Ultraviolet Coronagraph Spectrometer

V

VAATE	Versatile Affordable Advanced Turbine Engine
VAFB	Vandenberg Air Force Base
VLA	Very Large Array
VLBI	Very Long Baseline Interferometry
VSHFE	Very Small Heavy Fuel Engine
VTOL	Vertical Take-Off and Landing
VUV	vacuum ultraviolet

W

WAOB	World Agricultural Outlook Board
WIMP	weakly interacting massive particle
WRC	World Radiocommunication Conference
WRF-Chem	Weather Research and Forecasting with Chemistry

X

XRT	X-Ray Telescope