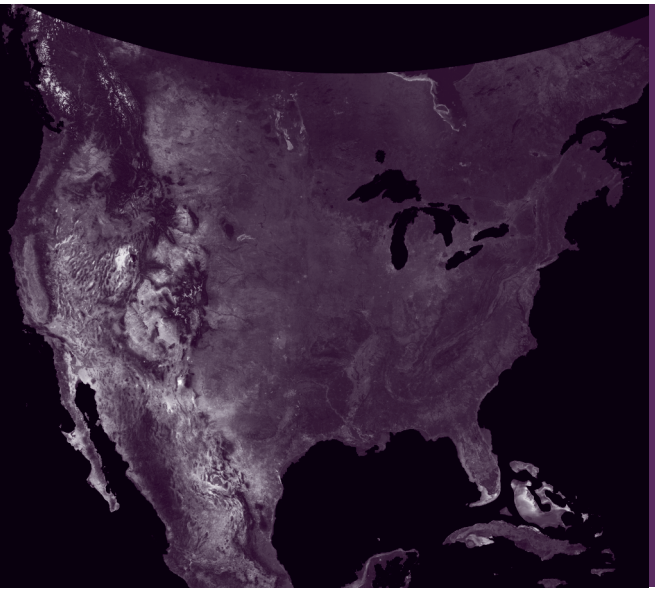
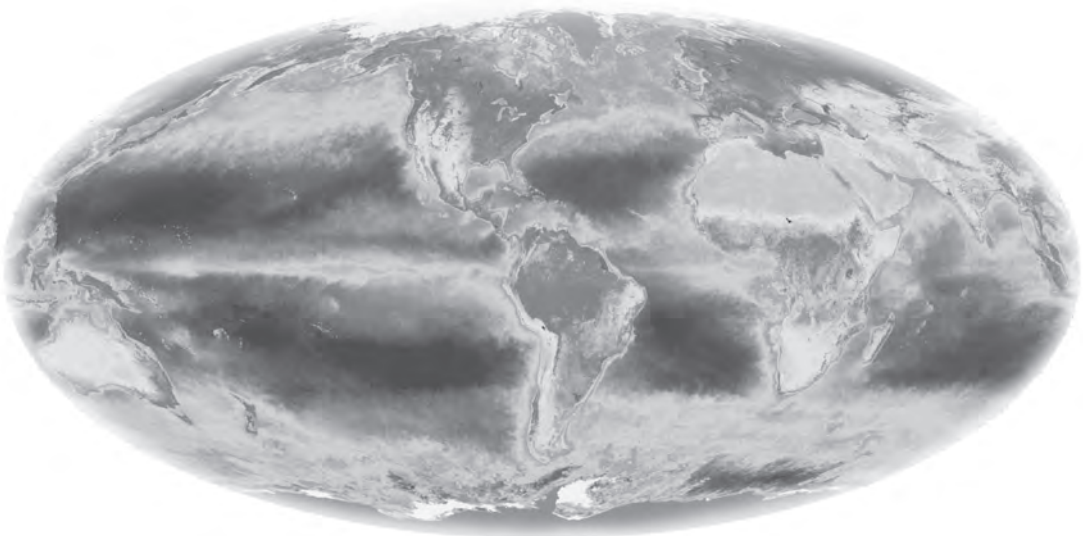
Aeronautics and Space Report of the President



Fiscal Year 2012 Activities

Aeronautics and Space Report of the President



Fiscal Year 2012 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, 2011, through September 30, 2012. Please note that these activities reflect the Federal policies of that time and do not include subsequent events or changes in policy.

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National Aeronautics and Space Administration

NASA

Human Exploration and Operations Mission Directorate

International Space Station

Following the completion of International Space Station (ISS) assembly in 2011, the focus of ISS operations transitioned from assembly to utilization in FY 2012. A new U.S. commercial cargo vehicle, provided by Space Exploration Technologies (SpaceX), conducted its demonstration flight to the ISS during FY 2012.

The ISS began FY 2012 with Expedition 29 crewmembers Sergei Volkov (Roscosmos), ISS Commander Mike Fossum (NASA), and Satoshi Furukawa (Japan Aerospace Exploration Agency [JAXA]) living on board. A Russian Progress cargo vehicle carrying several tons of supplies docked to the ISS on November 2, 2011. After launching on a Russian Soyuz rocket from the Baikonur Cosmodrome in Kazakhstan, Anton Shkaplerov (Roscosmos), Anatoly Ivanishin (Roscosmos), and Dan Burbank (NASA) joined the onboard crew on November 16, 2011. On November 21, 2011, after a short handover, Volkov, Fossum, and Furukawa undocked their Soyuz vehicle from the ISS and landed in Kazakhstan, ending Expedition 29.

Expedition 30 began on November 21, 2011. Cosmonauts Shkaplerov, Ivanishin, and ISS Commander Burbank remained on board and were joined on December 23, 2011, by Oleg Kononenko (Roscosmos), Andre Kuipers (European Space Agency [ESA]), and Don Pettit (NASA), when a Russian Soyuz vehicle docked to the ISS. Shkaplerov and Kononenko conducted a Russian Orlan spacewalk on February 16,

2012, to relocate a Strela crane and install the experiment Vynoslivost. Russian Progress cargo vehicles carrying several tons of supplies docked to the ISS on January 28, 2012, and April 22, 2012. In addition, the ESA Automated Transfer Vehicle (ATV3), named Edoardo Amaldi, docked to the Service Module aft port on March 28, 2012, also carrying several tons of supplies to the ISS. Expedition 30 ended on April 27, 2012, when Shkaplerov, Ivanishin, and Burbank undocked their Soyuz vehicle from the ISS and returned to Kazakhstan.

Expedition 31 began on April 27, 2012. Cosmonaut and ISS Commander Kononenko and astronauts Kuipers and Pettit remained on board and were joined on May 17, 2012, by Gennady Padalka (Russia), Sergei Revin (Russia), and Joe Acaba (NASA), when a Russian Soyuz vehicle docked to the ISS. On May 25, 2012, the first U.S. commercial cargo vehicle developed under the Commercial Orbital Transportation Services (COTS) program arrived at the ISS during its demonstration flight. Developed by SpaceX, the Dragon spacecraft was launched on a Falcon 9 rocket from Florida on May 22 and completed a series of demonstration objectives prior to its arrival at the ISS. The Dragon vehicle was captured with the ISS robotic arm and berthed to the ISS at the Node 2 nadir port. The SpaceX Dragon spacecraft stayed six days at the ISS for the demonstration flight; departed on May 31, 2012; and splashed down in the Pacific Ocean off the coast of Baja California, Mexico. Expedition 31 ended on July 1, 2012, when Kononenko, Kuipers, and Pettit undocked their Soyuz vehicle from the ISS and returned to Kazakhstan.

Expedition 32 began on July 1, 2012. Cosmonauts Padalka (ISS Commander) and Revin and astronaut Acaba remained on board and were joined on July 17, 2012, by Suni Williams (NASA), Yuri Malenchenko (Roscosmos), and Aki Hoshide (JAXA) when a Russian Soyuz vehicle docked to the ISS. On July 27, 2012, the JAXA HII Transfer Vehicle (HTV3), carrying several tons of supplies, was berthed to the Node 2 nadir port. A Russian Progress cargo vehicle carrying several tons of supplies docked to the ISS on August 2, 2012. Malenchenko and Padalka conducted a Russian Orlan spacewalk on August 20, 2012, to relocate the Strela cargo boom, deploy the Sphera satellite, and install five micrometeoroid shields on the Russian Service Module. The Biorisk experiment container was also retrieved, and support struts were installed on the Docking Compartment's

spacewalk ladder. Hoshide and Williams conducted U.S. Extravehicular Mobility Unit (EMU) spacewalks on August 30, 2012, and September 5, 2012, to replace a faulty Main Bus Switching Unit (MBSU) in the ISS electrical power system, route power cables for the Russian Multipurpose Laboratory Module (MLM), and replace a video camera on the ISS robotic arm. Expedition 32 ended on September 17, 2012, when Padalka, Revin, and Acaba undocked their Soyuz vehicle from the ISS and returned to Kazakhstan. This also marked the beginning of Expedition 33 with astronaut Suni Williams as the ISS Commander.

Research and technology development was conducted on the ISS throughout FY 2012. The crew time devoted to research increased significantly following the completion of ISS assembly in 2011. Crewmembers continued the checkout of Robonaut, a dexterous humanoid robot that has been on the ISS since February 2011, and performed the first operations of the Robotic Refueling Mission to demonstrate satellite servicing capabilities for legacy satellites using the Special Purpose Dexterous Manipulator and specially designed tools and taskboards.

The crew continued to study the long-term effects of microgravity on ISS crewmembers, including cardiac function, bone loss, immune function, nutrition, and brain function. The Space Communications and Navigation Testbed was delivered on HTV3 to investigate reprogrammable software-defined radio technology during space missions. A series of operational investigations began during Expedition 31 to prepare for communication delays of up to tens of minutes on future long-duration exploration missions. These initial investigations used routine ISS activities as a test bed to demonstrate crew autonomous operations.

The Alpha Magnetic Spectrometer particle physics detector continued to search for antimatter, dark matter, and cosmic rays to better understand the universe. Crewmembers activated a series of NanoRacks experiments brought up on the SpaceX Dragon vehicle and conducted the YouTube Space Lab contest for 14- to 18-year-old students in the areas of physics and biology. The new aquatic habitat for multigenerational research on small freshwater medaka and zebrafish was delivered on HTV3. In addition, the ISS program cohosted the 1st Annual ISS Research & Development Conference in June 2012 to introduce the public to scientific research and technology development on the ISS.

Space Life and Physical Sciences Research and Applications

Human Research Program

Long-term exposure to microgravity and the spaceflight environment causes changes in the anatomical structure and function of the eye for the majority of astronauts. These changes can include degraded vision, flattening of the globe, swelling of the optic disc, choroidal folds, and cotton-wool spots. Some astronauts also exhibit elevated intracranial pressure—an increase in the pressure of the fluid that surrounds the brain and spinal cord. Some of these changes in vision and pressure persist even after returning to Earth. Concerns about the long-term effects of these changes have heightened efforts to quickly characterize the health risk and the cause of this syndrome. NASA has assembled an expert team from clinical and research communities involved with the systems responsible: the cardiovascular system, the ocular system, and the central nervous system. The team and syndrome are named Visual Impairment/Intracranial Pressure (VIIP), as elevated intracranial pressure is the leading hypothesis to explain the changes. The VIIP team compiled an evidence report containing the results of an exhaustive literature review and mining of NASA's astronaut health database. With the help of the Human Research Program (HRP) Science Management Office, a Wiki-based version of the VIIP Evidence Report is now available to the public for expanded collaboration. The link to the VIIP Wiki site is *http://en.wikipedia.org/wiki/VIIP*.

The On-Line Tool for the Assessment of Radiation in Space (OLTARIS) is a Web-based set of tools and models that allow engineers and scientists to evaluate and optimize protection from space radiation for human or electronic systems such as spacecraft, spacesuits, rovers, habitats, and instruments. During FY 2012, significant upgrades were made to OLTARIS that greatly enhanced the analysis fidelity. First, vehicles can now be analyzed with a bidirectional, ray-by-ray transport method utilizing up to 100 different materials, in any order. This capability provides significant improvement for a detailed look at mature spacecraft designs in which components and materials have typically been defined in a master equipment list. Previous methods relied on interpolation-based estimates using three or four materials commonly defined as equivalent aluminum, polyethylene, regolith, or tissue, combined together in a fixed order. Users can now upload their own

vehicle trajectories and then analyze missions, either as an averaged environment over the entire trajectory to compute mission totals or at every point along the trajectory for a detailed response versus time history. Models, methods, and limitations have been independently verified and validated and are fully documented with online access. The tool set is configuration-managed and makes a current change log available to users. OLTARIS is capable of supporting commercial space partners and Advanced Exploration Systems habitat and space vehicle design teams to assess and mitigate radiation exposures. The Web site may be found at *https://oltaris.larc.nasa.gov/*.

Eating enough calories and exercising in space may help protect astronauts' bones and help solve one of the key problems facing future explorers heading beyond low-Earth orbit. This finding was published in the *Journal of Bone and Mineral Research*. The Nutritional Status Assessment project evaluated the mineral density of specific bones as well as the entire skeleton of astronauts who consumed sufficient calories and used the Advanced Resistive Exercise Device (ARED). The ARED was added to the ISS in 2006 and can produce resistance of as much as 600 pounds in microgravity, allowing astronauts to "lift weights" in weightlessness. The researchers found that astronauts using the ARED returned to Earth with more lean muscle and less fat and maintained their whole-body and regional bone mineral density at about the same levels as when they launched. Crewmembers using the ARED also consumed sufficient calories and vitamin D, among other nutrients. These nutrients support bone health and likely contributed to the results. Normal, healthy bone constantly breaks down and renews itself—a process called remodeling. Earlier studies of Russian Mir space station residents found an increased rate of bone breakdown, but little change in the rate of regrowth, so that an overall loss in bone density resulted. The new study, which examined crewmembers who ate well or used the ARED, found that bone breakdown still increased. However, bone formation also tended to increase, likely resulting in the maintenance of bone mineral density. The increase in both breakdown and formation suggests that the bone was being remodeled, but a key question remains as to whether this remodeled bone was as strong as the bone before flight. Additional studies to evaluate bone strength before and after flight are currently under way. Besides answering the bone strength question, further study is required to determine the best combination of exercise and diet for

long-duration crews. Dietary effects on bone are currently being studied on the ISS. In one experiment, researchers are evaluating the effect on bone health of different ratios of animal protein and potassium in the diet. In another, they are looking at the benefits of lowering sodium intake and studying its effect on bone.

ISS Research—Space Biology and Physical Sciences

The National Research Council's recent report, titled "Recapturing a Future for Space Exploration: Life and Physical Sciences," called on NASA to "reinvigorate its partnership with the life and physical sciences research community." NASA has taken several important steps in response. After nearly a decade of uncertainty about the future of animal research in space, NASA has reinitiated firm plans to conduct basic biological research with rodents on the ISS. The first flight of the new rodent research effort is planned for FY 2014. NASA has also reestablished its program in atomic physics, with a new payload in development that is projected to create the coldest conventional matter in the universe (not at the center of a black hole) aboard the ISS by 2017.

Exploration Systems Development

Within the Human Exploration and Operations Mission Directorate (HEOMD), Exploration Systems Development (ESD) is continuing NASA's exploration efforts, which include the Orion spacecraft, Space Launch System (SLS) heavy-lift launch vehicle, and Exploration Ground Systems (EGS) infrastructure required to conduct crewed missions of exploration into deep space, such as a proposed mission to send astronauts to a redirected asteroid that would be inserted into a stable orbit around the moon. Orion and SLS fit well within a broader U.S. Government launch strategy of procuring commercial launches of crew and cargo to the ISS while concentrating NASA's development efforts on exploration missions beyond Earth orbit. SLS and Orion are fundamental building blocks in a capability-based architecture designed for long-term human exploration of our solar system, particularly the goal of landing humans on Mars. Both Orion and SLS are being designed to support multiple missions and destinations rather than being optimized for one particular mission or architecture. The capabilities being developed will open a

broad range of exciting destinations for human exploration in the solar system. NASA's approach to expanding the human presence farther into the solar system includes sending humans to an asteroid in the next decade and eventually sending humans to Mars.

In 2012, NASA successfully completed an integrated Systems Requirements Review (SRR) in February for the full-up Orion, SLS, and ground systems capabilities. This milestone demonstrated that the requirements for the integrated programs meet the Agency's goals and provide a sound basis for the individual development of Orion, SLS, and ground systems. ESD directs cross-program integration to ensure that Orion, SLS, and the ground systems capabilities meet the needs of the Agency's long-term human exploration objectives, function as planned, and remain within the tight cost and schedule constraints. Guidelines were established for programmatic management and development; roles, responsibilities, and accountability were identified for each of the programs; and processes for integration and configuration management, risk management, and program performance reporting were established. ESD has also implemented procedures for decision making, as well as cost and schedule management; defined program deliverables; and completed the first phases of the NASA program management process.

ESD is progressing toward the integrated System Definition Review (SDR) in the third quarter of 2012, as the associated flow-down processes are properly performed and the programs are properly integrated to meet the needs of the human exploration framework. The status of the integrated system will be reviewed and assessed at periodic checkpoints as ESD proceeds through development and operations.

Orion Multi-Purpose Crew Vehicle

Orion's shape resembles its Apollo-era predecessors, but its technology and capabilities are far more advanced. The Orion Multi-Purpose Crew Vehicle (MPCV) features dozens of technology innovations that have been incorporated into the spacecraft's subsystem and component design. To support our exploration missions, the Orion teams at Johnson Space Center (JSC) and at Lockheed Martin are developing state-of-the-art life-support, propulsion, thermal protection, and avionics systems. Building upon the best of U.S. human spaceflight design and experience, the Orion spacecraft includes both crew and service modules, as well

as a launch abort system that will significantly increase crew safety. Our computer modeling scenarios are now so accurate that we have been able to forgo more expensive ground tests in some cases. We expect this trend to continue whenever possible without sacrificing safety.

The program delivered the first flight test crew module structure to Kennedy Space Center (KSC) for assembly and integration in July 2011. All planned engineering test activities were accomplished throughout FY 2012. The results confirmed our models and informed our design analysis cycles in support of the Systems Requirements Review and Systems Definition Review in May and June 2012.

Space Launch System

The SLS Program, managed at NASA's Marshall Space Flight Center (MSFC) with the Boeing, Alliant Techsystems (ATK), and Pratt & Whitney Rocketdyne industry partners, is developing the heavy-lift vehicle that will launch the Orion spacecraft and cargo for NASA's exploration missions. The SLS vehicle family will start with a lift capability of 70 metric tons (t) to low-Earth orbit (LEO), with the ability of evolving up to 130 t based on future mission requirements. The SLS is designed with one overarching purpose: to explore beyond Earth orbit with ambitious mass and propulsion requirements. The initial 70-t configuration will consist of an 8.4-meter-diameter core stage, building on Space Shuttle and Ares experience and powered by four RS-25D liquid-hydrogen/liquid-oxygen engines that formerly powered the Space Shuttle orbiter, and will build on the U.S. state-of-the-art capabilities in liquid propulsion. The core stage is being designed for use on future configurations of the SLS with the diameter, materials, and manufacturing processes remaining the same as the vehicle performance evolves. In this configuration, two five-segment solid rocket boosters (SRBs)—a more powerful version of the four-segment boosters used on the Space Shuttle—will be attached to the core stage for the initial boost phase of flight. For the first two missions of SLS, an Interim Cryogenic Propulsion Stage (ICPS) will be used to propel the Orion spacecraft from LEO. NASA has chosen Boeing's Delta IV upper stage as the ICPS for the first two flights. Contract negotiations are in progress.

The SLS NASA-industry team has successfully completed the SRR and the SDR, and it has gained Agency-level approval to proceed to the Preliminary Design

Review. The NASA/Boeing Core Stage element has successfully completed its SRR and SDR. Manufacturing process development has proceeded to support the core stage and vehicle design efforts. NASA has initiated activities to prepare the B-2 test stand at Stennis Space Center (SSC) for Core Stage testing that will be performed prior to shipment to KSC for a launch scheduled in December 2017. The Core Stage element is on the critical path for the SLS, and all hands are on deck to achieve the schedule. The initial segments for the first of two solid booster Qualification Motor tests have been poured at ATK. The 15 RS-25D liquid-hydrogen/liquid-oxygen engines have been delivered to SSC from KSC in preparation for installation and testing on the Core Stage.

SLS is also an integral part of the Exploration Flight Test 1 (EFT-1) planned for December 2014. SLS is responsible for designing and developing the structure adapter to attach the Orion spacecraft to the launch vehicle. The Block 1, 70-t vehicle will prove out the new Core Stage and integrated stack for the initial exploration missions and can support scientific payloads with requirements beyond commercial lift capabilities. Mission analysis has shown that the Block 1A, 105-t vehicle will provide significant mission capture capabilities for the next set of human missions beyond LEO. A 130-t Block 2 vehicle is also being designed consistent with congressional direction and would be used for full-capability asteroid missions and, ultimately, missions to Mars.

Exploration Ground Systems

The Exploration Ground Systems effort has also been making significant progress since September 2011. The KSC and SLS teams are working very closely to define and develop the necessary interfaces for the launch vehicle. In a similar manner, KSC has been working with the Orion program on the necessary prelaunch processing to be performed. Based upon the SLS and Orion needs, KSC has proceeded through the Systems Requirements and Systems Definition Reviews. KSC is also providing valuable operations expertise to the SLS and Orion teams to address operational issues in the design in order to help reduce eventual production and operations costs. In terms of infrastructure and hardware, KSC has completed the first phase of the mobile launcher construction. Refurbishment and upgrades to a crawler-transporter are being performed at a pace to support the December

2017 flight of SLS and Orion. These upgrades are needed due to the increased mass of the SLS/Orion integrated stack compared to the Space Shuttle configuration. Work has begun on the Vehicle Assembly Building and the platforms in High Bay 3 to support SLS. Launch Complex 39-B has been prepared for the SLS/Orion mobile launcher with the Space Shuttle hardware removed, lightning towers in place, and the needed refurbishment to the pad infrastructure.

Commercial Crew Development

During 2012, NASA signed Space Act Agreements (SAAs) with three companies to advance multiple integrated transportation systems, which could ultimately transport humans to low-Earth orbit. This effort is called Commercial Crew integrated Capability (CCiCap).

NASA's CCiCap partners are Sierra Nevada Corporation, Louisville, Colorado; Space Exploration Technologies (SpaceX), Hawthorne, California; and the Boeing Company, Houston, Texas.

NASA's partners will perform tests and mature integrated designs. This will then set the stage for a future activity that will launch crewed orbital demonstration missions to low-Earth orbit by the middle of the decade.

Additionally, NASA took the next step in its plan to launch American astronauts from U.S. soil, selecting three companies to conduct activities under Certification Products Contracts (CPCs) that will enable the future certification of commercial spacecraft as safe to carry humans to the International Space Station.

CPC contractors are the Boeing Company, Houston, Texas; Sierra Nevada Corporation Space Systems, Louisville, Colorado; and SpaceX, Hawthorne, California.

These companies will work with NASA's Commercial Crew Program (CCP) to discuss and develop products to implement the Agency's flight safety and performance requirements. This includes implementation across all aspects of the space system, including the spacecraft, launch vehicle, and ground and mission operations.

Commercial partners continued to make progress maturing their respective commercial crew transportation systems and completing technical, programmatic, and financial milestones.

Launch Services

The first launch for the Launch Services Program (LSP) in FY 2012 was the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) mission launching on a United Launch Services (ULS) Delta II launch vehicle on October 28, 2011. Also aboard this launch vehicle were five CubeSats from four universities in Alabama, Michigan, Montana, and Utah. The LSP then went on to achieve a 100 percent success rate by conducting three additional launches of NASA missions during FY 2012. LSP launched NASA's Mars Science Laboratory (MSL) toward the Red Planet aboard an Atlas V on November 26 and the Nuclear Spectroscopic Telescope Array (NuSTAR) spacecraft into low-Earth orbit on June 13. The Radiation Belt Storm Probe (RBSP) mission, the first twin-spacecraft mission designed to explore our planet's radiation belts, launched aboard an Atlas V on August 30, 2012. Additionally, LSP continued to provide launch-related systems engineering, launch integration, and mission design and analysis support to approximately 35 NASA-sponsored missions in various phases of development. To find out more about these and other NASA science missions, see the Science Mission Directorate section in this report.

LSP is working to expand the selection of launch vehicles and support the continued growth of the U.S. commercial space sector by providing competitive opportunities to U.S. commercial launch providers. In FY 2012, LSP signed the New Entrant Launch Vehicle Certification Strategy with the United States Air Force and the National Reconnaissance Office. This provides a coordinated certification strategy for new entrant launch vehicle certification and is intended to further enable competition and provide a consistent path for new entrants to compete for U.S. Government missions. On May 14, 2012, the SpaceX Falcon 9 v1.1 launch vehicle was added to the NASA Launch Services (NLS) II contract. Orbital Sciences Corporation's (OSC's) Antares 120 and 130 model launch vehicles were added to NLS II on June 26, 2012. Launch Service Task Orders (LSTOs) for six missions were awarded in FY 2012, including the Geostationary Operational Environmental Satellites (GOES)-R and -S missions awarded to ULS Atlas V launch vehicles on April 5. This was followed on July 16 by a multi-mission launch service award of the Orbiting Carbon Observatory (OCO)-2, the Soil Moisture Active Passive (SMAP), and the Joint Polar Satellite System (JPSS)-1. ULS received the contract to launch

OCO-2 on a Delta II launch vehicle after the termination of the OCO-2 Taurus XL LSTO on February 2, 2012. ULS also received the contracts to launch the SMAP and JPSS-1 missions on Delta II launch vehicles. On the very same day, SpaceX received an LSTO to launch the Jason-3 mission on a Falcon 9 launch vehicle.

Lastly, LSP was active with its support to the Taurus XL T9 Mishap Investigation Board (MIB) that reviewed the cause of the March 4, 2011, launch failure of OSC's Taurus XL launch vehicle. By the end of FY 2012, the MIB had completed its review and the NASA Glory MIB report was finalized.

Human Spaceflight Capabilities

The most notable test activity in FY 2012 was that of the J-2X engine, the first human-rated liquid-oxygen and liquid-hydrogen rocket engine to be developed in 40 years. The J-2X upper stage engine is vital to achieving full launch capability of the heavy-lift SLS, a critical component of NASA's deep space exploration program, currently under development. Additional testing was performed in support of NASA development projects, including a liquid-oxygen (LOX)/liquid-methane engine that could one day carry cargo to the moon.

The Orbital Sciences Corporation and Aerojet conducted several test firings of the AJ26 engine to clear the engines for use on the Antares first stage. These firings represented the final engine testing prior to shipping to Wallops Flight Facility and integrating on test and flight launch vehicles. The engines will enable COTS test and demonstration flights, as well as upcoming ISS resupply missions.

NASA Advanced Exploration Systems developed a small lander test bed called Morpheus to demonstrate autonomous precision landing and LOX-methane propulsion—two key technologies for landing on the moon or Mars. These landing systems will improve safety by detecting hazards such as rocks and craters in the landing zone and automatically maneuvering the lander to avoid them. LOX-methane propulsion systems may be used on Mars missions since crew could produce propellants for the trip home from the Martian atmosphere.

In support of the Space Shuttle's transition and retirement, the Rocket Propulsion Test (RPT) Program Office conducted final preparations for decontamination, cleanup, and removal of hypergolic propellant at JSC's White Sands Test

Facility (WSTF) prior to shipping the vehicles to their final display destinations in Virginia and Los Angeles. Removing the hypergolic propellants was necessary because the propellant is highly corrosive and poses a health hazard.

By the conclusion of FY 2012, the RPT program had safely performed over 118 tests, clocked over 300,000 seconds of test time, and neared 10,000 seconds of hot fire at various levels of thrust capacity.

Space Communications and Navigation

In FY 2012, the Space Communications and Navigation (SCaN) Program Office focused on the critical sustainability and development of the ground and space components of the networks that provide space communications for NASA's missions. The three networks—the Near Earth Network (NEN), the Space Network (SN) Tracking and Data Relay Satellite System (TDRSS), and the Deep Space Network (DSN)—continued to meet the space communications needs, such as Earth monitoring and support of deep space science missions, of a wide range of customers, both internal and external to NASA.

In FY 2012, SCaN maintained at least 99 percent proficiency of all of its networks, providing communication and navigation services to approximately 35 spacecraft using the DSN, approximately 30 spacecraft using the Space Network, and approximately 30 spacecraft using the Near Earth Network. The Near Earth Network also provided communication and navigation services to approximately 25 launches during launch and early orbit phases.

The DSN is an international network of antennas that supports interplanetary spacecraft missions and radio and radar astronomy observations for the exploration of the solar system and the universe. The network also supports selected Earth-orbiting missions. The SN consists of a space segment, composed of TDRSS, and a ground segment, which includes the White Sands Complex in New Mexico and the Guam Remote Ground Terminal. Data from the satellites and the International Space Station is downlinked to the ground segment. The NEN provides tracking, telemetry, and communications services, using antenna assets located around the world, for orbital missions and occasionally suborbital missions.

SCaN completed some key milestones during FY 2012. The SCaN Program System Engineering team continued to make progress toward an architecture

design for an integrated network. The Tracking and Data Relay Satellite (TDRS)-K spacecraft successfully completed its Pre-Ship Review, and the TDRS-L spacecraft successfully completed thermal testing. A contract for the TDRS-M spacecraft was signed. The Space Network Ground Segment Sustainment Project successfully completed its Preliminary Design Review. The Merritt Island Launch Area tracking station, which had provided tracking services since the Apollo era, was successfully closed after the Shuttle program ended. The Deep Space Network Aperture Enhancement Project successfully completed its system-level Preliminary Design Review. The Lunar Laser Communication Demonstrator Project completed its Pre-Environmental Review. The SCaN Program also completed phase 1 of its Disruption Tolerant Networking Project and a novel concept of arraying the TDRS signals. The Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) successfully launched on HTV3 to mate with the ISS. It is now called SCaN Test Bed. The Standards activity completed the Consultative Committee for Space Data Systems (CCSDS) Blue Book (the recommended standard) for Internet protocols for space links. The Spectrum Management Program was successful in its studies in protecting Global Positioning System (GPS) frequencies from introducing incompatible commercial mobile services in adjacent frequencies. NASA's analyses were submitted to the national regulators (the National Telecommunications and Information Administration and the Federal Communications Commission) to support the U.S. decision on this issue. The CCSDS is a major international organization that develops internationally agreed-upon and interoperable space communications standards that enable joint international missions and reduce cost and risk to space missions. The MSL Earth communications systems are using the CCSDS internationally agreed-upon space data communications standards to enable reliable transmission of data directly to Earth or through the European Space Agency's Mars Express Orbiter, which relays data to and from Earth.

Advanced Exploration Systems

The Advanced Exploration Systems (AES) Program is pioneering new approaches for high-priority capabilities needed for human exploration through rapidly developing prototype systems, demonstrating key capabilities in flight, and validating operational concepts.

In FY 2012, the AES Division executed 20 projects and achieved 49 of 56 major project milestones. These milestones included the following:

- The Radiation Assessment Detector (RAD) developed by the AES Program for the Mars Science Laboratory mission obtained the first radiation measurements from the surface of Mars. These measurements will improve our understanding of the risks to future human explorers.
- A crew of four simulated an asteroid exploration mission in a 12-day underwater test. The crew tested various methods for exploring the surface of a low-gravity asteroid and demonstrated mission operations with a communications time delay. On deep space missions, the communications time delay becomes too long for real-time mission control from the ground. Consequently, the crew must perform mission control functions such as planning and scheduling on their own.
- A prototype suit port was demonstrated in vacuum chamber tests. A suit port is an interface between a spacesuit and a crew habitat or vehicle. It allows an astronaut to quickly enter or exit the spacesuit without requiring an airlock. Suit ports will reduce the time needed to prepare for extravehicular activity, and they will be incorporated into the design of advanced spacesuits.
- NASA and the Canadian Space Agency tested a prototype lunar ice prospecting experiment in Hawaii. Propellants and oxygen produced from ice in the lunar soil could reduce the amount of consumables launched from Earth to support human missions.
- Ground-based radar is a low-cost way to image many asteroids that pass close to Earth, eliminating the need to send expensive robotic spacecraft to the asteroids in advance of human missions to gather critical data. The Goldstone radar imaged 16 near-Earth asteroids to determine their size, shape, and spin rate. Several of these asteroids could be candidates for human missions.
- The Human Spaceflight Architecture Team completed two full design analysis cycles that scoped key performance capabilities and mission requirements, with the results extensively briefed to NASA leadership, the NASA Advisory Council, the White House, Congress, industry, and

the public. The team completed a major study analysis of near-term mission options and a key report to Congress. The results drove SLS/MPCV architecture decisions, prioritized technology investment planning, and allowed comprehensive roadmaps for beyond-LEO capability development requirements to achieve national mission objectives with a "capability-driven architecture" approach for future human exploration.

- AES continued mission planning and preparatory analysis of all known near-Earth asteroid targets for potential human exploration and robotic precursor missions, including key test mission refinement.
- AES hosted four world-class Blue Sky innovation forums, supported four analog activities, and held two Exploration Community Workshop events to bring innovative ideas into human spaceflight activities, including the creation of the Voyages document, which further detailed the strategy outlined in the Capability Driven Framework.

Science Mission Directorate

NASA's Science Mission Directorate (SMD) conducts scientific exploration enabled by the use of space observatories and space probes that view Earth from space, observe and visit other bodies in the solar system, and peer out into our galaxy and beyond. From space, in space, and about space, NASA's science vision encompasses questions as practical as hurricane formation, as enticing as the prospect of lunar resources, and as profound as the origin of the universe. SMD seeks answers to significant questions that touch us all: How and why are Earth's climate and environment changing? How and why does the sun vary and affect Earth and the rest of the solar system? What are the impacts on humanity? How do planets and life originate? What are the characteristics of planetary systems orbiting other stars, and do they harbor life? Are we alone?

SMD has five program divisions: Astrophysics, Earth Science, Heliophysics, Planetary Science, and the Joint Agency Satellite Division (JASD). SMD also has a James Webb Space Telescope (JWST) program office. In FY 2012, SMD successfully launched four new space and Earth science missions designed to improve our understanding of solar processes, Earth system change, the nature of the universe,

and the history of the solar system. SMD lays the intellectual foundation for the robotic and human expeditions of the future while meeting today's needs for scientific information to address national issues such as climate change, space weather, and education.

Astrophysics Division

The science goals of the Astrophysics Division are breathtaking: we seek to understand the universe and our place in it. We are starting to investigate the very moment of the creation of the universe and are close to learning the full history of stars and galaxies. We are discovering how planetary systems form and how environments hospitable for life develop. Further, we will search for the signature of life on other worlds, perhaps to learn that we are not alone.

On December 12, 2011, astronomers using NASA's Hubble Space Telescope announced that they had seen further back in time than ever before and uncovered a previously unseen population of seven primitive galaxies that formed more than 13 billion years ago, when the universe was less than 3 percent of its present age. The greater depth of the new Hubble images, together with a carefully designed survey strategy, permitted this work to go further than previous studies. Notably, one of the galaxies might be a distance record breaker, observed just 380 million years after the Big Bang. The universe is estimated to be 13.8 billion years old.

Researchers on NASA's Kepler mission announced on December 20, 2011, that they had discovered the first Earth-sized planets orbiting a sunlike star outside our solar system. The planets, called Kepler-20e and Kepler-20f, were too close to their star to be in the so-called habitable zone where liquid water could exist on a planet's surface, but they were the smallest exoplanets ever confirmed around a star like our sun. The discovery marked the next important milestone in the ultimate search for planets like Earth.

On March 20, 2012, it was announced that studies using x-ray and ultraviolet observations from NASA's Swift satellite were providing new insights into the elusive origins of an important class of exploding star called Type 1a supernovae. Astronomers have known for decades that Type 1a supernovae originate with a remnant star called a white dwarf, which detonates when pushed to a critical mass.

The environment that sets the stage for the explosion, however, has been harder to pin down. These new studies suggest that the companion to the white dwarf is either a smaller, younger star similar to our sun or another white dwarf.

Scientists using NASA's Fermi Gamma-Ray Space Observatory announced on April 2, 2012, that observations of dwarf galaxies had provided new insights on dark matter. While scientists still do not know what makes up the mysterious dark matter thought to dominate the universe, a study using Fermi data to examine dwarf galaxies orbiting the Milky Way Galaxy has chipped away at the possibilities, offering intriguing hints about the nature of dark matter. Dark matter constitutes about 80 percent of the matter in our universe. By studying numerous dwarf galaxies—satellite systems that orbit our own Milky Way Galaxy—Fermi scientists have produced some of the strongest limits yet on the nature of the hypothetical particles suspected of making up dark matter.

On May 2, 2012, astronomers announced they had gathered the most direct evidence yet of a supermassive black hole shredding a star that wandered too close. NASA's Galaxy Evolution Explorer (GALEX), a space-based observatory, and the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS1) telescope on the summit of Haleakala, Hawaii, were among the first to help identify the stellar remains. The scientists believe that the star's hydrogen-filled envelope surrounding the core was lifted off a long time ago by the same black hole. The star may have been near the end of its life. After consuming most of its hydrogen fuel, it had probably ballooned in size and become a red giant. Astronomers think the bloated star was looping around the black hole in a highly elliptical orbit. On one of its close approaches, the star was stripped of its puffed-up atmosphere by the black hole's powerful gravity. The stellar remains continued their journey around the center, until they ventured even closer to the black hole to face their ultimate demise.

Researchers from NASA's Wide-Field Infrared Survey Explorer (WISE) mission announced on August 29, 2012, that they had found a bonanza of supermassive black holes and extreme galaxies called hot dust-obscured galaxies, or hot DOGs. Images from WISE have revealed millions of dusty black hole candidates across the universe and about 1,000 even dustier objects thought to be among the brightest galaxies ever found. These findings are helping astronomers better understand how galaxies and the behemoth black holes at their centers grow and evolve together.

For example, the giant black hole at the center of our Milky Way Galaxy, called Sagittarius A*, has 4 million times the mass of our sun and has gone through periodic feeding frenzies where material falls toward the black hole, heats up, and irradiates its surroundings. Bigger central black holes, up to a billion times the mass of our sun, may even shut down star formation in galaxies. These extreme objects can pour out more than 100 trillion times as much light as our sun.

Earth Science Division

Earth is a complex, dynamic system we do not yet fully understand. The Earth system, like the human body, comprises diverse components that interact in complex ways. We need to understand Earth's atmosphere, lithosphere, hydrosphere, cryosphere, and biosphere as a single, connected system. The purpose of NASA's Earth Science program is to develop a scientific understanding of Earth's system and its response to natural or human-induced changes, as well as to improve the prediction of climate, weather, and natural hazards.

On October 28, 2011, NASA successfully launched the Suomi National Polar-orbiting Partnership (Suomi NPP) spacecraft aboard a United Launch Alliance rocket from Vandenberg Air Force Base in California to begin its Earth observation mission. Suomi NPP continues to collect the quality data records from NASA's Earth Observing System (EOS) observations. It also serves as a demonstration and risk-reduction mission for the forthcoming series of Joint Polar Satellite System (JPSS) satellites and represents a critical first step in building this next-generation weather satellite system. Suomi NPP carries five science instruments and is the first satellite mission to address the challenge of acquiring a wide range of land, ocean, and atmospheric measurements for Earth system science while simultaneously addressing operational requirements for weather forecasting. Suomi NPP enables the National Oceanic and Atmospheric Administration (NOAA) to continue issuing accurate forecasts and providing advance warning for severe weather, such as deadly tornado outbreaks, blistering heat waves, floods, snowfall, and wildfires.

NASA's Gravity Recovery and Climate Experiment (GRACE) satellites celebrated their 10-year anniversary on March 17, 2012. Making precise measurements of Earth's gravity field while traveling as a pair in orbit, the GRACE satellites

revolutionized several scientific fields and provided precise information about what is happening to the world's water and ice; they also served as the scientific pathfinder for NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission. Launched on March 17, 2002, the twin GRACE spacecraft work together by using a microwave ranging system to measure differences in their separation as small as a hundredth of the thickness of a human hair. Using a high-quality GPS, the spacecraft relayed variations in separation along with their location down to earthbound tracking stations. GRACE satellites' measurements of extremely small temporal variations in Earth's gravity field have resulted in a 10- to 100-fold improvement in geoid (a model of Earth's gravity field) precision and the ability to detect changes in groundwater with astounding accuracy. Measurements of ocean bottom pressure surprised oceanographers, and GRACE profiled the global water vapor content of Earth's atmosphere. It was GRACE that determined that ice loss from the high Asian mountain ranges was only 4 billion tons a year, compared to the 50 billion tons estimated using ground-based instrumentation.

In April 2012, a study using measurements from NASA's Ice, Cloud, and land Elevation Satellite (ICESat) revealed that warm ocean currents attacking the underside of ice shelves were the dominant cause of recent ice loss from Antarctica. An international team of scientists used a combination of satellite measurements and models to differentiate between the two known causes of melting ice shelves: 1) warm ocean currents thawing the underbelly of the floating extensions of ice sheets and 2) warm air melting them from above. The researchers concluded that warm ocean currents melted 20 of the 54 ice shelves studied. Most of these were in West Antarctica, where inland glaciers flowing down to the coast and feeding into these thinning ice shelves accelerated, draining more ice into the sea and contributing to sea-level rise. This ocean-driven thinning was responsible for the most widespread and rapid ice losses in West Antarctica and the majority of Antarctic ice sheet loss during the period studied. The finding brought scientists a step closer to providing reliable projections of future sea level rise.

Heliophysics Division

Understanding the sun, heliosphere, and planetary environments as a single connected system is an important goal of the Heliophysics Division. We live in the extended atmosphere of an active star; while sunlight enables and sustains life, the sun's variability produces streams of high-energy particles and radiation that can harm life or alter its evolution. In addition to solar processes, the heliophysics domain of study includes the interaction of solar plasma and radiation with Earth, the other planets, and the galaxy. By analyzing the connections between the sun, solar wind, planetary space environments, and our place in the galaxy, we are uncovering the fundamental physical processes that occur throughout the universe. Understanding the connections between the sun and its planets will allow us to predict the impacts of solar variability on humans, technological systems, and the presence of life itself.

On December 14, 2011, the Heliophysics solar fleet observed Comet Lovejoy as it survived its encounter with the sun. The comet graced the southern sky of Earth after it unexpectedly survived a close encounter with the sun. This bright comet was also seen from the ISS in another stunning time-lapse sequence on December 21, 2011. Observations of Lovejoy's close call with the sun have helped researchers improve models used to describe the irregular nature of coronal magnetism.

NASA announced on January 31, 2012, that its Interstellar Boundary Explorer (IBEX) spacecraft had captured the best and most complete glimpse yet of what lies beyond the heliosphere—observations that showed that our solar system is different from the space right outside it. These new measurements yield clues about how and where our solar system formed, about the forces that physically shape our solar system, and about the history of other stars in the Milky Way. The IBEX spacecraft observes four distinct chemical elements: hydrogen, oxygen, neon, and helium. IBEX determined the distribution of these elements, outside the solar system, that are flowing as charged and neutral particles, which stream through the galaxy. IBEX also measured the interstellar wind traveling at a slower speed than previously measured by the Ulysses spacecraft and from a different direction. The improved measurements from IBEX showed a 20 percent difference in how much pressure the interstellar wind exerts on our heliosphere. The pressures on

our heliosphere from the material in the local interstellar medium and from the galactic magnetic fields determine its size and shape.

In July 2012, an unprecedented alignment among NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) probes, JAXA's Geotail satellite, and two of NOAA's Geostationary Operational Environmental Satellites in the night side of Earth's vast magnetic environment captured data that yielded comprehensive details of an energy-intensive process that forms the aurora, called a substorm. Their results showed that small events unfolding over the course of a millisecond can result in energy flows that last up to half an hour and cover an area 10 times larger than Earth. These flows ultimately power Earth's auroras, heat the plasma inside Earth's magnetic field, and energize the Van Allen radiation belts. Understanding the details of each step in the process is crucial for scientists to achieve their goal of someday predicting the onset and intensity of the dynamic variations of near-Earth space.

A massive cloud of solar material erupted off the sun's right side on July 23, 2012, zooming out into space and passing one of NASA's Solar TErrestrial RElations Observatory (STEREO) spacecraft along the way. Using the STEREO data, scientists at NASA's Goddard Space Flight Center clocked this giant cloud, known as a coronal mass ejection (CME), traveling between 1,800 and 2,200 miles per second as it left the sun. This was the fastest CME ever observed by STEREO, which, since its launch in 2006, has helped make CME speed measurements much more precisely, enabling us to better understand what causes these great explosions and to improve models of the sun's effects near Earth.

On August 30, 2012, NASA successfully launched the Radiation Belt Storm Probes into space; the renamed Van Allen Probes were released from the rocket's Centaur upper stage one at a time and sent off into different orbits, kicking off the two-year mission to study Earth's radiation belts. The scientific successes for the Van Allen Probes began almost immediately after launch, starting with a discovery made by the Relativistic Electron Proton Telescope (REPT) instrument on September 1, 2012: a new, third radiation belt formed at the interior of the outer belt. The new belt was destroyed four weeks later by another solar storm—another unprecedented observation. Just a few days later, on September 5, 2012, members of the Electric and Magnetic Field Instrument Suite and Integrated Science

(EMFISIS) team of the Van Allen Probes mission made an audio recording of radio waves in the belts, at a frequency audible to humans, known as "chorus." While scientists have known about chorus since the 1950s, these new, high-quality recordings became known as "the sounds of space" and drew a great deal of interest around the world. Chorus is caused by plasma waves in the belts and is suspected to be related to the process that accelerates electrons to speeds that can harm spacecraft and astronauts.

Planetary Science Division

The observation and discovery of our solar system's planetary objects is one of the oldest of scientific pursuits. With an exploration strategy based on progressing from flybys, to orbiting, to landing, to roving, and finally to returning samples from planetary bodies, the Planetary Science Division advances the scientific understanding of the solar system in extraordinary ways while pushing the limits of spacecraft and robotic engineering design and operations. Since the 1960s, NASA has broadened its reach with increasingly sophisticated missions launched to a host of nearby planets, moons, comets, and asteroids.

NASA successfully launched the Mars Science Laboratory (MSL) Curiosity rover into space on November 26, 2011. Curiosity carried the most advanced payload of scientific gear ever used on Mars's surface, a payload more than 10 times as massive as those of earlier Mars rovers. Curiosity inherited many design elements from NASA's twin Mars Exploration Rovers, Spirit and Opportunity, launched in 2003, including a six-wheeled drive, a rocker-bogie suspension system, and cameras mounted on a mast to help the mission's team on Earth select exploration targets and driving routes. Unlike earlier rovers, Curiosity carries equipment to gather samples of rocks and soil, process them, and distribute them to on-board test chambers inside analytical instruments. The U.S. Department of Energy radioisotope power generator provides electrical power to Curiosity; this safe and long-lived power supply gives the mission an operating lifespan on Mars's surface of a full Mars year (687 Earth days) or more.

Curiosity landed successfully on the floor of Mars's Gale Crater in August 2012. Curiosity landed in a riverbed that held key chemical ingredients in the bedrock

indicating that ancient Mars could have supported microbial life. Almost immediately, Curiosity sent back pictures of its landing site at Gale Crater with the eventual destination of Mount Sharp in the background. Since then, Curiosity has checked out its 10 science instruments, sent back detailed photos and weather observations, and "tasted" Martian soil. Key mission findings during the first three months after the landing included conglomerate rocks bearing rounded pebbles as evidence of vigorous ancient stream flow right in the area where Curiosity landed; mineral composition of Martian soil similar to soils in Hawaii that contain volcanic glass; and the first assessment of the natural radiation environment that future astronauts will encounter on the surface of Mars. In addition, the landing technology for putting such a large payload safely on the Martian surface could help with plans for future human Mars missions. Curiosity's successful and historic landing was a worldwide phenomenon; during the Curiosity landing, NASA's Web site received 15 million visits and sent out 36 million Webcast streams of NASA TV, breaking records that had just been set during the Venus transit (4.2 million Web site visits, 7.7 million Webcast streams).

NASA's twin GRAIL spacecraft entered lunar orbit on December 31, 2011, and on January 1, 2012, respectively. The twin spacecraft flew around the moon in tandem, working together to map the lunar gravity field in unprecedented detail to deduce information about the structure, density, and composition of the lunar interior. The lunar insertion maneuvers placed the spacecraft into a near-polar, elliptical orbit with an orbital period of approximately 11.5 hours. During GRAIL's science mission, the two spacecraft transmitted radio signals precisely defining the distance between them. As the two probes flew over areas of greater or lesser gravity caused by visible features such as mountains and craters, as well as masses hidden beneath the lunar surface, the distance between the two spacecraft changed slightly. Each spacecraft carried a set of cameras called Moon Knowledge Acquired by Middle school students (MoonKAM), marking the first time a NASA Planetary Science Division mission carried instruments expressly for an education and public outreach project. The GRAIL spacecraft have given us the best gravity map of the moon thus far.

On June 5, 2012, people across 159 countries witnessed the last transit of Venus across the sun in our lifetime. The culmination of a two-year planning effort by

NASA SMD's Education and Public Outreach teams involved over 7 million people watching the transit through NASA's online services and an estimated 1 billion people watching it worldwide through a variety of means. Over 10,000 astronomy clubs and science museums hosted Venus transit–related events. NASA transmitted real-time events from India, the United Kingdom, and six U.S. locations. The Agency used this opportunity to educate viewers on the scientific importance of planetary transits (especially in finding exoplanets), the historical importance of the transit in the calculation of the astronomical unit (distance from Earth to sun), and the technological importance of how technology has changed from transit to transit. (Transits occur only about every 105 years.)

NASA's Dawn spacecraft escaped from the gentle gravitational grip of the giant asteroid Vesta on September 5, 2012. Dawn left Vesta on its way to its second destination, the dwarf planet Ceres. The Dawn spacecraft was built to help scientists understand the conditions and processes acting at the solar system's earliest epoch on two complementary bodies—Vesta and Ceres. Also, Dawn's scientific drivers included 1) capturing the earliest moments in the origin of the solar system, enabling us to understand the conditions under which these objects formed; 2) determining the nature of the building blocks from which the terrestrial planets formed, improving our understanding of this formation; and 3) contrasting the formation and evolution of two small planets that followed very different evolutionary paths so that we could understand what controls that evolution. From July 2011 to September 2012, Dawn comprehensively mapped this previously uncharted world, revealing an exotic and diverse planetary building block. The findings helped scientists unlock some of the secrets of how the solar system, including our own Earth, formed. Dawn's journey in time to help us understand the conditions at the formation of the solar system provided context for the understanding of the observation of the extrasolar-planetary systems. Additionally, Dawn provided data on the role of size and water in planetary evolution and formed a bridge between the exploration of the rocky inner solar system and the icy outer solar system.

James Webb Space Telescope

The James Webb Space Telescope (JWST) will be a large (with a 6.5-meter-diameter mirror), infrared-optimized telescope designed to study and answer

fundamental astrophysical questions ranging from the formation and structure of the universe to the origin of planetary systems and the origins of life. A scientific successor to the Hubble Space Telescope (HST) and the Spitzer Space Telescope, the JWST observatory will be used by international teams of astronomers to conduct imaging and spectroscopic observations in the wavelength range of 0.6–27 microns. The mission of the JWST project is to develop, launch, and operate a state-of-the-art observatory for use by the international astronomy community substantially to advance our understanding of the origin and destiny of the universe; the creation and evolution of the first stars and galaxies to form after the Big Bang; the formation of stars and planetary systems within the Milky Way Galaxy; and characteristics of planetary systems, including our own.

The center section of the backplane structure that will fly on JWST was completed on April 24, 2012, marking an important milestone in JWST's hardware development. The backplane will support the telescope's beryllium mirrors, instruments, thermal control systems, and other hardware. The center section will hold JWST's 18-segment, 21-foot-diameter primary mirror nearly motionless while the telescope peers into deep space. The center section of the backplane also meets unprecedented thermal stability requirements. The backplane maintains the alignment of the telescope's optics through the rigors of launch and over a wide range of operating temperatures, which reach as cold as –406 degrees Fahrenheit. The JWST Program Office, located at NASA Headquarters, manages JWST.

Joint Agency Satellite Division

The Joint Agency Satellite Division (JASD) efficiently manages NASA's fully reimbursable satellite and instrument development program, which includes NOAA-funded missions. JASD offers the Federal agencies a single interface for planning, development, and management of their satellite projects.

Since its inception in 2010, JASD has consistently delivered to NASA's partner agencies and the science community. For example, the Suomi National Polar-orbiting Partnership (Suomi NPP) was the first system completed and launched under JASD management. After a successful launch in October 2011 and checkout in March 2012, NASA transferred operational control of Suomi NPP to NOAA. A

top priority for JASD is to ensure that Suomi NPP continues to operate optimally and is able to overlap with the planned follow-on polar orbiting weather satellite, JPSS. To that end, NASA and NOAA will continue to collaborate during the mission's five-year prime operations phase to ensure that the agencies' shared objectives are being met. The system's value is already apparent; Suomi NPP data are publicly available and are being used by the National Weather Service for weather forecasting.

On September 17, 2012, a European meteorological satellite soared into space with five environmental instruments aboard that were developed by the NASA Polar-orbiting Operational Environmental Satellites (POES) Project. These instruments were developed under a reimbursable agreement with NOAA. The five NASA-developed instruments included the Advanced Microwave Sounding Unit (AMSU)-A1 and AMSU-A2, the Advanced Very High Resolution Radiometer (AVHRR), the High-resolution Infrared Radiation Sounder (HIRS), and the Space Environment Monitor (SEM). These NASA-developed instruments continue to gather data that include remotely sensed vertical profiles of atmospheric temperature and moisture, as well as visible and infrared imagery of cloud cover and surface conditions such as vegetation, snow, and ice. The National Weather Service uses the data to develop the short-, medium-, and long-range weather forecast models.

Aeronautics Research Mission Directorate

A key enabler for American commerce and mobility, U.S. commercial aviation is vital to the Nation's economic well-being. NASA's Aeronautics Research Mission Directorate (ARMD) focuses on the most appropriate cutting-edge research and technologies to overcome a wide range of aeronautics challenges for America's current and future transportation system. As demands on the aviation transportation system grow, NASA is discovering ways to improve aviation safety and air traffic and reduce fuel consumption, noise, and emissions.

Aviation Safety Program

NASA developed and tested an analysis tool that can automatically review large-scale software systems for errors without needing to run the software. This capability is part of an ongoing NASA research effort to reduce the time and cost associated with ensuring the safety of complex, flight-critical systems. NASA's tool reduced the analysis time from the 3 to 4 hours typical of a currently available commercial product down to several minutes. The NASA tool also achieved a false-positive rate of 5 percent or less.

NASA also advanced its data-mining algorithms that look for anomalous events, occurring across thousands of flights, that can represent precursors to aviation safety incidents. In a validation test, the latest algorithm successfully predicted the occurrence of known safety events with at least 10 percent more lead time than prior methods. Earlier recognition can be a good indicator of an algorithm's ability to reliably identify a wide range of potential safety concerns. These tests were done on real flight datasets of at least 10 terabytes. NASA provided the capabilities to the Federal Aviation Administration (FAA), the Aviation Safety Information Analysis and Sharing (ASIAS) system, and multiple airlines.

In addition, NASA completed a Concept of Operations for an Integrated Vehicle Health Assurance System. In this concept, NASA provides its research approach for monitoring the health of aircraft systems during in-flight and post-flight analyses and then using that knowledge to confidently predict system malfunctions before they occur. The concept integrates ground-based inspection and repair information with in-flight measurement data for airframe, propulsion, and avionics subsystems. This approach may eventually enable airline maintenance practices to rely more on the actual system health of an individual aircraft and less on fleet-wide reliability averages.

Finally, NASA completed a first-generation engine icing simulation code that predicts the adverse effects on engine performance due to high ice water content icing. Aircraft flying through high-altitude thunderstorms encounter high concentrations of ice crystals. Under certain conditions, these ice crystals may cause ice to form inside a jet engine in a way that can degrade its performance, potentially leading to engine power loss. To better understand the hazards of high-altitude

icing, NASA modeled the conditions an engine would encounter throughout a hypothetical flight. NASA's model incorporated the effects of ice accumulation, melting, and sublimation (conversion from solid to gaseous state) into a basic jet engine performance computer simulation. A study used the model to estimate the risk of engine icing in ice crystal conditions and the effect of the blockage on engine performance. Results showed that ice particle size is an important factor affecting engine icing. The distribution of ice particle sizes in clouds is currently unknown and is of high interest to NASA and its U.S. and international partners. Working with partners, NASA is conducting studies that further explore the atmospheric conditions leading to ice crystal icing and the effects of that icing on engine performance. Results from these studies will help aircraft remain clear of hazardous icing conditions and make aircraft engines more resilient if those conditions do occur.

Airspace Systems Program

Results of NASA's research to define and validate the Efficient Descent Advisor (EDA) concept were officially transferred in FY 2012 to the FAA for further evaluation and potential operational use. The EDA concept helps air traffic controllers allow airliners of all sizes to more efficiently descend from cruising altitude to arrive at an airport using less engine power while maintaining a safe distance from other aircraft. As a result, airlines save money on fuel, fewer emissions are released into the atmosphere, and air traffic controller workload is reduced (since automation is added to the process). In fact, NASA simulations showed potential annual savings of $300 million in fuel.

NASA also successfully simulated airport operations using an integrated set of software that better manages scheduling and spacing of aircraft in congested terminal airspace. The technologies, which include Automatic Dependent Surveillance-Broadcast (ADS-B), a satellite-based aircraft tracking technology, produced more precise aircraft spacing, allowing for increased arrival rates and operational cost savings. The simulation was conducted with active FAA controllers, airline pilots, and datasets from Dallas/Fort Worth and Los Angeles airports. In addition, NASA successfully demonstrated safe interval management procedures to a single airport

with dependent parallel runways utilizing NextGen flight-deck technologies. Benefits analysis indicates that these technologies have the potential to save several percent of total operational fuel costs due to more efficient arrivals. Although dependent on the level of aircraft equipage, annual systemwide savings are estimated at between $200 million and $300 million. Results from these simulations are being used to refine the plans for a future technology demonstration.

NASA developed and tested a new decision-support system called Dynamic Weather Routing that automatically finds alternative routes that help airlines save time and fuel for en route aircraft. The biggest cause of airline flight delays is hazardous weather. Flight routes are based on predicted weather and established prior to aircraft departure. Because weather patterns and severity change over time, flight routes often become congested and inefficient, which results in delays, wasted fuel, and sometimes hazardous conditions for aircraft and travelers. Air traffic controllers currently lack automation tools to generate new routes that save time and fuel once the aircraft are airborne. Laboratory simulations and field tests of NASA's new Dynamic Weather Routing technology conducted with a U.S. air carrier have shown potential average savings in time of 10 minutes or in operating cost of $1,000 to $1,700 per flight impacted by severe weather.

In addition, NASA developed weather translation models that provided an estimate of the weather's impact (e.g., high surface winds, low visibility) on an airport's capacity for 1 to 8 hours in the future over a 15-minute interval. These models incorporated forecasts from three state-of-the-art, airport-centric weather forecasts from the National Weather Service. Two of the models on average were able to predict the weather-impacted Airport Arrival Rate (AAR) at two representative airports over a 1- to 8-hour look-ahead time horizon within 10 to 15 percent of the actual weather-impacted AAR. The third model was able to estimate the weather-impacted AAR over a 1-hour look-ahead time horizon within 5 percent of the actual weather-impacted AAR at three representative airports. This improvement in use of weather predictions will provide a substantial increase in airport arrival throughput.

NASA completed analyses of ground-based tests that characterized the emissions of hydro-treated renewable jet (HRJ) fuel, which is an alternative aviation fuel. The results showed that HRJ fuels and their blends had substantially reduced particulate emissions (characterized by small particles of solids and liquids), minor effects on gaseous emissions, and no measurable adverse effect on engine performance. These data are important to industry and other government agencies, such as the FAA and the Environmental Protection Agency (EPA), to help ensure that aircraft can safely and efficiently utilize alternative fuels.

In order to realize significant improvements in efficiency and reductions in the environmental impact of aviation, it may be necessary to develop new aircraft designs that have little resemblance to today's tube-and-wing aircraft. NASA completed wind tunnel testing of a new concept that was very different from a tube-and-wing and demonstrated its reduced noise potential and improved short takeoff and landing performance. Results from this test will be used to improve computational tools for a number of advanced aircraft configurations.

NASA also made advances in making air travel even more flexible and convenient. It is highly desirable to make modern helicopters quieter and more efficient so that they can safely carry more people and cargo and be more effective in conducting current missions and new missions, such as increased delivery and transportation. To support these improved capabilities, NASA made significant advances in rotary wing propulsion systems that included new types of engine compressors and new transmissions. Also, to make rotorcraft more efficient, NASA demonstrated advances in computational modeling for rotorcraft fuselage drag reduction systems. People are always looking to spend less time traveling and more time at their destinations. One way to help achieve this desire is faster air transportation. Although the noise associated with sonic booms has always been a limiting factor, this may change due to NASA research. NASA successfully completed wind tunnel tests that validated the computational tools developed for designing and shaping supersonic aircraft to produce quieter sonic booms. As part of its efforts to understand how much sonic boom noise must be reduced to allow unrestricted

overland flight, NASA conducted the first tests in a new facility for simulating sonic boom noise as heard indoors.

The new computational design tools under development can greatly decrease the time needed for designing air vehicles and allow industry to explore new configurations. NASA completed the first generation of the Integrated Design and Engineering Analysis (IDEA) software, which enables the rapid and automated conceptual design of a hypersonic air-breathing vehicle. Because of this new tool, the time to conduct a vehicle design and analysis was reduced from 3 months (with today's methods) to less than 24 hours with the fully automated IDEA software tool. Another software tool was used to calculate the airflow through the scramjet engine of a hypersonic air-breathing vehicle, which was then compared with real flight data obtained from an Air Force flight. This comparison helps refine and improve the software, which is used to design scramjet engines.

NASA studied hypersonic planetary physics by obtaining unique Martian atmospheric pressures, heat shield temperatures, and heat shield recession data (loss of mass due to the ablation of the heat shield) from the instrumentation installed on the Mars Science Laboratory carrying the Curiosity rover. These highly unique data are being analyzed by researchers at NASA and universities in order to inform all future Mars landing missions and to enable reduced vehicle mass or a larger, more capable scientific payload.

Integrated Systems Research Program

Throughout the initial phase (FY 2010–FY 2012) of the Environmentally Responsible Aviation (ERA) project, a variety of tests and associated analyses were conducted with the goal of maturing promising technologies that would simultaneously reduce transport aircraft fuel burn, noise, and emissions. Through these tests, environmentally friendly aircraft technologies were validated for performance and matured to the point that they could be tested together and in relevant environments. Through a series of reviews and assessments conducted in FY 2012, NASA selected eight large-scale, integrated technology demonstrations to advance ERA research based on the potential benefit of the technologies to meet project goals, as well as the associated costs and risks. The integrated technology demonstrations

build on work performed during the initial phase of the project and will focus on five areas: aircraft drag reduction through innovative flow-control concepts; weight reduction from advanced composite materials; fuel and noise reduction from advanced Ultra High Bypass (UHB) engines; emissions reduction from advanced engine combustors; and fuel consumption and community noise reduction through innovative airframe and engine integration designs. This integrated, relevant-environment testing is the focus of the second phase of the ERA project, which began in FY 2013.

Based on data obtained during extensive ground test campaigns, NASA completed an assessment of two types of highly fuel-efficient jet engine concepts by comparing their performance in reducing the rate of fuel consumption and noise. One of the systems, referred to as Open Rotor, does not encase the engine fan blades in an engine housing as is typical in traditional jet engine designs. The second system, referred to as a UHB Turbofan, is a much more fuel-efficient version of the aircraft engine commonly used by airlines today. Research has validated that both engine concepts have the potential to dramatically reduce fuel burn. The Open Rotor shows greater potential for fuel burn reduction (–36 percent vs. –27 percent), but at the price of a diminished noise-reduction benefit when compared to the UHB concept (–13 decibels [dB] vs. –24 dB). These results provide data to the aviation industry and regulatory community to help them make informed decisions on future aircraft propulsion systems, with a continual emphasis on reducing their impact on the environment.

NASA also conducted the final analysis of test data (in partnership with the FAA and the Boeing Company) for a Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS) curved panel, which successfully demonstrated the viability of this integrally stitched composite technology concept for conventional commercial aircraft fuselage structures. The excellent performance of this concept shows promise in enhancing the structural integrity of aircraft while reducing overall structural weight.

As part of a collaborative effort with the FAA Technical Center, NASA conducted a flight test of a large (Ikhana MQ-9) unmanned aircraft equipped with ADS-B. This demonstration was a critical step in the development of a Live Virtual Constructive-Distributive Environment (LVC-DE), an innovative way

to safely immerse a flying unmanned aircraft in the National Airspace System (NAS) through virtual techniques. The LVC-DE will provide the backbone for future flight tests (scheduled in FY 2015 and FY 2016) to validate the concepts and procedures developed by the project. In support of these flight tests, a comprehensive plan was developed that addresses, in an integrated manner, a number of the challenges whose resolution is vital for safe unmanned aircraft system (UAS) operations in the NAS. This plan also outlined the specific test objectives and concepts of operations for the LVC-DE flight tests that will integrate remotely operated unmanned aircraft with simulated air traffic to evaluate these technologies in a relevant environment.

Aeronautics Test Program

NASA's Aeronautics Test Program annually evaluates, in coordination with the Department of Defense (DOD), the status of its assets to ensure that tactical maintenance and repairs are considered from a national point of view relative to long-term requirements and risks. In doing so, the program ensures the availability of a critical suite of aeronautical test facilities that are capable of supporting the research, development, testing, and evaluation goals and objectives for NASA and the Nation. Facility condition assessments were completed in FY 2012, which provided data to inform strategic investment decisions and to identify and address critical maintenance issues. NASA will continue to mitigate operational risks through periodic condition assessments and sound tactical and strategic investments to ensure a portfolio that is ready for those who need to test and validate.

NASA successfully executed more than 10,000 hours of ground testing and approximately 800 hours of flight testing for NASA and the Nation, achieving high overall customer satisfaction ratings and excellent facility availability and performance. Ground test examples include operations in Glenn Research Center's (GRC's) 9×15-Foot Low Speed Wind Tunnel for low-speed aerodynamic, aeromechanical, and aeroacoustic testing of a series of second-generation, counter-rotating (open rotor) blade sets to determine the efficiency and noise characteristics for advanced UHB engine applications. Flight test examples include a project titled Waveform and Sonic Boom Perception and Response (WSPR) at Dryden Flight

Research Center (DFRC), which involved gathering first-ever qualitative data from supersonic flights of sonic boom impact and acceptability from a select group of more than 100 volunteer Edwards Air Force Base residents.

NASA also continued to address critical shortfalls identified in the 2012 National Aeronautics Research, Development, Test, and Evaluation Infrastructure Plan through efforts directed toward engine icing research at the Propulsion Simulation Laboratory at GRC and acoustic measurement at the 14×22-Foot Tunnel at Langley Research Center. Investments in test technology included advanced facility electronic systems required to meet modern research testing requirements and targeted investments in wind tunnel force measurement systems.

In addition, NASA completed a project to modify an existing G-III subsonic research aircraft testbed at DFRC, which will result in new experimental test capability to assess emerging flight technologies. One of the first intended uses of the aircraft is to enable NASA to explore and mature alternative unconventional aircraft designs with the potential to simultaneously meet research goals for community noise, fuel burn, and nitrogen oxides emissions.

Space Technology Mission Directorate

Space Technology enabled a new class of missions in FY 2012 by drawing on talent from the NASA workforce, academia, small businesses, and the broader space enterprise to deliver innovative solutions that dramatically improve technological capabilities for NASA and the Nation. A critical component to advancing our future in space is the rapid development and infusion of new technologies and capabilities; NASA is fueling an emerging aerospace economy and collaborating on the space technology needs of other Government agencies and the overall aerospace enterprise. NASA supports these objectives and contributes to the demands of larger national technology goals by investing in space technology.

In FY 2012, the Space Technology Program supported the Chief Technologist, who coordinates the Agency's overall technology portfolio to identify development needs, ensure synergy, and reduce duplication.[1] By coordinating these efforts, along

1. The Space Technology Mission Directorate did not exist officially until February 21, 2013. The Space Technology Program reported to the Chief Technologist.

with other technology programs within NASA, the Chief Technologist facilitates the integration of available and new technology into operational systems that support specific human-exploration missions, science missions, and aeronautics. The Space Technology Mission Directorate was established to focus on the development of crosscutting, advanced, and pioneering new technologies.

In FY 2012, Space Technology successfully demonstrated the feasibility of inflatable heat shields through the launch of the Inflatable Reentry Vehicle Experiment-3 (IRVE-3) from the Wallops Flight Facility in Virginia. Such heat shields offer the opportunity to significantly increase the landing mass and landing accuracy for future missions to other planets, such as Mars, and to provide significantly greater capability for return payloads to Earth.

Marking another FY 2012 accomplishment, the Mars Curiosity rover mission was successful with the MSL Entry, Descent, and Landing Instrument (MEDLI) on board. MEDLI streamed real-time atmospheric and heating data from sensors embedded within the vehicle's heat shield. Data from MEDLI will help engineers design safer, more efficient entry systems for future missions. MEDLI was joined on the trip to Mars by technologies from six Small Business Innovation Research companies, each with their own role to enhance Curiosity's primary mission.

Space Technology also involved universities and academic institutions in its development objectives through more than 350 fellowships, direct competitive awards, and partnerships between academia and NASA Centers and industry partners for its technology developments and demonstrations.

Department of Defense

DOD

Aeronautics Activities

Fixed-Wing Vehicles

The Air Force continued flight testing the F-35 Lightning II. Tests during FY 2012 expanded the aircraft's flight envelope and demonstrated night refueling and external weapons testing. The F-35A conventional takeoff and landing variant began its operational utility evaluation in September. The F-35B short takeoff/vertical landing variant completed its first night landing on an aircraft carrier in October 2011 aboard the USS Wasp. The F-35B also completed flight testing with asymmetric weapons loads.

The final F-22 stealth fighter rolled off the production line and was delivered to the Air Force in May 2012. This ended the production of F-22s. A total of 195 aircraft were built.

The Air Force began the live-fire test and evaluation (LFT&E) in-flight program for the KC-46A next-generation aerial refueling tanker. The LFT&E program is a comprehensive evaluation of the aircraft's system-level vulnerabilities to threats expected in combat. The program includes live-fire tests, modeling, simulation, and analysis. Results of the LFT&E program are used by the Air Force and the Director of Operational Test and Evaluation to make independent assessments of the readiness of the aircraft to enter service. The KC-46A design is based on the 767-200 platform.

Rotorcraft

The Army Aviation Missile Research Development and Engineering Center initiated the Multi-Role Rotor (MRR) program. The MRR program will develop and demonstrate active rotor technologies that improve hover and helicopter cruise performance and efficiency and reduce vibration and acoustic signatures of next-generation rotary wing aircraft.

The Army's Chinook CH-147F made its first flight in June 2012. The CH-147F includes an upgraded digital automatic flight control system and other enhancements that its predecessor lacked. The Army also tested the adaptive vehicle management system, an advanced rotorcraft flight control system. These systems provide tactile cues through the control sticks for greater stability and improved safety in reduced visibility. A modified H-6 helicopter was used for these tests.

Balloon Flight Systems

On August 7, 2012, the U.S. Army Space and Missile Defense Command (SMDC) conducted the first flight of the Long Endurance Multi-Intelligence Vehicle (LEMV) at Joint Base McGuire-Dix-Lakehurst, New Jersey. The first flight lasted for more than 90 minutes. The LEMV is a hybrid air vehicle capable of carrying multiple intelligence, surveillance, and reconnaissance (ISR) payloads for more than 21 days at altitudes greater than 22,000 feet. The LEMV is a recoverable and reusable multi-mission platform that can carry a wide variety of sensors and equipment. The LEMV is intended to conduct persistent ISR missions and to serve as a communications relay platform. The primary objective of the first flight was to perform a safe launch and recovery of the LEMV. A secondary goal was to verify the flight control system's operation. Additional objectives included airworthiness testing and demonstration, as well as system-level performance verification. All objectives were met during the first flight. The Army Space and Missile Defense Command Technical Center LEMV program office in Huntsville, Alabama, manages the program. During the first flight, the LEMV was crewed, though the air vehicle can also operate without crew. It can be forward-located to support

extended operations from austere locations and is capable of beyond-line-of-sight command and control.

In May 2012, the Air Force terminated the Blue Devil 2 (BD2) Airship project. BD2 was initially scheduled for rapid deployment to Afghanistan in February 2012, only 18 months after the contract award. To date, the airship has not achieved the first test flight status. The Air Force assumed responsibility for BD2 from the Army Engineer Research and Development Center (ERDC) in early 2011 but cancelled the program in favor of a conventional fixed-wing Unmanned Aerial Vehicle (UAV) program.

The Army operated the Persistent Ground Surveillance System (PGSS) in Afghanistan throughout 2012. The PGSS uses TCOM, L.P.'s tactical aerostat family and Lockheed-Martin's Persistent Threat Detection System (PTDS) payloads, providing sustained optical and infrared imaging, acoustic signature recognition, and communications relay to ground units. Field tests were also completed in FY 2012 for aerostats capable of carrying larger and heavier payloads and operating at a variety of altitudes.

The Department of Defense awarded a five-year, $50 million contract to Worldwide Aeros to develop Pelican, a small, rigid hybrid incorporating compressed helium to control lift.

Hypersonics

On November 17, 2011, the U.S. Army Space and Missile Defense Command conducted the first test flight of the Advanced Hypersonic Weapon (AHW) concept. The AHW is a first-of-its-kind glide vehicle, designed to fly within Earth's atmosphere at hypersonic speed and long range. The AHW was launched from the Pacific Missile Range Facility, Kauai, Hawaii, to the Reagan Test Site (RTS), Kwajalein Atoll, flying 2,300 miles in less than 30 minutes. The AHW flew a hypersonic, nonballistic glide path within the atmosphere while space, air, sea, and ground platforms collected vehicle performance data on all phases of the flight. The results support the deployment of prompt global strike technology. The objective of the test was to collect data on the hypersonic boost-glide technologies and test range performance for long-range atmospheric flight. A three-stage booster

system launched the AHW glide vehicle and successfully deployed it on the desired flight trajectory. The Army Space and Missile Defense Command Technical Center AHW program office in Huntsville, Alabama, manages the program. The booster system and glide vehicle were developed by Sandia National Laboratories, Albuquerque, New Mexico, and the thermal protection system by the U.S. Army Aviation and Missile Research Development and Engineering Center. The Department of Defense is using AHW to develop and demonstrate technologies for Conventional Prompt Global Strike and will use the data collected to model and develop future hypersonic boost-glide capabilities.

The X-51A Waverider was flown for the third time in August. Waverider is an unpiloted, scramjet-powered hypersonic demonstration aircraft. In the August flight, Waverider was successfully released from a B-52 at an altitude of 50,000 feet, and the solid rocket booster fired successfully, accelerating the vehicles to Mach 4.5. A failure in a tail control fin resulted in the loss of control of the vehicle, and the vehicle was destroyed 16 seconds after the solid rocket motor (SRM) was jettisoned and prior to the ignition of the scramjet engine.

Unmanned Aerial Systems

The Navy's X-47B Unmanned Combat Air System (UCAS) made its first flight from the Naval Air Station, Patuxent River, Maryland, in July 2012. Testing conducted during 2012 included an evaluation of the command interface, aerodynamic performance, and flight control systems.

The X-48C remotely piloted aircraft made its first flight in August at NASA Dryden. This version of the aircraft includes modifications to the predecessor (X-48B) to enhance the fan and jet noise shielding, as well as extensions to the after-center-body and wing-tip rudders. The engine was also changed from a triple-jet to a two-jet design. The X-48 family of vehicles is a joint research and development project between NASA, the Air Force Research Laboratory, and industry partners.

In June, the Defense Advanced Research Projects Agency (DARPA) concluded UAVForge, a crowdsourced competition program intended to solicit innovative ideas from the Unmanned Aerial Vehicle (UAV) do-it-yourself community. DARPA selected 9 teams from 140 competitors that submitted videos demonstrating early

flight behavior for their drones. The fly-off required each system to perform a vertical takeoff, navigate beyond the line of sight, land on a structure, and capture surveillance images before returning to the starting point. Although all the drones managed to take off and navigate, none completed the course objectives.

The Missile Defense Agency completed the first flight of Boeing's Phantom Eye hydrogen-powered, high-altitude, unpiloted aircraft. Phantom Eye is designed to remain on station for up to four days, providing intelligence, surveillance, reconnaissance, and other mission-support services.

In August, the Office of Naval Research completed the first fully autonomous vertical recovery of the Flexrotor aircraft. Flexrotor is a long-endurance, vertical takeoff/landing UAV intended to perform intelligence, surveillance, and reconnaissance missions.

Aircraft Engines, Subsystems, and Components, Along with Other Aeronautical Developments

The Department's Computational Research and Engineering Acquisition Tools and Environments (CREATE) program was initiated to develop major improvements in engineering design and analysis by developing scalable, multidisciplinary computational products and tools. During FY 2012, CREATE's Air Vehicles program (CREATE-AV) released three products: the fixed-wing analysis tool Kestrel v3.0; a rotorcraft analysis tool, Helios v3.0; and the grid-generation tool Capstone v3.0. Kestrel v3.0 adds automated overset capabilities for moving aircraft/body simulations. Helios v3.0 enables off-body adaptive mesh refinement and the capability to model multi-rotor designs. Capstone v3.0 allows for the cleanup of dirty geometry and the generation of surface and volume mesh models. CREATE is part of the Department's High Performance Computing Modernization Program (HPCMP).

The Air Force incorporated advanced heads-up displays into the KC-46A to aid in refueling operations. These displays use computer-generated, three-dimensional views created by sensor fusion. In a related development effort, DARPA continued the development of the Multifunction Radio Frequency and Video Synthetic Aperture Radar programs, both of which used advanced millimeter-wave or

extremely high frequency (EHF) radar to aid aircrews in visualizing through clouds or near ground clutter.

The Air Force Research Laboratory's Adaptive Versatile Engine Technology (ADVENT) program completed tests that demonstrate the effective application of adaptive fan technology to turbine engine designs. ADVENT is seeking to improve efficiency through advancing the technology of engine components and through adaptive engine technology.

The Army's Joint Precision Airdrop System and other airdrop programs delivered over 90 million pounds of supplies to deployed forces in Afghanistan. The High Speed Container Delivery System demonstrated the ability to accurately airdrop payloads of 16,000 pounds from as low as 250 feet from aircraft moving as fast as 250 knots.

Airborne Weapons Systems and Missiles

On February 15, 2012, the U.S. Army Space and Missile Defense Command successfully completed a test flight of the Economical Target-1 (ET-1) at Eglin Air Force Base (AFB), Florida. The ET-1 missile was launched from the Santa Rosa Test Site with the support of the 46th Test Wing on Eglin AFB into the ocean area within the test range. The ET-1 is a rail-launched, theater-class tactical ballistic missile target. The ET-1 was launched using another new Army Space and Missile Defense Command product, the 25K Transportable Target Launcher (25K TTL), a transportable, mission-configurable 25,000-pound-capacity launcher developed to support Defense Department operational testing of theater-class tactical ballistic missile targets. The Army Space and Missile Defense Command Technical Center Test Execution Support Division in Huntsville, Alabama, manages the ET-1 and 25K TTL programs.

The Missile Defense Agency's Airborne Laser Test Bed program concluded, marking the end of a program that successfully demonstrated the ability to track, target, and shoot down missiles using a megawatt-class laser on an aircraft.

The Air Force successfully tested a Minuteman III Stage 1 SRM. Over 4,000 Minuteman SRMs have been produced using the Air Force's "warm line" production

program, which strives to produce motors representative of the deployed motors and maintain critical skills and the supplier supply chain.

The 90th Missile Wing conducted a 4,800-mile, 30-minute test of the Minuteman III intercontinental ballistic missile in April. The missile was fired from Vandenberg AFB, and a single Mk21 reentry vehicle landed on target within the Ronald Reagan Ballistic Missile Defense Test Site in the vicinity of the Kwajalein Atoll.

In May and June, the Missile Defense Agency and the Navy successfully intercepted ballistic missile targets using Standard Missile 3 (SM-3) Block 1B missiles. SM-3 Block 1B includes upgrades to the on-board signal processor and a throttleable solid divert and attitude-control system.

The Air Force successfully tested a new 92-inch-diameter solid rocket motor at the Arnold Engineering Development Complex. The motor used emerging technologies from the propulsion applications program and integrated them with the high-payoff rocket propulsion technology program. The technology may support future conventional strike and operationally responsive strike missions.

In April, the Navy conducted successful flight tests of four Trident II D5 fleet ballistic missiles. The tests were the 139th, 140th, 141st, and 142nd successful tests of the D5, marking an unprecedented record of reliability for large ballistic missiles or space launch vehicles.

The Army tested a new propulsion system for the Tube-Launched, Optically Tracked Wireless (TOW) anti-armor missile. This enhanced propulsion system doubles the system's range and reduces flight time by one-third.

An upgraded version of the Joint Standoff Weapon (AM-15-iC-1) was successfully tested at the Point Magu Sea Range against a moving ship target. This prototype of the C-1 variant will become the military's first network-enabled weapon. The C-1 includes a Link-16 interface capable of providing target updates in flight. Upgraded seeker software can also target a specific impact aim point on the target.

The Army conducted successful tests of the upgraded Patriot Air Defense System, including the Patriot Advanced Capability 3 (PAC-3) missile (MIM-104C). PAC-3 was used to destroy a cruise missile target at the Utah Test and Training Range in April and a ballistic missile target over White Sands Missile Range in August.

Space Activities

Launch and Range Operations and Spacelift Developments

The Evolved Expendable Launch Vehicle (EELV) Program continued to place Defense Department and intelligence community satellites into orbit successfully during FY 2012. With nine launches in FY 2012, the United Launch Alliance (ULA) continued its record of 100 percent success. Of these, seven of the nine launches were national security space (NSS) missions, including a Wide-band Global Satellite Communications System launch. In June, the EELV Program completed the first flight of the RS-68A hydrogen-fueled first-stage engine on a Delta IV heavy launch from Cape Canaveral.

The Defense Advanced Research Projects Agency's Airborne Launch Assist Space Access (ALASA) program awarded launch system development concept contracts to Lockheed Martin, Boeing, and Virgin Galactic. These development contracts call for designs of launch systems capable of delivering 100-pound payloads to low-Earth orbit for $1 million.

The United Launch Alliance and Pratt & Whitney Rocketdyne, prime developer and engine provider to the Air Force's EELV Program, respectively, completed the design of the RL-10C-1 upper stage engine and began initial testing and certification activities.

In May, the EELV Program successfully tested an upgraded GEM-60 solid rocket motor. The GEM-60 is used to boost the EELV Program's Delta IV launch vehicle. The upgraded GEM-60 incorporates a vectorable nozzle and was qualified during a 90-second burn in which it delivered 270,000 pounds-force of thrust.

Global Positioning System

In 2012, the Global Positioning System (GPS) maintained 0.8-meter user range error for the signal-in-space performance, far exceeding the published standard of 3 meters' accuracy.

The Military GPS User Equipment (MGUE) Increment 1 program began in September 2012. MGUE is the first increment of M-Code–capable GPS user

equipment that will deliver significantly improved capability to counter current and emerging positioning, navigation, and timing (PNT) threats and enable military operations in GPS-denied and Navigation Warfare (NAVWAR) environments, in which current and legacy receiver performance could be degraded.

Satellite Communications

On September 13, 2012, the U.S. Army Space and Missile Defense Command (SMDC)/Army Strategic Command placed two nanosatellites into orbit using a United Launch Alliance Atlas V rocket launched from Space Launch Complex-3 at Vandenberg AFB, California. These two nanosatellites were launched as part of the Army's continuing effort to develop low-cost, tactically responsive space capabilities through the use of small satellite technologies. This is the second launch of SMDC-built nanosatellites (the first occurred in 2010). The satellites were launched in partnership with the National Reconnaissance Office (NRO) as part of the Operationally Unique Technologies Satellite (OUTSat) program. SMDC launched the two nanosatellites to provide ultra high frequency (UHF) communications to validate beyond-line-of-sight communications and data exfiltration capabilities for disadvantaged users. Launch operators confirmed the successful deployment of the spacecraft. The Technical Center's Concept Analysis Lab serves as the ground station and has established and maintained contact with both nanosatellites. Testing using the two nanosatellites is ongoing.

Additionally, SMDC received approval and funding for three Joint Capability Technology Demonstrations (JCTDs) to further evaluate the ability of nanosatellites and responsive space to fill warfighter capability gaps. The SMDC Nanosatellite Program-3 (SNaP-3) will capitalize on SMDC–Operational Nanosatellite Effect (ONE) work to further demonstrate the ability of nanosatellites to extend beyond-line-of-sight communications for disadvantaged users in challenging terrain. The Kestrel Eye JCTD will demonstrate responsive, persistent, affordable, "good enough" tactically actionable surveillance data to users in the field without further burdening national assets. The Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS) JCTD will build and launch a low-cost, dedicated launcher capable of placing nanosatellites in low-Earth orbit within days of notification. The

Army Acquisition Executive designated the Program Executive Office Missiles and Space as the JCTD manager for each of these JCTDs, managing any residual capability left behind after JCTD completion, with the goal of continued acquisition to provide users with an enduring responsive space capability. The SMDC Technical Center Space Division in Huntsville, Alabama, manages the nanosatellite program.

On May 4, 2012, the Air Force successfully launched the second Advanced Extremely High Frequency (AEHF-2) satellite to provide protected communications to U.S. and international military forces. The governments of Canada, the Netherlands, and the United Kingdom are key international partners with the United States in the AEHF Program.

The Navy launched the first of five Mobile User Objective System (MUOS) satellites on February 24, 2012, to support telecommunications for the joint warfighter. MUOS provides narrowband communications using two payloads: a legacy UHF capability and a new Wideband Code Division Multiple Access (WCDMA) payload. The MUOS constellation will replace the aging UHF Follow-On (UFO) constellation, allowing time for the joint force to transition from UFO to the more modern third-generation cellphone technology (i.e., WCDMA).

Space-Based Intelligence, Surveillance, and Reconnaissance

The Air Force's Commercially Hosted Infrared Payload (CHIRP) demonstration completed its nine-month base contract in July 2012 with extended operations. CHIRP, launched in September 2011, provided continuous quarter-disk Earth view north of the equator and westward to the horizon from the satellite Société Européenne des Satellites (SES)–2's 87° west longitude geostationary slot. The CHIRP program validated the concept of dramatically reduced commercially hosted mission costs and abbreviated development schedule compared to dedicated spacecraft missions, with launch just 39 months from contract initiation. The mission demonstrated wide-field-of-view overhead persistent infrared surveillance for future missile warning/defense, intelligence gathering, and battlespace awareness.

Satellite Control and Space Situation Awareness

Two prototype radar systems supporting the Space Fence program demonstrated the ability to track objects in low-Earth orbit. The completed Space Fence system will provide unqueued surveillance of small objects and satellites in low- and medium-Earth orbit to provide spaceflight safety, early detection and custody of threats, and awareness to satellite operators.

The Space Based Space Surveillance (SBSS) System reached initial operating capability. SBSS improves the ability of the Department of Defense to detect and track space objects in orbit around Earth.

In 2012, the Operationally Responsive Space (ORS) Office continued to support the on-orbit operations of the ORS-1 satellite, launched in June 2011 from NASA's Wallops Flight Facility, Virginia. In addition to directly supporting the intelligence needs of joint force commanders, ORS-1 continued to advance technical, logistic, and launch objectives and capabilities required to rapidly deploy space-based support capabilities.

Other Space Developments

In May 2012, the Air Force Research Laboratory's Massive Heat Transfer Experiment (MHTEX) completed 12 months of successful operation aboard the International Space Station. MHTEX demonstrated the ability to start thermal management from a variety of initial conditions and passively control temperatures from multiple heat-loading sources under varying environmental conditions. The key technology demonstrated by MHTEX is the advanced hybrid evaporator, which enables the system to start without the need for a dedicated pump to purge the system of bubbles.

In June, the second X-37B Orbital Test Vehicle (OTV-2) landed at Vandenberg AFB, concluding a 469-day mission for the Air Force Rapid Capabilities Office. This flight more than doubled the duration of OTV-1, completed in 2010, after 225 days in space. The Boeing-built, 29-foot-long X-37B conducted on-orbit experiments during this mission. The objective of the program is to demonstrate technologies required to reuse a space vehicle.

Federal Aviation Administration

FAA

In 2012, the Federal Aviation Administration (FAA) continued moving toward its Next Generation Air Transportation System goals. Known as NextGen, it is a comprehensive overhaul of the entire National Airspace System (NAS) to make air travel more convenient and dependable while ensuring that flights remain safe, secure, and as hassle-free as possible.

In a continuous roll-out of improvements and upgrades, the FAA is building the capability to guide and track air traffic more precisely and efficiently to save fuel and reduce noise and pollution. NextGen is better for the environment and better for the economy.

NextGen also provides solutions to improve surface operations. This effort focuses on improved airport surveillance information and automation to support airport configuration management, runway assignments, and enhanced cockpit displays to provide increased situational awareness for controllers and pilots; a key step is sharing airport surface information with authorized stakeholders.

Accurate aircraft position information on the ground is critical to smooth airport operations. Precise arrival and location information makes it easier for air traffic controllers, airlines, and other flight operators to manage the complex task of moving hundreds of flights along taxiways and runways and to and from gates. It is what the aviation community refers to as surface situational awareness.

Airport Surface Collaborative Decision Making tools improve this awareness. They not only increase efficiency at the airport and help reduce delays, but also enhance safety. In 2012, one of those tools, known as Airport Surface Detection

Equipment (ASDE-X) on System Wide Information Management (SWIM), provided access to surface data from 26 airports (with more to be added) through a single distribution point. Access to precise position data helps airlines manage delays. The data come from airport ground surveillance systems, which track airplanes on runways and taxiways and those aircraft flying within 5 miles of the airport; the systems are able to determine the aircraft's precise position and identification. Controllers use this information as an advisory alerting capability, an additional safety tool that helps them keep aircraft out of each other's way. While there are safety benefits for controllers, airlines can also use the data to validate the exact moment one of their flights touches down. As a result, flight operations centers (FOCs) are able to more efficiently coordinate the teams of people who meet the flight and get the aircraft ready for its next trip. In FY 2012, the FAA reached a major milestone in its move to a NextGen satellite-based navigation system when it published more than 3,000 Wide Area Augmentation System (WAAS) approaches nationwide. GPS alone does not meet the FAA's navigation requirements for accuracy, integrity, and availability. WAAS corrects for GPS signal errors caused by atmospheric disturbances, timing, and errors in satellite orbit. It also provides vital information regarding the health of each GPS satellite. GPS, augmented with WAAS, provides the national airspace with a satellite-based capability to determine an aircraft's airborne position with accuracy for en route navigation, nonprecision approach, and precision approach. The new technology—cheaper and easier to install and maintain than traditional navigation aids—will lower minimums at many airports and give new access during bad weather. Using WAAS, aircraft can access over 2,500 runway ends in poor weather conditions with minimums as low as 200 feet. WAAS can even get pilots into places where the Instrument Landing System (ILS) may not be available. This milestone has an additional benefit for pilots and passengers across the national airspace as ILS technology fades and needs repair and maintenance: replacing it with the more precise technology is now an option.

In 2012, the FAA took on a new safety challenge—devising a plan to safely accelerate the integration of civil unmanned aircraft systems (UASes) into the NAS by September 30, 2015. Congress established this requirement in the FAA reauthorization act. In response, the FAA created a UAS Integration Office,

bringing together specialists in aviation operations and safety as a portal for everything related to civil and public use of UASes in the NAS. The office achieved the first milestone among Congress's UAS requirements—streamlining the process for public agencies to operate UASes in the NAS. Significant progress also included the development of a UAS Concept of Operations (ConOps) defining how the integration of UASes affects and is affected by NextGen capabilities and enabling technologies and operational improvements into the 2020s. Operational scenarios consider various UAS types in all classes of airspace. Combined with the FAA's Integration of Civil UAS in the NAS Roadmap, the ConOps enables UAS stakeholders to view the transition from today's accommodation of UAS operations to integration into all phases of flight.

Also in 2012, the UAS NextGen Demonstration—which involved FAA Air Traffic Operations, DHS Customs and Border Protection (CBP), the United States Air Force 45th Space Wing, and NASA's Kennedy Space Center—showed how NextGen technologies provide information to advance UAS integration into the NAS. The FAA observed a CBP flight operating under an FAA-issued Certificate of Authorization. The observation included a pseudo pilot and a pseudo controller interacting with each other during off-nominal events induced by the research team. The research team assessed the ability of an independent Ground Based NAS Voice System prototype to restore communication between the pseudo UAS pilot and pseudo air traffic controller in the event of a lost-link/lost-communication scenario and also tested the viability of providing an independent Cockpit Display of Traffic Information (CDTI) system to aid a UAS pilot in tracking own-ship information in the event of lost link/lost communication. This system was integrated with ADS-B, the Traffic Information Service-Broadcast (TIS-B), and primary radar information for increased situational awareness of surrounding traffic.

Late in 2012, the FAA launched a one-year operational trial of a new approach to oceanic preferred routes. The Oceanic Conflict Advisory Trial (OCAT) is a system aimed at removing a potential bottleneck from oceanic preferred-route procedures. OCAT gives airline FOCs access to Web-based Advanced Technologies and Oceanic Procedures (ATOP) data drawn from the latest conflict probe algorithms. OCAT could replace the Dynamic Airborne Reroute Procedure, which enables flightcrews to consult with their airline's FOC to determine whether a revised

route, adapting to weather and other real-time variables, would enable them to reduce fuel consumption and emissions. The FOC can judge on its own whether its preferred clearance change appears to be free of conflicts with other flights. After the FOC has done whatever trial-and-error work is necessary and found the change to be acceptable, the flightcrew can request the change and the FAA control center can consider it under existing procedures. The potential bottleneck comes into play if the revised route might conflict with other traffic. In that event, the FAA control center, equipped with ATOP conflict probe capabilities, would have to deny the pilot's request for a revision. The FOC and the pilot would go back to square one. With its launch over the Pacific Ocean, OCAT is available to participating airlines throughout the vast airspace of the Oakland Oceanic ATOP flight information region, the world's largest. At nearly 19 million square miles, it covers nearly 10 percent of Earth's surface.

The FAA Office of Commercial Space Transportation (AST) licenses and regulates U.S. commercial space launch and reentry activities and the operation of non-Federal launch and reentry sites to protect public health and safety, safety of property, and national security and foreign policy interests of the United States. In addition, AST encourages, facilitates, and promotes U.S. commercial space transportation.

In FY 2012, there were a total of three FAA-licensed launches and zero permitted launches. No fatalities, serious injuries, or significant property damage to the uninvolved public occurred during these licensed events. Two were issued to Energia for launch from the Pacific Ocean on Zenith 3SL vehicles. The third was a SpaceX license for launch of the Falcon 9 from Cape Canaveral Air Force Station (CCAFS) with the Dragon Reentry Capsule. The FAA also licensed the reentry of the Dragon capsule on this mission.

The Commercial Space Transportation Safety Program launched an ADS-B payload into space on two missions that reentered Earth's atmosphere. In the first, ADS-B flew on a sounding rocket in April 2012 where the payload withstood a maximum acceleration of 16 g's during a 12-second launch and successfully transmitted throughout the flight. During this flight, the payload provided information on the capability, limitations, and considerations for GPS-based systems in space launch and reentry environments. Tracking was conducted by FAA ground-based

terminals in New Mexico and Texas, displaying the entry, descent, and landing of the rocket in real time at the William J. Hughes Technical Center. On the second mission, the payload flew at the Team America Rocket Challenge in May 2012 on a large amateur rocket and was tracked in real time by mobile equipment and the FAA ground-based terminals in Northern Virginia.

In FY 2012, AST issued five Launch Licenses for future launches to the following:

- Launch Operator License to Lockheed Martin Commercial Launch Services to conduct Atlas V launches from Vandenberg AFB.
- Launch-specific license to SpaceX to conduct the Falcon 9 flight 003 launch from CCAFS.
- Reentry license to SpaceX to reenter Dragon C2 reentry vehicle from Earth orbit with a nominal landing in the Pacific Ocean. This was the first licensed mission involving the transport of cargo to and from the ISS.
- Launch-specific license to SpaceX to conduct Falcon 9 flights 004 and 005 from CCAFS. This license covers two launches, which are the first 2 of 12 NASA Commercial Resupply Services (CRS) missions.
- Reentry license to SpaceX to reenter Dragon CRS-1 and -2 reentry vehicles from Earth orbit with a nominal landing in the Pacific Ocean. This license covers two reentries.

AST issued just one Experimental Permit the same year to Scaled Composites to conduct SpaceShipTwo missions from Mojave. One Reusable Launch Vehicle (RLV) Mission Operator License was issued to Armadillo Aerospace to conduct STIG-B launches from Spaceport America in New Mexico. One license renewal was issued to Lockheed for Atlas V launches from CCAFS. One Safety Approval was issued to the National AeroSpace Training and Research (NASTAR) Center for the ability of its Falcon 12/4 Altitude Chamber to replicate pressures experienced at altitude levels.

AST conducted 91 safety inspections on over 36 different types. The goal of every AST 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; Camden, Arkansas; Mojave, California; Kodiak, Alaska; Wallops Flight Facility, Virginia; Las Cruces, New Mexico;

McGregor, Texas; Burns Flat, Oklahoma; Hawthorne, California; Long Beach, California; Jacksonville, Florida; Black Rock, Nevada; Southampton, Pennsylvania; and the equator.

To support all new and renewed licenses in FY 2012, AST carried out several environmental reviews. Specifically, AST issued the Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the launch and reentry of SpaceShipTwo reusable suborbital rockets at the Mojave Air and Space Port, California. AST also issued the Final EA and FONSI to support the issuance of an Experimental Permit to SpaceX for operation of the Grasshopper vehicle at the McGregor Test Site, Texas. AST continued to monitor the New Mexico Spaceport Authority's compliance with Federal historic preservation requirements and other requirements related to biological resources for the development of Spaceport America.

The FAA Center of Excellence for Commercial Space Transportation (COE-CST) is a partnership of academia, industry, and government developed to address current and future challenges for commercial space transportation. In FY 2012, the COE-CST produced over 35 technical reports that help AST investigate and develop new regulations. These reports are also a vital resource for industry members who will draw upon the publicly available resource of research to bring their goods and services to the emerging commercial space market.

In previous years, AST has produced several informational annual reports on the state of the established and emerging industry segments directly related to commercial space transportation. These reports contained valuable information; were widely cited in the trade press; and were of interest to the public, the space industry, and the U.S. Government. Beginning in FY 2012, however, AST sought to minimize overlap and sometimes repetitive reporting by producing and releasing this information under the cover of one comprehensive document, *The Annual Compendium of Commercial Space Transportation 2012*. This report serves as reference, status report, and forecast and is structured to tell the commercial space industry story.

AST's Space Transportation Infrastructure Matching Grants (STIM) program is solely discretionary and designed to fund projects that develop and expand commercial space transportation infrastructure. Three STIM grants were awarded in FY 2012. These went to the Front Range Airport Authority (Colorado); the

Department of Business, Economic Development, and Tourism (Hawaii); and the East Kern Airport District (Mojave, California).

Information about the FAA Office of Commercial Space Transportation, regulations, reports, and other documents can be found at *http://ast.faa.gov*.

Department of Commerce

DOC

During FY 2012, the Department of Commerce (DOC) continued to participate in the national management of the Global Positioning System (GPS) as a member of the National Executive Committee for Space-Based Positioning, Navigation, and Timing, the senior body that advises and coordinates Federal agencies on GPS matters. DOC hosted four meetings of the committee and its Executive Steering Group to discuss major policy issues, including protecting GPS users from potential interference due to a communications network (LightSquared) licensed to broadcast in frequencies next to those of GPS. Based on extensive testing and analysis, DOC's National Telecommunications and Information Administration (NTIA) advised the Federal Communications Commission (FCC) in February 2012 that there were no mitigation strategies that would both solve the interference issues and provide the company with an adequate commercial network deployment. DOC also collaborated with the members of the National Executive Committee to dispute patent claims filed by the United Kingdom that threatened to burden the GPS program and its users with licensing fees and royalties. These efforts were successful in preserving open access to GPS service in support of U.S. policy.

DOC continued to host the secretariat of the National Executive Committee and participate in its daily operations, including public outreach about GPS. DOC staff transformed *http://www.gps.gov* from a static Web site to a dynamic portal providing a robust foundation for the Government's GPS outreach campaign. DOC consolidated two other GPS-related Federal Web sites into *http://www.gps.gov* prior to their discontinuation, improving public access to GPS information.

DOC participated in bilateral consultations, led by the State Department, with Japan and Europe to discuss cooperation on GPS issues. DOC's Office of Space

Commercialization continued to serve as the U.S. cochair of a U.S.-European working group that met twice during FY 2012 to discuss trade issues affecting satellite navigation markets.

National Oceanic and Atmospheric Administration

NOAA's environmental satellites are key tools for forecasting weather, analyzing climate, and monitoring hazards worldwide. In FY 2012, another year full of severe weather events and destructive natural disasters, NOAA was aided by the October 2011 launch and operation of the first of our next generation of satellites, the Suomi National Polar-orbiting Partnership (NPP). Twenty-four-hour global coverage from NOAA's satellites provides scientists and managers with a continuous stream of information used in preparation for events that will impact our climate, weather, and oceans. NOAA manages and operates three types of environmental satellites: Geostationary Operational Environmental Satellites (GOES), Polar-orbiting Operational Environmental Satellites (POES), and ocean altimetry (Jason).

NOAA's Geostationary Satellites

GOES continuously monitor the Western Hemisphere by circling Earth in a geosynchronous orbit 22,000 miles above the equator, meaning they remain over one position on the surface by orbiting at a speed matching that of Earth's rotation. Information from GOES is used for short-term weather forecasting and severe storm tracking. GOES imagery is also used to estimate rainfall during thunderstorms and hurricanes for flash flood warnings, as well as estimate snowfall accumulation and overall extent of snow cover. This information helps meteorologists issue winter storm warnings and spring snow-melt advisories. In FY 2012, GOES-11 was decommissioned after 11 years in space and replaced by GOES-15, flown at 135° west and serving as "GOES-West," while GOES-13 flew at 75° west and served as "GOES-East." GOES-12 flew at 60° west and served as GOES–South America, providing extra coverage for meteorologists in that region.

NOAA's Polar-Orbiting Satellites

POES circle Earth in an almost north-south orbit at an altitude of approximately 517 miles, passing close to both poles. Earth constantly rotates counterclockwise underneath the path of the satellite, allowing a different view with each orbit. It takes the satellite approximately 1.5 hours to complete a full orbit. In a 24-hour period, the 14 orbits of each polar-orbiting satellite provide two complete views of weather around the world. POES provides full global coverage with advanced sensors for weather and climate data, collecting information on temperature, atmospheric conditions, wind speed, cloud formation, and drought conditions over all of Earth. In FY 2012, NOAA-19 served as NOAA's primary polar-orbiting satellite, but NOAA was excited to launch and begin operation of the first of its next generation of polar-orbiting satellites, Suomi NPP, on October 28, 2011. Suomi NPP is a joint NOAA-NASA mission and serves as a bridge between NOAA's current fleet of polar-orbiting satellites and the upcoming next-generation Joint Polar Satellite System (JPSS).

NOAA's Ocean Altimetry Satellite

Principally NOAA, with its partners NASA, Centre National d'Études Spatiales (CNES), and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), operates Jason-2, a sea surface topography mission that flies an altimeter to provide high-precision measurements of sea surface height. Because the temperature of the ocean and ocean currents can change the height of the sea and these characteristics can affect the world's weather, including tropical storms, Jason-2 has been crucial to improvements in weather modeling and tropical storm intensification forecasting. Its follow-on, Jason-3, is currently under development.

NOAA's Additional Space-Based Capabilities

In addition to those three main types of environmental satellites, NOAA also flies two other types of instruments on some of its satellites together with international partners.

Argos is a data collection and location relay system administered under an agreement between NOAA and Centre National d'Études Spatiales (CNES) initiated in 1974. Through the Argos program, CNES provides sensors for flight on NOAA and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) satellites. These sensors collect a wide variety of in situ measurements, including data on atmospheric pressure, sea temperature, ocean current velocity, animal migration patterns, and river water levels.

Cosmicheskaya Sistyema Poiska Avariynich Sudov–Search and Rescue Satellite-Aided Tracking (COSPAS-SARSAT) is an international satellite-aided search-and-rescue system that uses satellites to locate emergency beacons carried by ships, aircraft, or individuals and communicate location information to search-and-rescue authorities; the system has rescued over 35,000 people worldwide since 1982. The governing parties of the system are the U.S./NOAA, France/CNES, Russia, and Canada. NOAA provides space on its polar-orbiting satellites for the French processor and Canadian receiver.

International Agreements

On September 17, 2012, NOAA's close partner, EUMETSAT, successfully launched the Meteorological Operational (MetOp)-B polar-orbiting satellite. Under existing agreements with NOAA, EUMETSAT launches and operates polar-orbiting environmental satellites in the midmorning orbit, NOAA in the afternoon orbit. Both agencies then share the data fully and openly. Together, EUMETSAT's MetOp satellites and NOAA's polar-orbiting spacecraft provide the majority of global data for numerical weather forecasts and provide observations that help predict environmental phenomena, including wildfires, volcanic eruptions, snow cover, sea ice, vegetation health, sea surface temperatures, and disaster mitigation. Each agency's satellites carry similar sets of sensors—some used for forecasting, others for assessing surface conditions.

Figure 1. Artist's rendering of the Suomi-NPP satellite.

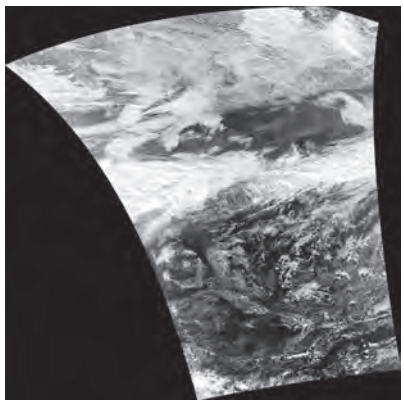

Figure 2. First image taken by Suomi NPP's Visible Infrared Imaging Radiometer Suite (VIIRS) on November 21, 2011.

National Institute of Standards and Technology

In FY 2012, the National Institute of Standards and Technology (NIST) continued to provide Federal agencies and the aerospace industry with the research, guidance, standards, products, and services needed to advance the administration'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 2012, aerospace companies purchased 216 SRMs, representing a wide variety of metal alloys, biological materials, calibration solutions, and environmental materials. NIST provides the tools, methodologies, standards, and measurement services needed by aerospace parts manufacturers, assemblers, and NASA to maintain their accurate and traceable use of the International System of Units (SI) units of length, mass, and time, as well as their derived units (force, acceleration, sound pressure, and ultrasonic power). For example, NIST performed calibrations of length standards for U.S. aerospace companies to ensure that the dimensions of their manufactured parts conform to design specifications. Traceable NIST measurements (mass, force, vibration, acoustics, electricity, thermometry, humidity, flow,

pressure, viscosity, fluid density, radiometry, and length) are essential for aircraft manufacturing. Further, in the manufacture of the company's new 787 airplanes, every tool used in the assembly process has been calibrated in Boeing's metrology laboratories with direct traceability to NIST. Structural testing of the airplane is performed by scores of load cells with capacities of up to 3.54 meganewtons (MN) (800 kilopounds-force [klbf]). These load cells are central to the structural testing of the first full-scale composite wing/titanium wing box. The load cells, used to analyze the integrity of the wing box structure, are directly traceable to NIST either through direct comparison with NIST-calibrated load cells or through calibration in the Boeing 221-kilonewton (kN) (50-klbf) force deadweight machine whose masses were calibrated at NIST. Other direct applications of NIST measurements included the use of NIST-calibrated weights to support wind tunnel applications; weighing airplanes; and torque, pressure, and force measurements.

NIST provided quality assessment of atomic data used by astronomers who are interpreting observations from NASA's land- and space-based missions, including the Hubble Space Telescope, the Chandra X-ray Observatory, the Far Ultraviolet Spectroscopic Explorer, and the Spitzer Infrared Observatory. In FY 2012, NIST provided results for atomic sulfur, neon, titanium, chromium, nickel, barium, strontium, iron, silver, mercury, and other elements of particularly strong current interest. For each type of atom, NIST provided a single, self-consistent set of best values from the frequently inconsistent, incomplete, and heterogeneous-quality data scattered across the open literature. NIST published these evaluated datasets in peer-reviewed scientific journals and disseminated them publicly through NIST's online Atomic Spectra Database (*http://www.nist.gov/pml/data/asd.cfm*). These data are used as standards across the astrophysics community and facilitate the comparison of results from different astronomers. This work was partially funded by NASA.

NIST measured atomic properties required to make use of observations from NASA's ultraviolet and infrared spaced-based observatories. Comprehensive data for iron and chromium atoms, two of the most important atoms for interpreting data from these observatories, were recently published by NIST. The NIST analyses provide more than an order of magnitude increase in accuracy compared to the previous data, which were over 30 years old. Additional data for chromium and cobalt are currently being analyzed. This work was partially funded by NASA.

NIST provided a new release of its online Atomic Spectra Database, v.4.1.1. Following this release, the average volume of data downloaded per month by all users doubled compared to the previous versions. This change indicates that data are of high importance. The new release features more than 10,000 spectral lines of neutral and singly ionized iron, new transition probability data of C I-II and N I-II, new data on spectra of singly and multiply ionized argon, and energy levels of the first few spectra of all chemical elements of the 5th, 6th, and 7th rows of the periodic table from Sr to Ac. In this last release, we also updated and extended transition probability data on sulfur (S I-XV); updated energy levels of Tc I, Ru II, Rh II, Ag I, Cd I, In I, Sn I, Sb I-II, Te I-II, and I I; and updated lists of spectral lines, including energy-level classifications for Tc I-II, Ru I-II, Rh I-II, Pd I-II, Ag I, Cd I, In I, Sn I, Sb I-II, Te I-II, I I-II, and Cs II. This work was partially funded by NASA.

NIST provided calibration services and research to enable the aerospace industry and Government agencies to obtain temperature, pressure, vacuum, humidity, and leak thermodynamic measurements traceable to international standards. Calibrations are used to provide traceability to maintain quality systems, for process control, and to qualify instrumentation for flight and space travel. For humidity, NIST delivered a simplified calibration standard that specifically allows microelectronics packages to easily undergo reliability analysis and failure testing prior to use in aerospace and satellite applications. In the area of temperature, NIST calibrated platinum resistance thermometers (PRTs) to monitor critical temperatures inside the Curiosity rover's Multi-Mission Radioisotope Thermoelectric Generator. In vacuum, NIST performed calibrations of vacuum gauges and helium leak artifacts for NASA Johnson Space Center. NIST also calibrates high-accuracy pressure transducers used by NASA and the aerospace industry to ensure the accuracy of air data test sets needed for critical altitude flight instrumentation calibration and certification.

NIST used its new Measurement Service, Special Tests of Aperture Area, to provide accurate measurements of the area of optical apertures. Precision optical apertures are used in a variety of remote sensing instruments, such as satellite sensors, that measure the amount of optical radiation coming from Earth or the sun and in various radiometric standards needed to calibrate remote sensing instruments.

NIST optical area measurements provide the surface area used in total and spectral irradiance measurements of the sun by satellite-based instruments such as the Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM).

NIST provided calibration support for the infrared and optical sensors for several satellite missions under development: the Joint Polar Satellite System (JPSS), the Geostationary Operational Environmental Satellite—R Series (GOES-R), and the Landsat Data Continuity Mission (LDCM). NIST activities included the provision of radiometric standards, the validation of radiometric standards used by the sensor development teams, and the calibration and characterization of satellite sensors.

NIST collaborated with NASA's Goddard Space Flight Center (GSFC) to develop photodetectors for space applications. With funding from NASA, NIST designed and fabricated nanotextured gallium nitride (GaN) and GaN nanowires that serve as raw material for photocathode detectors. Goddard collaborators activated the material with cesium and packaged the units into complete imaging systems. In FY 2012, we tested nanowires with graded doping and found that the nanowires had a higher quantum efficiency at 254 nanometers (nm) than any previously tested GaN samples. NIST collaborated with the Jet Propulsion Laboratory (JPL) on the development of superconducting nanowire single photon detectors (SNSPDs). SNSPDs are a type of single-single photon detector with extremely low noise and very-high-speed response. These devices are of interest to JPL for space communications and to NIST for various quantum information experiments. In FY 2012, NIST characterized various JPL devices. NIST also packaged some JPL devices with our self-aligned single-mode optical fiber packaging scheme.

NASA's next-generation satellite observatories require new detectors with improved sensitivity and scalability. With NASA funding, NIST developed new detectors based on the voltage-biased superconducting transition-edge sensor (TES). The TES offers new capabilities for the detection of electromagnetic signals, from millimeter waves through x-rays. Following on their successful development at NIST, the TES has become the reference technology and a leading candidate for future NASA satellite missions at x-ray, millimeter, and submillimeter wavelengths, as well as for many NASA-funded ground-based and suborbital instruments (including balloon-borne instruments and instruments intended for the Stratospheric Observatory for Infrared Astronomy [SOFIA]). More recently, NIST

has developed integrated TES polarimeters for measuring the polarization of the cosmic microwave background. These devices incorporate multiple TESes per pixel to measure the power in the different polarizations of the cosmic microwave background (CMB). This integrated detector utilizes fully micromachined silicon feedhorns for beam formation. This integrated detector technology has been deployed on the South Pole Telescope in early FY 2012. With NASA funding, NIST is also developing Superconducting Quantum Interference Devices (SQUIDs) and SQUID-based multiplexers to read out large arrays of TES detectors in a manageable number of output channels. NIST is providing SQUID systems to many researchers, both at NASA Centers (GSFC and JPL) and in academia (including the California Polytechnic Institute, Stanford University, the Massachusetts Institute of Technology, the University of California Berkeley, Princeton University, Cornell University, and others), who are working on NASA-funded projects. SQUIDs and SQUID multiplexers developed at NIST are currently deployed in many ground- and balloon-based instruments (Atacama Cosmology Telescope [ACT], the Background Imaging of Cosmic Extragalactic Polarization 2 [BICEP2]/Keck Array, the South Pole Telescope [SPT], the background-limited infrared-submillimeter spectrograph [BLISS], the Goddard Institut de RadioAstronomie Millimétrique [IRAM] Superconducting 2 Millimeter Observer [GISMO], SPIDER, the E and B Experiment [EBEX], and others) and will be used in most of NASA's future TES instruments. Recent developments for improved detector readout include the demonstration of TES readout with dissipationless microwave SQUID multiplexers, the demonstration of code-domain multiplexers with subframe sampling for measurement of fast x-ray pulses, and new low-power SQUID amplifiers for use at focal plane temperatures.

In collaboration with GSFC (Microwave Sensors and Hydrological Sciences Branch), NIST demonstrated the world's first SI-traceable brightness-temperature or radiance calibration of a microwave black-body target, as used in space-based radiometers that monitor Earth's climate. NIST has designed the world's first facility to precisely measure the performance of millimeter-wave antennas using a robotic arm. It will operate at first to 210 gigahertz (GHz) and ultimately to 600 GHz. This facility will allow NIST to perform accurate calibrations of radiometer antennas above 110 GHz, a capability currently not available to the aerospace community.

National Ocean Service

The devastating earthquake and tsunami that struck Japan on March 11 claimed thousands of lives and left massive destruction in its wake—dumping an estimated 1.5 million tons of debris into the marine environment. In response, NOAA used its satellites and its ocean models to monitor and predict the movement of this marine debris to ensure safe ocean transport and help coastal communities prepare for debris landfall.

NOAA's National Geodetic Survey released GEOID12A, the latest model of the geoid (pronounced "jee-oid"), which can be described as the "shape" of mean sea level around the globe. Surveyors, engineers, and the scientific community use the geoid—a model derived through complex math and gravity measurements—to measure surface elevations with a high degree of accuracy. While the science behind the construction of geoid models is very complex, one reason why we need such models is surprisingly simple: a small difference in height measurement on land determines which way water flows, and this makes the development of new and better geoid models an ongoing priority.

By providing a more accurate means of determining elevations, the new model will assist those involved in floodplain management, coastal and emergency response, port operations, and river flow monitoring. More accurate elevations also help lessen risks to coastal communities caused by hurricanes, storm surges, tsunamis, and other flood-related events. Engineering and other activities requiring accurate elevations also benefit, including precision agriculture and the construction and maintenance of dams, levees, roads, and other infrastructure.

NOAA's National Geodetic Survey (NGS) defines and manages the National Spatial Reference System—the coordinate system that defines latitude, longitude, height, scale, gravity, orientation, and shoreline throughout the United States. The first major improvement to this reference system, NGS's National Adjustment of 2011 Project, integrated new position information for more than 80,000 survey marks with NGS's more advanced Global Positioning System receiver-based control points. As a result, the coordinates of the Nation's reference system are now consistent across space and time. Consistency in the National Spatial Reference System is critical because people rely on positioning data for countless engineering

and scientific applications—to plan roads to improve traffic flow, to check the integrity of buildings, to ensure that airplanes land safely on the runway, and even to measure small changes in sea level over time. Surveyors and others use the reference system throughout the country to ensure that their positional coordinates are compatible with those determined by others so that when experts create maps; mark off property boundaries; and plan, design, and build roads, bridges, and other structures, everything matches up.

NOAA's NGS is working to improve the Alaska/Arctic geodetic framework to ensure greater positioning accuracy and precision for latitude, longitude, and height. This precision is particularly important for hydrographic surveying and shoreline mapping to produce nautical charts and other products necessary for safe maritime transportation. Over the last couple of years, in support of this effort, NGS has collected over 347,000 square miles of gravity data across the Alaska/Arctic region, compiled approximately 390 miles of Arctic shoreline and 933 miles of Alaska shoreline, and added over 40 stations to the network of Continuously Operating Reference Stations.

For every dollar American taxpayers spend on the National Geodetic Survey's Coastal Mapping Program at NOAA, they receive more than $35 in benefits. This statistic was the result of an independent socioeconomic scoping study. The program provides critical baseline data to accurately map the U.S. shoreline. These data are important for national security, maritime shipping, and navigation. The program also provides geographical reference data needed to manage, develop, conserve, and protect coastal resources. Direct economic benefits of the program alone were estimated at $100 million—15 times program costs. Also, the study estimated that the Coastal Mapping Program supports 1,500 jobs outside of the program. NOAA derives shoreline data through various remote sensing technologies including aerial imagery, satellite imagery, and Light Detection and Ranging (LIDAR).

The U.S. Integrated Ocean Observing System (IOOS) Program at NOAA launched a new online map (*http://www.ioos.noaa.gov/observing/observing_assets/glider_asset_map.html*) that displays where partner data collection gliders are currently patrolling and where they have been. The map provides users with one-stop access to a current snapshot of where uncrewed, underwater gliders are located at sea. Once a glider returns from a mission, users can scroll over visualizations of

collected data. Additionally, users can retrieve a historical collection of data from previous missions, reaching back to 2005. Eventually, this Web site will provide access to glider data for all IOOS regions and their partners, which will allow scientists easier retrieval of data for use in models and forecasting tools. This new online map comes in the same year that IOOS partners completed the first step in an effort to send a glider around the world. In May 2012, IOOS scientists recovered a glider after it completed a nearly 11-month-long first leg of the journey, traveling from the arctic waters of Iceland to the subtropical waters of the Canary Islands.

Recent advances in technology have made it possible to outfit animals with environmental data collection devices, just one of the practices in the emerging field of animal telemetry—using animals and technology to collect data remotely. In the ocean realm, these devices, or "tags," can track animals over long distances for multiple years, collecting valuable data below the ocean surface from difficult-to-reach places where conventional data collection techniques are technically or economically unfeasible. Data from tags attached to marine animals will soon flow to the IOOS. NOAA's IOOS Program, along with other Federal, state, and academic partners, took significant steps toward establishing a U.S. Animal Telemetry Network, which would ultimately support IOOS with oceanographic and biological data. As part of this effort, the IOOS Program made progress in a couple of regions.

On the West Coast, IOOS and its partners made data from tagged marine mammals (primarily elephant seals) in the Pacific more accessible to ocean modelers from the Naval Oceanographic Office and the National Weather Service's National Centers for Environmental Prediction. The modelers involved expressed enthusiasm about now having access to 8,000 ocean observations that were previously inaccessible. In the Great Lakes region, the Great Lakes Acoustic Telemetry Observation System is tracking more than 1,700 fish from four species to answer fisheries management and ecology questions. Tracking information will influence a range of fish population restoration actions.

The IOOS supported the intergovernmental Group on Earth Observations (GEO) effort to develop a global high frequency radar (HFR) network. HFR systems measure ocean surface current speed and direction along the coast to benefit search-and-rescue efforts, oil-spill response, harmful algal bloom (HAB) monitoring, water quality assessments, ecosystem assessments, and fisheries management.

Over the last several years, the United States and other nations have developed national HFR networks. The related information technology infrastructures in these countries are now poised to go global, and countries are moving in that direction. The 2012 World Radiocommunication Conference allocated frequencies for international HFR operations in the 3- to 50-megahertz range, which is important because without established frequencies, any operational network suffers service interruptions due to interference. The frequency allocations agreed upon at the conference capped off more than five years of work by the U.S. IOOS Program and the Office of Radio Frequency Management to get permanent frequencies for HFR operations. Experts from the U.S. commercial sector and representatives from Japan, Australia, Korea, Canada, France, and Germany worked toward this decision as well. GEO is a voluntary partnership of governments and international organizations working to integrate the variety of Earth observation systems to support environmental decision making in an increasingly complex world. GEO provides a framework within which these partners can develop new projects and coordinate their strategies and investments.

In July 2012, NOAA and partners announced a new seasonal HAB forecast for Lake Erie. The forecast, developed by NOAA's National Centers for Coastal Ocean Science (NCCOS) at the request of regional managers and stakeholders, predicted a mild bloom for the 2012 season, a welcome change for water utilities, recreational anglers, and others living and working on the lake who have endured increasingly severe algae blooms since 2008. The algae problem is caused by the blue-green alga *Microcystis*, which can produce toxins and overgrowths that harm fish, people, and the environment. The new seasonal forecast supplements weekly near-real-time forecasts—also developed by NCCOS—that help water treatment plant operators know when to use extra carbon filtration to preserve the quality of local drinking water. This planning information saves water companies money because it takes tons of additional activated charcoal to produce potable water during a HAB event. Data for the seasonal and weekly HAB forecasts come from an instrument called a Moderate Resolution Imaging Spectroradiometer, or MODIS, carried aboard a NASA environmental observation satellite called Aqua.

During FY 2012, NOAA developed a Web-based collection of 7,800 historical U.S. shoreline topographic images—the earliest dating back to 1841. The NOAA

Historical Shoreline Survey Viewer (*http://specialprojects.nos.noaa.gov/tools/shorelinesurvey.html*) allows users to view these historical images in Google Earth along with current satellite-derived shoreline images to see how U.S. coastlines have changed over time. The tool also provides data download options for users who wish to conduct more advanced analyses in Geographic Information Systems.

International Trade Administration

Industry and Trade Policy

The Office of Transportation and Machinery (OTM) participated in the planning and implementation process for the Next Generation Air Transportation System (NextGen) through the interagency Joint Planning and Development Office (JPDO), which oversees the initiative. OTM staff initiated collaboration with the Aerospace Industries Association to form a NextGen Vendors Group to improve outreach to industry, garner market intelligence, create strategies for increased foreign market access, and build a catalog of NextGen-related products and services to help promote exports. OTM cohosted a matchmaking briefing for the NextGen Vendors Group at the Air Traffic Control (ATC) Global 2012 Exhibition and Conference in Amsterdam, Netherlands, with foreign air navigation service providers.

OTM staff worked with the FAA, the Transportation Security Administration (TSA), NASA, and the U.S. Air Force (USAF) in preparations for the International Civil Aviation Organization's (ICAO) 12th Air Navigation Conference (ANC-12) in Montreal in November 2012, providing the Commerce perspective on various topics, including required navigational performance, remotely piloted aircraft, and satellite navigation. OTM staff worked with the FAA, the Export-Import (Ex-Im) Bank, the Millennium Challenge Corporation, the Small Business Administration (SBA), the Overseas Private Investment Corporation, and the U.S. Trade and Development Agency (USTDA) to produce and distribute a brochure that lists U.S. Government sources of funding for air traffic management renovation projects around the world and provides information on U.S. vendors of NextGen

equipment and services. The brochure fulfilled a request from ICAO member countries for addressing how members will finance required system upgrades. OTM also hosted a delegation of Nepalese officials (including the President of the Federation of Nepalese Chambers of Commerce and Industries), representatives from U.S. airport design companies, and officials from USTDA and Ex-Im Bank. The participants discussed current and planned airport and aviation infrastructure projects in Nepal, plans by the Nepalese Airlines Corporation to purchase supplemental aircraft, the potential market for new helicopters and general aviation aircraft, and the competitive market in Nepal.

OTM continued its participation in aviation security activities, including work on the JPDO Aviation Security Working Group. Through the JPDO, whose other members include DHS, DOD, and the FAA, OTM staff participated in meetings to improve interagency coordination of NextGen research and contributed to discussions of the potential impact of abnormal solar activity and high-altitude electromagnetic pulse events/attacks, leveraging International Trade Administration (ITA) and White House resources. OTM staff also facilitated meetings between aviation security trade associations and a delegation from the Netherlands looking to partner with U.S. firms to make The Hague the gateway to the European Union (EU) security market.

Throughout the year, OTM organized and led three meetings of the Industry Trade Advisory Committee for Aerospace Equipment (ITAC 1). The committee provides advice to the Secretary of Commerce and U.S. Trade Representative on aerospace-related trade policy issues.

ITA continued to support the Office of the U.S. Trade Representative on issues relating to the enforcement of U.S. rights under the World Trade Organization concerning trade in civil aircraft. In particular, OTM has provided support for the ongoing U.S.-EU trade dispute over subsidies to manufacturers of large civil aircraft, providing industry expertise in areas relating to changes in the market and actions of the major stakeholders.

ITA's OTM and Office of Financial Service Industries (OFSI) continued to participate in the Group on the Sector Understanding on Export Credits for Civil Aircraft (the "Aircraft Sector Understanding," or ASU) at the Organization for Economic Cooperation and Development (OECD). The governments of almost

all countries with major aircraft manufacturers are signatories to the ASU, an annex to the OECD Arrangement on Officially Supported Export Credits, which establishes rules for export credit agencies. The OECD rules aim to ensure that government-provided export financing is not a competitive factor in civil aircraft sales competitions. A new ASU, which had been completed in early 2011, will go into full effect in 2013. As a member of the U.S. delegation, ITA helped ensure that the interests of industry were addressed as the new ASU was implemented and provided advice on how Ex-Im Bank programs affect the aerospace industry.

ITA and NOAA continued their active participation in the implementation of the current National Space Policies, which include industrial base and competitiveness issues. ITA's OTM actively participated in the implementation of several actions that were identified in the June 2010 National Space Policy, which revised and updated several aspects of the previous policies. In order to ensure that commercial interests continue to be adequately addressed, OTM and NOAA continued to ensure that all of the policies' implementation actions will improve U.S. industry's competitiveness, stimulate the American economy, increase exports, and create U.S. jobs.

OTM continues to represent commercial remote sensing satellite industry interests within the Remote Sensing Interagency Working Group (RSIWG), led by the State Department. 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' technology. The RSIWG consulted with several foreign countries on satellite cooperation and met with representatives from industry 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 of aircraft, helicopters, airport construction, communications, and remote sensing satellites; commercial projects; and air traffic management projects.

In July 2012, ITA organized and supported the Commerce Department's participation in the Farnborough International Airshow and arranged senior-level meetings for the Under Secretary for International Trade with foreign government

and industry officials as well as U.S. industry executives. ITA's OTM met with numerous U.S. and foreign government and industry officials to discuss ongoing policy issues impacting the competitiveness of U.S. industry.

Industry and Trade Promotion

In FY 2012, ITA's U.S. and Foreign Commercial Service (US&FCS) Aerospace Team recorded 249 export successes valued at over $1.9 billion. An export success is an activity in which Department of Commerce 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 impacted deals with small- and medium-sized companies, as well as larger corporations, such as Bell Helicopter, Boeing, Honeywell, Lockheed Martin, and Raytheon.

The CS Aerospace Team held over 500 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 Aerospace Team participated in 45 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 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 Farnborough International Airshow, the Aerospace Trade Mission to Canada, the Seoul Air Show, the South Africa Aerospace and Defense Show, the Dubai Air Show, and the Seattle Aerospace Defense Supplier Summit, among others.

Bureau of Industry and Security

Export Control Jurisdiction of Commercial Satellites and Related Components

Section 1248 of the National Defense Authorization Act of Fiscal Year 2010 (Public Law 111-84) provides that the Secretaries of Defense and State shall carry

out an assessment of the risks associated with removing satellites and related components from the United States Munitions List (USML). The Departments delivered the 1248 Report to Congress in April 2012. The report summarizes a risk assessment of U.S. space export control policy, which concludes that most communication and lower-performing remote sensing satellites and related components can be moved from the USML to the Commerce Control List (CCL) without harm to national security. In particular, the Departments believe that the following items are more appropriately designated as dual-use items on the CCL and controlled under the Export Administration Regulations: communications satellites that do not contain classified components; remote sensing satellites with performance parameters below certain thresholds; and systems, subsystems, parts, and components associated with these satellites and with performance parameters below thresholds specified for items remaining on the USML.

Department of the Interior

DOI

The Department of the Interior has a responsibility to monitor land-cover conditions and changes in the United States. This responsibility includes monitoring wildlife habitat, coastal changes, fires, and natural resources. Many of the applications and techniques developed for analysis are also applied to global resource management and even planetary science. To effectively monitor these conditions and changes, Interior scientists rely on a number of remote sensing archives and capabilities. The Interior agencies work closely with commercial data providers, NASA analysts, and state agencies.

New Mexico's Abandoned Mine Land Program used terrestrial light detection and ranging (LIDAR) data to support an engineering project in Silver City. The project involved evaluating and safeguarding the Legal Tender Mine upon which the surrounding community established a system of trails. Multiple open stopes (excavations) are scattered across the abandoned mine that is visited by local townspeople and often used by wildlife. Considering the community's desire to continue to utilize the aboveground area as a hiking and biking area, an engineering contract was established to assess mine wall stability. Terrestrial LIDAR data were collected, and a high-definition laser scanning survey of the mine interior was provided to the engineers to create a three-dimensional (3D) visualization (figure 1) that was used to determine the stability and strength of the below-ground pillars and walls. This information is essential to support the recreational planning efforts for the site.

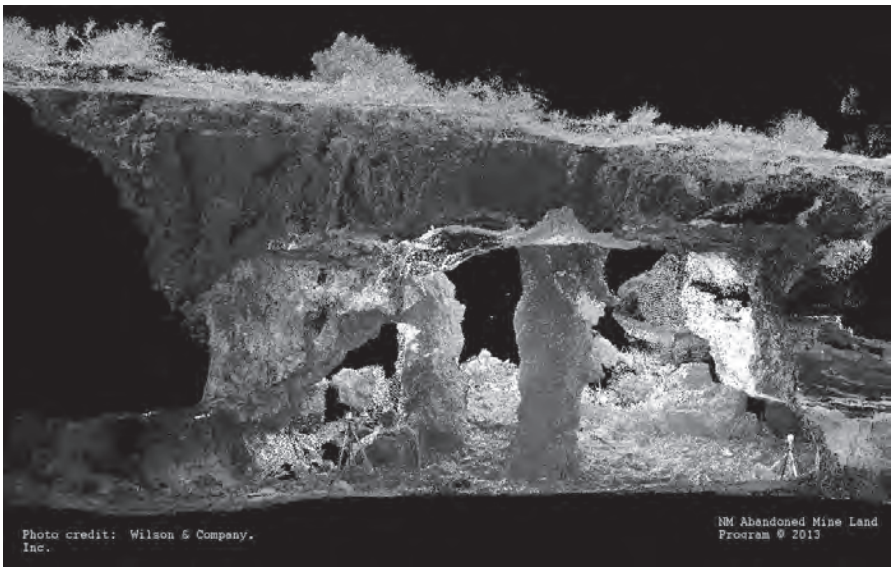

Figure 1. This image shows a side view of a LIDAR 3D model of the large underground chamber, pillars, and top surface draped with an aerial photograph.

Vegetation structure plays an important role in the partitioning of energy, the movement and fate of water, and the provision of habitat. How vegetation structure changes as a function of climate (phenology) is of interest for climate, carbon cycling, hydrologic, and biologic modeling, as well as resource management. Multiple sources of remotely sensed data are being used to develop metrics that provide insight into the changing phenology of vegetation in Shenandoah National Park, Virginia. The primary goals of this research are to develop efficient and accurate means of remotely sensing vegetation structure and to understand the importance of these measurements for hydrologic and biologic science. Increasing the length of record from remote sensing systems and continuing the development of new sensor technology and missions present both opportunities and challenges for the study of vegetation structure.

Conservation planners associated with the Gulf Coastal Plains and Ozarks (GCPO) and Gulf Coast Prairie (GCP) Landscape Conservation Cooperative (LCC) require contemporary and standardized vegetation maps from coastal Texas to Alabama. Marsh salinity zone maps are used by conservation planners to model habitat availability for priority taxa (e.g., waterfowl and alligator) and for understanding impacts to priority habitats. The United States Geological Survey (USGS) National Wetlands Research Center has been funded by the U.S. Geological Survey South Central Climate Science Center to map marsh vegetation salinity

classes (i.e., fresh, intermediate, brackish, and saline) from Corpus Christi, Texas, to Mobile Bay, Alabama. Researchers from Texas A&M University-Kingsville and the University of Louisiana-Lafayette collected ground reference data via helicopter surveys. Imagery from Landsat Thematic Mapper (TM) 5 and Satellite Pour l'Observation de la Terre (SPOT) 4 and 5 were combined with elevation data and other ancillary data (e.g., National Wetlands Inventory [NWI] maps and the Coastal Change Assessment Program [C-CAP]). These data were classified into marsh salinity classes using classification and regression tree (CART) analyses and combined with existing classifications of marsh vegetation salinity in Louisiana to develop a contemporary and continuous coastal vegetation layer for much of the Gulf of Mexico coast.

Many low-lying U.S. coastal communities are threatened by tsunami hazards and could be inundated only minutes following a substantial local earthquake. To support tsunami preparedness efforts in the U.S. Pacific Northwest, USGS geographers modeled pedestrian-evacuation travel times using high-resolution imagery (e.g., 1-meter, 2011 National Agriculture Imagery Program [NAIP)] and LIDAR-derived, 1-meter elevation data. Modeling results were merged with various population data to estimate the number of people in each community who might not have enough time to evacuate before waves arrived from tsunamis associated with a Cascadia subduction zone earthquake. This information has helped the state of Washington begin planning for tsunami vertical-evacuation structures in southwest Washington.

Oblique digital photography was collected along the coast in the aftermath of Hurricane Sandy from Montauk Point, New York, to Cape Lookout, North Carolina, from November 4 through November 6, 2012. The imagery allowed scientists to document and assess the damage caused by the storm, capturing the scope of the event throughout the entire impact zone. The data were collected using a Nikon D1X digital camera while flying along the coastline at an elevation of 500 feet and about 1,000 feet offshore. The platform used for this flight was a Piper Navajo Chieftain. GPS data collected during the flight allowed geolocation of the imagery.

Collection of the post-Sandy imagery is part of an ongoing effort to document the effects of severe coastal storms. More than 43 flights during the past 17 years have documented both pre- and post-storm conditions along the coast. This

imagery is used to analyze conditions following a storm, to help direct responders and researchers to areas of high impact after a storm, and to inform the public of the impact of the storm through the USGS Web site, often before people are able to return to their property.

Sagebrush ecosystems are among the most abundant and threatened habitats in North America. Exotic plant invasions, oil and gas drilling, housing developments, altered fire patterns, over-grazing, climate change, and other factors all contribute to the degradation and fragmentation of sagebrush ecosystems. These impacts can have detrimental effects on species that depend on sagebrush, such as sage grouse. Effective management and preservation of habitats require long-term landscape knowledge that is local in detail. Geographic Information Systems (GISes) utilizing satellite imagery can provide these kinds of information, but sagebrush habitats have traditionally proven to be a difficult environment for remote sensing. In 2006, the USGS Fort Collins Science Center (FORT) and Earth Resources Observation and Science (EROS) Center, in cooperation with the Bureau of Land Management (BLM), began an effort to combine intensive, targeted field sampling with three resolutions of satellite imagery to map and characterize sagebrush habitat for the entire state of Wyoming.

BLM staff are studying the impacts of agriculture development on water resources in a remote region along the Nevada-Utah border. BLM utilized historical Landsat imagery to build a chronology of land-use changes in the region. Given a rich archive of scenes dating back decades, Landsat is the only data source of its kind with the required spatial and temporal detail to enable BLM to build such a database. BLM evaluated 76 Landsat scenes dating back to 1995 in order to build a detailed image-based chronology of center pivot agricultural field establishment.

Tidewater glaciers are a prominent feature along the southeastern and south-central coasts of Alaska and play an important role in landscape and ecosystem processes. Many tidewater glaciers calve large icebergs into the marine environment; the icebergs then provide important resting and pupping areas for harbor seals, a species of conservation concern in Alaska. Glacier Bay National Park historically supported one of the largest aggregations of harbor seals in Alaska, but the population has declined by up to 75 percent since 1992. Glacier Bay National Park, in collaboration with the University of Alaska Fairbanks Geophysical Institute and

the National Marine Mammal Laboratory, is using GPS, GIS, and remote sensing technologies to monitor trends in the abundance of harbor seals in Glacier Bay and to assess the relationship between the availability of glacial ice and harbor seal spatial distribution. Aerial digital imagery of the primary glacial ice site at Johns Hopkins Inlet provides a permanent record of seal distribution and captures important information regarding ice conditions and characteristics in Glacier Bay.

The National Park Service (NPS) Alaska Regional Office GIS team has been using the newest SPOT 5 satellite imagery to update hydrography features in the National Hydrography Dataset (NHD) within Denali National Park and Preserve. The NHD is the surface water layer of the USGS National Map, which contains features such as lakes, ponds, glaciers, streams, rivers, canals, dams, and stream gages. Much of the current NHD in Alaska was derived from original USGS topographic mapping based on 1950s aerial photography and compiled at a scale of 1:63,360. Compared to current imagery and spatial layers that are derived from more recent mapping efforts, the older data contain positional inaccuracies and cartographic inconsistencies (e.g., disconnected rivers, streams flowing uphill, and displaced water bodies). Given the natural changes in surface hydrology due to the dynamic nature of water flow and the accelerating influence of the changing climate, updating the original NHD for Alaska is a key mapping priority.

The NPS Alaska regional compliance team frequently uses aerial photography and satellite imagery to convey resource conditions and locations to the public in National Environmental Policy Act (NEPA) documents. These images accurately portray the lay of the land and affected resources, and the reviewers find them aesthetically pleasing and informative. Satellite imagery has been used in conjunction with wetlands field data for a proposed access road through a sensitive area to a new barge landing location near Brooks Camp in Katmai National Park. This information has been used by engineers to realign the landing site and storage area to avoid wetlands except for a small culvert for drainage between two wetlands. This imagery is extremely helpful for communications with staff such as planners and engineers and with the general public.

Mining Coal Basin Mine deposits in Pitkin County, Colorado, began in 1895 and continued until 1908, when production ceased for many years. Mid-continent Resources began producing coking coal at the Coal Basin Mine in 1956 and

continued until the mine shut down in 1991. The state of Colorado wanted to test the utility of an Unmanned Aircraft System to map abandoned mine land features as well as vegetation cover on the site. In 2012, Office of Surface Mining (OSM) inspectors and USGS and BLM Unmanned Aircraft Systems (UAS) staff supported the state in collecting high-resolution images using an RQ-11A Raven UAS. The Coal Basin Mine site is at 10,000 feet in elevation. The high elevation, associated low air pressures, and high winds proved to be problematic for consistent collection of imagery. However, important information was gathered on this mission to determine the capability of the RQ-11A Raven at high altitudes.

The New Mexico Abandoned Mine Land Program has used remote sensing techniques to monitor land cover change over time. High-resolution satellite images and aerial photography, in conjunction with ground surveys, were used to measure reclamation success for the Swastika Mine and the Dutchman Canyon project in northern New Mexico. The objectives of using remotely sensed data in this project were to 1) develop a baseline dataset to support multi-year change detection analysis of vegetation and stream channel form over a large area and 2) develop the methodology to apply to other potential reclamation projects. The geomorphic reclamation plan called for the coal spoils to be redistributed and buried beneath a reformed valley. The reclamation also reformed the drainages to a more natural landform. After the geomorphic reclamation construction process, wetland vegetation was planted in and along the channel. Final plantings of willow and cottonwood poles, native shrubs, and seeds of grass/forb mixes is expected before summer 2013.

Earth's natural satellite (the moon) is currently under observation by the NASA Lunar Reconnaissance Orbiter (LRO) spacecraft. USGS Astrogeology staff are involved in a number of studies as part of the science team for the Lunar Reconnaissance Orbiter Camera, which is obtaining hundreds of terabytes of high-resolution (0.5–2-meter-per-pixel) images of the moon; the DIVINER infrared imaging spectrometer; and the Miniature Radio Frequency (Mini-RF) radar system, which produces 7.5-meter-per-pixel views inside the permanently shadowed polar craters where ice may be found. Controlled mosaics of the optical and radar images produced by Astrogeology are setting records as the largest products of these types in the history of lunar exploration. Astrogeology scientists are playing a leading

role in cataloging and understanding the diversity of explosive volcanic features on the Moon, some of which could contain high concentrations of materials useful for future astronauts. Several "new" or previously unrecognized small lunar volcanoes have been identified recently, suggesting that these kinds of eruptions were much more common on the moon than believed earlier.

Mars is a major focus of U.S. and international space programs, with five currently operational spacecraft: Mars Odyssey, Mars Express, Mars Exploration Rover Opportunity, Mars Reconnaissance Orbiter, and Mars Science Laboratory Curiosity. The USGS Astrogeology Science Center is involved in all of these missions as science team members and supports mission operations, ground software development, and data archiving. The USGS leads the development of software to process raw images into geolocated data products and the creation of topographic maps from imagery. The topographic maps have been especially useful in planning the traverses of the Mars rovers, in finding landing sites that are devoid of rocky terrain and slopes, and in adjusting the software parameters for the altitude-sensing radar systems used by Mars landers. Data and imagery returned by the rovers confirm the accuracy of the USGS topographic maps. Science research subjects range from bizarre solar-powered "geysers" in the dry-ice polar caps to giant turbulent lava flows that formed in the last few million years, and from imaging microscopic salt grains to global-scale rearrangement of windblown dust.

Information on the potential, locations, and mechanisms of carbon sequestration is essential in order to formulate carbon management and sequestration policies and strategies. This USGS project fulfills the requirements of section 712 of the Energy Independence and Security Act (EISA) of 2007 by conducting a comprehensive assessment of the potential for carbon sequestration and greenhouse gas emissions reductions from terrestrial ecosystems across the United States. Remote sensing information from satellites (e.g., Landsat and MODIS) has been used to quantify the spatial and temporal dynamics of land-use and land-cover change, disturbances (insects, hurricanes, fire, etc.), and ecosystem performance (e.g., net primary productivity) that are essential for this assessment.

In 2012, the USGS completed mapping historical wildfires (1972 to 2010) for the full Mojave bioregion of California, Nevada, Arizona, and Utah using Landsat data. This work documented wildfire information related to burn perimeters,

severity, frequency, and post-fire vegetation characteristics, which is useful to local, state, and Federal land managers. A statistically robust field sampling of current vegetation and seedbank characteristics continued in 2012. This project is expected to result in a better understanding of the effects of fires in the Mojave Desert ecosystem and treatment effectiveness.

In summer 2010, the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) launched the Migratory Bird Habitat Initiative (MBHI) in response to the Deepwater Horizon oil spill. The goal of the program is to enhance migratory bird habitat on private lands and thus offset habitat loss caused by the oil spill. Rice fields and other lands that could be flooded were managed to create mudflats during the migration period. In collaboration with NRCS and the University of Delaware, researchers at the USGS National Wetlands Research Center used weather surveillance radar, a mobile marine radar system, a thermal infrared camera, and ground-based visual counts to assess migratory bird use of fields enrolled in the MBHI. The weather radar analyses included MBHI fields within 80 kilometers of the weather radars located at Houston, Texas; Lake Charles, Louisiana; Memphis, Tennessee; Little Rock, Arkansas; and Paducah, Kentucky. In the region around Lake Charles, additional mobile radar, thermal imaging, and visual surveys were conducted on 12 sites (69 fields). Preliminary radar data analysis indicates that the bird density of MBHI fields increased in response to the management activities implemented in September and October.

In the arid Southwest, much remains unknown about how migratory birds use different habitats when they stop to rest and refuel during migration. The relatively unpopulated and remote expanses of the West present logistical and cost challenges to field-based studies of migration ecology. USGS scientists at the Fort Collins Science Center and the Northern Rocky Mountain Science Center turned to data collected remotely by weather surveillance radars (Weather Surveillance Radar 88 Doppler [WSR-88D]) and satellites (land-use and land-cover data from the USGS National Map Seamless Server). These data sources were used to calculate the densities and distributions of migrating birds using different stopover habitats across the southwestern United States. Results indicate that parts of Arizona and New Mexico upland forest support high densities of migrants, as do human-developed habitats located in areas with little upland forest. Scrub/shrub

and grassland habitats support low to intermediate densities, but because these habitats dominate the southwestern landscape, they may support larger numbers of migrating birds than previously recognized. These results are important to those working to conserve migratory birds in the Southwest.

The only wild and self-sustaining population of whooping cranes migrates through the Central Flyway of North America, traveling between wintering grounds along the Gulf Coast of Texas and breeding grounds in Canada. Over the past few decades, growth of this population has been positive and steady, but, with only approximately 300 individuals, recovery remains tenuous. In an effort to recognize and quantify potential barriers to recovery, USGS and other project partners have captured 57 cranes and marked them with Platform Transmitting Terminals with GPS capabilities. These transmitters use a satellite uplink and acquire multiple GPS locations per day over several years. The precision of the GPS data allows researchers to discover where birds reside during the breeding season in Canada, during the winter season in coastal Texas and other previously unknown areas, and at hundreds of stopover sites on public and private lands during migrations each spring and fall. Analysis of these data provides reliable scientific information to assist the Canadian Wildlife Service and the U.S. Fish and Wildlife Service (USFWS) in future management and recovery efforts for this species.

The Eastern Population (EP) of Sandhill cranes is rapidly expanding in size and geographic range. The core of their breeding range is in Wisconsin, Michigan, and southern Ontario; however, the EP range has expanded in all directions as the population has grown. Little is known about the geographic extent of breeding, migration, and wintering ranges of EP cranes or about the migration chronology and use of staging areas. Between 2009 and 2012, GPS satellite Platform Transmitting Terminals (PTTs) were attached to 30 EP Sandhill cranes to assess their movements throughout the year. Cranes were tagged at refuges in Indiana, Minnesota, Tennessee, and Wisconsin. Location and migration data for these birds are currently being received from Collecte Localisation Satellites (CLS) America, Inc., Maryland, translated by software developed by North Star Science and Technology, LLC, Maryland, and viewed using Environmental Systems Research Institute (Esri) ArcGIS software.

The Migratory Bird Program within the USFWS is currently undertaking multiple research projects to evaluate the effects of climate change on migratory bird populations in North America. The goal is to adapt monitoring programs and population models that inform the harvest management of waterfowl species in the face of climate change. National Environmental Prediction Center North American Regional Reanalysis (NCEP/NARR) climate data and percent surface water products derived from MODIS (Yellowstone Ecological Research Center Customized Online Aggregation & Summarization Tool for Environmental Rasters [COASTER], *http://COASTERdata.net*) provide information on historical trends in precipitation, temperature, and waterfowl habitat conditions in the Canadian and U.S. prairies. These data, along with waterfowl population data from the long-term Waterfowl Breeding Population and Habitat Survey, are used to model spatial patterns in density dependence and waterfowl population response to changing habitat conditions. Incorporating climate change predictions into these models, in the form of temperature and precipitation trends, allows scientists to simulate how population distributions and dynamics may shift and to identify strategies to adapt monitoring efforts and harvest management models in order to better manage waterfowl populations in the face of a changing climate.

Malheur Lake at Malheur National Wildlife Refuge in Harney County, Oregon, is the largest freshwater marsh in the western United States and historically one of the most productive migratory waterbird habitats along the Pacific Flyway. The lake's size is highly dynamic, a result of being shallow, within a closed basin, and replenished primarily by runoff from spring snowmelt. To improve our baseline knowledge for habitat management and monitoring, a terrain model of the lake bottom was needed in order to construct a better area-depth-volume relationship and evaluate lake-size averages and extremes. LIDAR data and traditional surveying methods are unsuitable because of water and substrate composition. Shorelines were delineated from a series of freely available Landsat Thematic Mapper satellite images from 1985 through 2011. Image dates were compared to historical lake-level staff gage readings. From the imagery, "contour" lines were delineated around the lake shoreline to help define a large portion of a new terrain model. The analysis showed that the lake area typically fluctuates between an average low of 25,000 acres and an average high of 45,000 acres, with recent extremes of 500 and 124,000 acres.

The USGS uses Advanced Very High Resolution Radiometer (AVHRR) satellite data and weather information to assess fuel conditions and create the Fire Potential Index (FPI) to identify areas most susceptible to fire ignition. The forecast for large fire probability has been improved to include all land nationwide. The forecast is based upon historical large fire occurrence from the Monitoring Trends in Burn Severity project and FPI. The USGS produces seven-day forecast maps showing the probability distributions for the number of ignitions and number of large fires (>1,000 acres) for each Predictive Service Area (PSA).

Historically, fire has been influential in shaping and maintaining the biotic components of the Greater Everglades ecosystem. As a result, Everglades National Park has been at the forefront of NPS fire policy development. In 1948, Everglades National Park was the first to allow prescribed burns and one of the first parks to develop a fire management plan. Big Cypress National Preserve began its fire program in 1978. Since then, fire management researchers have acquired a substantial amount of wildfire history data in the form of paper records, tabular data, fire perimeters hand drawn on 1:24,000-scale USGS topographic maps, aerial photography from 1940 to 2010, and GPS perimeters. Fire history geodatabases were constructed from this collection of data to describe in detail the location and attributes of fires that have occurred from 1948 through 2011. The important role of wildfire on the landscape makes the availability of these data in a GIS format vital for many park planning and operational functions, including ongoing fire management activities, fire ecology studies, and a variety of resource management issues related to the Comprehensive Everglades Restoration Plan.

There is a growing consensus that natural disturbances will intensify under forecasted global climate change. The southwestern United States, for example, is expected to undergo both extended periods of drought and longer wildfire seasons. The temporal response of desert grassland communities to the effects of drought and fire is being examined using a time series of Landsat Thematic Mapper images from 1984 through 2011 (n = 309 scenes). The study area is the 474-square-kilometer Buenos Aires National Wildlife Refuge (BANWR) in Arizona, where refuge managers and surrounding private landowners have focused on repeated, prescribed fire as the primary habitat restoration tool for these grasslands.

A time series of vegetation cover using the Soil-Adjusted Total Vegetation Index (SATVI) was calculated by a science team. The SATVI was independently calibrated and validated with plot data from multiple long-term grassland monitoring databases in the region. Using a comprehensive fire atlas that contained 25 years of mapped information from 211 prescribed fires and wildfires, we 1) located grassland areas with multiple overlapping fire, 2) correlated periods of fire and drought based on the Palmer Drought Severity Index (PDSI), and 3) stratified our sample areas by fire return and drought periodicity. Within these areas, we collected total vegetation cover information using 20-meter × 50-meter line intercept plots (n = 91) and calculated cover of bare soil, annuals, native and non-native grasses, woody plants, and overall species richness.

Vegetation sampling and remote sensing results indicate that grass and woody plant covers in areas that received multiple (four) prescribed fires were indistinguishable from those found in unburned areas when those prescribed fires occurred in years when the growing season experienced extremely low precipitation and, ultimately, the positive ecological effects from earlier fire were negated. Areas that had fewer prescribed burns but were followed by average or slightly below average precipitation had higher grass cover and lower woody cover than matched unburned areas. The results provide range managers with information to understand the optimal timing of prescribed burning and fire suppression activities that promote ecosystem resilience and habitat restoration.

The USGS, working in partnership with the interagency Multi-Resolution Land Characteristics (MRLC) Consortium, is producing the next version of the National Land Cover Database (NLCD). NLCD 2011 data products are derived from Landsat and quantify land cover and urban imperviousness changes between 2006 and 2011 for the conterminous United States and Alaska at 30-meter resolution. Monitoring land-cover change with scientifically credible geospatial data layers provides support for a broad spectrum of applications in land management, environmental studies, modeling, and policy decisions. These data (and associated products) require continuous production, updating, and improvement to provide the most relevant land-cover information for the Nation, with updates planned at five-year intervals. All NLCD information can be accessed at *http://www.mrlc.gov*.

The Monitoring Climate and Landscape Change in the Desert Southwest research program utilizes a combination of in situ and remote sensing technologies and algorithms to monitor the changing landscape of the Navajo Nation due to climatological influences. The tribal land, equivalent in size to the state of West Virginia, is the least instrumented and least climatologically studied area of the United States. Landsat, MODIS, and GOES imagery; GPS; terrestrial LIDAR data; weather station data; and time-series imagery are being combined and correlated to develop novel remote sensing algorithms to determine drought impact and severity, dust storm vulnerability, and sand dune mobility. These methodologies are intended to help the Navajo Nation and the surrounding region better assess and plan for impacts of climatic change on the reservation.

Land use in areas near or adjacent to protected areas can influence the success of protected areas as a conservation method. The USGS Western Geographic Science Center developed a methodology to assess the threat of future land-use conversions to California's protected areas under different climate/emission scenarios. Utilizing spatially explicit, annual, scenario-based projections of land use and land cover (LULC) from 2006 to 2100 produced by the USGS LandCarbon project (based on data sources derived from the Landsat archive), USGS staff examined scenario outcomes at the state level and by conversion type. We determined the amount of protected area for each of California's unique ecoregions and mapped the footprint of projected LULC change per scenario. Conversion potential was examined spatially against protected areas to identify potential threats to existing protected areas. Variability between scenario outcomes enabled the identification of ecoregions particularly susceptible to LULC change pressures. The identification of protected areas in close proximity to lands with a high likelihood of future conversion can help prioritize future conservation efforts.

The USGS conducts national-scale mineral resource and geoenvironmental assessments to map and characterize mineral exposures related to mined and unmined hydrothermally altered rocks and mine waste. The presence and mineralogy of altered rocks are important factors determining the occurrence of concealed mineral deposits. Investigations have determined that sulfide-bearing altered rocks and mine waste are diffuse sources of acidic solutions that can transport metals

into the hydrologic system. These rocks and waste materials contain minerals that can be identified using spectral analysis remote sensing data.

The Landsat Program is a joint effort of the USGS and NASA to gather Earth resource data using a series of moderate-resolution land-observing satellites that can record both natural (floods, wildfires, insect damage, invasive species) and human-induced (forest clearcuts, crop types, agricultural irrigation) changes on the landscape. Whereas NASA's role is the development and launch of Earth-observing instruments and spacecraft, the USGS is responsible for satellite flight operations and all ground data reception, processing, archiving, product generation, and distribution. For over 40 years, the primary objective of the Landsat Program has been to record land-surface conditions across the globe through the collection of consistently calibrated image data.

In fiscal year 2012, the Landsat operations team at the USGS Earth Resources Observation and Science (EROS) Center entered over 150,000 new Landsat 5 and 7 images into the Landsat archive, plus more than 600,000 historical Landsat images provided by current or former International Cooperator receiving stations. During the same period, users downloaded over 3 million Landsat scenes from EROS servers, with each scene covering over 12,000 square miles. Also, most of the final work was completed at EROS by the Landsat 8 ground-system development team in preparation for the February 11, 2013, launch of the satellite.

To assess the uses and value of Landsat imagery, social scientists and economists at the USGS Fort Collins Science Center completed an extensive, highly informative survey of Landsat imagery users, with followup surveys planned to provide longitudinal data on how the users and uses of the imagery are changing over time in response to changes in the provision of the imagery. The 2012 survey was completed by over 11,000 people registered as Landsat users with USGS. The results show that Landsat imagery is applied in projects at numerous scales around the globe by users in many sectors. Landsat imagery is highly valued by these people, who identified considerable economic benefits from the use of the imagery. Also in 2012, case studies focusing on the use of Landsat imagery in water, forestry, and mineral and energy exploration applications provided an in-depth look at the market and nonmarket value of the imagery. These efforts document the widespread and increasing use and value of Landsat imagery.

After a major disaster, satellite images or aerial photographs are frequently the fastest, most effective way to determine the scope and severity of the event. With that goal, the USGS operates the Hazard Data Distribution System (HDDS) to process and deliver satellite and aerial imagery in near-real time during natural or human-caused disasters (e.g., hurricanes or oil spills). For example, after Hurricane Katrina struck New Orleans, Louisiana, in 2005, Landsat satellite images showed when and where the floodwaters drained. High-resolution satellite imagery showed the landscape and building damages before and after the magnitude-7 earthquake hit Haiti in January of 2010. More recently, the USGS used satellite imagery to help assess the scope of damage from Hurricane Sandy. The imagery is available to all U.S. emergency management officials at the Federal, state, local, and tribal levels.

Remote sensing information from Landsat and similar moderate-resolution, Earth-observing satellites provides measurable economic benefits to society. For a case study of 35 counties in northeastern Iowa, USGS scientists and economists demonstrated the value of information (VOI) from remote sensing by using improved agricultural production and nitrate-leaching estimates enabled by Earth-observing satellites. As compared to the situation without satellite information, these estimates can provide additional benefits to society through a more optimal allocation of production without sacrificing public health and groundwater quality in an agricultural region. In Iowa, groundwater pumped from aquifers is used as the source for drinking water by as many as 80 percent of residents. For this application in northeastern Iowa, the marginal benefit of the VOI (in 2010 dollars) is estimated to be $838 million ± $197 million per year, which corresponds to a net present value of $38.1 billion ± $8.8 billion for that flow of benefits into the foreseeable future.

A $3.5 million, 5-year grant from NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program was recently awarded to a USGS-led multi-agency team of scientists studying future global food security. The proposal is entitled "Global Cropland Area Database (GCAD30) Through Landsat and MODIS Data Fusion for the Years 2010 and 1990 and Its Dynamics over Four Decades Using AVHRR and MODIS." The main goal of this project is to produce consistent and unbiased estimates of global agricultural cropland areas, types, watering methods, and cropping intensities using multi-sensor Earth Observation Data from satellites and cropland mapping algorithms. The project

will create a Global Cropland Area Database consisting of four distinct products: cropland extent/area, crop type, irrigated versus rainfed crops, and cropping intensity. The data and products will make a significant contribution toward addressing global water and food security in the 21st century, taking into consideration the complexities of ballooning populations; greater nutritional demands from expanding economies; and the virtual water and food trade in modern, globally interlinked economies.

Using remote sensing and non–remote sensing approaches, current research presents an exhaustive overview of global croplands and their water use. Global cropland area estimates from different studies are quite close and range between 1.47 and 1.53 billion hectares. However, significant uncertainties exist in determining irrigated areas that consume nearly 80 percent of all water used by humans. The estimates show that the total water use by global croplands varies between 6,685 and 7,500 cubic kilometers per year and that of this total, around 4,586 cubic kilometers per year is consumed by rainfed croplands (green water use) and the rest is consumed by irrigated crops (blue water use). Irrigated areas use about 2,099 cubic kilometers per year (1,180 cubic kilometers per year of blue water and the rest from rain that falls over irrigated croplands). However, 1.6 to 2.5 times the blue water required by irrigated croplands is actually withdrawn from reservoirs or groundwater, suggesting an irrigation efficiency of only between 40 and 62 percent. The weaknesses, trends, and future directions to precisely estimate the global croplands are examined. Finally, the research links global croplands and their water use to a paradigm for ensuring future food security.

Agricultural irrigation is a primary use of fresh water in the United States. It is difficult to accurately quantify the amount of water used for irrigation at large spatial scales. Remote sensing has been successfully used to map the amount of land under irrigation through time, particularly in arid regions. However, operational use of remote sensing to quantify water use for irrigation has not yet been realized. In addition, in the eastern United States, relatively lush nonagricultural vegetation cover, humid conditions, and smaller patch sizes of agricultural fields pose additional challenges for mapping irrigated land and for estimating water use through irrigation. The USGS Eastern Geography Science Center is exploring the combination of remotely sensed and detailed ground-based data to estimate

water use for irrigation on intra-annual timescales in the East. The research leverages USGS remote sensing expertise and local knowledge of irrigation practices to develop and improve tools for water resource management.

To meet the demands of food security early warning, the Famine Early Warning Systems Network (FEWS NET) has prioritized the development and implementation of alternate capabilities to monitor growing-season conditions using satellite imagery and models. A new FEWS NET remote sensing product provides estimates of actual evapotranspiration (ETa), which is directly proportional to crop yield. The estimate is based on the Operational Simplified Surface Energy Balance (SSEBop) model, expected to be published in 2013 in the *Journal of American Water Resources Association* (Senay et al.). The ETa products are important because drought is the climate hazard that most threatens rural livelihood systems in countries that receive the great majority (between $1 and $2 billion) of annual food assistance provided by the U.S. Agency for International Development through the Office of Food for Peace. In these countries, it is difficult to characterize location, condition, and magnitude of emerging food production problems due to sparsely located and late-reporting climate stations and extension services.

The ETa product monitors actual vegetation water use in near-real time across rainfed and irrigated agriculture, natural vegetation, and wetlands. Using MODIS data, the product is currently operational to a 1-kilometer resolution on eight-day, monthly, and seasonal time steps for Africa, central and southern Asia, and the conterminous United States.

The Bureau of Reclamation routinely monitors more than 3.5 million acres of agriculture and riparian vegetation along the Lower Colorado River from Hoover Dam to the Southerly International Boundary. Data generated include crop and riparian types, acreages, and associated water-use estimates. Remote sensing and GIS are the primary tools used for this activity. These data assist Reclamation in accounting for water use by each state and individual water user, analyzing needs, verifying fallowed lands for conservation programs, and performing other water management.

The Bureau of Reclamation is charged with measuring consumptive water use (water that is removed from a watershed) within the Colorado River Basin. Irrigated agriculture accounts for the majority of consumptive use. Historically, Reclamation

staff have combined estimates of crop acreage with local weather and crop development information to estimate seasonal consumptive water use by agriculture, but actual water use can decline from reference values due to crop stress caused by salinity problems, damage due to pests or disease, or water shortage. Reclamation scientists are researching the use of remote sensing–based energy balance models to map actual consumptive water use by agricultural crops. Because crops under stress exhibit changes in surface reflectance and emitted thermal radiation, satellite measurements of these variables can be used in the energy balance models to provide a better estimate of actual consumptive use than traditional methods.

Remotely sensed measurements of surface albedo (reflectance) and emitted thermal radiation are used to estimate the net radiation available to drive the evapotranspiration (ET) process at each pixel location. Vegetation index values derived from satellite imagery are used to estimate the amount of heat lost to the soil and the air at each pixel. The residual net minus losses to soil and air represents the energy available to evaporate water at each pixel. The residuals are summed for a 24-hour period and converted to a daily depth of evaporated water, and local weather data are used to estimate daily water use between image acquisition dates. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images are uniquely suited for this work because 1) they offer the spectral bands in the visible through thermal wavelengths needed to characterize net radiation, 2) their spatial resolution is adequate for mapping ET within individual agricultural fields, and 3) they are acquired on a frequent schedule that allows characterization of crop phenological development.

Federal Communications Commission

FCC

The Federal Communications Commission (FCC) formulates rules and administers proceedings 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 radiofrequency usage with other countries. The FCC's activities in FY 2012 related primarily to commercial communications satellites and Earth observation satellites.

The FCC took several significant actions in administrative and rule-making proceedings in FY 2012. In March 2012, the FCC released a Notice of Inquiry seeking comment on potential ways to free up radio frequencies to address the increased demand for mobile broadband services by removing unnecessary barriers to flexible use of 40 megahertz of radio frequencies currently assigned to the Mobile Satellite Service (MSS) in the 2-gigahertz band. In September 2012, the FCC began a comprehensive review of licensing and operating rules for satellite services by releasing a Notice of Proposed Rulemaking that proposed changes in Part 25 of the FCC rules. The proposals were designed to modernize the rules to better reflect evolving technology, eliminate unnecessary technical and information filing requirements for applicants requesting space and earth station licenses, and reorganize and simplify existing requirements.

During FY 2012, the FCC, together with the National Telecommunications and Information Administration (NTIA), continued a testing process concerning interference with Global Positioning System (GPS) receivers that might be caused under a proposal by LightSquared Subsidiary, LLC, an MSS licensee, to

use radio-frequency spectrum allocated to MSS for a terrestrial service that would provide mobile broadband service. Based on findings and recommendations from NTIA, on February 15, 2012, the FCC concluded that it was highly unlikely that LightSquared would be able to resolve interference concerns satisfactorily. The FCC therefore sought public comment on two proposals—setting aside a 2011 order that conditionally approved the LightSquared proposal and modifying LightSquared's satellite license to suspend LightSquared's authority for terrestrial operations indefinitely.

On December 12, 2011, the FCC issued its third report and analysis of competitive market conditions with respect to domestic and international satellite communications services. The report focused on the 2008, 2009, and 2010 calendar years.

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

- October 14, 2011: To ViaSat, Inc., to launch and operate a satellite at the longitude 115.1° west orbit location.
- February 23, 2012: To Intelsat License, LLC, to launch and operate a replacement C-/Ku-band satellite at the longitude 53.0° west orbit location.
- March 15, 2012: To Intelsat License, LLC, to launch and operate a replacement C-/Ku-band satellite at the longitude 72.1° east orbit location.
- June 12, 2012: To EchoStar Satellite Operating Corporation to launch and operate a satellite at the longitude 101.9° west orbit location.
- June 22, 2012: To EchoStar Satellite Operating Corporation to launch and operate a satellite at the longitude 61.5° west orbit location.
- July 12, 2012: To DIRECTV Enterprises, LLC, to launch and operate a satellite at the longitude 79.0° west orbit location.
- July 26, 2012: To Intelsat License, LLC, to launch and operate a replacement C-/Ku-/Ka-band satellite at the longitude 68.5° east orbit location.
- August 3, 2012: To Hughes Network Systems, LLC, to launch and operate a satellite at the longitude 77.3° west orbit location.
- September 19, 2012: To Skybox Imaging, Inc., to launch and operate two nongeostationary remote sensing satellites.

The FCC granted a number of license modifications and Special Temporary Authorizations for satellite networks. Many involved routine testing or redeployment

of satellites within a multi-satellite system. Several of these actions, however, warrant particular mention:

- October 26, 2011: The FCC granted DIRECTV Enterprises, LLC, authorization for a geostationary satellite at the longitude 99° west orbit location to expand its coverage to Puerto Rico.
- February 24, 2012: The FCC granted SES Americom, Inc., authorization to relocate satellite AMC-2 to operate at the longitude 4.98° east orbit location in accordance with International Telecommunication Union (ITU) filings of Sweden.
- February 24, 2012: The FCC granted SES Americom, Inc., authorization to relocate satellite AMC-5 to operate at the longitude 80.90° west orbit location in accordance with ITU filings of Argentina.
- June 28, 2012: The FCC granted SES Americom, Inc., authorization to relocate the AMC-3 satellite to operate at the longitude 67° west orbit location in accordance with International Telecommunication Union filings of Colombia on behalf of the Andean Community.

The FCC added three non-U.S.-licensed space stations to its permitted space station list to allow these space stations to provide domestic and international satellite service to U.S. earth stations that have routine technical parameters. Specifically, on October 13, 2011, the FCC added Gibraltar's NSS-703 space station using the C-band and Ku-band at the longitude 47.05° west orbit location to the permitted list. On March 15, 2012, the FCC added the Netherlands' SES-4 space station using the C-band and Ku-band at the longitude 22° west orbit location to the permitted list. On April 11, 2012, the FCC added Telesat Canada's ANIK F3 space station using the Ka-band at the longitude 118.7° west orbit location to the permitted list.

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

- June 29, 2012: The FCC granted, with conditions, Brazil's Star One C3 space station access to the United States market using the Ku-band at the longitude 75° west orbit location.

- July 27, 2012: The FCC granted the United Kingdom's Jupiter 97W space station access to the United States market using the Ka-band at the longitude 97.1° west orbit location.
- August 1, 2012: The FCC granted the United Kingdom's Jupiter 91W space station access to the United States market using the Ka-band at the longitude 90.9° west orbit location.

U.S. Department of Agriculture

USDA

USDA Foreign Agricultural Service

The Foreign Agricultural Service's (FAS) Office of Global Analysis (OGA) served as a major source of objective and reliable global agricultural production information to the World Agricultural Outlook Board (WAOB), the primary source of the USDA's global commodity outlook. The outlook reports for FY 2012 provided public access to information affecting world food security and became crucial to decisions affecting U.S. agriculture, trade policy, and food aid. Reports included regional, national and subnational monitoring and analysis of crop conditions, yield potential, and the impact of events affecting crop production.

The satellite imagery resources were managed through the USDA's Satellite Imagery Archive (SIA) program. The SIA program was established by the USDA's Remote Sensing Coordinating Committee (RSCC), which is chaired by the USDA's Office of the Chief Information Officer. The SIA fulfilled its mission of providing USDA-wide, cost-effective sharing of satellite data through a centralized purchasing, receipt, inventory, storage, and dissemination to USDA agencies of satellite imagery. The following agencies participated in the program: FAS, the Risk Management Agency (RMA), the National Agricultural Statistics Service (NASS), the U.S. Forest Service (USFS), the Natural Resources Conservation Service (NRCS), the Agricultural Research Service (ARS), and the Farm Service Agency (FSA).

The success of USDA's SIA was also a practical demonstration of collaborative agreements with NASA, NOAA, the USGS, and the National Geospatial-Intelligence Agency (NGA). During FY 2012, the USDA satellite imagery library enabled all USDA agencies to access satellite imagery at substantially reduced individual agency cost. The key performance indicators of the program were measured by timely distribution and receipt of requested satellite imagery and the provision of bulk satellite imagery at a measurable economic benefit to the USDA agencies. In addition, FAS OGA performed the physical management of the SIA facility and the online Archive Explorer (AE) system at *http://www.pecad.fas.usda.gov/archive_explorer/default.aspx*. The Archive Explorer, a Web-enabled browse and search tool, allowed users to browse, select, and retrieve the contents of the SIA.

U.S. Forest Service

As the primary forestry agency of the United States and the largest agency in the USDA, the USDA Forest Service (USFS) continues to sustain the health, diversity, and productivity of the Nation's forests and grasslands. This work is conducted via three specific agency mission areas: Research and Development (USFS R&D), the National Forest System (NFS), and State and Private Forestry (USFS S&P).

USFS R&D conducts research to address forestry and natural resource issues both internationally and domestically, including the development of relevant science and technologies. Partnerships with states, tribes, and other Federal agencies, as well as universities and private industry, are integral to accomplishment of the USFS R&D mission. Additionally, the USFS administers and manages 155 national forests and 20 national grasslands collectively known as NFS lands. These lands encompass 193 million acres in 44 states and Puerto Rico and are managed for the purpose of sustainable multiple uses to meet the diverse needs of people. Lastly, USFS S&P provides assistance to private landowners and state, tribal, and community forestry agencies in the stewardship of approximately 500 million acres of non-Federal forest lands throughout the United States. This assistance includes the provision of information and support to partner agencies to protect forests from wildland fires, insects, disease, and invasive plants.

To address the data needs of these USFS mission areas in FY 2012, the USFS collaborated with NASA, as well as NOAA, the USGS, and other agencies, to apply operational satellite and airborne imagery and the most advanced remote sensing and geospatial technologies. Specific FY 202 USFS accomplishments are summarized below.

- Collected comprehensive EOS, MODIS, and Suomi NPP VIIRS direct broadcast data for the United States and Canada and completed operational processing and dissemination of relevant fire-mapping and geospatial data products to fire managers and the general public (*http://activefiremaps.fs.fed.us*).
- Continued activities with NASA Goddard Space Flight Center Direct Readout Laboratory under a USFS-NASA interagency agreement to test and operationally implement direct readout technologies to support resource management including land, atmosphere, and ocean science processing algorithms for EOS and Suomi NPP sensors (*http://directreadout.fs.fed.us*).
- Continued utilizing MODIS imagery for operational detection of forest damage and changing forest health conditions in our Nation's forests (*http://foresthealth.fs.usda.gov/portal/Flex/FDM?dL=0*).
- Collaborated with NASA and USFS science partners to participate in Soil Moisture Active Passive (SMAP) mission workshops and respond to NASA Research Opportunities in Space and Earth Sciences (ROSES) Requests for Proposals (RFPs) for potential applications using SMAP observational data/science products.
- Continued to distribute 250-meter forest attribute data surfaces derived from MODIS imagery and other geospatial predictor data using nearest neighbor imputation methods (*http://fsgeodata.fs.fed.us/rastergateway/forest_type/index.php*).
- Continued to distribute 250-meter forest carbon estimates derived from MODIS imagery and other geospatial predictor data using nearest neighbor imputation methods (*http://fsgeodata.fs.fed.us/rastergateway/biomass/index.php*).

- Continued conducting operational crewed wildfire mapping missions in FY 2012 using Autonomous Modular Sensor (AMS) via coordination between the USFS, NASA Ames Research Center, and the NASA Airborne Sciences Program.
- Continued coordination with NASA Goddard Space Flight Center on testing and evaluation of the Multi-Angle Implementation of Atmospheric Correction (MAIAC) for MODIS and its potential use for land and atmosphere remote sensing applications.
- Coordinated with NASA Goddard Space Flight Center on evaluating test data collected by the Goddard LiDAR Hyperspectral and Thermal (G-LiHT) sensor for potential land remote sensing and resource management applications.
- Operationally applied Landsat 5 TM, Landsat 7 Enhanced Thematic Mapper (ETM), and Landsat 8 Operational Land Imager (OLI) imagery to map the location, extent, and severity of approximately 200 large wildfires in FY 2012–13 to support post-fire emergency stabilization/hazard mitigation activities and forest restoration planning/management activities (*http://www.fs.fed.us/eng/rsac/baer* and *http://www.fs.fed.us/postfirevegcondition*).
- Continued to operationally apply Landsat 4/5 TM and Landsat 7 ETM imagery to inventory and map and characterize historical large fires to assess the effectiveness of national fire management policies as part of the Monitoring Trends in Burn Severity (MTBS) project. MTBS mapping activities through FY 2013 include the completion of 17,025 historical fires (~120 million burned acres) spanning from 1984 to 2011 (*http://www.mtbs.gov*).
- Coordinated with the University of Maryland, NASA, and the USGS to execute and test Landsat 8 and VIIRS I-band prototype fire detection algorithms and evaluate derived output products to support USFS operational fire support activities.
- Continued technology transfer activities between the USFS and NASA Ames Research Center regarding unmanned aircraft systems (UAS) and related technologies under the auspices of the NASA-USFS Wildfire

Research Applications Partnership and a USFS-NASA interagency agreement (*http://geo.arc.nasa.gov/sge/WRAP/index.html*).

- Coordinated with NASA Ames Research Center on the final development of the Wide Area Imager (WAI) (developed under the NASA Small Business Innovation Research [SBIR] program) and subsequent fire-mapping demonstration missions.
- Used Landsat 5 TM, Landsat 8 OLI, and National Agriculture Imagery Program (NAIP) imagery to initiate and complete mid-level vegetation-mapping products for National Forest lands and adjacent land areas throughout the country.
- Used Landsat 5 TM, Landsat 8 OLI, and NAIP imagery to model Tree Canopy Cover (TCC) for the entire continental U.S. as part of the Multi-Resolution Land Characteristics (MRLC) Consortium National Land Cover Database 2011 update.
- Used Landsat TM/ETM/OLI and MODIS imagery to map and assess damage to forests in the immediate aftermath of severe storms and other catastrophic events during FY 2012–13 (e.g., Hurricane Sandy in 2012).
- Completed an assessment in coordination with the EPA of the effects of land-cover change on water quality using Landsat TM/ETM time-series stacks to detect and monitor forest land-cover change in the Lake Superior and Lake Michigan watersheds from the mid-1980s to the present. This activity has been extended to include Lake Huron, Lake Erie, and Lake Ontario as well.
- Used Landsat TM/ETM/OLI and NAIP imagery in conjunction with other core geospatial datasets to conduct ecological and soil-type mapping on NFS lands; this imagery is used by the USFS, NRCS, and other agencies for resource management, planning, and decision making (*http://www.fs.fed.us/eng/rsac/programs/teui/about.html*).
- Continued to use Landsat TM/ETM time-series stacks, NAIP imagery, and USFS Forest Inventory and Analysis plot data to support carbon and biomass monitoring for 55 selected forested sites across the United States in support of the North American Forest Dynamics (NAFD) Project (*http://daac.ornl.gov/NACP/guides/NAFD_Disturbance_guide.html*).

- Continued to develop standards and practices for integrating LIDAR into forest and resource management (defining acquisition specifications, data quality assessment, analysis/modeling procedures for forest parameters, etc.). This is relevant to recent and potential USFS/NASA JPL LIDAR collaboration such as the acquisition and processing of hyperspectral imagery (from the Airborne Visible/Infrared Imaging Spectrometer [AVIRIS]) and LIDAR data for the 2013 Rim Fire in California.

National Agricultural Statistics Service

The National Agricultural Statistics Service (NASS) used remote sensing data to construct and sample area frames for agricultural statistical surveys, estimated crop area and yield, continued investigations of a NASA science grant on crop progress/condition, began contributing to a new NASA science grant on fallowed California agricultural land, and published papers on a Web-service-based application for exploring and disseminating geospatial data products, as well as methods to derive a new cultivated dataset. The cultivated dataset was published via the CropScape Web portal. NASS used remote sensing data and techniques to improve the quality and accuracy of its statistics. For example, NASS used Landsat imagery, digital NAIP orthophoto quadrangles, and other remotely sensed inputs for the contiguous United States (CONUS) and Puerto Rico to select the yearly area-based samples for the June Agricultural Survey. In addition, NASS updated an area-based sampling frame for Oklahoma.

NASS began implementing a new Cropland Data Layer (CDL)–based automated stratification method into NASS Area Frame operations. Analysts derived remote sensing–based acreage indications from a crop-specific land-cover categorization in the CDL. The new Oklahoma frame was built at reduced cost with improved objectivity, efficiency, and accuracy when compared with the previous frame. The CDL data are used as the basis for the objective stratification of NASS Area Frame primary sampling units (PSUs) rather than visual interpretation of aerial photography or satellite data.

The remote sensing acreage estimation program used Disaster Monitoring Constellation (DMC) satellite data to produce crop acreage estimates for crops at

the state and county levels for 41 states during the 2012 crop year. Acreage estimates were created for 18 different crops covering all market-sensitive crops and states. With the expanded coverage and timeliness, NASS's Agricultural Statistics Board (ASB) was able to utilize the remote sensing acreage indications as independent input for setting the official estimates for their monthly Crop Production Reports. Primary satellite imagery inputs came from the Foreign Agricultural Service Satellite Imagery Archive, which provided 1,659 DMC images through a cooperative partnership. In addition, NASS distributed the CDL for 48 states to stakeholders for the previous 2011 crop season via the USDA Geospatial Data Gateway and the CropScape data visualization portal at *http://nassgeodata.gmu.edu/CropScape*.

NASS utilized MODIS normalized difference vegetation index (NDVI) products for modeling corn and soybean yield indications over the 12 largest production states. Updated yield estimates were delivered operationally to the ASB as an independent indication for setting official August, September, and October yield estimates by state, district, and county. New to 2012 activities were the inclusion of MODIS land surface temperature (LST) products that provided another independent variable for yield estimation.

NASS continued work with George Mason University on a NASA-funded science grant titled "A National Crop Progress Monitoring System Based on NASA Earth Science Results." Research focused on crop growth modeling, crop phenology stage detection algorithm development, system prototyping and implementation, and crop progress ground truth data collection for validation. Prototyping efforts continued on a Web-based national vegetation condition geospatial monitoring application based on MODIS data products and incorporated several vegetation metric indices for vegetation greenness and drought anomaly assessment.

NASS has fully implemented a new CDL-based automated stratification method into NASS Area Frame operations. As a result, new state area frames are being built at reduced cost with improved objectivity, efficiency, and accuracy. The CDL data are used as the basis for the objective stratification of NASS Area Frame primary sampling units rather than visual interpretation of aerial photography or satellite data.

USDA Farm Service Agency

The Farm Service Agency (FSA) administered farm commodity, credit, conservation, disaster, and loan programs as laid out by Congress through a network of Federal, state, and county offices. Geospatial systems and data played a fundamental role in the management of FSA's programs. The agency maintained a nationally consistent geospatial dataset representing farm and field boundaries known as Common Land Units (CLUs). FSA used CLUs, digital soil surveys, 1-meter imagery, satellite imagery, and other datasets for program implementation, management, and monitoring, as well as for response and recovery efforts during natural disasters. FSA also utilized NASS remotely sensed data for analysis of commodity and conservation programs.

FSA used remotely sensed data to digitize conservation practices on farms participating in the Conservation Reserve Program, a cost-sharing and rental payment program that encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover. FSA used several satellite and locally collected datasets in conjunction with weather data to immediately respond to and coordinate efforts with other Federal, state, and local agencies for disaster response activities. Some examples include Missouri River flooding, spring flash flooding in Minnesota and Wisconsin, and extreme drought in southwestern states. These data were also used during the recovery period to assist impacted producers and support FSA administration of the Emergency Loan, Emergency Conservation, and Livestock Indemnity Programs.

As the primary source of aerial imagery for the USDA, FSA administered NAIP, leveraging partnership funds from other Federal entities to acquire imagery during the growing season over CONUS. In 2012, FSA collected imagery for 22 states and initiated the AgSat Blanket Purchase Agreement through which the collection of imagery in non-CONUS regions to support agency work for the agriculture producer was made possible. NAIP, as well as FSA's large imagery archive, was accessible to the public through the USDA Geospatial Data Gateway, via Web services, and on media.

USDA Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is the primary Federal agency working with private landowners to help protect and conserve the Nation's natural resources. For more than 50 years, the NRCS has used remote sensing products to carry out conservation programs. Aerial and satellite imagery processed in the form of digital orthoimagery remains the primary remote sensing product used by NRCS to inventory, monitor, manage, and assess our natural resources in GIS nationwide.

Elevation

NRCS acquired and integrated LIDAR data partnership efforts and is implementing an efficient data management system in order to create an enterprise solution for high-resolution elevation data that meet NRCS business needs. This will also contribute to a seamless, national elevation dataset in partnership with the National Digital Elevation Program (NDEP) (*http://www.ndep.gov*). NRCS also supports the Alaska Mapping Imitative Partnership to acquire elevation data for the state using Interferometric Synthetic Aperture Radar (IfSAR) data where cloud cover and remote locations preclude the use of LIDAR over much of the state.

This data will support the strategic goals to

- get more conservation on the ground and
- increase organizational effectiveness and efficiency.

High-accuracy elevation data are required to streamline NRCS workflow processes in support of resource and conservation planning, soil survey, and engineering applications. This will benefit the products and services provided by the disciplines of soil conservation, soil science, engineering, and others to accomplish mission-critical objectives:

- Advance the performance of voluntary, incentive-based conservation.
- Proactively recognize and address emerging natural resource issues.
- Improve quality and accountability to deliver better products and services.

Currently, LIDAR data are being utilized extensively in agricultural and forestry settings and other resource assessment applications. The information

provides land-use managers with accurate topographic data to install and implement conservation practices. However, new uses are being explored, particularly in urbanized settings, where precise elevation data on buildings, bridges, levees, dikes, and flood-control structures is helpful for emergency response and homeland security purposes.

Benefits to NRCS by participating in high-resolution elevation projects include the following:

- New data allow out-of-date USGS topographic maps in the service centers to be replaced.
- The quality of the LIDAR is superior to legacy USGS products.
- Better-quality elevation data support better decisions and analysis far beyond our existing capabilities and put us at the forefront of emerging technologies.
- Better-quality elevation data produce more accurate orthoimagery products.
- Partnerships with NDEP to purchase LIDAR save NRCS money by lowering the cost per unit and expanding the areas of interest.

LIDAR can be used for the following:

- Planning and design alternatives for Wetlands Reserve Program (WRP) wetland restoration. Particularly valuable for studying off-site effects of practices and limiting in-field surveying required.
- Planning and design alternatives for conservation ponds and flood-retarding and grade-stabilization structures.
- Breach routing analysis for determining dam hazards and developing emergency action plans.
- Flood modeling for studying/quantifying cumulative effects of proposed flood-retarding structures in a watershed for benefit-cost analysis.
- Terrace, waterway, and diversion planning and partial at-desk design, limiting in-field survey to finite areas and circumstances.
- Improved placement of soil map unit boundaries based on topographic position, modeling ecological land types, and visualization for overall improvement of conservation planning.

The Conservation Engineering Division, Conservation Planning and Technical Assistance Division, Easement Programs Division, Ecological Sciences Division, Resources Inventory and Assessment Division, and Soil Survey Division will

all benefit from high-resolution elevation data. Programs such as Conservation Planning, Conservation of Grazing Lands, the Conservation Reserve Program, the Customer Service Toolkit, the Emergency Watershed Protection Program, the Environmental Quality Incentives Program, the Grassland Reserve Program, the Healthy Forest Reserve Program, the Rapid Watershed Assessment, the Soil Survey Program, the Watershed Protection and Flood Prevention Program, the Watershed Rehabilitation Program, and the Wetlands Reserve Program are just a few of the programs that can benefit from these data.

Aerial Imagery

By partnering with the USDA Farm Service Agency and other Federal and state agencies, the NRCS acquired statewide 1-meter orthoimagery for 19 states and parts of Alaska, Hawaii, and the Pacific Basin. NRCS participates in many Federal Government interagency coordination committees such as the National Digital Orthophoto Program and the National Digital Elevation Program to avoid duplication of orthoimagery and digital elevation acquisitions. The USDA Geospatial Data Gateway Web site made available all orthoimagery purchased by the NRCS to internal users and the general public.

NRCS orthoimagery acquisitions for Hawaii and the Pacific Basin use predominately high-resolution commercial satellites from DigitalGlobe. All acquisitions were contracted at USDA-FSA-APFO (Aerial Photography Field Office), USGS-EDC (EROS Data Center) or DOD-NGA. All orthoimagery acquisitions are at 0.6-meter resolution or higher and 4–8 multi-spectral bands depending on the satellite sensor. NRCS acquired imagery in FY 2012 for Hawaii (the islands Hawai´i and Kaho´olawe) and the U.S. Pacific Basin (Guam, the Commonwealth of the Northern Mariana Islands, American Samoa, and the Marshall Islands).

NRCS orthoimagery acquisitions for Alaska used a combination of aerial cameras and satellite sensors, depending on the location. Aerial cameras at a 1-meter ground resolution were used at an area northeast of Fairbanks called Yukon Flats and an area southeast of Fairbanks called Delta Junction. NRCS used high-resolution commercial satellites from DigitalGlobe for Fairbanks, Fort Wainwright, Glenallen, and Naknek. These acquisitions were for 0.6-meter,

8-band digital orthoimagery. NRCS used satellite contracts with DOD-NGA and USDA-FSA-APFO.

The NRCS used the USDA Small Area Aerial Photography Contract to acquire high-resolution aerial photography (4" ground-resolving distance) and scans over 72,455 confidential statistical sites to collect natural resource data for the annual National Resources Inventory (NRI) program in the CONUS. The NRCS also contracted for aerial photography over 450 NRI sites in Puerto Rico and the U.S. Virgin Islands, as well as 375 sites in Hawaii. The NRCS also used the USDA Small Area Aerial Photography Contract to acquire 21,811 photos over 13,114 Stewardship Land easements in CONUS and Hawaii. Nationally, Stewardship Lands easements cover approximately 2.71 million acres, and the imagery is used to monitor restoration efforts on each property enrolled. NRCS also used the Small Area Contract to acquire 2,050 photos for random status reviews of tracts in Iowa. The photos were used to make determinations on conservation compliance, wetland conservation, and early-release Conservation Reserve Program provisions.

Satellite Remote Sensing

The NRCS continued using satellite imagery from the USGS Hazard Data Distribution System to respond to natural disasters like the New Mexico wildfires. For the New Mexico fires, NRCS provided pre- and post-event imagery from satellite and aerial sources via Web services to state offices supporting their ability to deliver Emergency Watershed Protection assistance.

Positioning, Navigation, and Timing

The NRCS and the clients it serves utilize space-based positioning, navigation, and timing (PNT) solutions on a daily basis all year round. NRCS users of space-based PNT continue to enjoy unsurpassed coverage of the Global Positioning System (GPS). Although the stated policy for constellation sustainment is 24 satellites, the NRCS has derived increasing benefits from the current 28-satellite configuration and hopes to continue to do so. Positioning accuracy and satellite availability continue to be the cornerstones of GPS that NRCS has come to

heavily rely on for performance of its mission across CONUS, the Pacific Basin, the Caribbean, and Alaska. The NRCS also enjoys the increased precision and accuracy obtained from space-based position correction provided by the FAA Wide Area Augmentation System (WAAS).

- NRCS employees in field service centers across the country utilize handheld GPS devices or handheld computers with GPS to spatially capture resource concerns and inventory locations. The locations are incorporated into the Customer Service Toolkit and are utilized for the preparation of conservation plans and plan alternatives. The Customer Service Toolkit is a value-added augmentation to the USDA Enterprise GIS software known as ArcGIS.
- NRCS grazing lands specialists utilized space-based PNT to navigate to hundreds of sample locations scattered across the United States as part of the 2012 Grazing Lands National Resources Inventory. Intensive data collection to determine vegetative composition and grazing land health was performed on each of the sites visited.
- NRCS engineers utilize survey-grade, high-accuracy GPS that replaces legacy line-of-sight systems in many areas of the United States. The engineers integrate surveyed GPS data with LIDAR elevation data to produce designs and visualizations of projects.
- The NRCS provides technical guidance for nutrient management and irrigation water management to agriculture producers across the country. Many of these producers are users of precision agriculture and precision guidance technology that is enabled by the use of space-based PNT.

National Science Foundation

NSF

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

Division of Astronomical Sciences

The Division of Astronomical Sciences (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 are accessible to the community on the basis of scientific merit. The NSF's national astronomical facilities included the National Radio Astronomy Observatory (NRAO), the Arecibo Observatory (AO), the National Optical Astronomy Observatory (NOAO), and the National Solar Observatory (NSO). The NSF also served as the executive agency for the Gemini Observatory—an international partnership operating optical/infrared telescopes

in both the Northern and Southern Hemispheres—providing the United States' share of support for the program.

AST, in partnership with Europe, Canada, Japan, and Taiwan, continued construction on the Atacama Large Millimeter/submillimeter Array (ALMA), an interferometer located near San Pedro de Atacama, Chile. FY 2012 saw delivery of the final North American antennas. Fifty-two antennas have been transported to the 16,500-foot high-altitude site for commissioning and science operations. Science observations by the community, begun during FY 2011, continued using a 16-element subset of the full array.

AST continued its oversight of the Daniel K. Inouye Solar Telescope (DKIST) (formerly 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 earned the strong recommendation of the National Research Council of the National Academy of Sciences. When completed in 2019, the ATST will be the world's flagship ground-based telescope designed specifically for the study of solar magnetic fields on scales as small as 30 kilometers. Fabrication of the major telescope subsystems and instruments continued in FY 2012, and the primary mirror blank was cast. After nearly 30 months' delay resulting from a challenge by a native Hawaiian group, final permits from the state of Hawaii authorizing construction to begin on the site on Haleakala peak on Maui were issued and site activities began. The impacts of the delay on cost and schedule were evaluated in a comprehensive recosting exercise, the results of which were under external and internal review as FY 2012 closed.

In FY 2012, AST provided continued funding for the design and development (D&D) of the Large Synoptic Survey Telescope (LSST) and began meeting the requirements to authorize construction support. LSST is a joint project of the NSF and the Department of Energy (DOE), with private and international partners; an interagency joint oversight group met biweekly, both internally and with representatives from the project, throughout FY 2012. The LSST Project will produce a purpose-built wide-field survey telescope and use the attached 3.3-gigapixel camera to image the entire accessible sky repeatedly for at least 10 years, producing more than 20 terabytes of data nightly. The LSST database will enable breakthrough

research not just in cosmology (dark energy and dark matter), but also in galactic structure and solar system astronomy. LSST also opens up the time domain and will revolutionize the study of transient events. DOE supports the camera; NSF supports the telescope, site, and data systems. Following reviews in FY 2011, DOE issued CD-1 approval ("Approve Alternative Selection and Cost Range") in April 2012. In May 2012, additional external reviews, recommended by previous panels, further endorsed the project. In July 2012, the NSF and DOE signed a Memorandum of Understanding setting out their respective responsibilities for the LSST Project. Also in July 2012, the National Science Board gave permission to the NSF Director to add funding for LSST within the Major Research Equipment and Facility Construction (MREFC) account in a future budget request. Private funding supported long lead-time items and risk reduction, especially the continued polishing of the primary/tertiary mirror, and further work on hardware development of the detectors. The interest and support by both research and education communities continued to be strong, with specialist workshops and dedicated sessions at meetings of the American Astronomical Society.

The Atacama Cosmology Telescope (ACT) is a 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 (CMB, 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 detectors cooled to one-third of a degree above absolute zero. During FY 2012, the telescope continued to operate successfully in its fourth year of full science operations, obtaining measurements that span size scales on the sky two to three times finer than any previous experiment to measure the microwave background. Under renewed funding, work was begun to upgrade and expand the bolometer cameras and add polarization measurement capability. The new receiver was cooled to 100 millikelvins (mK) multiple times, and tests of the first science-grade detectors took place. A detector test facility developed at Princeton came into full operation. An anti-reflection coating facility was set up at the University of Michigan to develop coatings using grooved silicon. The telescope and site have

been upgraded to accommodate the new receiver. The major scientific findings of FY 2012 included 1) a new way to measure dark energy using the lensing of the CMB, 2) the first detection of the kinetic Sunyaev-Zel'dovich effect (predicted over 40 years ago), and 3) the discovery and multi-wavelength followup of "El Gordo," the brightest and most massive known cluster of galaxies in the distant universe.

The POLARBEAR telescope is a 3.5-meter-diameter off-axis millimeter-wave antenna designed to measure the polarization of the cosmic microwave background radiation. The observatory is located near the ACT and ALMA facilities on the Atacama plateau in Chile. The telescope was successfully commissioned at the remote site during FY 2012 and is being used to measure the linear polarization of the cosmic microwave background to search for so-called B-modes, which, if detected, will open up a new window on the early universe and the physics of inflation. Unlike previous radio telescopes, POLARBEAR was designed for a very large field of view to accommodate a large imaging camera. Wide-area coverage is key to obtaining a broad sampling of the microwave background sky and high signal-to-noise measurements.

Division of Atmospheric and Geospace Sciences

The Division of Atmospheric and Geospace Sciences' (AGS) high-altitude aircraft, the Gulfstream V (GV), is a highly modified and instrumented midsize jet operated by the National Center for Atmospheric Research (NCAR), a Federally Funded Research and Development Center of the NSF. The High-performance Instrumented Airborne Platform for Environmental Research (HIAPER) GV is FAA-certified to operate at 51,000 feet, and its ability to fly for long durations (over 12 hours), its long range (over 6,000 kilometers), and its scientific payload capacity (6,000 pounds) have enabled scientific research previously not possible with existing platforms. The GV is the most advanced airborne research platform in the U.S. civilian fleet. The German Aerospace Center (DLR) recently completed modifications, including advanced instrumentation, to a Gulfstream 550 that can collaborate with the NSF's GV aircraft in scientific campaigns. During FY 2012, the DLR's 550 staff and the GV's staff continued collaboration on instrument pod development and shared instrumentation. In FY 2012, the GV continued to

conduct long-duration flights for the HIAPER Pole to Pole Observations (HIPPO) deployment to study the carbon cycle and greenhouse gases as part of a multi-year campaign. The HIAPER GV also participated in additional field projects during FY 2012 and remained one of the world's most advanced airborne research platforms.

NCAR's Research Aircraft Facility continued to operate and maintain the GV through FY 2012, and the GV's expected lifetime is 10 to 25 years, during which new instrumentation innovations will be continually integrated onto the airframe as appropriate. NCAR also operated and maintained the NSF's heavy-lift C-130Q research aircraft. In FY 2012, the C-130Q participated in the Ice in Clouds—Tropical (ICE-T) experiment, flying through cumulonimbus clouds in the vicinity of the Virgin Islands in the Caribbean. The primary goal of ICE-T was to understand how ice particles originate in these clouds and how they impact the subsequent spread of ice in clouds from this climatologically important region.

The AGS Geospace Section (GS) supported a wide variety of research programs in space science in FY 2012. 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 GS-funded activities in FY 2012 included the Geospace Facilities (GF) program; the Space Weather Research (SWR) program; the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) program; the Geospace Environment Modeling (GEM) program; and the Solar, Heliosphere, and INterplanetary Environment (SHINE) program.

The National Space Weather Program (NSWP) is a multi-agency Federal program aimed at mitigating the adverse effects of space weather on the Nation's technological infrastructure by providing timely, accurate, and reliable space environment observations, specifications, and forecasts.

In addition, during FY 2012, a formal NSF Science and Technology Center called the Center for Integrated Space Weather Modeling (CISM) completed its 10-year program 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 these models for use in operational space weather forecasting centers of the United States Air Force and NOAA.

Throughout FY 2012, the Community Coordinated Modeling Center (CCMC) for space weather research, cosponsored by the NSF and NASA and located at NASA's Goddard Space Flight Center, 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 GS efforts. The Geospace Facilities program in FY 2012 continued to enable 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. Throughout FY 2012, observations made by the Advanced Modular Incoherent-Scatter Radar (AMISR) at Poker Flat, Alaska, demonstrated the unique capabilities of this new instrument, including its ability to image the ionospheric effects of auroral particle precipitation in three dimensions. These observations provided a wealth of data particularly useful to modelers interested in validating space weather models. A second AMISR system has been operating at Resolute Bay in Arctic Canada since 2009. This radar is ideally situated to observe the properties of the ionosphere in the polar cap, a region that is characterized by high ionospheric variability that often causes disruption of important navigation and communication systems.

GS also continued to support the study of magnetospheric physics within the international Super Dual Auroral Radar Network (SuperDARN) consortium through the addition of new radar installations in central Oregon and Adak, Alaska. Along with two other midlatitude SuperDARN radars that had been constructed in southern Virginia and central Kansas in 2009, the new sites extended the longitudinal coverage of this growing instrument chain.

In FY 2012, GS continued to support its program for CubeSat-based small satellite science missions for Geospace and atmospheric research and education. Two NSF-funded CubeSat missions were launched successfully in September 2012 as

part of NASA's Educational Launch of Nanosatellites (ELaNa) program and with support from the National Reconnaissance Office (NRO) CubeSat office. This brings the total number of satellites launched and operated successfully in space so far under this program to four. Both of the CubeSats launched earlier produced first-of-their-kind observations and findings during FY 2012 that formed the basis for scientific and engineering publications. During the fourth CubeSat competition in May 2012, GS received proposals for a total of 25 new missions. As was the case for the previous CubeSat solicitations, the quality of the proposals in terms of both scientific creativity and technological innovation was exceptional. For lack of funding, no additional new projects were started in FY 2012.

GS continued support for the satellite-based Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) through FY 2012. AMPERE utilized the 66 networked satellites of the existing Iridium constellation to create a new facility for collecting geomagnetic field data. The AMPERE facility has provided the first-ever real-time observations of the electric currents that link Earth's magnetosphere and ionosphere and 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 AMPERE data server facility has been established and placed online, and data for the years 2010 through 2012 have been made freely available to researchers, with new data being added continually.

The GS solar physics community also continued to benefit from the Division of Astronomical Sciences' ongoing efforts to develop and manage the DKIST being constructed in Hawaii. Also in FY 2012, GS continued to provide oversight for much-needed upgrades at the Owens Valley Solar Array in California.

In FY 2012, the AGS Atmosphere Section (AS) continued to support the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC). The University Corporation for Atmospheric Research (UCAR) and its collaborator, Taiwan's National Space Organization (NSPO), designed and built the COSMIC six-satellite constellation, which was launched on April 14, 2006, with the support and assistance of the USAF's Space Test Program (STP). Shortly thereafter, data became available from the three payloads: the special space-based

GPS radio occultation (RO) receivers, the so-called Tiny Ionosphere Photometers, and the Tri-Band Beacons. These data have been provided freely to the world scientific community.

COSMIC radio occultation data have been assimilated at many operational weather prediction centers, including the U.S. National Centers for Environmental Prediction (NCEP), the European Centre for Medium-Range Weather Forecasts (ECMWF), Météo France, the United Kingdom's Met Office, Meteorological Service of Canada, Taiwan's Central Weather Bureau, and others. All of these centers have reported that RO data are having a significant positive impact on numerical weather forecasts. In ionospheric studies, COSMIC RO data have accelerated the development of physical models for space weather prediction by providing dense, accurate, and global electron-density measurements. These data are used for model testing and initialization, including for the response of the global ionosphere to the impact of solar storms.

During FY 2012, all six COSMIC satellites were operating and providing data. On average, COSMIC produced from 1,500 to 2,000 GPS RO soundings per day. Ninety percent of these were processed and delivered to operational centers within 3 hours. COSMIC has supported more than 1,100 registered users from 52 countries. In collaboration with UCAR's Unidata, COSMIC soundings have been provided in real time to support the university community.

Office of Polar Programs

For FY 2012, the NSF's Office of Polar Programs (OPP) sponsored a number of projects in ground-based space science and astronomy. Full-scale observations at the U.S. Amundsen-Scott South Pole Station continued with the 10-meter off-axis radio telescope (South Pole Telescope, or SPT), with a program of measurements of the CMB. Observations were completed with BICEP2 (Background Imaging of Cosmic Extragalactic Polarization 2), a small-aperture (25-centimeter) telescope also focusing on the CMB. The High Elevation Antarctic Terahertz (HEAT) robotic telescope, an 80-centimeter telescope, was deployed at Ridge A (East Antarctic Plateau, 930 kilometers north from the South Pole Station along ~73° east meridian) in January to make spectroscopic maps of the Milky Way in

frequency bands from 0.5 to 2 terahertz (600 to 150 microns wavelength). The IceCube Neutrino Observatory (ICNO), jointly operated at the South Pole by OPP and NSF's Division of Physics, continued data collection of high-energy neutrino events through FY 2012 as well.

Recent scientific results from SPT provide new support for the most widely accepted explanation of dark energy, the mysterious force that is responsible for the accelerating expansion of the universe. These results are also beginning to home in on the masses of the neutrinos, the most abundant particles in the universe, which until recently were thought to be without mass. In 2012, SPT has begun its second major observing project—to search for the CMB polarization with a new powerful detector, focusing on gravitational lensing and targeting the polarization's B-mode to find imprints of primordial, inflation-induced gravitational waves. The BICEP2 telescope obtained an upper limit to the CMB's B-mode signal.

Through FY 2012, ICNO collected data for almost 2 years (23 months) from a complete array of 86 strings of optical photodetectors deployed in deep ice under the South Pole Station in Antarctica at a depth between 1.4 kilometers and 2.4 kilometers. This makes ICNO the largest (by volume—1 cubic kilometer) neutrino detector in the world available for science observations. Data collection continued with the advance filtering and reconstruction of neutrino events. ICNO's results published in 2012 provide new insights into the origin of cosmic rays, finding surprisingly that gamma-ray bursts produce no neutrinos, which challenges 15 years of predictions from the theory that gamma-ray bursts produce the highest-energy cosmic rays.

Department of State

DOS

The Department of State (DOS) carries out diplomatic efforts to support U.S. space policies and programs internationally. 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 activities and international organizations. DOS also maintains outreach programs to advance U.S. space and foreign policy objectives.

DOS continued to represent the United States in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and its two subcommittees. With numerous countries and private-sector entities now engaged in space activities, DOS considers promoting the safe and responsible use of space by all current and future spacefaring nations a vital goal. At UNCOPUOS, State led U.S. participation in the Working Group on Long-Term Sustainability of Outer Space Activities. This working group is tasked with examining and proposing voluntary best practices guidelines to ensure the safe and sustainable use of outer space for peaceful purposes and the benefit of all countries. Its Terms of Reference were finalized in 2011, and in the same year, the Working Group formed four expert groups to discuss interrelated topics relevant to long-term space sustainability such as the connection between sustainable development on Earth and the sustainability of space activities, space situational awareness, space debris, space weather, and regulatory issues. The expert groups met at the UNCOPUOS June meeting and held informal meetings on the margins of the International Astronautical Conference (IAC) in Cape Town, South Africa. Still building on the results of the International Heliophysical Year and the International Space Weather Initiative to improve international cooperation in understanding the impact of space weather

on satellites and Earth's environment in general, DOS continued to promote space weather as an important foreign policy topic worldwide.

In FY 2012, DOS continued its strategic international efforts to implement the National Space Based Positioning, Navigation, and Timing (PNT) Policy, as well as the U.S. National Space Policy. DOS coordinated and led interagency meetings to prepare for the seventh annual meeting of the International Committee on Global Navigation Satellite Systems (ICG-7), held November 4–9, 2012, in Beijing. DOS served as the cochair of the eighth meeting of the ICG Providers' Forum and the intersessional meeting of the Working Group on Compatibility and Interoperability, both of which were held in June 2012.

Also in June 2012, DOS organized a workshop on global navigation satellite systems (GNSS) interference detection and mitigation (IDM), held in Vienna, Austria. This was a result of a formal ICG recommendation adopted during ICG-6 in 2011, and participants included China, the European Union (EU), Japan, Russia, the United States, the International Telecommunication Union (ITU), the International Civil Aviation Organization (ICAO), and Malaysia. The workshop produced six preliminary outcomes for further discussion at ICG-7: 1) ICG should develop educational materials on interference sources; 2) ICG should identify an official monitoring center recognized by ITU; 3) ICG providers should exchange information on domestic spectrum management applicable to GNSS; 4) ICG should compare the ITU interference report to the report form used by the United States and others to make guidelines for future reporting; 5) ICG should provide guidelines to providers who wish to contribute to interference reporting; and 6) ICG and providers should identify experts to participate in the next IDM workshop.

The United States and the European Union continued close cooperation under the auspices of the 2004 GPS-Galileo Cooperation Agreement. The second plenary meeting held under the U.S.-EU and Its Member States GPS-Galileo Cooperation Agreement of 2004 (Agreement) was hosted by the United States at the State Department in Washington, DC, on June 27, 2012. This plenary, the first since the Agreement was fully ratified in December 2011, reviewed proposed Terms of Reference for each Working Group, to include uniform language on the treatment

of intellectual property (IP), and reviewed progress by the Galileo Public Regulated Service (PRS) discussion group.

The United States and Japan held three days of technical, GPS, and civil space–related discussions on January 17–19, 2012, in Washington, DC. The Earth Observation (EO) Workshop on January 17 recognized the importance of openly exchanging satellite-based EO data but also called for studies to determine the usefulness of data supplied by Japan to U.S. users. The GPS Plenary on January 18 pursued planning for a workshop on interference detection and mitigation to improve GNSS service in the Asia-Pacific region. The Civil Space Dialogue on January 19 addressed a draft U.S.-Japan framework agreement on space cooperation, information sharing with Japan on the uncontrolled reentry of satellites, the continuation of International Space Station operations after 2016, and exchanges of views on the European Union's proposed International Code of Conduct for Outer Space Activities and the Study on the Long-Term Sustainability of Outer Space Activities.

The sixth meeting of the U.S.-EU Space Policy Dialogue was held in Prague November 28–29, 2012. The two sides reviewed progress in GPS-Galileo cooperation and efforts to improve the sustainability of outer space operations, including through ongoing discussions in this area in UNCOPUOS and the proposed Code of Conduct for Outer Space Activities. It was agreed to hold bilateral workshops on space situational awareness and critical infrastructure protection of space- and ground-based assets. The two sides agreed to expand their extensive bilateral work on EO satellites, including promoting the open and free exchange of civil EO satellite data, cooperating on a Joint Polar System of weather satellites, and working to use EO satellites to better understand climate change. The meeting also reviewed progress toward the U.S.-hosted International Space Exploration Forum in January 2014, which will build upon efforts to promote global cooperation in this area that started at the November 2011 EU-hosted Lucca Conference on Space Exploration.

The Russian embassy in Washington, DC, met with DOS representatives on May 22, 2012, to propose the start of consultations for possible cooperation in the monitoring of civil Global Navigation Satellite System (GLONASS) signals in the United States. The proposal was part of a larger Russian effort to expand their

monitoring capability worldwide in order to improve the accuracy of positioning and timing corrections applicable to both GPS and GLONASS.

Representatives of the United States and the Russian Federation met in Vienna on June 9, 2012, to reaffirm their intentions to discuss matters relating to GPS and GLONASS cooperation. Both sides reaffirmed that the United States and the Russian Federation intended to continue to provide the GPS and GLONASS civil signals appropriate for commercial, scientific, and safety-of-life use on a continuous, worldwide basis, free of direct user fees. Throughout the remainder of FY 2012, U.S. technical experts sought more details about the May 22, 2012, Russian proposal in multiple informal meetings on the margins of other international meetings.

DOS supported a strong public outreach and diplomatic campaign to underscore the reliability and accuracy of GPS. DOS speakers gave presentations at many international conferences, including the Moscow International GNSS Conference, meetings of the international section of the Civil GPS Service Interface Committee, and the annual Institute of Navigation PNT conference.

Department of Energy

DOE

The Department of Energy (DOE) participates in the national effort to further U.S. interests in space. Three organizations within DOE provide this capability: the National Nuclear Security Administration's (NNSA) Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D), the DOE Office of Science, and the DOE Office of Nuclear Energy (NE).

Office of Defense Nuclear Nonproliferation Research and Development

The Nuclear Detonation Detection program builds the Nation's operational sensors to monitor the entire planet from space to detect and report surface, atmospheric, or space nuclear detonations (NuDets). The Space-based Nuclear Detonation Detection subprogram provides much of the Nation's capability to detect, report, locate, and identify nuclear explosions using orbiting satellites. The DNN R&D develops, builds, and delivers these satellite payloads to meet interagency performance and schedule commitments and provides launch and on-orbit operational support for the current generation of the U.S. NuDet Detection System (USNDS).

Since the Vela satellite program began in 1960, NNSA and its predecessors have provided the underlying science and technology capability for space-based detection of foreign nuclear weapon detonations to meet test ban treaty monitoring and missile warning needs. Today, these associations continue and have expanded to include military support missions and space control. These efforts span decades of overlapping generations of instruments deployed on multiple platforms in different

orbital configurations. NNSA continues full-scale production and delivery of sensor packages to ensure that payloads are ready, as needed, to meet national security requirements. To ensure that the technologies and capabilities developed for the program support stakeholder needs, DNN R&D actively engages in intergovernmental working groups that reduce duplication among agencies, bring new user requirements to the fore, and improve the quality of relevant technology across the funding agencies. Strong synergy exists between the work performed in the USNDS program and planetary science and astrophysics. The current gamma-ray spectrometers used for USNDS have a shared heritage with the NASA Swift mission, which evolved from earlier USNDS sensors. This mission exemplifies how collaboration between National Laboratories and NASA for astrophysics has benefited USNDS capabilities and vice versa. Additionally, the NASA Living With a Star Program contributes to, and is benefited by, the NNSA-developed payloads that monitor and operate in the near-Earth space environment.

The NNSA weapons laboratories, most notably Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL), supply the science, technology, and engineering required for USNDS, with Lawrence Livermore National Laboratory (LLNL) contributing to the end-to-end testing of USNDS. These NNSA laboratories have unique and comprehensive capabilities in understanding nuclear weapons, as well as knowledge of the signatures and observables associated with a nuclear detonation and the propagation of signals from the weapon to the sensor. Moreover, these laboratories provide capabilities in the design, construction, calibration, deployment, and operation of satellite-based detection instruments, along with detailed modeling and analysis. As the basis for 24/7/365 global monitoring, the user/operations communities routinely receive analysis, insights, and computer codes based on this research. These capabilities represent an important noncommercial source of national space expertise and competency that NNSA is committed to sustaining and nourishing.

Two payloads built by NNSA at these laboratories accomplish the NuDets reporting mission—the Global Burst Detector (GBD) and the Space and Atmospheric Burst Reporting System (SABRS). The GBD payload is hosted on all GPS satellites. The SABRS payload is carried on satellite hosts in geosynchronous orbit. In order to maintain a vital capability to design and implement these systems, DNN

R&D supports demonstration-validation payloads to explore new technologies and new sensing modalities and to increase the technology readiness level (TRL) for parts that might be used in future payload designs.

Office of Science

The DOE Office of Science (SC) supports several activities that contribute to a broad range of space interests. These activities include SC fundamental research that is of mutual interest to the NASA mission and NASA researchers, collaborative research efforts with NASA, and the operation of SC scientific facilities that are available to NASA and the broader scientific community for space-related research.

SC supports fundamental research in plasma science that contributes to SC-NASA mutual interests in knowledge of magnetospheric/ionospheric, solar, and astrophysical systems. A major area of research supported by SC's Office of Fusion Energy Sciences (FES) is centered on developing a comprehensive understanding of astrophysical magnetized-plasma processes, including particle acceleration in cosmic gamma ray bursts, magnetic reconnection and turbulent processes in Earth's magnetosphere and the solar corona, the formation and evolution of astrophysical jets, and dynamo processes creating planetary/galactic magnetic field structures. Some specific examples are 1) large-scale plasma simulation codes that are applied to study space weather; 2) the Large Plasma Device (LAPD) at the University of California, Los Angeles, which enables controlled studies of Alfven waves that carry energy and momentum from the sun to Earth and throughout the universe; 3) the Magnetic Reconnection Experiment (MRX) at Princeton Plasma Physics Laboratory (PPPL), which permits laboratory studies of reconnection in Earth's magnetotail; 4) the Magneto-Rotational Instability facility (MRI), also at PPPL, which elucidates the physics of accretion disks around black holes; and 5) a newly established center at PPPL in partnership with the Max Planck Society that specifically explores the application of plasma science to astrophysical problems. In addition, FES sponsors unmagnetized-plasma research that uses lasers and light-source x-rays to probe the properties of warm dense matter similar to that found in planetary cores.

Projects funded by the Office of Science and executed through joint collaboration with NASA include the development of experimental techniques of fundamental physics for use in space to investigate high-priority national science objectives. Examples of these efforts include the Alpha Magnetic Spectrometer (AMS) and the Fermi Gamma-ray Space Telescope (FGST). The AMS, also designated AMS-02, is a particle physics experiment designed and built primarily by SC and launched on the Space Shuttle in May 2011. AMS-02 is now mounted on the International Space Station, where it searches for various types of unusual matter by measuring cosmic rays. Among the experiment's science goals are the search for evidence of dark matter and cosmic domains of antimatter. The Large Area Telescope (LAT), the primary instrument on NASA's FGST, is a particle physics detector in space to study the gamma-ray sky. SC managed the LAT fabrication and now operates the LAT Science Operations Center. Researchers use the data to learn about high-energy acceleration mechanisms generated by supermassive black holes and supernovae and to search for dark matter.

The Office of Science and NASA engage in collaborative research efforts in the areas of atmospheric science and environmental phenomena. The SC and NASA completed a successful joint experiment in 2011, the Midlatitude Continental Convective Clouds Experiment (MC3E), at the Atmospheric Radiation Measurement Climate Research Facility's (ARM) Southern Great Plains (SGP) site in central Oklahoma, resulting in several publications by teams of DOE and NASA scientists. Findings from this experiment support the development of model improvements and critical algorithms for the NASA Global Precipitation Mission satellite. NASA scientists are co-investigators in the DOE experiment, the Marine ARM GPCI[1] Investigation of Clouds (MAGIC), that is studying marine clouds by deploying the Second ARM Mobile Facility (AMF2) on the Horizon Lines container ship Spirit making regular transects between Los Angeles and Hawaii from October 2012 to September 2013. In addition, the NASA Orbiting Carbon Observatory–2 (OCO-2) Science/Validation Team has deployed ground-based solar-viewing Fourier transform spectrometer (FTS) mobile laboratories at the DOE ARM SGP and Darwin Tropical West Pacific (TWP) sites for several years; this is scheduled to continue through

1. GPCI: Global Energy and Water Cycle Experiment (GEWEX) Cloud System Studies (GCSS) Pacific Cross-section Intercomparison; GPCI is a project comparing data from the major climate models.

2016. These data have been utilized to validate space-based CO_2 retrievals from a variety of different NASA satellite instruments.

Since astronauts are spending more time in space, NASA has long been engaged in working on ground-based studies to understand the possible risks to human beings exposed to space radiation. The Office of Science has been working with NASA in a couple of areas to help support NASA's mission interests in this area of concern. SC provides scientific user facilities for the scientific community, including particle accelerators and ion beams for biological and electronic systems radiation studies. The NASA Space Radiation Laboratory (NSRL) was established at DOE's Brookhaven National Laboratory (BNL) to study the radiobiological effects of using beams of heavy ions extracted from BNL's Booster accelerator that are also produced to deliver into SC's Relativistic Heavy Ion Collider facility. Jointly managed during the four-year construction period by SC and NASA's Johnson Space Center, the NSRL facility provides a leading capability for radiobiology studies in the United States. In addition, since FY 2001, DOE and NASA have engaged in coordinated efforts to better understand and predict the health risks associated with exposure to low-dose radiation. SC's Low Dose Radiation Research Program has coordinated with NASA's Space Radiation Project within NASA's Human Research Program. The SC Low Dose program focuses on doses of radiation measured at or below current workplace exposure limits; current collaborations are limited due to a decreasing emphasis on human radiation research within SC's research portfolio.

Office of Nuclear Energy

The Office of Nuclear Energy (NE) supports NASA's space science and exploration programs by maintaining the necessary nuclear facilities' infrastructure capabilities to produce and deliver power systems for Federal user agencies, such as NASA. These capabilities, funded by DOE, support NE's production of space radioisotope power systems for current space mission applications. The Office of Nuclear Energy also conducts research and development for NASA-funded radioisotope power system and space reactor power and propulsion system technology programs.

DOE and its predecessors have provided radioisotope power systems (RPSs) that have safely enabled deep space exploration and national security missions for over five decades. Radioisotope power systems convert the heat from the natural radioactive decay of plutonium-238 (Pu-238) into electricity. RPSs are capable of producing either heat or electricity for decades under the harsh conditions encountered in deep space. They have proven to be safe, reliable, and maintenance-free in missions to study the Moon and all of the planets in the solar system except Mercury. Systems that utilize RPS-powered systems are currently in many different stages of their mission lives. The Mars Science Laboratory Curiosity rover landed on Mars in August 2012. Curiosity is the largest and most capable rover ever sent to another planet and is powered by a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) that was designed, built, and delivered by DOE. It is currently exploring Mount Sharp, in Gale Crater on Mars. Voyagers 1 and 2, each powered by three Multi-Hundred Watt RTGs, left Earth in 1977 to conduct a grand tour of the outer planets. Voyager 2 is continuing to explore the heliosheath on the edge of the solar system, while Voyager 1, at more than 11 billion miles from Earth, is the farthest humanmade object from Earth—and, as of August 2012, it is the first such object to enter interstellar space. Both spacecraft remain operational and are sending back useful scientific data after over 35 years of operation; they are expected to continue functioning until 2025. The Cassini mission launched in 1997 and entered orbit around Saturn in 2004. The Cassini spacecraft uses three DOE-supplied General Purpose Heat Source (GPHS)–RTGs and is the largest spacecraft ever launched to explore the outer planets. It is successfully returning data and images of Saturn and its surrounding moons, using a broad range of scientific instruments, and is expected to continue to operate until at least 2017. The New Horizons spacecraft, launched in 2006 and powered by a single GPHS-RTG, is the fastest spacecraft to ever leave Earth. New Horizons has already returned images and scientific data from Jupiter and will continue its journey of 3 billion miles to study Pluto and its moon, Charon, in 2015. It may also go on to study one or more objects in the vast Kuiper Belt, the largest structure in our planetary system.

DOE is working with NASA to develop an Advanced Stirling Radioisotope Generator (ASRG). This radioisotope power system uses dynamic energy conversion for greater system efficiency than that of an RTG. The system was offered for

use on the competed Discovery-12 Mission to be launched as early as 2016, but an ASRG-powered mission was not selected.

The stockpile of Pu-238 used to power these missions to explore the solar system and for other Government applications is limited. NE is working with NASA to reestablish domestic Pu-238 production in order to ensure continued availability of these power systems for future science missions. DOE received funds from NASA in late FY 2011 to reestablish this capability and initiated the Pu-238 Supply Project in FY 2012. The project will use existing facilities at the Oak Ridge National Laboratory (ORNL) and the Idaho National Laboratory. In 2012, the project completed initial subscale tests of targets containing neptunium-237 (Np-237) in an existing reactor at ORNL to determine the parameters for full-scale target irradiation of Np-237 targets to produce Pu-238.

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

In FY 2012, exoplanets, or planets orbiting distant stars, continued to be a hot topic. SAO astronomers announced the discovery of the first two Earth-sized planets, with diameters of 8,200 miles or less. Both orbit the same star at distances much closer than Mercury orbits our sun, making them too hot for life.

Researchers also discovered a unique double-planet system where a lava world experiences a "planetrise" every time it nears its Jupiter-like neighbor. When the two planets experience a conjunction every 97 days, they are separated by only 1 million miles. As a result, the larger world appears five times bigger than the full moon in its neighbor's sky.

SAO continued to be at the forefront of a decades-long effort to map the universe. In August 2012, researchers unveiled the largest three-dimensional (3D) map of galaxies ever created. The Sloan Digital Sky Survey III cataloged more than 1 million galaxies out to a distance of 6 billion light-years—almost halfway across the visible universe. It also mapped quasars—giant black holes actively feeding on stars and gas—up to 12 billion light-years from Earth.

NASA's Spitzer Space Telescope, launched in August 2003, continues to produce exciting new views of the universe at infrared wavelengths. Spitzer is the fourth

and final space telescope in NASA's Great Observatory series. Spitzer's Infrared Array Camera (IRAC) was developed at SAO and constructed at the NASA Goddard Space Flight Center. Spitzer is operated for NASA by the Jet Propulsion Laboratory. Spitzer's "cold mission" lasted more than 5.5 years and was terminated by the depletion of its liquid-helium coolant on May 15, 2009. However, two of the cameras in IRAC, at 3.6- and 4.5-micron wavelengths, continue to operate during the new "warm mission" phase.

SAO scientists, in collaboration with the Spitzer Science Center, continue to play an important role in the operation of IRAC, the data analysis, and its use for astronomical observations.

In FY 2012, SAO astronomers published data from the Spitzer Extended Deep Survey (SEDS). SEDS is a unique undertaking, covering 1.5 square degrees of the sky in the near infrared with Spitzer's IRAC instrument to observe the faintest objects ever seen on a field of this size. SEDS also benefits from extensive coverage by allied teams, particularly using the Hubble Space Telescope. The combination of the IRAC catalogs with those from Hubble has already resulted in numerous other discoveries, including galaxies seen as they were when the universe was in its infancy. In addition, after integrating all the light from all sources seen in the SEDS field, SAO researchers concluded that at least half of the enigmatic "extra-galactic background light" must originate in discrete objects (galaxies) rather than coming from an ill-defined, diffuse source.

Spitzer/IRAC observations also discovered four extremely reddened infrared sources that were not detected at visible or near-infrared wavelengths by very deep observations with the Hubble Space Telescope. The nature of these objects remains a mystery. One possibility is that these objects are galaxies in the early universe with an old population of stars.

In FY 2012, SAO astronomers released the results of a Spitzer survey of the Cygnus-X star-forming region. Cygnus-X is one of the brightest regions of the sky at all wavelengths and is one of the richest known massive star-formation regions in the galaxy. Massive stars are important because their energetic winds and ultra-violet flux have major effects on molecular clouds and galactic structure. They are important influences in the enrichment of the interstellar medium and provide feedback to the star-formation process. A large fraction of stars form in massive

clusters, including stars like our sun, so such a study is important in understanding our own origins. However, massive star formation is not well understood.

SAO astronomers surveyed about 25 square degrees in the Cygnus-X region using Spitzer. They detected approximately 4 million sources and performed a search for protostars, or newly forming stars, at various stages of evolution. They found approximately 1,200 deeply embedded protostars, 2,600 protostars with dusty envelopes, and 24,000 protostars with disks, which are possibly forming planetary systems. This sample of protostars is larger than the total number discovered by Spitzer in all other surveys combined at that point.

The Chandra X-ray Observatory is NASA's flagship mission for x-ray astronomy, and the Smithsonian Astrophysical Observatory has operated the mission on behalf of NASA since its launch in 1999.

During FY 2012, scientists using Chandra made many significant and exciting discoveries. Among them was an exceptional galaxy cluster that was the largest ever seen in the distant universe. Galaxy clusters, the largest objects in the universe that are held together by gravity, form through the merger of smaller groups or subclusters of galaxies. Because the formation process depends on the amount of dark matter and dark energy in the universe, clusters can be used to study these mysterious phenomena. The newly discovered galaxy cluster is the most massive, is the hottest, and gives off the most x-rays of any known cluster at its distance of 7 billion light-years or beyond.

Later in FY 2012, other astronomers made another remarkable discovery involving a separate galaxy cluster that is slightly closer to Earth at a distance of 5.7 billion light-years. This cluster became known as the Phoenix Cluster not only for the constellation in which it is found, but also for its remarkable properties. For example, stars are forming in the Phoenix Cluster at the highest rate ever observed for the middle of a galaxy cluster. While galaxies at the center of most clusters may have been dormant for billions of years, the central galaxy in this cluster seems to have come back to life with a new burst of star formation.

Researchers also used Chandra to discover an extraordinary outburst produced by a black hole in a nearby galaxy called M83, which has provided direct evidence for a population of old, volatile stellar black holes during FY 2012. The Chandra observations provided new insight into the nature of a mysterious class of black

holes that can produce as much energy in x-rays as a million suns radiating at all wavelengths.

In FY 2012, Chandra launched a new exhibit called "Here, There, and Everywhere" to illustrate how familiar phenomena on Earth and across the universe are connected by basic physical laws. This exhibit will travel to 30 locations, including libraries and other public spaces, from 2012 through 2015.

The Solar Dynamics Observatory provides better-than-high-definition-quality images of the sun's surface and outer atmosphere. SAO is a major partner in the Atmospheric Imaging Assembly (AIA)—a group of four telescopes that photograph the sun in 10 different wavelength bands, or colors, once every 12 seconds.

The Hinode mission is a joint U.S.-Japanese-European mission designed to study the detailed physics of the sun's atmosphere. SAO is the lead institution on the X-ray Telescope (XRT) on the Hinode spacecraft. The XRT is a telescope that images energetic x-rays that are produced in the hottest parts of the sun's corona.

AIA and Hinode XRT observations formed the bases of the thesis work by a graduate student supported by SAO. In this work, mathematical magnetic-field models are constructed that are consistent with the high-resolution AIA and XRT observations. These models show how magnetic energy is stored in the corona, as well as the conditions that are needed to release the energy quickly in flares and coronal mass ejections.

In FY 2012, XRT provided stunning images of the structure of regions of activity in the sun's atmosphere. These regions are locations where large solar eruptions originate. The images from XRT allowed scientists to systematically study the structure and evolution of the magnetic fields within these regions, leading to a better understanding of the conditions that can cause large eruptions.

Also in FY 2012, the NASA suborbital rocket Hi-C was flown from White Sands Missile Range. SAO built the telescope for this mission and provided critical technical and scientific support. Hi-C produced the highest-resolution images of the solar corona ever made. It identified (for the first time) braided structures within coronal loops. Data from the Hi-C mission resulted in more than 15 refereed publications, the most ever for any rocket flight.

In public outreach, SAO continued its popular monthly Observatory Night lectures and observing sessions. Begun by observatory director Harlow Shapley

in 1930, these public nights offer the local community an opportunity to learn about the latest advances in astronomy as well as view the moon, stars, and planets through a variety of telescopes. Attendees routinely fill the observatory auditorium and a nearby overflow room to capacity. The lectures are Webcast live and archived online to reach a broader audience.

SAO participated in the sixth annual Cambridge Science Festival—a celebration showcasing the leading edge in science, technology, engineering, and mathematics. This multifaceted, multicultural event takes place every spring in Cambridge, Massachusetts.

SAO hosted a special event to view the planet Venus transiting across the face of the sun. The next such transit will not occur until 2117. SAO also provided occasional Author's Night programs, as well as Sci-fi Movie Nights that explored the theme "Everything I learned about science, I learned at the movies."

In FY 2012, a new exhibition, developed jointly by SAO and the Smithsonian's National Museum of Natural History, revealed the dynamic and evolving universe through breathtaking photographs and informative captions. "The Evolving Universe" explored how the stars, galaxies, and universe undergo the same stages as life on Earth: from birth to maturity and, eventually, to death. This remarkable journey from present-day Earth to the far reaches of space and time was on view in the museum in Washington, DC, through July 2013.

In FY 2012, NASM continued to educate and inspire the public through exhibits, research, and education programs, including discovery stations, lecture series, family educational events, publications, and intern training. In terms of major artifact acquisitions, NASM received from NASA significant artifacts associated with the Space Shuttle Program, newly available after the program ended in 2011. Among those objects acquired was Space Shuttle Discovery, placed on display at the Steven F. Udvar-Hazy Center, Dulles, Virginia. The Discovery exhibit was opened with a four-day festival highlighting the history of this notable spacecraft. Other exhibitions opened this year included "Jet as Art" and "Fly Marines: The Centennial of Marine Corps Aviation 1912–2012."

Staff members in NASM's Center for Earth and Planetary Studies (CEPS) continued to participate on the science teams of several spacecraft missions. Three of six full-time CEPS scientists served on mission teams during the year. Dr. John

Grant is a Participating Scientist for the Mars Exploration Rover (MER) mission that is currently operating on Mars. He is a chair of the MER Science Operations Working Group, and in that capacity he leads day-to-day science planning for the Opportunity rover. He conducts real-time mission planning using a data station installed on-site at CEPS. CEPS staff are also on the science teams for the Mars Science Laboratory; the Mars Advanced Radar for Subsurface and Ionosphere Sounding instrument on Mars Express; both the High Resolution Imaging Science Experiment and the Shallow Subsurface Radar instruments on the Mars Reconnaissance Orbiter; the Lunar Reconnaissance Orbiter; and the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission to Mercury.

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, and Mercury. Research topics included lunar tectonic studies, comparative planetology, aeolian processes on terrestrial planets, lunar and Martian radar studies, Martian valley networks and impacts, and Mercury surface features. Dr. Ross Irwin received a 2012 Presidential Early Career Award for Scientists and Engineers for his work on the role of water in shaping the landscape of Mars.

In addition, during FY 2012, NASM completed 8 new books and a total of 18 articles in history. In science, NASM CEPS authored or coauthored 19 peer-reviewed papers and 50 abstracts.

APPENDICES

Appendix A-1

U.S. Government Spacecraft Record

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

	Earth Orbit[a]		Earth Escape[b]	
Calendar Year	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	22[f]	0	0	0
2009	24[f]	1	0	0
2010	15	0	0	0
2011	16	1	3	0
2012 (through September 30, 2012)	10	0	0	0
TOTAL	**1,693**	**157**	**109**	**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	Iran
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	19	26			1	11			7	3		
2009	25	29			3	4			9	4		1
2010	15	30			2	15			6	1	1	
2011	17	33			3	18			7	3		1
2012*	10	18			2	13			6	2		1
*(through September 30, 2012)												
TOTAL	**1,444**	**2,937**	**10**	**8**	**81**	**165**	**1**	**1**	**210**	**34**	**6**	**3**

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.

Appendix B
Successful Launches to Orbit on U.S. Vehicles

October 1, 2011–September 30, 2012

Launch Date Spacecraft Name COSPAR* Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
October 28, 2011 Suomi NPP 2011-061A Delta 2-7920	Meteorology	818 811 101.1 98.7	Renamed Suomi National Polar-orbiting Partnership (NPP) from National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP)
November 26, 2011 Mars Science Laboratory 2011-070A Atlas 5-541	Planetary science	325 166 89.4 28.9	
January 20, 2012 WGS F4 2012-003A Delta 4M+5,4	Military communications	66,960 503 1,332.4 23.9	Wideband Global Satellite Communications (SATCOM) (WGS)
February 24, 2012 MUOS 1 2012-009A Atlas 5-551	Military communications	34,410 220 604.9 26	Mobile User Objective System (MUOS)
April 3, 2012 USA 234 (NROL-25) 2012-014A Delta 4M+5,2	Military/classified	1,096 1,084 106.9 122	
May 4, 2012 AEHF 2 2012-019A Atlas 5-531	Military communications	45,969 26,171 1,450.6 4.5	Advanced Extremely High Frequency (AEHF)
May 22, 2012 Dragon C2+ 2012-027A Falcon 9	International Space Station	406 392 92.5 51.6	Dragon C2/C3
June 13, 2012 NuSTAR 2012-031A Pegasus XL	Space science	639 620 97.3 6	Nuclear Spectroscopic Telescope Array (NuSTAR)
June 20, 2012 USA 236 (NROL-38) 2012-033A Atlas 5	Military/classified	35,886 862 645.9 20.7	
June 29, 2012 USA 237 (NROL-15) 2012-034A Delta 4H	Military/classified	35,674 219 629.2	
August 30, 2012 RBSP-A/B 2012-046A-B Atlas 5-401	Earth science	330,715 601 359.2 10.1	Radiation Belt Storm Probes (RBSP) Renamed Van Allen Probes
September 13, 2012 STS-134/Endeavour 2011-020A Space Shuttle	Military/classified	1,051 511 100.4 64.5	Carried OUTsat (Operationally Unique Technologies Satellite) and released 11 CubeSats

*U.N. Committee on Space Research

Appendix C
HUMAN SPACEFLIGHTS

October 1, 2011–September 30, 2012

Spacecraft	Launch Date	Crew	Flight Time (d:h:min)	Highlights
Soyuz TMA-22 (Expedition 29)	November 13, 2011	Anton Shkaplerov Anatoly Ivanishin Dan Burbank	165:08:31	Final planned flight for the Soyuz-TMA design
Soyuz TMA-03M (Expedition 30)	December 21, 2011	Oleg Kononenko Andre Kuipers Don Pettit	192:19:58	Considered the first normal flight of the Soyuz TMA-M spacecraft (the prior two were seen as test flights)
Soyuz TMA-04M (Expedition 31)	May 14, 2012	Joe Acaba Gennady Padalka Sergei Revin	124:23:52	First commercial resupply by the SpaceX Dragon
Shenzhou 9	June 16, 2012	Jing Halpeng Liu Wang Liu Yang	12:15:24	China's first women in space China's longest spaceflight to date First crewed docking to the Chinese Tiangong 1 Space Laboratory Module
Soyuz TMA-05M (Expedition 32)	July 14, 2012	Sunita Williams Yuri Malenchenko Akihiko Hoshide	126:22:16	First boost above 400 km mean altitude First CubeSat deployment from the Kibo Robotic Arm

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			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
2009	17,775	17,275	26,528	1,868	200	1,078	64	27	485	14	45,671
2010	18,725	18,228	26,463	2,057	203	1,261	67	27	484	15	46,748
2011	18,432	17,898	27,234	2,186	229	1,444	66	20	412	15	47,318
2012	17,773	17,203	26,677	2,580	199	1,876	76	7	406	16	46,460

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 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 the 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 2012 dollars)

FY	Inflation Factors	NASA Total	NASA Space	DOD	Other[a]	DOE[b]	DOC	DOI	USDA	NSF[c]	DOT	Total Space
1959	6.269	2,075	1,636	3,072	213	213						4,921
1960	6.181	3,239	2,856	3,467	266	266						6,589
1961	6.105	5,885	5,653	4,969	415	415						11,037
1962	6.017	10,982	10,813	7,811	1,197	891	307					19,821
1963	5.951	21,859	21,580	9,225	1,529	1,274	256					32,334
1964	5.878	29,976	29,482	9,398	1,252	1,234	18					40,132
1965	5.809	30,495	29,844	9,143	1,400	1,330	70					40,387
1966	5.709	29,547	28,919	9,643	1,222	1,068	154					39,784
1967	5.589	27,754	26,994	9,300	1,190	1,028	162					37,485
1968	5.416	24,843	23,993	10,410	943	785	152	1	5			35,346
1969	5.232	20,880	19,996	10,531	891	617	105	1	5	163		31,418
1970	5.004	18,745	17,749	8,397	706	515	40	5	5	140		26,851
1971	4.747	15,718	14,721	7,178	769	451	128	9	5	175		22,668
1972	4.521	14,950	13,884	6,361	603	249	140	27	9	178		20,847
1973	4.317	14,703	13,352	7,006	636	233	173	43	9	179		20,994
1974	4.136	12,562	11,412	7,305	654	174	248	37	12	182		19,371
1975	3.859	12,459	11,248	7,300	609	116	247	31	8	207		19,157
1976	3.493	12,399	11,264	6,926	588	80	251	35	14	207		18,777
TQ*	3.259	3,037	2,767	1,499	140	16	72	10	3	39		4,406
1977	3.159	12,061	10,867	7,620	611	69	287	32	19	204		19,098
1978	3.032	12,310	10,985	8,302	685	103	312	30	24	215		19,972
1979	2.840	13,055	11,447	8,624	704	168	278	28	23	207		20,775
1980	2.629	13,774	12,302	10,115	607	105	244	32	37	189		23,024
1981	2.415	13,328	12,058	11,662	566	99	210	29	39	189		24,285
1982	2.199	13,290	12,155	14,686	688	134	319	26	33	175		27,529
1983	2.058	14,149	13,023	18,562	673	80	366	10	41	175		32,258
1984	1.971	14,703	13,520	20,099	778	67	465	6	37	203		34,397
1985	1.901	14,396	13,164	24,271	1,110	65	804	4	29	209		38,545
1986	1.841	14,375	13,193	26,010	878	64	569	4	42	198		40,080
1987	1.800	19,657	17,652	29,310	838	86	500	14	34	201	2	47,801
1988	1.753	15,884	14,587	30,987	1,299	422	617	25	32	202	2	46,873
1989	1.698	18,629	17,148	30,411	951	165	511	29	36	206	5	48,510
1990	1.635	20,149	18,736	25,531	827	129	397	51	41	202	7	45,094
1991	1.577	22,102	20,572	22,362	1,218	396	396	46	41	333	6	44,152
1992	1.519	21,751	20,052	22,823	1,212	339	497	52	44	275	6	44,087
1993	1.481	21,188	19,344	20,886	1,082	244	480	49	37	266	6	41,312
1994	1.449	21,109	18,866	19,075	916	107	452	45	45	260	7	38,858
1995	1.419	19,656	17,796	15,102	1,076	85	499	44	45	394	9	33,975
1996	1.389	19,290	17,463	15,997	1,150	64	656	50	51	321	8	34,610
1997	1.363	18,686	16,980	15,985	1,076	48	611	57	53	299	8	34,041
1998	1.338	18,266	16,490	16,541	1,124	138	582	58	52	286	8	34,155
1999	1.322	18,044	16,466	17,449	1,298	139	760	78	49	264	8	35,213
2000	1.304	17,740	16,332	16,879	1,377	214	750	78	57	270	8	34,588
2001	1.279	18,200	17,015	18,323	1,358	185	738	77	46	297	15	36,696
2002	1.250	18,579	17,333	19,669	1,475	207	805	80	35	332	15	38,477
2003	1.229	18,886	17,652	23,832	1,604	235	798	91	52	414	15	43,088
2004	1.205	18,526	17,253	23,027	1,764	252	897	86	73	441	14	42,043
2005	1.175	19,031	17,899	23,134	1,822	269	948	82	86	423	14	42,855
2006	1.138	18,915	17,939	25,164	1,874	279	979	93	96	414	14	44,977
2007	1.100	17,921	17,132	24,671	1,849	220	1,004	96	72	445	13	43,652
2008	1.069	18,296	17,638	26,502	1,815	208	921	96	63	512	14	45,955
2009	1.045	18,568	18,046	27,712	1,951	209	1,126	67	28	507	15	47,708
2010	1.031	19,312	18,800	27,293	2,121	209	1,301	69	27	499	15	48,214
2011	1.021	18,819	18,274	27,806	2,231	234	1,474	67	20	421	15	48,311
2012	1.000	17,773	17,203	26,677	2,580	199	1,876	76	7	406	16	46,460

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 2010 actual	2011 actual	2012 actual	2013 est.[1]	Budget Outlays 2010 actual	2011 actual	2012 actual
NASA[2]	18,222	17,898	17,203	16,335	18,406	17,017	16,606
DOD[3]	26,463	27,234	26,677	25,555	24,142	25,924	26,457
DOE[4]	203	229	199	185	204	177	158
DOC[5]	1,398	1,444	1,876	1,865	567.1	803.2	1,074.3
DOI	67	66	76	75	67	66	76
USDA	26.6	19.5	6.7	6.4	21.6	18.1	17.3
DOT	15	15	16	15	15	15	16
NSF[6]	484	412	406	401	515	543	489

(1) FY 2013 figures incorporate the effect of sequestration.

(2) 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) DOD FY 2011, 2012, and 2013 figures for Budget Authority and Outlays are estimated at the time of preparing this report.

(4) Department of Energy budget figures do not include any physics research and operations funding for ground-based experiments managed in the High Energy Physics program.

(5) Beginning in 2010, the Department of Commerce has defined the entire National Environmental Satellite, Data, and Information Service budget that is within the National Oceanic and Atmospheric Administration (NOAA) as a space activity. Prior years did not include some items, such as NOAA's National Climatic Data Center archives and Comprehensive Large Array-data Stewardship System (CLASS). The Budget Outlays columns reflect dollars "costed" in a fiscal year specific to that same fiscal year's appropriated dollars.

(6) Totals for NSF include Large Synoptic Survey Telescope (LSST) and all telescope activities. Outlay information includes American Recovery and Reinvestment Act (ARRA).

Appendix D-3

FEDERAL AERONAUTICS ACTIVITIES BUDGET

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority 2010 actual	2011 actual	2012 actual	2013 est.[1]	Budget Outlays 2010 actual	2011 actual	2012 actual
NASA[2]	497	534	570	530	500	601	584
USDA	55.4	37.1	36.9	34.5	52.6	35.3	36.8
DOD[3]	14,166	14,170	1,4221	1,4099	13,573	13,577	13,509
DOI	28	24	27	26	29	25	27
DOT	3,104	2,905	2,884	2,733	2,742	2,895	3,102

(1) FY 2013 figures incorporate the effect of sequestration.

(2) 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) DOD FY 2011, 2012, and 2013 figures for Budget Authority and Outlays are estimated at the time of preparing this report.

Acronyms

25K TTL	25K Transportable Target Launcher
3D	three-dimensional

A

AAR	Airport Arrival Rate
ACM	Adjacent Center Metering
ACT	Atacama Cosmology Telescope
ADS-B	Automatic Dependent Surveillance-Broadcast
ADVENT	Adaptive Versatile Engine Technology
AE	Archive Explorer
AEHF	Advanced Extremely High Frequency
AES	Advanced Exploration Systems
AFB	Air Force Base
AGS	NSF Division of Atmospheric and Geospace Sciences
AHW	Advanced Hypersonic Weapon
AIA	Atmospheric Imaging Assembly
ALASA	Airborne Launch Assist Space Access
ALMA	Atacama Large Millimeter/submillimeter Array
AMF2	Second ARM Mobile Facility
AMISR	Advanced Modular Incoherent-Scatter Radar
AMPEREA	Active Magnetosphere and Planetary Electrodynamics Response Experiment
AMS	Autonomous Modular Sensor; Alpha Magnetic Spectrometer
AMSU	Advanced Microwave Sounding Unit
ANC	Air Navigation Conference
AO	Arecibo Observatory
APFO	Aerial Photography Field Office
ARED	Advanced Resistive Exercise Device
ARM	Atmospheric Radiation Measurement Climate Research Facility
ARMD	Aeronautics Research Mission Directorate
ARRA	American Recovery and Reinvestment Act
ARS	Agricultural Research Service
AS	NSF Atmosphere Section
ASB	Agricultural Statistics Board
ASDE-X	Airport Surface Detection Equipment
ASIAS	Aviation Safety Information Analysis and Sharing
ASRG	Advanced Stirling Radioisotope Generator
AST	FAA Office of Commercial Space Transportation; NSF Division of Astronomical Sciences
ASU	Aircraft Sector Understanding, short for Group on the Sector Understanding on Export Credits for Civil Aircraft
ATC	Air Traffic Control
ATK	Alliant Techsystems
ATOP	Advanced Technologies and Oceanic Procedures
ATST	Advanced Technology Solar Telescope
ATV	Automated Transfer Vehicle
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer

B

BANWR	Buenos Aires National Wildlife Refuge
BD2	Blue Devil 2
BICEP2	Background Imaging of Cosmic Extragalactic Polarization 2
BLISS	background-limited infrared-submillimeter spectrograph
BLM	Bureau of Land Management
BNL	Brookhaven National Laboratory

C

C-CAP	Coastal Change Assessment Program
CART	classification and regression tree
CBP	Customs and Border Protection
CCAFS	Cape Canaveral Air Force Station
CCiCap	Commercial Crew integrated Capability
CCL	Commerce Control List
CCMC	Community Coordinated Modeling Center
CCP	Commercial Crew Program
CCSDS	Consultative Committee for Space Data Systems
CDL	Cropland Data Layer
CDTI	Cockpit Display of Traffic Information
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions
CEPS	Center for Earth and Planetary Studies
CfA	Center for Astrophysics
CHIRP	Commercially Hosted Infrared Payload
CISM	Center for Integrated Space Weather Modeling
CLASS	Comprehensive Large Array-data Stewardship System
CLS	Collecte Localisation Satellites
CLU	Common Land Unit
CMB	cosmic microwave background
CME	coronal mass ejection
CNES	Centre National d'Études Spatiales
COE-CST	Center of Excellence for Commercial Space Transportation
CoNNeCT	Communications, Navigation, and Networking reConfigurable Testbed
ConOps	Concept of Operations
CONUS	contiguous United States
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
COSPAS-SARSAT	Cosmicheskaya Sistyema Poiska Avariynich Sudov–Search and Rescue Satellite-Aided Tracking
COTS	Commercial Orbital Transportation Services
CPC	Certification Products Contract
CREATE	Computational Research and Engineering Acquisition Tools and Environments
CREATE-AV	Computational Research and Engineering Acquisition Tools and Environments Air Vehicles
CRS	Commercial Resupply Services
CS	Commercial Service

D

D&D	design and development
DARPA	Defense Advanced Research Projects Agency
dB	decibel
DFRC	Dryden Flight Research Center
DHS	Department of Homeland Security
DKIST	Daniel K. Inouye Solar Telescope
DLR	German Aerospace Center

DMC	Disaster Monitoring Constellation
DNN R&D	Office of Defense Nuclear Nonproliferation Research and Development
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
DSN	Deep Space Network

E

EA	Environmental Assessment
EBEX	E and B Experiment
ECMWF	European Centre for Medium-Range Weather Forecasts
EDA	Efficient Descent Advisor
EDC	EROS Data Center
EELV	Evolved Expendable Launch Vehicle
EFT-1	Exploration Flight Test 1
EGS	Exploration Ground Systems
EHF	extremely high frequency
EISA	Energy Independence and Security Act
ELaNa	Educational Launch of Nanosatellites
EMFISIS	Electric and Magnetic Field Instrument Suite and Integrated Science
EMU	Extravehicular Mobility Unit
EO	Earth Observation
EOS	Earth Observing System
EP	Eastern Population
EPA	Environmental Protection Agency
ERA	Environmentally Responsible Aviation
ERDC	Engineer Research and Development Center
EROS	Earth Resources Observation and Science
ESA	European Space Agency
ESD	Exploration Systems Development
Esri	Environmental Systems Research Institute
ET	evapotranspiration
ET-1	Economical Target-1
ETa	actual evapotranspiration
ETM	Enhanced Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
Ex-Im Bank	Export-Import Bank

F

FAA	Federal Aviation Administration
FAS	Foreign Agricultural Service
FCC	Federal Communications Commission
FES	Fusion Energy Sciences
FEWS NET	Famine Early Warning Systems Network
FGST	Fermi Gamma-ray Space Telescope
FOC	flight operations center
FONSI	Finding of No Significant Impact
FORT	USGS Fort Collins Science Center

FPI	Fire Potential Index
FS	Forest Service
FSA	Farm Service Agency
FTS	Fourier transform spectrometer

G

G-LiHT	Goddard LiDAR Hyperspectral and Thermal
GALEX	Galaxy Evolution Explorer
GaN	gallium nitride
GBD	Global Burst Detector
GCAD30	Global Cropland Area Database
GCP	Gulf Coast Prairie
GCPO	Gulf Coastal Plains and Ozarks
GCSS	GEWEX Cloud System Studies
GEM	Geospace Environment Modeling
GEO	Group on Earth Observations
GEWEX	Global Energy and Water Cycle Experiment
GF	Geospace Facilities
GHz	gigahertz
GIS	Geographic Information System
GISMO	Goddard IRAM Superconducting 2 Millimeter Observer
GLONASS	Global Navigation Satellite System
GNSS	global navigation satellite systems
GOES	Geostationary Operational Environmental Satellites
GPCI	GCSS Pacific Cross-section Intercomparison
GPHS	General Purpose Heat Source
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GRAIL	Gravity Recovery and Interior Laboratory
GRC	Glenn Research Center
GS	NSF Geospace Section
GSFC	Goddard Space Flight Center
GV	Gulfstream V

H

HAB	harmful algal bloom
HDDS	Hazard Data Distribution System
HEAT	High Elevation Antarctic Terahertz
HEOMD	Human Exploration and Operations Mission Directorate
HFR	high frequency radar
HIAPER	High-performance Instrumented Airborne Platform for Environmental Research
HIPPO	HIAPER Pole to Pole Observations
HIRS	High-resolution Infrared Radiation Sounder
hot DOG	hot dust-obscured galaxy
HPCMP	High Performance Computing Modernization Program
HRJ	hydro-treated renewable jet
HRP	Human Research Program
HST	Hubble Space Telescope
HTV3	HII Transfer Vehicle

I

IAC	International Astronautical Conference
IBEX	Interstellar Boundary Explorer
ICAO	International Civil Aviation Organization
ICE-T	Ice in Clouds—Tropical
ICESat	Ice, Cloud, and land Elevation Satellite
ICG	International Committee on Global Navigation Satellite Systems
ICNO	IceCube Neutrino Observatory
ICPS	Interim Cryogenic Propulsion Stage
IDEA	Integrated Design and Engineering Analysis
IDM	interference detection and mitigation
IFR	Instrument Flight Rules
IfSAR	Interferometric Synthetic Aperture Radar
ILS	Instrument Landing System
IOOS	Integrated Ocean Observing System
IP	intellectual property
IRAC	Infrared Array Camera
IRAM	Institut de RadioAstronomie Millimétrique
IRVE-3	Inflatable Reentry Vehicle Experiment-3
ISR	intelligence, surveillance, and reconnaissance
ISS	International Space Station
ITA	International Trade Administration
ITAC	Industry Trade Advisory Committee
ITU	International Telecommunication Union

J

JASD	Joint Agency Satellite Division
JAXA	Japan Aerospace Exploration Agency
JCTD	Joint Capability Technology Demonstrations
JPDO	Joint Planning and Development Office
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JSC	Johnson Space Center
JWST	James Webb Space Telescope

K

klbf	kilopounds-force
kN	kilonewton
KSC	Kennedy Space Center

L

LANL	Los Alamos National Laboratory
LAPD	Large Plasma Device
LAT	Large Area Telescope
LCC	Landscape Conservation Cooperative
LDCM	Landsat Data Continuity Mission
LEMV	Long Endurance Multi-Intelligence Vehicle
LEO	low-Earth orbit

LFT&E	live-fire test and evaluation
LIDAR	Light Detection and Ranging
LLNL	Lawrence Livermore National Laboratory
LOX	liquid oxygen
LRO	Lunar Reconnaissance Orbiter
LSP	Launch Services Program
LSST	Large Synoptic Survey Telescope
LST	land surface temperature
LSTO	Launch Service Task Order
LULC	land use and land cover
LVC-DE	Live Virtual Constructive-Distributive Environment

M

MAGIC	Marine ARM GPCI Investigation of Clouds
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MBHI	Migratory Bird Habitat Initiative
MBSU	Main Bus Switching Unit
MC3E	Midlatitude Continental Convective Clouds Experiment
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MEDLI	MSL Entry, Descent, and Landing Instrument
MER	Mars Exploration Rover
MetOp	Meteorological Operational
MGUE	Military GPS User Equipment
MHTEX	Massive Heat Transfer Experiment
MIB	Mishap Investigation Board
Mini-RF	Miniature Radio Frequency
mK	millikelvin
MLM	Multipurpose Laboratory Module
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
MN	meganewton
MODIS	Moderate Resolution Imaging Spectroradiometer
MoonKAM	Moon Knowledge Acquired by Middle school students
MPCV	Multi-Purpose Crew Vehicle
MREFC	Major Research Equipment and Facility Construction
MRI	Magneto-Rotational Instability
MRLC	Multi-Resolution Land Characteristics
MRR	Multi-Role Rotor
MRX	Magnetic Reconnection Experiment
MSFC	Marshall Space Flight Center
MSL	Mars Science Laboratory
MSS	Mobile Satellite Service
mt	metric ton
MTBS	Monitoring Trends in Burn Severity
MUOS	Mobile User Objective System

N

NAFD	North American Forest Dynamics
NAIP	National Agriculture Imagery Program
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum
NASS	National Agricultural Statistics Service

NASTAR	National AeroSpace Training and Research
NAVWAR	Navigation Warfare
NCAR	National Center for Atmospheric Research
NCCOS	National Centers for Coastal Ocean Science
NCEP/NARR	National Environmental Prediction Center North American Regional Reanalysis
NDEP	National Digital Elevation Program
NDVI	normalized difference vegetation index
NE	DOE Office of Nuclear Energy
NEN	Near Earth Network
NEPA	National Environmental Policy Act
NextGen	Next Generation Air Transportation System
NFS	National Forest System
NGA	National Geospatial-Intelligence Agency
NGS	National Geodetic Survey
NHD	National Hydrography Dataset
NIST	National Institute of Standards and Technology
NLCD	National Land Cover Database
NLS	NASA Launch Services
nm	nanometer
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
Np-237	neptunium-237
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project; National Polar-orbiting Partnership (with Suomi)
NPS	National Park Service
NRAO	National Radio Astronomy Observatory
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
NRO	National Reconnaissance Office
NSF	National Science Foundation
NSO	National Solar Observatory
NSPO	Taiwan's National Space Organization
NSRL	NASA Space Radiation Laboratory
NSS	national security space
NSWP	National Space Weather Program
NTIA	National Telecommunications and Information Administration
NuDets	nuclear detonations
NuSTAR	Nuclear Spectroscopic Telescope Array
NWI	National Wetlands Inventory

O

OCAT	Oceanic Conflict Advisory Trial
OCO	Orbiting Carbon Observatory
OCT	Office of the Chief Technologist
OECD	Organization for Economic Cooperation and Development
OFCM	Office of the Federal Coordinator for Meteorology
OFSI	Office of Financial Service Industries
OGA	Office of Global Analysis
OLI	Operational Land Imager
OLTARIS	On-Line Tool for the Assessment of Radiation in Space
ONE	Operational Nanosatellite Effect
OPP	Office of Polar Programs

ORNL	Oak Ridge National Laboratory
ORS	Operationally Responsive Space
OSC	Orbital Sciences Corporation
OSM	Office of Surface Mining
OTM	Office of Transportation and Machinery
OTV	Orbital Test Vehicle
OUTSat	Operationally Unique Technologies Satellite

P

PAC-3	Patriot Advanced Capability 3
Pan-STARRS1	Panoramic Survey Telescope and Rapid Response System
PDSI	Palmer Drought Severity Index
PGSS	Persistent Ground Surveillance System
PNT	positioning, navigation, and timing
POES	Polar-orbiting Operational Environmental Satellites
PPPL	Princeton Plasma Physics Laboratory
PRS	Public Regulated Service
PRSEUS	Pultruded Rod Stitched Efficient Unitized Structure
PRT	platinum resistance thermometer
PSA	Predictive Service Area
PSU	primary sampling unit
PTDS	Persistent Threat Detection System
PTT	Platform Transmitting Terminal
Pu-238	plutonium-238

R

R&D	Research and Development
RAD	Radiation Assessment Detector
REPT	Relativistic Electron Proton Telescope
RFP	Request for Proposal
RLV	reusable launch vehicle
RMA	Risk Management Agency
RO	radio occultation
ROSES	Research Opportunities in Space and Earth Sciences
RPS	radioisotope power system
RPT	Rocket Propulsion Test
RSCC	Remote Sensing Coordinating Committee
RSIWG	Remote Sensing Interagency Working Group
RTS	Reagan Test Site

S

S&P	State and Private Forestry
SAA	Space Act Agreement
SABRS	Space and Atmospheric Burst Reporting System
SAO	Smithsonian Astrophysical Observatory
SATCOM	Wideband Global Satellite Communications
SATVI	Soil-Adjusted Total Vegetation Index
SBA	Small Business Administration
SBIR	Small Business Innovation Research
SBSS	Space Based Space Surveillance
SC	DOE Office of Science

SCaN	Space Communications and Navigation
SDR	System Definition Review
SEDS	Spitzer Extended Deep Survey
SEM	Space Environment Monitor
SES	Société Européenne des Satellites
SGP	Southern Great Plains
SHINE	Solar, Heliosphere, and INterplanetary Environment
SI	International System of Units
SIA	Satellite Imagery Archive
SIM	Spectral Irradiance Monitor
SLS	Space Launch System
SM-3	Standard Missile 3
SMAP	Soil Moisture Active Passive
SMD	Science Mission Directorate
SMDC	Space and Missile Defense Command
SN	Space Network
SNaP-3	SMDC Nanosatellite Program-3
SNL	Sandia National Laboratories
SNSPD	superconducting nanowire single photon detector
SOFIA	Stratospheric Observatory for Infrared Astronomy
SpaceX	Space Exploration Technologies
SPOT	Satellite Pour l'Observation de la Terre
SPT	South Pole Telescope
SQUID	Superconducting Quantum Interference Device
SRB	solid rocket booster
SRM	solid rocket motor; Standard Reference Material
SRR	Systems Requirements Review
SSC	Stennis Space Center
SSEBop	Operational Simplified Surface Energy Balance
STEREO	Solar TErrestrial RElations Observatory
STIM	Space Transportation Infrastructure Matching Grants
STP	Space Test Program
Suomi NPP	Suomi National Polar-orbiting Partnership
SuperDARN	Super Dual Auroral Radar Network
SWIM	System Wide Information Management
SWORDS	Soldier-Warfighter Operationally Responsive Deployer for Space
SWR	Space Weather Research

T

TBFM	Time Based Flow Management
TCC	Tree Canopy Cover
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TES	transition-edge sensor
THEMIS	Time History of Events and Macroscale Interactions during Substorms
TIM	Total Irradiance Monitor
TIS-B	Traffic Information Service-Broadcast
TM	Thematic Mapper
TOW	Tube-Launched, Optically Tracked Wireless
TRACON	Terminal Radar Approach Control
TRL	technology readiness level
TSA	Transportation Security Administration
TWP	Tropical West Pacific

U

UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UCAR	University Corporation for Atmospheric Research
UCAS	Unmanned Combat Air System
UFO	UHF Follow-On
UHB	Ultra High Bypass
UHF	ultra high frequency
ULA	United Launch Alliance
ULS	United Launch Services
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
US&FCS	U.S. and Foreign Commercial Service
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
USML	United States Munitions List
USNDS	U.S. NuDet Detection System
USTDA	U.S. Trade and Development Agency

V

VIIP	Visual Impairment/Intracranial Pressure
VIIRS	Visible Infrared Imager Radiometer Suite
VOI	value of information

W

WAAS	Wide Area Augmentation System
WAI	Wide Area Imager
WAOB	World Agricultural Outlook Board
WCDMA	Wideband Code Division Multiple Access
WGS	Wideband Global SATCOM
WISE	Wide-Field Infrared Survey Explorer
WRP	Wetlands Reserve Program
WSPR	Waveform and Sonic Boom Perception and Response
WSR-88D	Weather Surveillance Radar 88 Doppler
WSTF	White Sands Test Facility

X

XRT	X-ray Telescope

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