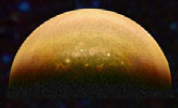
National Aeronautics and Space Administration



FY 2018
Volume of Integrated Performance

FY 2016 Annual Performance Report
FY 2017 Annual Performance Plan Update
FY 2018 Annual Performance Plan Proposal

www.nasa.gov

Introduction

The *NASA 2014 Strategic Plan* established a framework of long-term goals for all of the Agency's activities. The *2018 Volume of Integrated Performance*[1] builds upon the Strategic Plan framework. This document is a companion to NASA's FY 2018 President's Budget Request,[2] in accordance with the requirements of the *Government Performance and Results Act Modernization Act of 2010*.

The *2018 Volume of Integrated Performance* consolidates NASA's reports on prior year (FY 2016) performance with an updated performance plan for the current fiscal year (FY 2017), as well as a proposed performance plan for the requested budget fiscal year (FY 2018). Together, this holistic approach provides a retrospective and prospective view of NASA's performance, consistent with Office and Management and Budget guidelines. The document is organized into the following sections:

- Part 1—Performance Management at NASA summarizes how the Agency is organized, governed, and managed. It explains NASA as an organization and its approach to performance management, strategic planning, and performance reporting, and how the Agency uses data, evidence, evaluations, and reporting to manage performance. It concludes with a high-level summary of performance for FY 2016.
- Part 2—Performance Priorities and Management Challenges describes how NASA prioritizes select performance objectives, in response to both federal and internal Agency mandates. Examples include NASA's approach to the Strategic Review process, FY 2017–FY 2018 agency priority goals, and NASA's contributions to the FY 2014–FY 2017 cross-agency priority goals. It concludes by describing how NASA leverages internal reviews to address various management challenges and includes a discussion of NASA's response to the management challenges recently identified by NASA's Office of Inspector General (full response published in NASA's *FY 2016 Agency Financial Report*) and the Government Accountability Office's High Risk List.
- Part 3—Performance Reporting and Planning presents NASA's FY 2016 Annual Performance Report and FY 2017 updated and FY 2018 Annual Performance Plan by strategic goal and strategic objective. It shows up to six years of historical performance alongside two years of plans for future performance. This presentation provides a unique opportunity to see performance trends across multiple years within a program, as well as the linkages between multiyear performance goals and their annual components and how these performance measures in turn support the strategic objectives. Where NASA may not be on target to meet a performance goal, or did not achieve an annual performance indicator, a rating explanation or explanation of performance has been provided describing the corrective actions the Agency intends to take in the future. In addition, this section incorporates a summary of the annual Strategic Review by strategic objective and includes tables capturing total budget authority for each strategic objective.

[1] The *2018 Volume of Integrated Performance* is produced by NASA's Office of the Chief Financial Officer with contractor support provided by The Tauri Group and Deloitte Consulting LLP.

[2] The FY 2018 President's Budget Request (see the NASA FY 2018 Budget Estimates and related documents) can be found on NASA's Budget Documents, Strategic Plans and Performance Reports website.

- Part 4—Supporting Information comprises all of the supplemental information, including a list identifying the changes made to the updated FY 2017 Annual Performance Plan and captions and credits for the images used in Parts 1, 2, and 3.

The *2018 Volume of Integrated Performance* captures the full spectrum of NASA's activities to accomplish national priorities in civil aeronautics research, space exploration, science, and advanced research and development.

Table of Contents

Part 3: Performance Reporting and Planning

Part 4: Supporting Information

Part 1: Performance Management at NASA

Part 1 summarizes NASA as an organization and its approach to strategic planning, performance management, and performance reporting. It also explains how the Agency is organized, including the governance and management structure, and how it uses data, evaluations, and reporting to manage performance. Parts 2 and 3 describe NASA's performance priorities and management challenges, its reported performance for FY 2016, and its Annual Performance Plans for FY 2017 and FY 2018.

A Performance-Based Organization

NASA is a performance-based organization, as defined and described by the Office of Management and Budget's *Circular A-11*. A performance-based organization commits to manage towards specific, measurable goals derived from a defined mission, using performance data to continually improve operations. The concept of a performance-based organization was codified in the *Government Performance and Results Act (GPRA) of 1993* and updated in the *GPRA Modernization Act of 2010*. As a performance-based organization, NASA is dedicated to results-driven management focused on optimizing value to the American public. NASA sets concrete goals and holds itself accountable to those goals through a transparent framework that guides how it measures progress.

NASA Vision and Mission

NASA's Vision and Mission are defined collaboratively through internal and external stakeholder input. NASA last revised its Vision and Mission statements in the *NASA 2014 Strategic Plan*.

NASA's Vision is:

> We reach for new heights and reveal the unknown for the benefit of humankind.

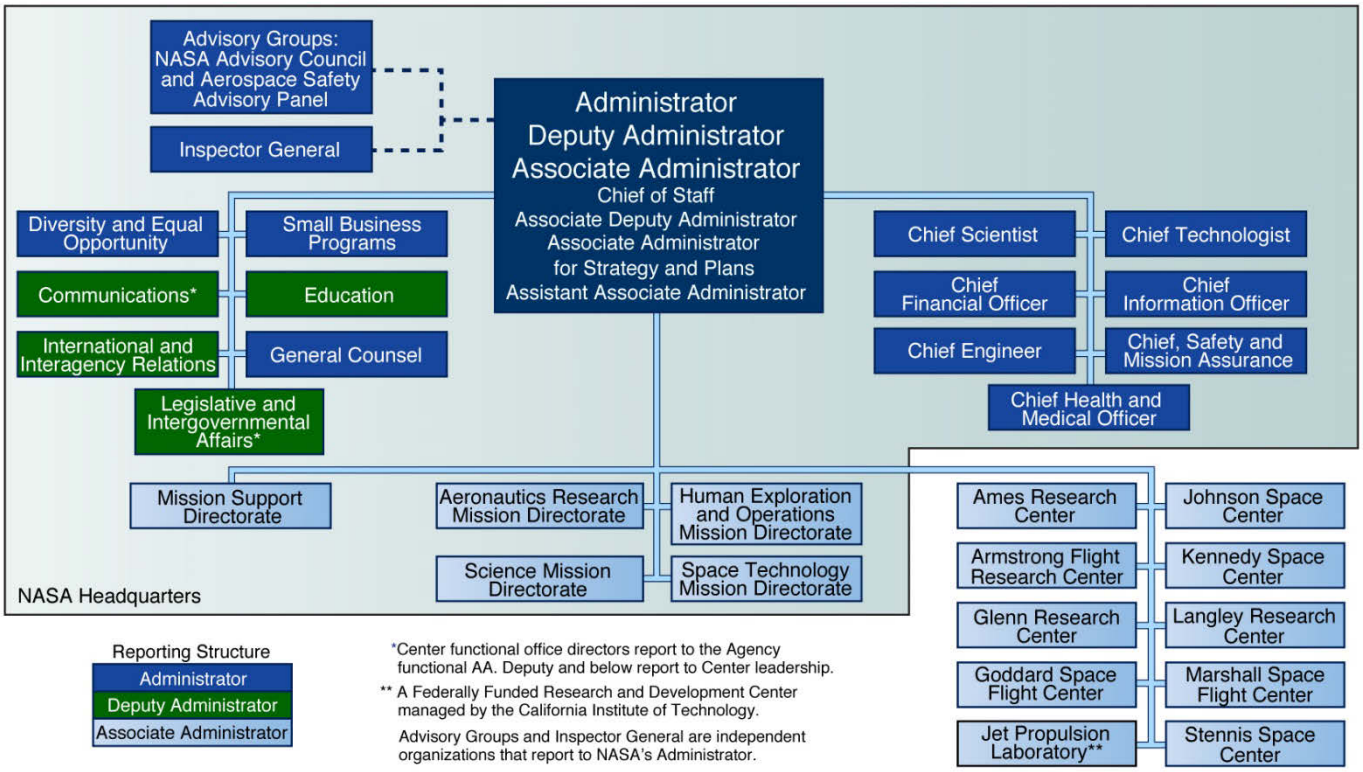
NASA's Mission is to:

> Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

Organizational Structure

NASA's organizational structure is designed to accomplish its Mission through sound business, management, and safety oversight. Under the leadership of the Administrator, NASA offices at Headquarters in Washington, DC, guide and direct the Agency. The Office of the Administrator provides top-level strategy and direction for the Agency. The Administrator and his staff give programmatic direction for NASA's missions and guide the operations of the Centers. NASA's Centers and facilities execute the mission work—engineering, operations, science, and technology development—and supporting activities. Figure 1 depicts NASA's organizational structure, current as of April 2017.

Figure 1: NASA's Organization



The *NASA Organization* (NASA Policy Directive 1000.3E) establishes components that have budget oversight and performance management responsibilities for distinct portfolios that support NASA's Mission. These components include mission support offices, the Administrator's staff offices, and NASA's Office of Inspector General, as described below.

- The **Science Mission Directorate (SMD)** carries out scientific exploration to expand the frontiers of Earth science, heliophysics, planetary science, and astrophysics. Through a variety of robotic observatory and explorer craft and through sponsored research, the directorate provides virtual human access to the farthest reaches of space and time, as well as practical information about changes on Earth.
- The **Aeronautics Research Mission Directorate (ARMD)** conducts cutting-edge research that generates innovative concepts, tools, and technologies to transfer to the aviation community for further development. Every U.S. commercial aircraft and U.S. air traffic control tower has NASA-developed technology in use. ARMD is committed to transforming aviation by dramatically reducing its environmental impact, improving efficiency while maintaining safety in more crowded skies, and paving the way to revolutionary aircraft shapes and propulsion.
- The **Space Technology Mission Directorate (STMD)** rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise. This organization employs a merit-based competition model with a portfolio approach spanning a range of discipline areas and technology readiness levels to advance technologies for the benefit of the aerospace industry, NASA, and other government agencies, and to address national needs. To conduct research and technology development, STMD works with NASA's Centers, academia, and industry, and leverages partnerships with other government agencies and international partners. STMD invests in bold, broadly applicable, transformational technologies that have high potential for offsetting mission risk, reducing cost, and advancing existing capabilities, thereby executing more challenging missions and capabilities for NASA and the Nation. STMD engages and

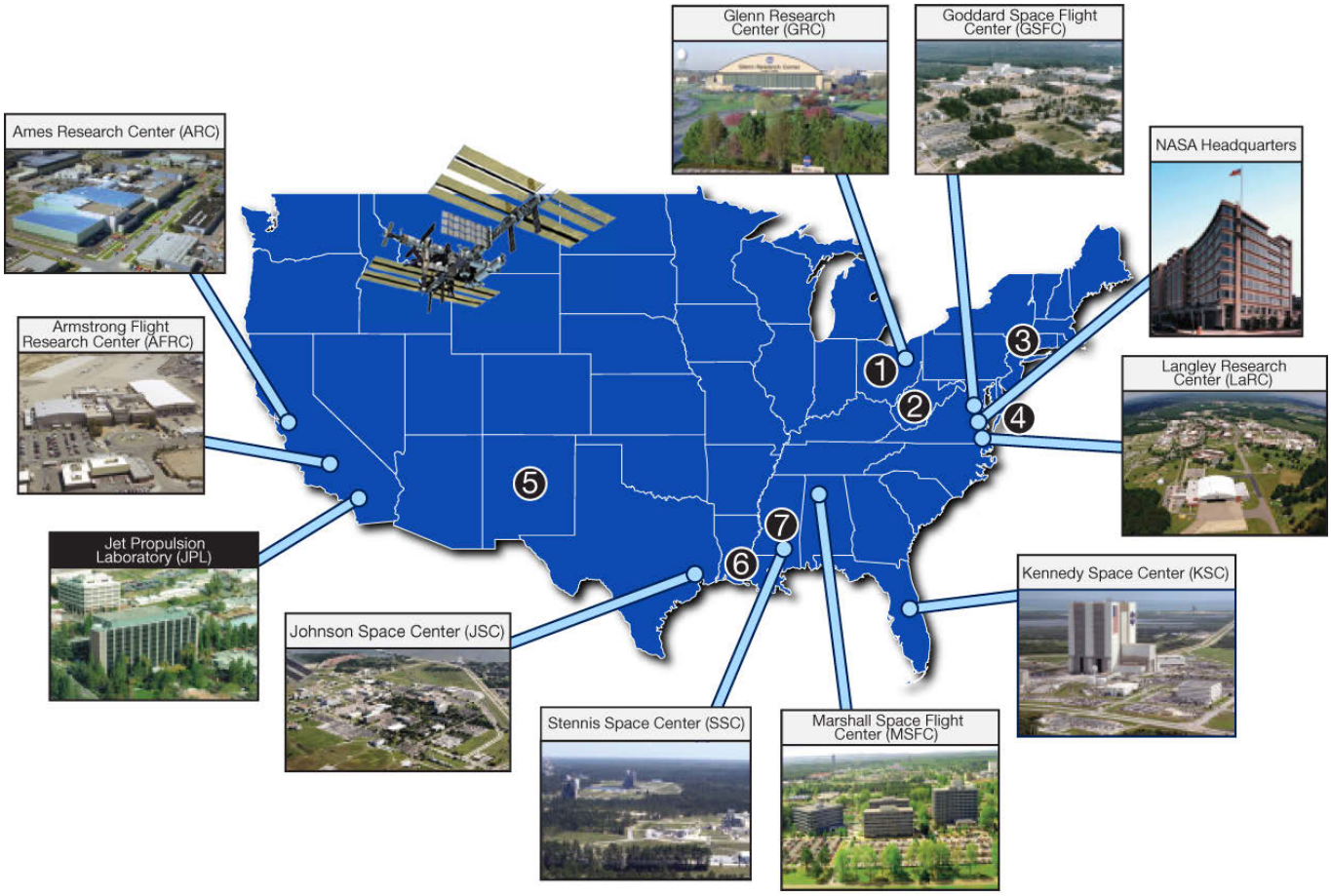
inspires thousands of technologists and innovators, creating a community of NASA's best and brightest working on the Nation's toughest challenges.

- The **Human Exploration and Operations Mission Directorate (HEOMD)** is responsible for NASA space operations in and beyond low Earth orbit, developing new exploration and transportation systems, and performing scientific research to enable sustained and affordable human exploration. HEOMD manages Launch Services and Space Communications and Navigation for the Agency, and works with the Mission Support Directorate to develop supporting capabilities to ensure the availability of appropriate Rocket Propulsion Test capabilities that support human and robotic exploration requirements.
- The **Mission Support Directorate (MSD)** provides effective and efficient institutional support to enable the Agency to successfully accomplish its missions. It focuses on reducing institutional risk to NASA's current and future missions by improving processes, stimulating efficiency, and providing consistency and uniformity across institutional capabilities and services.
- The **Office of Education (Education)** provides Agency leadership and programmatic oversight for NASA's external educational programs. Education has the responsibility to leverage NASA's unique mission content, facilities, and workforce. Education is a crosscutting process that engages the public in shaping and sharing the experience of exploration and discovery. The Office of Education is proposed for elimination in the FY 2018 President's Budget Request.
- The **Administrator's Staff Offices** support the Administrator's responsibilities by providing a range of high-level guidance and support in critical areas like safety and mission assurance, technology planning, equal opportunity, information technology, financial administration, small business administration, international relations, and legislative and intergovernmental affairs.
- The **Office of Inspector General (OIG)** is an independent and objective unit, created by Public Law 95-452, the Inspector General Act. The OIG conducts independent and objective audits and investigations and other evaluations of Agency programs and operations; promotes economy, effectiveness, and efficiency within the Agency; prevents and detects crimes, fraud, waste, and abuse; reviews and makes recommendations regarding existing and proposed legislation and regulations; and keeps the NASA Administrator and Congress fully and currently informed of problems in Agency programs and operations.

NASA's workforce transforms NASA's Mission into reality. NASA employs about 17,300[3] civil servants at Headquarters in Washington, DC, its Centers, and other facilities across the country. NASA staffs each location with a contractor workforce for technical and business operations support. Figure 2 shows the distribution of NASA's Centers and major facilities. NASA also has many other facilities throughout the country and around the world.

[3] This number includes civil servants on duty and extended leave at the beginning of FY 2017.

Figure 2: NASA Centers and Facilities Nationwide



Select NASA Facilities
(noted by numbers on map)

1) Plum Brook Station, Sandusky, OH, managed by GRC
2) Software Independent Verification and Validation Facility, Fairmont, WV, managed by GSFC
3) Goddard Institute for Space Studies, New York, NY, managed by GSFC
4) Wallops Flight Facility, Wallops, VA, managed by GSFC
5) White Sands Test Facility and Space Network, White Sands, NM, managed by JSC
6) Michoud Assembly Facility, New Orleans, LA, managed by MSFC
7) NASA Shared Services Center, Stennis Space Center, MS, managed by SSC

Note: JPL is a Federally Funded Research and Development Center in Pasadena, California. The California Institute of Technology manages JPL.

Governance and Strategic Management

NASA is dedicated to results-driven management, is focused on optimizing value to the American public, and has been acknowledged as a federal leader of performance-based leadership. To achieve mission success, NASA emphasizes continuous collaboration between its Centers, facilities, and Headquarters. NASA organizes its management processes within multiple levels of reviews, business processes, and governance councils. Additional information on NASA's governance and strategic management can be found in NASA's *Governance and Strategic Management Handbook* (NASA Policy Directive 1000.0B).

Governance and Performance Leadership

NASA governs with three Agency-level councils. Each council has a distinct charter and responsibility. The Executive Council (EC) focuses on major Agency-wide decisions and provides strategic guidance and top-level planning. The Mission Support Council (MSC) is a functional council, focused on mission-enabling decisions. The Program Management Council (PMC) is an integral part of NASA's program and mission decisions, with emphasis on managing performance as programs reach Key Decision Points.

In addition to the governing councils, NASA has a Senior Management Council (SMC), which is a body of NASA senior leadership that provides advice and counsel to the Executive Council on key issues of the Agency and provides input on the formulation of Agency strategy.

The GPRA Modernization Act requires all agencies to designate a Chief Operating Officer (COO) and a Performance Improvement Officer (PIO) for managing Agency performance. The Administrator appoints the COO and PIO. Currently, NASA's Associate Administrator serves as the COO and the Director of the Strategic Investments Division serves as the PIO. They set goals; assure timely, actionable performance information is available to decision-makers at all levels of the organization; and conduct frequent data-driven reviews that guide decisions and actions to improve performance outcomes and reduce costs.

NASA leadership receives performance information from a variety of sources, including the Baseline Performance Review, the Strategic Reviews, and executive reviews. Each month, NASA conducts an internal assessment and reporting forum, the Baseline Performance Review, which tracks performance against Agency plans. The Baseline Performance Review, led by the COO, is a bottom-up review of how well the Agency has performed against its strategic goals and other performance metrics, such as cost, schedule, contract, and technical commitments. NASA annually reviews progress towards strategic objectives by assessing the impact of strategies and the implementation of key activities, including multiyear performance goals, annual performance indicators, agency priority goals, and cross-agency priority goals. NASA also identifies mission challenges, risks, and opportunities using a variety of evidence, evaluations, studies, and analysis.

Enterprise Risk Management

OMB Circular No. A-123, "Management's Responsibility for Enterprise Risk Management and Internal Control," as well as Circular No. A-11, require federal agencies to implement enterprise risk management (ERM). Per OMB, ERM will provide an enterprise-wide, strategically-aligned portfolio view of organizational risks, challenges, and opportunities. ERM will provide better insight about how to most effectively prioritize and manage risks to mission delivery. NASA's governing councils serve as the agency's risk management platform and the COO serves as the Accountable Official for risk management.

While NASA cannot mitigate all risks related to achieving its strategic goals and objectives, the organization is implementing ERM to identify, measure, and assess challenges related to mission delivery, to the extent possible. ERM is integrated with the Strategic Review process, providing an analysis of the risks and opportunities NASA faces towards achieving its strategic objectives.

Performance Framework

Figure 3 depicts the strategic plan performance framework, consisting of strategic goals and strategic objectives from the *NASA 2014 Strategic Plan*. (See Figure 4 for a complete list of NASA's strategic goals and strategic objectives.) In its Annual Performance Plan, NASA sets both its short-term performance goals, which are targets within the four-year span of the Strategic Plan, and its annual performance indicators, which are designed to show progress achieved during the budget year. The Annual Performance Plan measures and communicates NASA's

progress towards achieving its Vision and Mission. Agency priority goals and cross-agency priority goals are a subset of performance goals that receive additional senior management focus. These are described in further detail in "Part 2: Performance Priorities and Management Challenges."

Figure 3: 2014 Strategic Plan Performance Framework

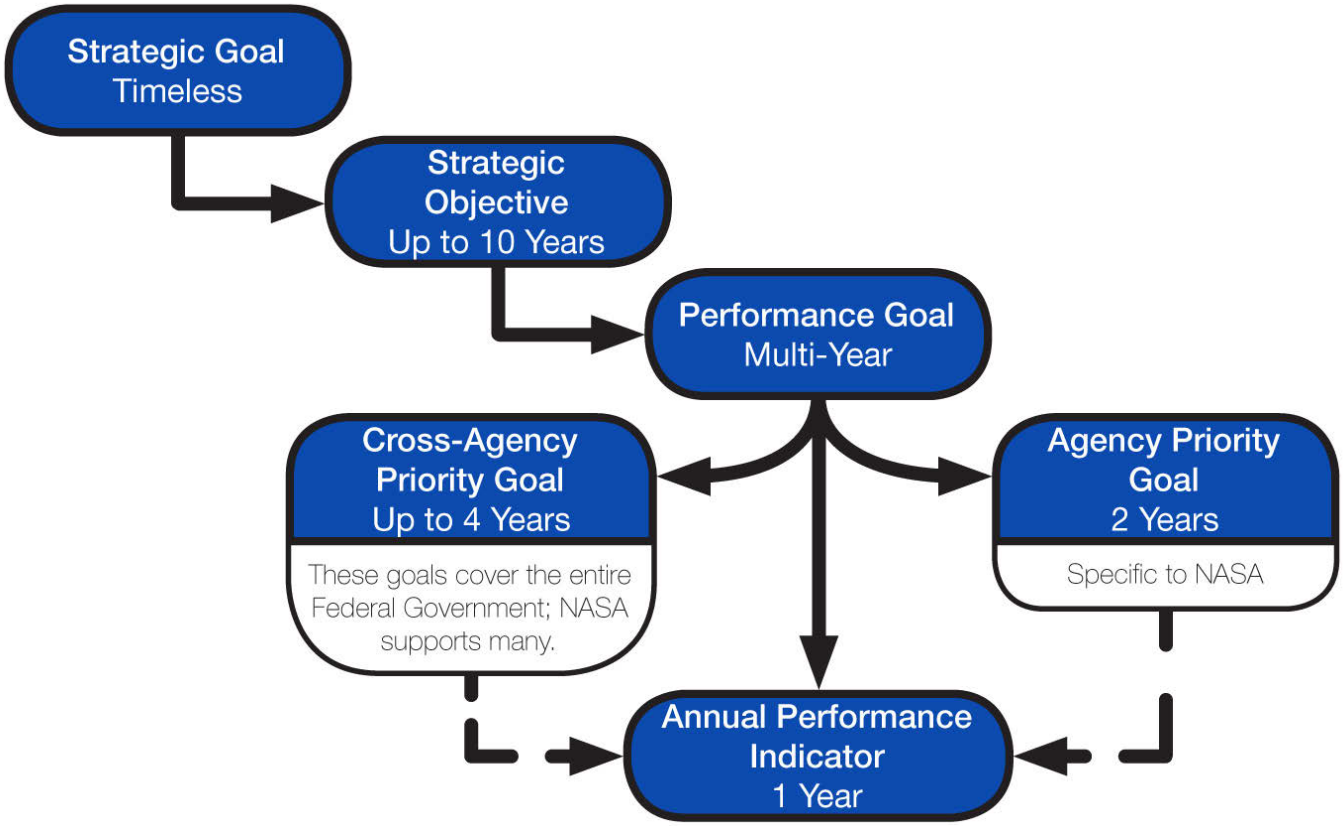
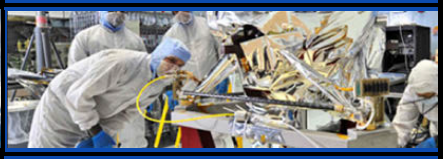


Figure 4: NASA's Strategic Goals and Strategic Objectives

Strategic Goal 1	Strategic Goal 2	Strategic Goal 3
		
Expand the frontiers of knowledge, capability, and opportunity in space.	**Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.**	**Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.**
By empowering the NASA community to…	By engaging our workforce and partners to…	By working together to…
Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration. **Objective 1.2:** Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity. **Objective 1.3:** Facilitate and utilize U.S. commercial capabilities to deliver cargo and crew to space. **Objective 1.4:** Understand the Sun and its interactions with Earth and the solar system, including space weather. **Objective 1.5:** Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere. **Objective 1.6:** Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars. **Objective 1.7:** Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies.	**Objective 2.1:** Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research. **Objective 2.2:** Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet. **Objective 2.3:** Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit. **Objective 2.4:** Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.	**Objective 3.1:** Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions. **Objective 3.2:** Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's Mission. **Objective 3.3:** Provide secure, effective, and affordable information technologies and services that enable NASA's Mission. **Objective 3.4:** Ensure effective management of NASA programs and operations to complete the mission safely and successfully.

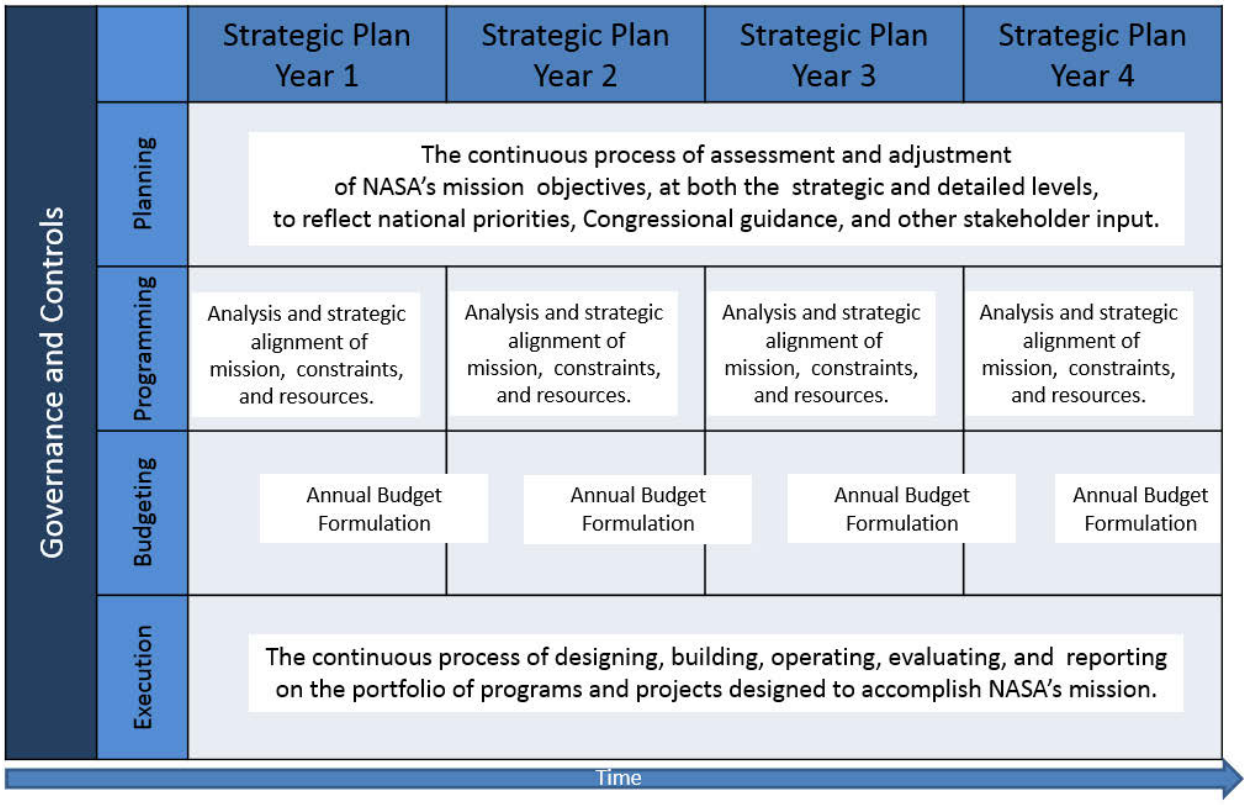
Performance Management

NASA has a culture of data-driven performance management. The Agency continually improves its performance management system to increase accountability, transparency, and oversight. This leads to more consistent performance reporting across NASA's missions and ensures the optimal use of the resources entrusted to the Agency by its stakeholders.

Performance Planning and Evaluation

NASA evaluates its performance in a continuous cycle (Figure 5) that spans fiscal years. Each year, NASA sets its multiyear and annual goals—the performance goals and annual performance indicators—in the Agency's Annual Performance Plan. NASA develops its Annual Performance Plan in conjunction with the upcoming fiscal year budget request. To ensure the integration of performance and budget information, both documents are organized around similar mission areas and themes. NASA releases its Annual Performance Plan to the public on the same date as the President's Budget Request.

Figure 5: Planning, Programming, Budgeting, and Execution Cycle



During the development of NASA's upcoming Annual Performance Plan, the Agency is also assessing its performance for the current fiscal year (also known as the execution fiscal year). Once NASA organizations begin executing against the commitments in the Strategic Plan and Annual Performance Plan, Agency managers and performance analysts monitor and evaluate performance. NASA assesses the Agency's progress toward achieving its strategic objectives, performance goals, and annual performance indicators. NASA also evaluates the efficacy of its execution fiscal year measures, as well as planned measures for the upcoming fiscal year. The Annual Performance Plan Update reflects any measure revisions, additions, or deletions resulting from these evaluations or due to strategic, budgetary, or programmatic changes that have occurred during budget execution.

The Agency monitors and evaluates performance toward its plans and commitments using ongoing, periodic, and one-time assessments, through which managers identify issues, gauge programmatic and organizational health, and provide appropriate data and evidence to NASA decision-makers. Assessments include the following:

- Ongoing monthly and quarterly analyses and reviews of Agency activities;
- Annual program and project assessments in support of budget formulation;
- Annual reporting of performance, management issues, and financial position;
- Annual Strategic Reviews of each strategic objective;
- Periodic, in-depth program or special purpose assessments; and
- Recurring or special assessment reports to internal and external organizations.

Performance Assessments

During the third and fourth quarters of each fiscal year, program officials submit to NASA management a self-evaluation, which includes a rating for each performance goal and annual performance indicator and the supporting information that justifies the rating. The results of the performance assessments are presented to NASA's COO and PIO, which keeps them informed of NASA's performance progress, allows them to make course corrections throughout the year to maintain alignment with the strategic goals and objectives, and helps inform budget discussions.

NASA publishes its preliminary, summary performance ratings in the Agency Financial Report. The COO and PIO review and approve the performance ratings before they are published in the Agency Financial Report. NASA publishes its detailed, final performance assessments in the Annual Performance Report, which includes the ratings (including any changes made after the publication of the Agency Financial Report), rating explanations, and performance improvement plans, where necessary.

Using Evidence, Evaluation, and Research to Set Strategies and Measure Progress

Given the constrained fiscal environment and the need to ensure that taxpayer resources are expended appropriately, NASA must ensure that its programs and activities are managed and operated effectively and efficiently. To that end, the Agency uses laws, executive orders, governance, and management best practices to promote a strong culture of results and accountability. This is done through a dynamic, dialog-driven process of collecting evidence (data, research, or end product) and conducting rigorous independent evaluations, both internal and external to NASA, of that evidence. In many cases, these evaluations assess progress against a pre-determined set of indicators or other targets so that deviations can easily be identified and addressed.

NASA uses several different types of metrics to assess performance, given the goals of a specific program or project. For example, progress towards key milestones can be an effective way to determine whether a flight project is on track. Verification and validation of data supports strategic planning and determines the general accuracy and reliability of performance information. These processes provide a level of confidence to stakeholders that the information the Agency provides is credible.

Internal Reviews

Program and Project Technical Reviews

NASA monitors and assesses the engineering process of designing, building, and operating spacecraft and other major assets. Performance metrics for such investments focus, in part, on comparisons of actual versus planned

schedule and cost, which can be assessed on a monthly basis using tools such as Earned Value Management. As detailed in *NASA Space Flight Program and Project Management Requirements* (NASA Procedural Requirements 7120.5E) and *NASA Research and Technology Program and Project Management Requirements* (NASA Procedural Requirements 7120.8), the Agency holds formal internal independent assessments as programs and projects progress through a series of gatekeeping Key Decision Points. Such Key Decision Points provide managers time to review all aspects of technical progress and project performance in order to promote thoughtful work on a project or to delay or terminate work if needed. The Key Decision Point reviews focus on the program or project's assessment of status, as well as that of the Standing Review Board or Center independent review team, and multiple organizations have the opportunity to weigh in on the information that is presented. Key Decision Points may be scheduled at any time of the year, in accordance with the lifecycle schedule, depending on the formulation, development, or construction plan. NASA conducts additional technical reviews between the Key Decision Points to assess progress and continually monitors overall performance through the Baseline Performance Review. Project performance is independently assessed on a monthly basis and is reported quarterly at the Baseline Performance Review.

Technology Readiness Levels

NASA assesses technology development programs against incremental milestones (technology readiness levels). It regularly measures the technology readiness level advancement of an individual technology investment, with overall technology portfolio assessments occurring each year.

Operations and Mission Support Assessments

The Agency's operational, or support- and service-type, programs generally assess progress on meeting their specific objectives against targets for output or capacity of the activity, quantifiable estimates of improvement with aggressive targets (e.g., reducing operating costs by two percent in two years), customer satisfaction, or routine on-site assessments. These assessments are often done annually.

External Reviews and Assessments

NASA Science Advisory Committee Strategic Reviews

NASA's research programs often have broad objectives, such as "understand how the universe works." To measure the performance of these types of investments, NASA establishes and measures performance against smaller, achievable goals to help demonstrate impact and overall contribution to the knowledge on the subject. It conducts assessments on these programs yearly, and it captures lessons learned as part of an annual strategic process. These assessments are done in coordination with the Science Advisory Committees.

NASA's Aeronautics Research Mission Directorate enlists experts in the aeronautics community to assess progress along six major research thrusts to ensure that NASA is developing and maturing the technologies and capabilities according to the blueprint. See the *NASA Aeronautics Strategic Implementation Plan* for more information.

Peer and Subject Community Review

NASA relies on evaluations by the external community. Papers from NASA-supported research undergo independent peer review for publication in professional journals. The Agency uses external peer review panels to objectively assess and evaluate proposals for new work in its science areas, technology development, and education. NASA often leverages internal and external evaluators to assess strategies, impact, implementation, efficiency and effectiveness, cost-to-benefit ratio, and relevance of work being performed. NASA relies on senior

reviews by external scientists for advice on the most productive use of funding for science missions that have completed their primary missions and have entered extended operations.

The National Academies of Sciences, Engineering, and Medicine

A series of decadal surveys and other analyses, conducted by the National Academies, help inform decisions about the Science Mission Directorate's investment portfolio and other aspects of NASA's research and development efforts. These external evaluations of user needs and requirements, in combination with performance assessments of ongoing activities, help ensure that NASA's research priorities and investments stay current with the needs of the research community. The Space Technology Roadmaps are a similar planning tool, reflecting the research and development and technology needs of NASA, the government, and industry.

Verification and Validation of Performance Information

During the development of the Annual Performance Plan, NASA's mission directorates and mission support offices provide detailed information for each of their performance goals and annual performance indicators, including the frequency of data collection, any data limitations, and known internal or external performance challenges. In addition, program officials provide a brief description of the internal procedures that they will use to determine the end-of-year rating, including the identification of any NASA governance bodies involved in assigning the rating, and list the materials that they will use at the end of the year to verify and validate their performance.

Each year, NASA follows a systematic process to validate its annual performance indicators during the preparation of the Annual Performance Plan. NASA uses an "alternative form," or milestone-based, approach to its performance reporting. In practice, this means that the majority of NASA's annual performance indicators are unique to each fiscal year. During the development of the Annual Performance Plan, program officials submit rationales for inclusion for each of their proposed annual performance indicators, which provide background and explain why a particular indicator is critical to NASA.

Following the end of each fiscal year, NASA selects a subset of its annual performance indicators for verification. The assessment is conducted independently by the NASA Office of the Chief Financial Officer, not by the mission directorate or mission support office with reporting responsibility for the annual performance indicator. NASA uses the results of these assessments to improve the quality of its data reporting, and to inform the development of its Annual Performance Plan during the following year.

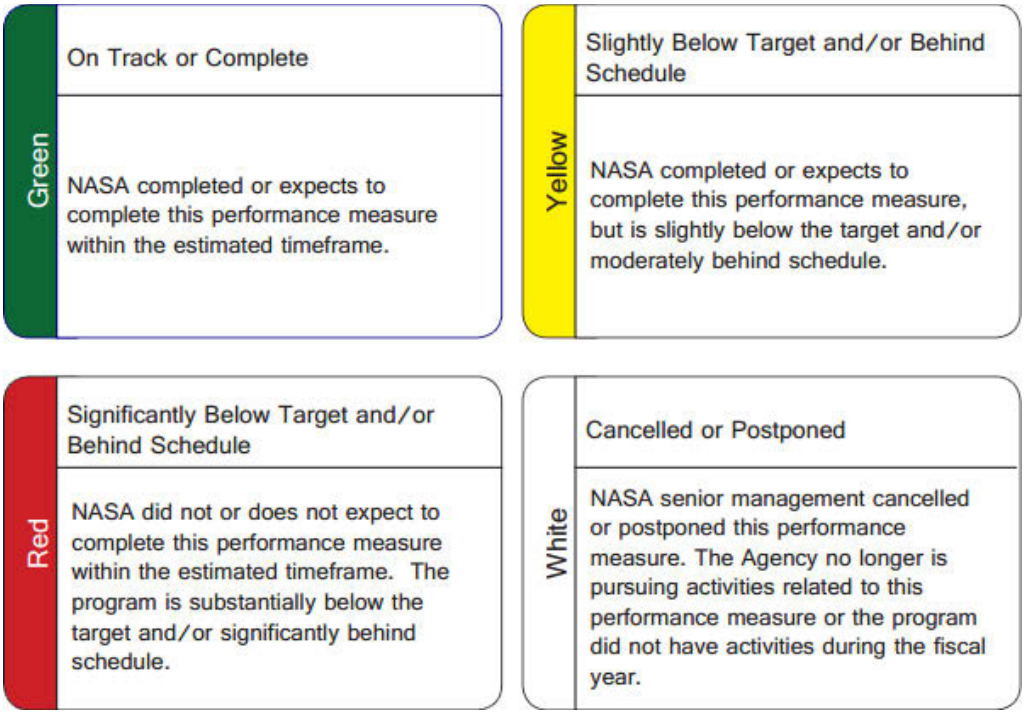
Summary of Performance

NASA evaluates progress towards achieving its performance measures on a traffic light rating system (i.e., the green, yellow, and red color ratings). In collaboration with NASA management, program officials define their own parameters for the success criteria during the development of their performance measures. NASA uses these success criteria, combined with explanations of the ratings and sources provided by the program officials, to review and validate each rating, as described in the "Performance Management" section. NASA bases many of the performance ratings on internal assessments. External entities, such as science review committees and aeronautics technical evaluation bodies, validate select ratings prior to publication by NASA.

On occasion, NASA will assign a white rating to a performance measure that cannot be assessed against its success criteria. White ratings are reserved for performance measures that are cancelled or postponed. Program officials do not develop measure-specific success criteria for white ratings. Only senior management can assign white ratings.

While the success criteria are specific to each performance measure, Figure 6 provides high-level examples of the types of criteria that may be used to determine performance measure ratings. The generic success criteria in the figure are illustrative of the types of individualized criteria assigned to each performance measure and broadly apply to the performance measures.

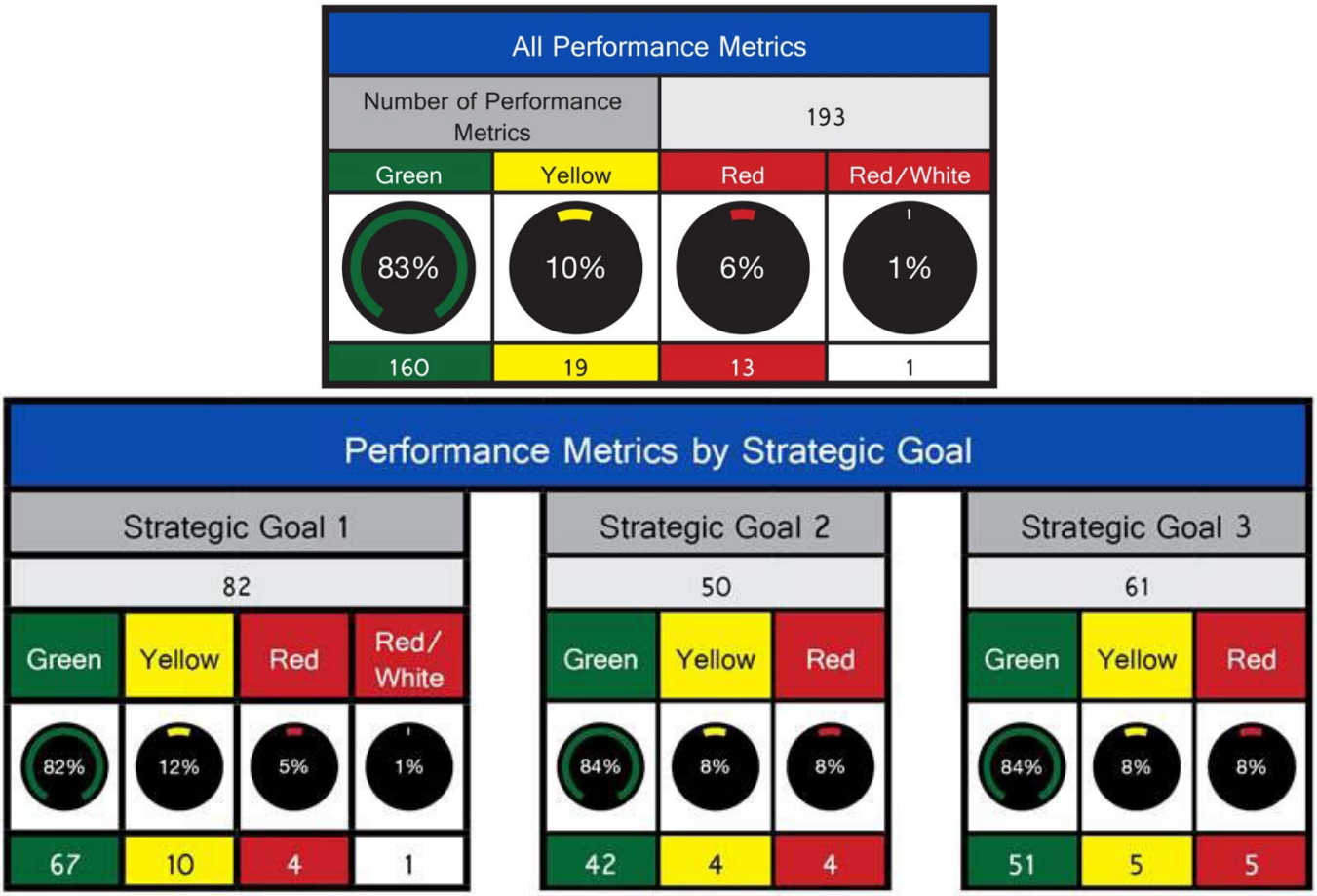
Figure 6: Generic Performance Goal and Annual Performance Indicator Success Criteria[4]



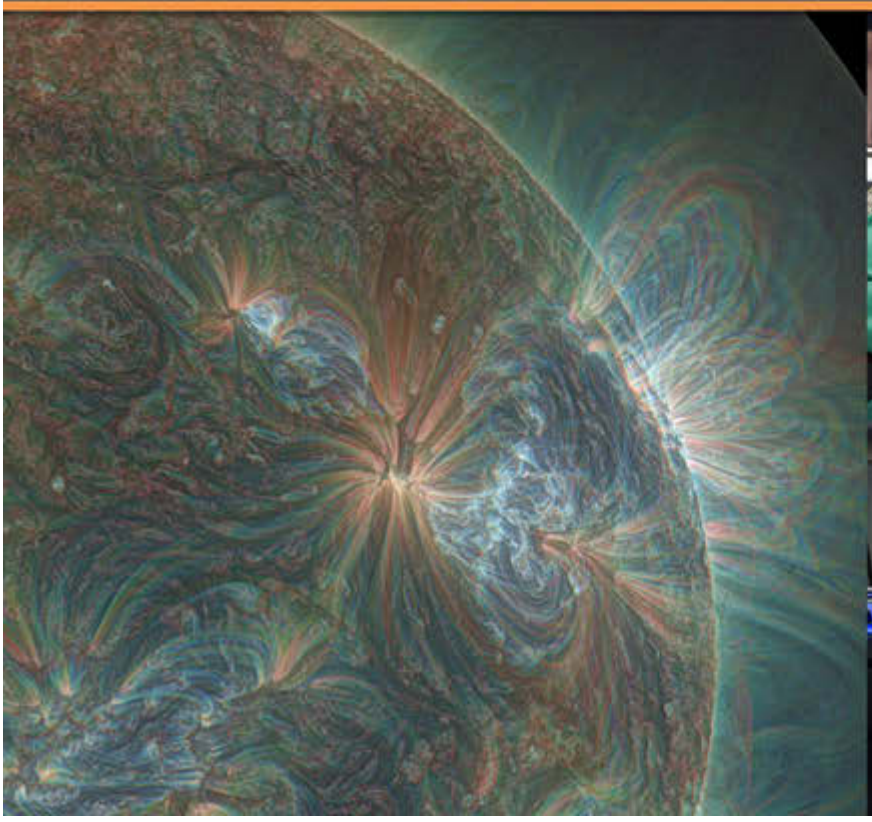
The summary of NASA's assessment of progress for the Agency as a whole and by strategic goal is provided in Figure 7. Additional information regarding the strategic objectives, performance goals, and annual performance indicators, including explanations for those rated yellow or red, is available in "Part 3: Performance Reporting and Planning."

[4] These are generic criteria provided for informational purposes only. NASA develops measure-specific criteria to rate all of the Agency's performance goals and annual performance indicators.

Figure 7: Summary of FY 2016 Ratings Across All Metrics



Part 2: Performance Priorities and Management Challenges



Strategic Reviews

All major federal agencies are required to perform Strategic Reviews. Congress provides direction for these reviews through the *Government Performance and Results Act (GPRA) Modernization Act of 2010* and the Office of Management and Budget provides implementation guidance. The Strategic Reviews are an annual assessment of each strategic objective, with an analysis of an agency's progress toward its strategic direction. This report contains the results of NASA's third Strategic Review, conducted in spring 2016.

Process

Per the *NASA 2014 Strategic Plan*, NASA has 3 strategic goals and 15 strategic objectives. Each strategic objective leader conducts a self-assessment of the impact (looking at the long-term outlook) and implementation (given near-term plans and performance) for their strategic objective. They also identify risks, challenges, and opportunities. Based on this self-assessment, the strategic objective leader provides a rating for the strategic objective: noteworthy progress, demonstrating satisfactory performance, or being a focus area for improvement.

NASA's Performance Improvement Officer and staff perform a crosscutting assessment to identify common themes and issues. The Performance Improvement Officer's crosscutting assessment also analyzes each strategic objective, validates self-assessment inputs, and performs a relative characterization across all 15 strategic objectives. Based on this assessment, the Performance Improvement Officer recommends an independent rating to NASA's Chief Operating Officer for each strategic objective. Both the self-assessment and the crosscutting assessment use a variety of sources of evidence and inputs.

Results and Impacts

For the 2016 Strategic Review, the Chief Operating Officer reviewed the summary of the self-assessments and the crosscutting assessment at the end of April 2016 and decided on final ratings for the strategic objectives and next steps for NASA. As a result of the 2016 Strategic Review, NASA determined that 8 out of 15 strategic objectives demonstrated satisfactory performance. Five strategic objectives are considered as making noteworthy progress, and two strategic objectives are focus areas for improvement. These ratings represent NASA's assessment of performance and expectations for future outcomes as of May 2016. Full details, including these ratings, progress updates, and next steps, are provided in "Part 3: Performance Reporting and Planning." NASA uses Strategic Review inputs, findings, and results throughout the Agency's budget process and as an input to the annual performance planning process.

Agency Priority Goals

In accordance with the GPRA Modernization Act, NASA identified four agency priority goals for the FY 2016-FY 2017 reporting cycle that will benefit the United States in the areas of human spaceflight, space operations,

and astrophysics (see Figure 8). The agency priority goals do not provide a comprehensive picture of every high-profile activity within NASA, but they do represent several key projects.

Figure 8: NASA's FY 2016-FY 2017 Agency Priority Goals

Goal Statement	Responsible Organization
Achieve critical milestones in development of new systems for the human exploration of deep space. By September 30, 2017, NASA will have begun integration and testing of the Exploration Mission (EM)-1 Orion Crew Module (CM), including the first power-on of the vehicle; delivered all four EM-1 Space Launch System (SLS) Core Stage RS-25 engines to the Michoud Assembly Facility in preparation for integration into the Core Stage; and completed construction of Exploration Ground Systems (EGS) Pad B.	Human Exploration and Operations Mission Directorate, Exploration Systems Development
Increase the occupancy of the International Space Station's (ISS's) internal and external research facilities by adding new instruments and capabilities. By September 30, 2017, NASA will increase the occupancy of the ISS internal and external research facility sites with science and technology payload hardware to 75 percent.	Human Exploration and Operations Mission Directorate, International Space Station Program
Facilitate the development of and certify U.S. industry-based crew transportation systems while maintaining competition, returning International Space Station crew transportation to the United States. By September 30, 2017, the Commercial Crew Program (CCP), along with its industry partners, will make measurable technical and programmatic progress toward the certification of commercial crew transportation systems, including the completion of at least one Design Certification Review.	Human Exploration and Operations Mission Directorate, Commercial Crew Program
Revolutionize humankind's understanding of the Cosmos and humanity's place in it. By October 2018, NASA will launch the James Webb Space Telescope (Webb). To enable this launch date, NASA will complete the testing of the Webb Optical Telescope Element plus Integrated Science Instrument Module by September 30, 2017.	Science Mission Directorate, James Webb Space Telescope Program

Results and Impacts

More detailed information on each of NASA's agency priority goals, including overviews and contributing programs, is available at http://performance.gov.

Cross-Agency Priority Goals

Cross-agency priority (CAP) goals focus on major issues that require active collaboration between multiple federal agencies to implement and are intended to accelerate progress on a limited number of presidential priority areas. The Office of Management and Budget selected 16 CAP goals to cover the FY 2014-FY 2017 reporting period.

Per the GPRA Modernization Act requirement to address CAP goals in the Agency Strategic Plan, the Annual Performance Plan, and the Annual Performance Report, please refer to http://www.performance.gov for the Agency's contributions to those goals and progress, where applicable. NASA currently contributes to the CAP goals noted in Figure 9. The figure includes links to the individual CAP goal pages on performance.gov, each of which provides an overview, progress update, and, where appropriate, other supporting information for the goal.

To ensure effective leadership and accountability across the Federal Government, each CAP goal has a named senior leader both within the Executive Office of the President and within one or more of the key delivery agencies. NASA is not a goal leader for any of the FY 2014-FY 2017 CAP goals, but does contribute to the 11 CAP goals noted below.

Figure 9: Cross-Agency Priority Goals Supported by NASA, FY 2014-FY 2017

Cross-Agency Priority Goal	Overview, Progress Update, and Supporting Information
Cybersecurity	https://www.performance.gov/content/cybersecurity?view=public
Climate Change (Federal Actions)	https://www.performance.gov/content/climate-change-federal-actions?view=public
Science, Technology, Engineering, and Mathematics (STEM) Education	https://www.performance.gov/content/stem-education?view=public
Category Management	https://www.performance.gov/content/category-management?view=public
Smarter IT Delivery	https://www.performance.gov/content/smarter-it-delivery?view=public
Shared Services	https://www.performance.gov/content/shared-services?view=public
Benchmark and Improve Mission-Support Operations	https://www.performance.gov/node/3397/view?view=public
Open Data	https://www.performance.gov/content/open-data?view=public
Lab-To-Market	https://www.performance.gov/content/lab-market?view=public
People and Culture	https://www.performance.gov/content/people-and-culture?view=public
Freedom of Information Act (FOIA)	https://www.performance.gov/node/123814/view?view=public

As part of the CAP goal requirements, agencies complete internal, data-driven reviews of their progress in implementing each of the goals. To meet this requirement, NASA leverages its Baseline Performance Review, which is described in more detail in "Part 1: Performance Management at NASA." The Baseline Performance Review is a monthly forum for the program offices and mission-support offices to report on their performance results to NASA leadership. The meetings are data-driven and ensure that performance information is communicated regularly across the Agency. During its highlighted Baseline Performance Review month, the responsible organization for each CAP goal within NASA reports on its progress towards the goal to the Chief Operating Officer, Performance Improvement Officer, and other senior NASA leadership.

Management Challenges

NASA leverages its internal reviews to identify management challenges, but also looks to external opinions for guidance. NASA's Office of Inspector General (OIG) provides an annual list of the top management and performance challenges. Every year, the Government Accountability Office (GAO) performs numerous audits of

NASA's activities. GAO's High Risk List, which is updated every two years, specifically addresses management challenges across the government and has called out NASA acquisition management as a long-standing issue.

A summary of the challenge areas identified by OIG and the GAO in their most recent assessments is provided in Figure 10. NASA has identified those strategic objectives that are related to the challenge and has provided a connection to the relevant content in Part 3 of this report that allows insight into the leadership responsible for addressing the challenge area and the relevant performance planning information used to gauge progress within the portfolio. More detailed information on specific steps taken in response to OIG and the GAO is also provided in this section.

Figure 10: Management Challenges Identified by OIG and the GAO

Challenge Area (Source)	External Assessment of Challenge (excerpted from report)	Relevant Strategic Objective(s)
Positioning NASA for Deep Space Exploration (OIG)	NASA's long-term objective for its human exploration program is a crewed mission to Mars. To meet this challenging goal, the Agency must develop more sophisticated rockets, capsules, and related hardware, as well as strategies to mitigate risks posed by radiation and other space-induced hazards that could prevent astronauts from performing their missions or affect their mental and physical health. Successful development of the Space Launch System (SLS), the Orion Multi-Purpose Crew Vehicle (Orion), and launch infrastructure under development by the Agency's Ground Systems Development and Operations (GSDO) Program are among the projects critical to achieving NASA's human exploration goals beyond low Earth orbit.	1.1
Managing the International Space Station and the Commercial Cargo and Crew Programs (OIG)	In November 2015, NASA formally extended the life of the ISS through 2024, ensuring this unique facility, which has operated in low Earth orbit for more than 15 years, remains available to support research into the development of new exploration technologies and ways to mitigate the dangers posed by deep space travel. A critical component of sustaining the ISS is ensuring safe and reliable transportation of cargo and crew to and from the Station.	1.2, 1.3
Managing NASA's Science Portfolio (OIG)	With a relatively constant annual budget averaging approximately $5 billion since FY 2009, NASA's Science Mission Directorate (SMD) oversees more than 100 projects and programs in various phases of development and operation. The selection and balance of NASA's science missions is heavily influenced by stakeholders external to the Agency… Although NASA is addressing the [National Research Council's] (NRC's) top priorities in each of the science disciplines, past surveys generally underestimated the cost of recommended missions and overestimated the amount of money NASA would have to dedicate to them… Similar to problems encountered with its space exploration programs, NASA has struggled to accurately estimate the amount of time and money required to complete its science projects.	1.4, 1.5, 1.6, 2.2

Challenge Area (Source)	External Assessment of Challenge (excerpted from report)	Relevant Strategic Objective(s)
Overhauling NASA's Information Technology Governance (OIG)	In 2016, NASA spent approximately $1.4 billion or 7.3 percent of its $19.3 billion budget on information technology (IT)… IT governance is a process for designing, procuring, and protecting IT resources. Because IT is intrinsic and pervasive throughout NASA, the Agency's IT governance structure directly affects its ability to attain its strategic goals. For this reason, effective IT governance must balance compliance, cost, risk, security, and mission success to meet the needs of internal and external stakeholders. However, for more than 2 decades NASA has struggled to implement an effective IT governance approach that appropriated aligns authority and responsibility commensurate with the Agency's overall mission.	3.3
Securing NASA's Information Technology Systems and Data (OIG)	NASA manages approximately 1,200 publicly accessible web applications, or about half of all publicly accessible, nonmilitary Federal Government websites. Coupled with the Agency's statutory mission to share scientific information, the large number of networks and websites present unique IT security challenges.	3.3
Addressing NASA's Aging Infrastructure and Facilities (OIG)	NASA controls approximately 5,000 buildings and structures with an estimated replacement value of about $34 billion, making the Agency one of the largest Federal Government property holders. However, more than 80 percent of the Agency's facilities are 40 or more years old and beyond their design life. While the Agency strives to keep these facilities operational, and when not operational, in sufficient condition so they do not pose a safety hazard, NASA has not been able to fully fund required maintenance for its facilities for many years. In 2016, NASA estimated its deferred maintenance costs at $2.4 billion.	3.1
Ensuring the Integrity of NASA's Contracting and Grants Processes (OIG)	Approximately 77 percent of NASA's $18 billion FY 2015 budget was spent on contracts to procure goods and services, and the Agency awarded an additional $905 million in grants and cooperative agreements. Accordingly, NASA managers face the ongoing challenge of ensuring the Agency receives fair value for its money and that recipients spend NASA funds appropriately to accomplish stated goals.	3.1
Ensuring the Continued Efficacy of the Space Communications Network (OIG)	NASA's satellites and other spacecraft must communicate with Earth to receive commands from human controllers and return scientific data for study. To meet this need, NASA initiated the Space Communications and Navigation (SCaN) Program in 2006 with the goal of creating an integrated Agency-wide space communications and navigation architecture… Without SCaN services, NASA could not receive data from its satellites and robotic missions or control the missions from Earth, relegating space hardware worth tens of billions of dollars to little more than orbiting debris.	3.2

Challenge Area (Source)	External Assessment of Challenge (excerpted from report)	Relevant Strategic Objective(s)
NASA Acquisition Management (GAO)	NASA plans to invest billions of dollars in the coming years to explore space, understand Earth's environment, and conduct aeronautics research. NASA has made progress over the past 5 years in a number of key acquisition management areas, but it faces significant challenges in some of its major projects largely driven by the need to improve the completeness and reliability of its cost and schedule estimating, estimating risks associated with the development of its major systems, and managing to aggressive schedules.	1.1, 1.3, 1.4, 1.5, 1.6, 2.2, 3.2, 3.4

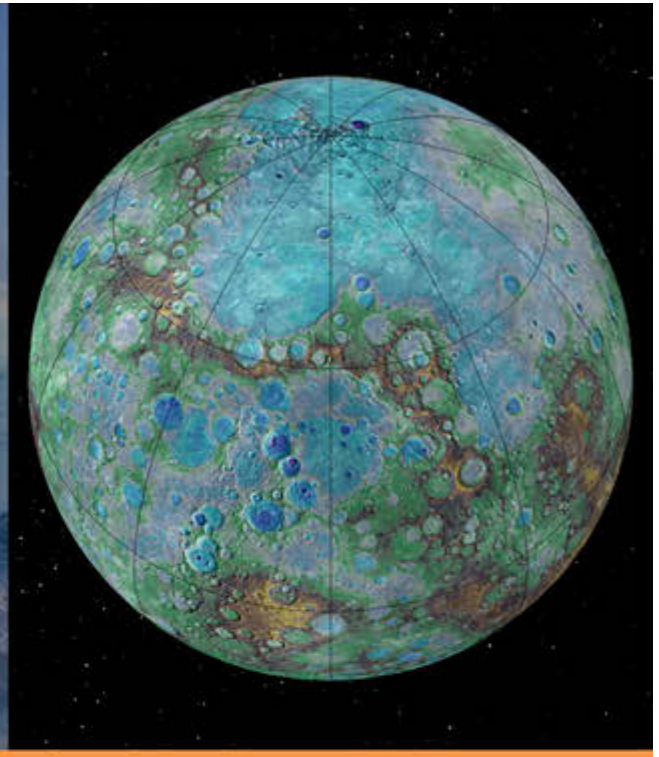
Response to OIG Management Challenges

Each fiscal year, as required by the Reports Consolidation Act of 2000, NASA's OIG issues a document summarizing what the Inspector General considers to be the most serious management and performance challenges facing the Agency and briefly assesses the Agency's progress in addressing those challenges. The letter, "2016 Report on NASA's Top Management and Performance Challenges," and NASA's comments on each management challenge raised by OIG are located in NASA's FY 2016 Agency Financial Report (see page 110). This listing of NASA's Top Management and Performance Challenges is a key input to the Agency's leadership when evaluating strategies and making adjustments to strategic and performance plans.

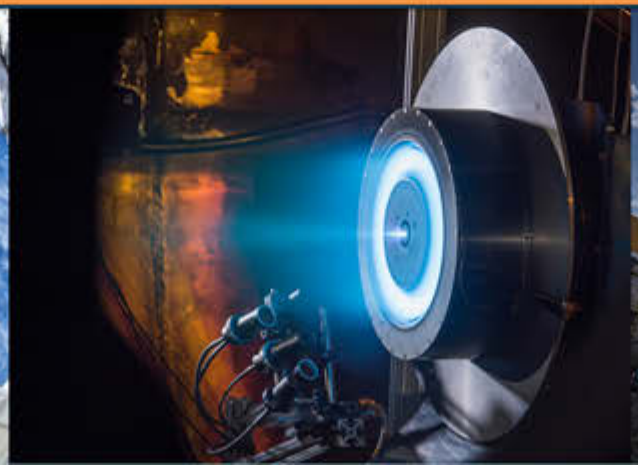
Response to GAO Management Challenges (High Risk)

The GAO has identified five criteria that must be met before an agency can remove a focus area from the High Risk List: (1) a demonstrated strong commitment to, and top leadership support for, addressing problems; (2) the capacity to address problems; (3) a corrective action plan; (4) a program to monitor corrective measures; and (5) demonstrated progress in implementing corrective measures. As part of the 2017 High Risk Report, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others* (GAO-17-317), the GAO included a scorecard detailing which of these criteria have been met, partially met, or have not been met for each High Risk area. NASA has fully met the leadership, corrective action plan, and monitoring criteria, and has partially met the criteria for capacity and demonstrated progress. This rating is unchanged from the 2015 High Risk Report; however, the GAO has acknowledged that NASA has continued to strengthen and integrate its acquisition management function.

These changes have yielded more credible cost and schedule baselines and both the GAO and OIG have observed that NASA's management of its major flight projects has improved. The effectiveness of these tools is particularly evident for the smaller (under $1 billion lifecycle costs) projects. For NASA's largest projects, such as the James Webb Space Telescope, the Space Launch System (SLS), and Orion, the GAO has observed that risks remain. Despite this, these programs all continue to perform within their cost and schedule baselines.



Part 3: Performance Reporting and Planning



Part 3 Table of Contents

Strategic Goal 2: Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.

Strategic Objective 2.1: Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research.

Strategic Objective 2.2: Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet.

Strategic Objective 2.3: Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit.

Strategic Objective 2.4: Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.

Strategic Goal 3: Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.

Strategic Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions.

Strategic Objective 3.2: Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's Mission.

Strategic Objective 3.3: Provide secure, effective, and affordable information technologies and services that enable NASA's Mission.

Strategic Objective 3.4: Ensure effective management of NASA programs and operations to complete the mission safely and successfully.

How to Read the Strategic Objective Information

The information presented below the strategic objectives is the result of NASA's third Strategic Review, completed in spring 2016 in accordance with Office of Management and Budget (OMB) guidance. In addition, supporting performance goals and annual performance indicators are provided in a table for each strategic objective.

Budget

Each strategic objective consists of Contributing Programs. NASA provides the past and requested budget authority for these programs in its annual President's Budget Request, available at http://www.nasa.gov/news/budget/index.html. Through this budget–performance crosswalk NASA is able to estimate a budget for each strategic objective.

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget							

The budget totals provided in the table above consist of a summation of the budget authority for each program that contributes to the strategic objective. These programs are provided under the "Contributing Program" header for each strategic objective. The source for the budget data is NASA's FY 2018 President's Budget Request.

- FY 2016 reflects funding amounts specified in Public Law 114-113, Consolidated Appropriations Act, 2016, as executed under the Agency's current FY 2016 Operating Plan.
- Totals for FY 2017 are not available at this time; the initial operating plan is not approved.

Note that totals of all budgets provided for strategic objectives will not add to the NASA total budget request; funds associated with the Inspector General do not map to specific strategic objectives and are not included in any strategic objective budget roll-up.

Strategic Review Assessment Rating

NASA identified a subset of strategic objectives as achieving noteworthy progress or as a focus area for improvement. The "Progress Update" section will note if NASA, in consultation with OMB, assessed the strategic objective as making noteworthy progress or as a focus area for improvement.

How to Read the Performance Goal and Annual Performance Indicator Information

Performance Goal Table and Fiscal Year Results

For each performance goal, NASA provides a table of information summarizing both results and plans. It provides six years of trended ratings, including the reporting fiscal year. Each table also includes "Planned Future Performance" for FY 2017 and FY 2018. The table will note if the performance goal does not continue beyond FY 2016. If NASA is introducing the performance goal in FY 2017 or FY 2018, the performance goal language will be provided in the "Planned Future Performance" field, the FY 2016 rating field will be "Does not trend until FY 2017 (or FY 2018)," and the FY 2011 through FY 2016 rating fields will be "No PG this fiscal year."

The table also indicates the "Contributing Theme" and "Contributing Program" responsible for pursuing activities as described in the performance goal. The "Data Quality for FY 2018" fields in the table provide information on how NASA verifies and validates the rating for each performance goal.

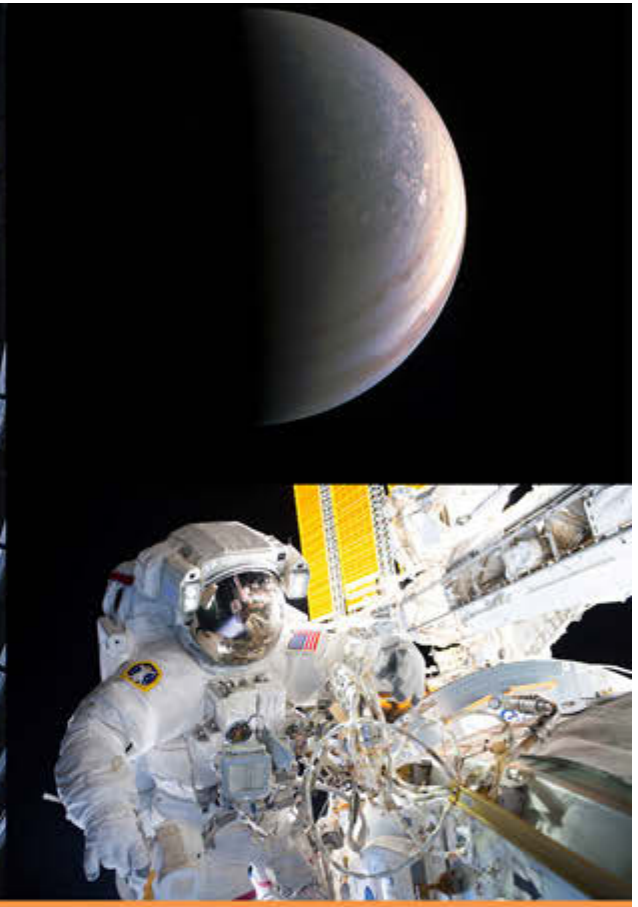
The "FY 2016 Performance Results" immediately following each table summarizes the work related to the performance goal. It includes a performance improvement plan for performance goals rated yellow or red.

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Advance engineering, technology, and science research.	1.1.2.1 Green	1.1.2.1 Green	1.1.2.1 Green	1.2.3 Green	1.2.3 Green	1.2.3 Green
Planned Future Performance						
For FY 2017: 1.2.3: Advance engineering, technology, and science research.						
For FY 2018: 1.2.2: Demonstrate key capabilities needed to enable human exploration in deep space.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					
Data Quality for FY 2018						
Data Source(s): International Space Station (ISS) Monthly Performance Metrics. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

Annual Performance Indicator Table

The annual performance indicator tables follow the same format as those for the performance goals. NASA does not summarize the performance results or provide data quality information for the annual performance indicators; however, it provides an "Explanation of Rating" for annual performance indicators rated yellow or red.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the U.S.-Russian joint human health and performance research project on the International Space Station one-year mission.	ERD 11 4 Green	ERD 12 1 Green	ERD 13 1 Green	ERD 14 1 Green	ERD 15 5 Green	ERD 16 5 Green
Planned Future Performance						
For FY 2017: ERD-17-5: Complete the selection and implementation of the contract for the first year of the Translational Research Institute to support the translation of cutting edge research into risk mitigation systems for human exploration missions.						
For FY 2018: No API this fiscal year						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Human Research Program					



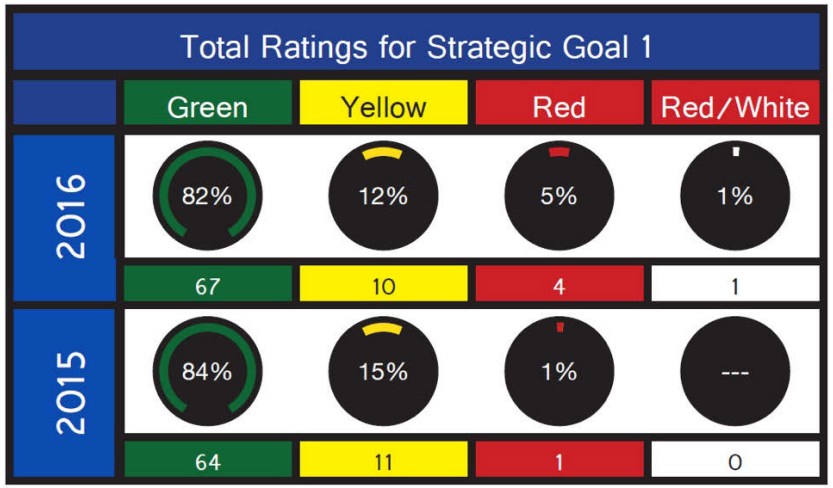
Strategic Goal 1

Expand the frontiers of knowledge, capability, and opportunity in space.

Strategic Goal 1: Expand the frontiers of knowledge, capability, and opportunity in space.						
Strategic Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.	Strategic Objective 1.2: Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity.	Strategic Objective 1.3: Facilitate and utilize U.S. commercial capabilities to deliver cargo and crew to space.	Strategic Objective 1.4: Understand the Sun and its interactions with Earth and the solar system, including space weather.	Strategic Objective 1.5: Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere.	Strategic Objective 1.6: Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.	Strategic Objective 1.7: Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies.
FY 2016 Performance Goals						
• 1.1.1: Achieve critical milestones in development of new systems for the human exploration of deep space. (Agency Priority Goal) • 1.1.2: Complete Design Reviews for planetary In-Situ Resource Utilization Demonstrations. • 1.1.5: Incorporate autonomous controls in life support subsystems testing to increase performance and reliability. • 1.1.6: Formulate robotic mission for overall Asteroid Redirect Mission (ARM).	• 1.2.1: Increase the occupancy of the International Space Station's (ISS's) internal and external research facilities by adding new instruments and capabilities. (Agency Priority Goal) • 1.2.2: Maintain capability for six on-orbit crew members. • 1.2.3: Advance engineering, technology, and science research. • 1.2.4: Ensure vital assets are ready, available, and appropriately sized to conduct NASA's Mission. • 1.2.5: Conduct basic and applied biological and physical research to advance and sustain U.S. scientific expertise. • 1.2.6: Provide cargo transportation to support on-orbit crew members and utilization.	• 1.3.1: Facilitate the development of and certify U.S. industry-based crew transportation systems while maintaining competition. (Agency Priority Goal) • 1.3.2: Invest financial and technical resources to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space transportation capabilities.	• 1.4.1: Demonstrate progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system. • 1.4.2: Demonstrate progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system. • 1.4.3: Demonstrate progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth. • 1.4.4: By December 2017, launch two missions in support of Strategic Objective 1.4.	• 1.5.1: Demonstrate progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact and evolve. • 1.5.2: Demonstrate progress in exploring and observing the objects in the solar system to understand how they formed and evolve. • 1.5.3: Demonstrate progress in exploring and finding locations where life could have existed or could exist today. • 1.5.4: Demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere. • 1.5.5: Demonstrate progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration. • 1.5.6: By December 2017, launch at least two missions in support of Strategic Objective 1.5.	• 1.6.1: Launch the James Webb Space Telescope. (Agency Priority Goal) • 1.6.2: Demonstrate progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity. • 1.6.3: Demonstrate progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe. • 1.6.4: Demonstrate progress in discovering and studying planets around other stars and exploring whether they could harbor life. • 1.6.5: By December 2018, launch at least one mission in support of Strategic Objective 1.6.	• 1.7.1: Explore and advance promising early stage solutions to space technology challenges through investment across the U.S. innovation community. • 1.7.2: Advance technologies that offer significant improvement to existing solutions or enable new space science and exploration capabilities. • 1.7.3: Mature new crosscutting space technology capabilities for demonstration.

Summary of Performance for Strategic Goal 1

Summary of Ratings of All Performance Measures for FY 2016 and 2015



Summary of Ratings for Performance Goals and Annual Performance Indicators by Strategic Objective, FY 2016

Lead	Strategic Objective	Performance Goals					Annual Performance Indicators				
		Total	Green	Yellow	Red	White	Total	Green	Yellow	Red	Red/White
HEOMD	1.1	4	2	2	0	0	7	3	3	0	1
HEOMD	1.2	6	5	0	1	0	10	8	0	2	0
HEOMD	1.3	2	2	0	0	0	2	2	0	0	0
SMD	1.4	4	4	0	0	0	7	6	1	0	0
SMD	1.5	6	6	0	0	0	12	11	0	1	0
SMD	1.6	5	5	0	0	0	7	5	2	0	0
STMD	1.7	3	3	0	0	0	7	5	2	0	0
Total		30	27	2	1	0	52	40	8	3	1
Summary			90%	7%	3%	0%		77%	15%	6%	2%

Strategic Objective 1.1

Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.

Lead Office

Human Exploration and Operations Mission Directorate (HEOMD)

Goal Leader

Greg Williams, Deputy Associate Administrator for Policy and Plans, HEOMD

Contributing Programs

Advanced Exploration Systems, Exploration Ground Systems, Orion, Space Launch System

Budget for Strategic Objective 1.1

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$3,851	–	$3,794	$4,120	$4,373	$4,298	$4,310

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and NASA's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Under Strategic Objective 1.1, NASA is developing a new human deep-space exploration architecture, consisting of the Space Launch System (SLS), Orion spacecraft, and Exploration Ground Systems (EGS) programs, as well as the Advanced Exploration Systems (AES) program. A significant accomplishment during FY 2016 was the second (and final) qualification motor test (QM-2) of the SLS booster. QM-2 was a two-minute, full-duration ground test in which temperatures inside the booster reached nearly 6,000 degrees Fahrenheit. This was the last full-scale test of the booster before Exploration Mission (EM)-1, an uncrewed test flight to distant retrograde lunar orbit (and the first pairing of Orion with SLS). In addition, the AES program continues to mature enabling technologies critical for exploration missions in such areas as habitation (life support), crew

mobility systems (extravehicular activity), and vehicle systems (lander technology). For example, the AES program sponsored the Spacecraft Fire Experiment (Saffire), the first in a series of experiments designed to study how fire operates in microgravity. Saffire intentionally lit a large-scale fire inside an empty Cygnus resupply vehicle after it left the International Space Station. Better understanding of how fire spreads in microgravity will help address a critical risk to crew safety. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans to have a new human deep-space exploration architecture with SLS, Orion, and other high-priority capabilities needed for human exploration and pioneering. During FY 2016, NASA experienced setbacks in its AES portfolio due to budgetary constraints, technical issues, and testing anomalies.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, please see https://www.nasa.gov/content/j2m-getting-to-mars-sls-and-orion and http://www.nasa.gov/directorates/heo/aes/index.html. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Additional details on the FY 2016 performance for supporting performance goals and annual performance indicators are provided in this report. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.			
Performance Goal 1.1.1: Achieve critical milestones in development of new systems for the human exploration of deep space. (Agency Priority Goal)	Performance Goal 1.1.2: Complete Design Reviews for planetary In-Situ Resource Utilization Demonstrations.	Performance Goal 1.1.5: Incorporate autonomous controls in life support subsystems testing to increase performance and reliability.	Performance Goal 1.1.6: Formulate robotic mission for overall Asteroid Redirect Mission (ARM).
Annual Performance Indicators			
• ESD-16-1: Conduct the second of two Space Launch System (SLS) booster qualification motor test firings (QM-2). • ESD-16-2: Begin assembly and integration of the Orion Exploration Mission-1 flight article in the Armstrong Operations and Checkout Building at the Kennedy Space Center. • ESD-16-3: Complete the Exploration Ground Systems Program System Integration Review (SIR).	• ERD-16-2: Complete the Critical Design Review (CDR) for the In-Situ Resource Utilization Demonstration Experiment on the Mars 2020 mission.	• ERD-16-3: Demonstrate concepts and technologies for extended extravehicular activity (EVA). • ERD-16-4: Analyze the performance of sensors, controls, and multiple life-support system components in integrated tests.	• ERD-16-1: Complete the Asteroid Redirect Robotic Mission (ARRM) integrated requirements review.

Summary of Performance for Strategic Objective 1.1

Performance Goal Ratings for Strategic Objective 1.1, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	4	2	2	0	0
2015	3	2	1	0	0
2014	2	2	0	0	0
2013	1	1	0	0	0
2012	1	1	0	0	0
2011	0	0	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.1, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	Red/White
2016	7	3	3	0	1
2015	5	4	1	0	0
2014	4	4	0	0	0
2013	2	2	0	0	0
2012	2	2	0	0	0
2011	2	2	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.1.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Achieve critical milestones in development of new systems for the human exploration of deep space. (Agency Priority Goal)	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.1.1 Green	1.1.1 Yellow	1.1.1 Green
Planned Future Performance						
For FY 2017: 1.1.1: Achieve critical milestones in development of new systems for the human exploration of deep space. (Agency Priority Goal)						
For FY 2018: 1.1.1: Achieve critical milestones in development of new systems for the human exploration of deep space.						
Contributing Theme: Exploration Systems Development	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Schedules and Quarterly Program Status Report (QPSR) packages. **Verification and Validation:** Review by the Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA made significant progress towards its agency priority goal in FY 2016, and is on track to meet the goal in FY 2017. NASA is developing the Nation's first human deep-space exploration capability with the Space Launch System (SLS) and the Orion spacecraft. With the support of the Exploration Ground Systems (EGS) program, SLS and Orion will enable astronauts to travel deeper into the solar system than ever before, and are essential for exploration of deep space, including future human exploration of Mars.

NASA successfully completed its second booster qualification hot fire test on June 28, 2016. The SLS booster qualification motor (QM-2) firing was the last full-scale test of the booster before Exploration Mission (EM)-1, the first uncrewed test flight of SLS with the Orion spacecraft. During QM-2, the booster was tested at a cold motor conditioning target of 40 degrees Fahrenheit, the coldest end of its accepted propellant temperature range. When ignited, temperatures inside the booster reached nearly 6,000 degrees. The two-minute, full-duration ground qualification test provided NASA with critical data that will support certification of the booster for flight. The first full-scale booster qualification ground test, QM-1, was successfully completed in March 2015 and demonstrated acceptable performance of the booster design at 90 degrees Fahrenheit, the highest end of the booster's accepted propellant temperature range. Testing at the thermal extremes on the launch pad is important to understand the effect of temperature on how the propellant burns.

During FY 2016, NASA began the assembly and integration of the Orion EM-1 flight article in the Armstrong Operations and Checkout Building at the Kennedy Space Center (KSC). In August 2016, the assembly of the Orion crew module reached a significant milestone with the completion of the first propellant system tube welds on the exterior of the Orion pressure vessel. The propellant lines will provide hydrazine to the spacecraft thrusters during missions into deep space. This marks the transition from the completion of the structures assembly to the beginning of the fluid systems integration. On August 25, the heat shield that will protect the Orion crew module during reentry arrived at KSC. The heat shield measures 16.5 feet in diameter and is the

world's largest structure of its kind. Once the Orion spacecraft is complete, EM-1 will send it on a path thousands of miles beyond the moon over the course of three weeks, farther into space than human spaceflight has ever travelled before.

NASA did not complete the EGS System Integration Review (SIR) during FY 2016, but is on track to do so in FY 2017. The SIR evaluates the readiness of a project and its associated supporting infrastructure to begin system assembly, integration, and testing. In July 2016, the EGS program completed the installation of the fifth of ten planned new work platforms for the SLS rocket inside the Vehicle Assembly Building (VAB) at KSC, reaching the halfway point for the installation of the new platforms. Each of the platforms weighs between 300,000 and 325,000 pounds, and they measure about 38 feet long and close to 62 feet wide. Prior to rolling out to the launch pad, the SLS rocket and Orion spacecraft will be brought together in the VAB for processing and assembly.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Conduct the second of two Space Launch System (SLS) booster qualification motor test firings (QM-2).	HEC 11 1 Green	ESD 12 1 Green	ESD 13 1 Green	ESD 14 1 Green	ESD 15 1 Green	ESD 16 1 Green
Planned Future Performance						
For FY 2017: ESD-17-1: Deliver all four Exploration Mission-1 Space Launch System (SLS) Core Stage RS-25 engines to the Michoud Assembly Facility in preparation for Core Stage integration.						
For FY 2018: ESD-18-1: Complete manufacture and assembly of full flight set of booster motor segments for shipment to Ground Systems Development and Operations for Exploration Mission-1 vehicle integration.						
Contributing Theme: Exploration Systems Development	**Contributing Program:** Space Launch System					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Begin assembly and integration of the Orion Exploration Mission-1 flight article in the Armstrong Operations and Checkout Building at the Kennedy Space Center.	HEC 11 2 Green	ESD 12 2 Green	ESD 13 2 Green	ESD 14 2 Green	ESD 15 2 Green	ESD 16 2 Green
Planned Future Performance						
For FY 2017: ESD-17-2: Install avionics and power on Orion Exploration Mission-1 flight article in the Armstrong Operations and Checkout Building at the Kennedy Space Center.						
For FY 2018: ESD-18-2: Complete assembly and integration of the Orion Exploration Mission-1 flight article in the Armstrong Operations and Checkout Building at the Kennedy Space Center and deliver it to Plum Brook Station for integrated environmental testing.						
Contributing Theme: Exploration Systems Development	**Contributing Program:** Orion Multi-Purpose Crew Vehicle					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Exploration Ground Systems Program System Integration Review (SIR).	No API this fiscal year	No API this fiscal year	No API this fiscal year	ESD 14 3 Green	ESD-15-3 Yellow	ESD-16-3 Yellow
Planned Future Performance						
For FY 2017: ESD-17-3: Complete construction of Exploration Ground Systems (EGS) Pad B.						
For FY 2018: ESD-18-3: Complete Exploration Ground Systems (EGS) final integrated test and checkout (ITCO) Systems Acceptance Review/Operational Readiness Review (SAR/ORR).						
Contributing Theme: Exploration Systems Development	**Contributing Program:** Exploration Ground Systems					

Explanation of Rating
As noted above, the Exploration Ground Systems Program did not complete its System Integration Review (SIR) in FY 2016. The SIR Board was rescheduled to FY 2017.

Performance Goal 1.1.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Complete Design Reviews for planetary In-Situ Resource Utilization Demonstrations.	No PG this fiscal year	1.3.3.1 Green	1.3.3.1 Green	1.1.2 Green	1.1.2 Green	1.1.2 Yellow
Planned Future Performance						
For FY 2017: 1.1.2: Complete Design Reviews for planetary In-Situ Resource Utilization Demonstrations.						
For FY 2018: 1.1.2: Develop planetary In-Situ Resource Utilization technologies.						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems					
Data Quality for FY 2018						
Data Source(s): Link(s) to press releases and Design Review Board documents. **Verification and Validation:** Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC) and NASA Policy Directive (NPD) 7120.8 or tailored 7120.5 for the In-Situ Resource Utilization (ISRU) payload. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results
NASA's Advanced Exploration Systems (AES) program is pioneering new approaches to develop prototype systems, demonstrate key capabilities, and validate operational concepts for future human missions beyond Earth orbit. The AES program focuses on crew safety and mission operations in deep

space, and its activities are strongly coupled to vehicle development. Early integration and testing of prototype systems reduces risk and improves the affordability of exploration mission elements.

NASA is planning a robotic mission to Mars in 2020 to further address key questions about the potential for life on Mars. The Mars 2020 mission will explore a site likely to have been habitable, seek signs of past life, fill a returnable cache with the most compelling samples, and demonstrate technology needed for the future human and robotic exploration of Mars. This includes a demonstration of In-Situ Resource Utilization (ISRU) technologies to produce propellant and consumable oxygen from the Martian atmosphere.

The Critical Design Review (CDR) for the ISRU demonstration experiment on the Mars 2020 mission was planned for completion in FY 2016. The CDR is a significant review that demonstrates that a project design has the ability to meet requirements with appropriate margins and acceptable risk within defined project constraints, including available resources to determine if the design is appropriately mature to continue with the final design and fabrication phase. However, there were technical issues with the core sub-system, the solid oxide electrolysis unit, which is designed to produce oxygen using Martian atmosphere. Resolution of these issues required additional testing, which delayed the CDR.

Performance Improvement Plan
The Critical Design Review was rescheduled for FY 2017 to provide more time to mature the solid oxide electrolysis unit. This delay does not impact the overall schedule for the Mars 2020 mission.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete the Critical Design Review (CDR) for the In-Situ Resource Utilization Demonstration Experiment on the Mars 2020 mission.	No API this fiscal year	No API this fiscal year	No API this fiscal year	ERD 14 6 Green	ERD 15 3 Green	ERD-16-2 Yellow
Planned Future Performance						
For FY 2017: ERD-17-2: Complete the Flight Qualification Review (FQR) and Pre-Ship Review (PSR) for the Mars Oxygen ISRU (In-Situ Resource Utilization) Experiment (MOXIE).						
For FY 2018: ERD-18-1: Deliver the Mars Oxygen ISRU (In-Situ Resource Utilization) Experiment (MOXIE) flight article to the Mars 2020 rover for assembly, test, and launch operations.						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems					

Explanation of Rating
As noted above, the Critical Design Review will be held in FY 2017 to provide more time to mature the solid oxide electrolysis unit. This delay does not impact the schedule for the Mars 2020 mission.

Performance Goal 1.1.4

Does not trend until FY 2018.
Planned Future Performance
FY 2017: No performance goal this year.
FY 2018: Launch three deep-space six-unit (6U) CubeSats on Exploration Mission-1.
Contributing Theme: Exploration Research and Development — **Contributing Program:** Advanced Exploration Systems
Data Quality for FY 2018
Data Source(s): Integrated test reports with Advanced Exploration Systems (AES)-approved project plan milestones with monthly and quarterly reviews. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: ERD-18-3: Deliver three Advanced Exploration Systems (AES)-sponsored six-unit (6U) CubeSats for integration into the Exploration Mission (EM)-1 flight.
Contributing Theme: Exploration Research and Development — **Contributing Program:** Advanced Exploration Systems

Performance Goal 1.1.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Incorporate autonomous controls in life support subsystems testing to increase performance and reliability.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.1.5 Green	1.1.5 Yellow
Planned Future Performance						
For FY 2017: 1.1.5: Incorporate autonomous controls in life support subsystems testing to increase performance and reliability.						
For FY 2018: 1.1.3: Deliver two flight instruments that address critical environmental control and life support technology gaps.						
Contributing Theme: Exploration Research and Development — **Contributing Program:** Advanced Exploration Systems						

Data Quality for FY 2018
Data Source(s): Integrated test reports with Advanced Exploration Systems (AES)-approved project plan milestones with monthly and quarterly reviews. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

NASA's Advanced Exploration Systems (AES) program is developing advanced life support systems that will enable human exploration beyond low Earth orbit. The Autonomous Systems and Operations (ASO) project is working to define vehicle capabilities, roles and responsibilities of ground and crew, and their interactions, in order to enable NASA missions to distant destinations. The Life Support Systems (LSS) project is developing life support systems for humans who will one day live and work in deep space. Currently, a robust supply chain provides astronauts on the International Space Station (ISS) with oxygen, water, and food. The LSS project is advancing technologies that will enable crews to travel further from Earth with reduced reliance on resupply missions from home. The further humankind goes from Earth, the greater the need will be to fully recycle oxygen and water through "closed loop" recycling and recovery systems.

Building on work in FY 2015 to integrate water recovery and air revitalization systems with control algorithms, in FY 2016, the ASO and LSS projects developed algorithms to detect faults that discern false positives and false negatives during the operation of the Plasma Pyrolysis Assembly (PPA). The PPA extracts hydrogen from methane and helps to minimize life support resupply costs for extended duration missions. In test runs lasting hours, no false positives or false negatives were detected. The algorithms were developed using large datasets of the PPA in operation. Detecting faults early in LSS hardware will improve both system performance and system availability. If faults are detected before full system failure, astronauts can elect to make a repair and improve or restore overall system performance. Improvements in system availability arise when the repair or replacement of a degraded component is quicker or simpler than the repair or replacement of a fully failed component, thus getting the system back to full operations more quickly.

However, although the tests reliably detected process failure faults, testing did not yield conclusive process improvement protocols (i.e., the quantity of hydrogen recovered from methane, which leads to increased recovery of oxygen). Further testing is required.

Performance Improvement Plan

During the first quarter of FY 2017, NASA will conduct additional tests to identify failures with the fault management technique. Testing will be followed by a defined run of experiments to demonstrate process improvement.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate concepts and technologies for extended extravehicular activity (EVA).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ERD 16 3 Red/ White
Planned Future Performance						
For FY 2017: ERD-17-3: Complete the manufacture and assess the performance of the Portable Life Support System (PLSS) 2.5.						
For FY 2018: No API this fiscal year						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems					

Explanation of Rating

The extravehicular activity (EVA) project was reduced by $4 million in FY 2016. This cut delayed the development and vacuum chamber testing of the Z-2 spacesuit to the point where it would have conflicted with the test schedule of the James Webb Space Telescope.

In lieu of the originally planned tests in the vacuum chamber, tests will be conducted with the upper torso of the Z-2 spacesuit in the Neutral Buoyancy Laboratory (NBL). During FY 2016, the Advanced Space Suit project began testing the Z-2 suit in the NBL. This was the first in a series of 16 underwater tests planned to address key operational questions for future exploration spacesuits.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Analyze the performance of sensors, controls, and multiple life-support system components in integrated tests.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ERD 15 4 Green	ERD-16-4 Yellow
Planned Future Performance						
For FY 2017: ERD-17-4: Integrate autonomous controls with different life support subsystems and conduct a system-level test to demonstrate increased system efficiency.						
For FY 2018: No API this fiscal year						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems					

Explanation of Rating

As noted previously, during the first quarter of FY 2017, additional tests will be conducted to identify failures with the fault management technique. This will be followed by a defined run of experiments to demonstrate process improvement.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year	
For FY 2018: ERD-18-2: Deliver both the Spacecraft Atmosphere Monitor and Brine Water Processor to the International Space Station for a technology demonstration.	
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems

Performance Goal 1.1.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Formulate robotic mission for overall Asteroid Redirect Mission (ARM).	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.1.6 Green
Planned Future Performance						
For FY 2017: 1.1.6: Formulate robotic mission for overall Asteroid Redirect Mission (ARM).						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems					

FY 2016 Performance Results

During FY 2016, NASA continued development of the Asteroid Redirect Mission (ARM), designed to visit a large, near-Earth asteroid, collect a multi-ton boulder from its surface, and use it in an enhanced gravity tractor asteroid deflection demonstration. The spacecraft would redirect the multi-ton boulder into a stable orbit around the Moon, where astronauts would explore it and return with samples. The Asteroid Redirect Robotic Mission (ARRM) portion of ARM would rendezvous with the asteroid, extract a large boulder, and then maneuver it into orbit around the Moon. The subsequent Asteroid Redirect Crewed Mission portion of ARM would involve sending astronauts to retrieve samples of the boulder for study back on Earth. In addition to advancing the technologies for a manned mission to Mars, ARM would demonstrate technologies that may be used for planetary defense.

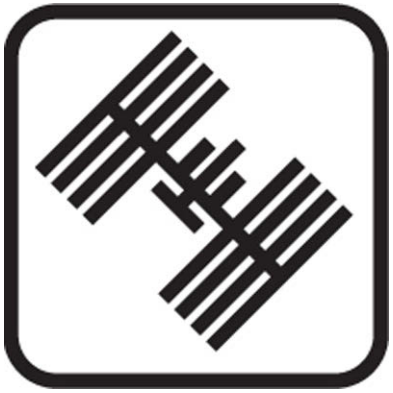
NASA successfully held its ARRM Requirements Closure Technical Interchange Meeting (TIM) on December 15-16, 2015. In support of this effort, ARM chartered a Formulation Assessment and Support Team (FAST), selecting 18 scientists and engineers to participate on the team out of over 100 applicants from across academia and industry. FAST released a draft report to the public in November 2015 to collect feedback on mission requirements in advance of the TIM. FAST released their final report on February 18, 2016.

In addition, NASA successfully completed Key Decision Point-B (KDP-B) for ARRM at an Agency Program Management Council (APMC) held on July 15, 2016. KDPs are gatekeeping reviews held to determine the readiness of a program or project to progress to the next phase of the life cycle. At KDP-B, the

APMC assessed ARRM maturity and approved the project to proceed to Phase B formulation. Approval was also granted for ARM to initiate the second phase of spacecraft acquisition and to proceed with plans for a Broad Agency Announcement Umbrella for Partnerships solicitation for Hosted Payloads on ARRM and Investigation Team Membership. NASA released the Broad Agency Announcement on September 7, 2016. The Jet Propulsion Laboratory released a Request for Proposals for an ARRM spacecraft bus subcontract on September 8, 2016.

ARM is proposed for cancellation in the FY 2018 President's Budget Request.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete the Asteroid Redirect Robotic Mission (ARRM) integrated requirements review.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ERD 16 1 Green
Planned Future Performance						
For FY 2017: ERD-17-1: Complete the Asteroid Redirect Robotic Mission (ARRM) early design studies.						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Advanced Exploration Systems					



Strategic Objective 1.2

Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity.

Lead Office

Human Exploration and Operations Mission Directorate (HEOMD)

Goal Leader

Greg Williams, Deputy Associate Administrator for Policy and Plans, HEOMD

Contributing Programs

Crew and Cargo Program, Human Research Program, Human Space Flight Operations, International Space Station

Budget for Strategic Objective 1.2

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$3,106	–	$3,438	$3,783	$3,671	$3,737	$3,696

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has determined that performance toward this strategic objective is making noteworthy progress.

Through the Strategic Review and NASA's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. The International Space Station (ISS) program, Human Research Program, and Human Space Flight Operations program fall under Strategic Objective 1.2. The ISS is the cornerstone of human exploration and operations, and NASA has made significant progress towards greater research utilization. Commercial companies are also successfully flying payloads on the ISS. A significant accomplishment during FY 2016

was the completion of the U.S.-Russian joint one-year mission on the ISS, in which U.S. astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko both spent almost a full year on station, the longest continuous space mission ever assigned to a NASA astronaut. The one-year crew mission is the latest step in the ISS's role as a platform for preparing humanity for exploration into deep space. These investigations are expected to yield beneficial knowledge on the medical, psychological, and biomedical challenges faced by astronauts during long-duration spaceflight.

NASA's critical next steps include maintaining the ISS as a safe and functional on-orbit platform, and continuing commercial and International Partner cargo missions to resupply the ISS. NASA will continue to expand the ISS on-orbit research program, including continuing to increase utilization of internal and external research facilities. For example, during FY 2016, NASA successfully attached the Bigelow Expandable Activity Module (BEAM) prototype expandable space habitat to the ISS. Expandable habitats greatly decrease the amount of transport volume necessary for future space missions. BEAM is also an example of NASA's commitment to partnering with industry to enable the growth of the commercial use of space. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA expects to advance benefits to humanity through research, enable a commercial demand-driven market in low Earth orbit, enable long-duration human spaceflight beyond low Earth orbit, and provide a basis for international exploration partnerships. NASA experienced setbacks in FY 2015 when both of its commercial cargo partners had anomalies on commercial resupply missions, leading both providers to temporarily suspend flights. The loss of commercial resupply missions, while regrettable, demonstrated the robustness of NASA's commercial resupply strategy of dissimilar redundancy. Both commercial providers resumed flights in FY 2016 and are meeting their contractual obligations to deliver supplies to the ISS. In addition, continuing to leverage the ISS to enable commercialization of low Earth orbit across broad sectors of the U.S. economy is both a challenge and an opportunity for the Agency.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://www.nasa.gov/mission_pages/station/main/index.html. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 1.2: Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity.					
Performance Goal 1.2.1: Increase the occupancy of the International Space Station's (ISS's) internal and external research facilities by adding new instruments and capabilities. (Agency Priority Goal)	Performance Goal 1.2.2: Maintain capability for six on-orbit crew members.	Performance Goal 1.2.3: Advance engineering, technology, and science research.	Performance Goal 1.2.4: Ensure vital assets are ready, available, and appropriately sized to conduct NASA's Mission.	Performance Goal 1.2.5: Conduct basic and applied biological and physical research to advance and sustain U.S. scientific expertise.	Performance Goal 1.2.6: Provide cargo transportation to support on-orbit crew members and utilization.
Annual Performance Indicators					
• ISS-16-1: Increase facility occupancy beyond the FY 2015 baseline.	• ISS-16-2: In concert with International Partners, maintain a continuous six-crew capability on the International Space Station by coordinating and managing resources, logistics, systems, and operational procedures.	• ERD-16-5: Complete the U.S.-Russian joint human health and performance research project on the International Space Station one-year mission. • ISS-16-3: Accomplish a minimum of 90 percent of the on-orbit research and technology development objectives.	• SFS-16-1: Ensure the astronaut corps meets all mission-related training requirements and mission-related health standards.	• ISS-16-10: Organize a Science Definition Team and define the research objectives and requirements for a series of experiments to be conducted within the framework of the GeneLab open science concept and complete the definitions for two experiments. • ISS-16-5: Deliver to the International Space Station three physical sciences payloads and conduct successful Cold Atom Laboratory Pre-Ship Review. • ISS-16-6: Through the Center for the Advancement of Science in Space (CASIS) cooperative agreement, release two Requests for Proposal, complete proposal evaluation, and select research projects for International Space Station execution in FY 2016. • ISS-16-7: Produce 500 peer-reviewed publications from projects in human research, space biology, and physical sciences.	• ISS-16-8: Complete at least three flights, delivering research and logistics hardware to the ISS, by U.S.-developed cargo delivery systems.

Summary of Performance for Strategic Objective 1.2

Performance Goal Ratings for Strategic Objective 1.2, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	6	5	0	1	0
2015	6	2	4	0	0
2014	6	6	0	0	0
2013	4	4	0	0	0
2012	4	4	0	0	0
2011	4	4	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.2, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	10	8	0	2	0
2015	10	6	3	1	0
2014	10	10	0	0	0
2013	7	6	1	0	0
2012	6	6	0	0	0
2011	5	5	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.2.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Increase the occupancy of the International Space Station's (ISS's) internal and external research facilities by adding new instruments and capabilities. (Agency Priority Goal)	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.2.1 Green	1.2.1 Yellow	1.2.1 Green
Planned Future Performance						
This performance goal continues through FY 2017.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

FY 2016 Performance Results

The International Space Station (ISS) is a world-renowned laboratory that performs multidisciplinary research in science and technology. NASA is increasing the occupancy of the ISS to conduct scientific research, for exploration-related technology development, and to foster commercial investment in space. Increasing facility occupancy is a function of the demand for the use of the ISS, which is driven by the funding of research by NASA, other government agencies, and the private sector; and the capacity of the laboratory to support research, which is determined by the infrastructure in orbit, the transportation system, and the crew availability.

During FY 2016, the following payloads were launched to the ISS:

- On December 6, 2015, Orbital ATK's Cygnus vehicle (Orb-4) launched with more than 7,700 pounds of supplies and payloads, including the Space Automated Bioproduct Laboratory (SABL) facility, which will study cell cultures, bacteria, and other microorganisms.
- On March 22, 2016, Orb-6 launched with more than 7,000 pounds of supplies and payloads, including a 3-D printing facility, miniature exercise device, fire safety experiment, life science experiments, student experiments, and small research satellites.
- On April 8, 2016, the Space Exploration Technologies Corporation's (SpaceX's) Commercial Resupply Services (CRS) flight SpaceX CRS-8 launched with nearly 7,000 pounds of payload and payload resupply for the ISS, including the Bigelow Expandable Activity Module (BEAM), a prototype expandable space habitat that will be attached to the station for two years of in-orbit viability tests.
- On July 18, 2016, SpaceX CRS-9 launched with nearly 5,000 pounds of supplies and payloads for the ISS, including some key biological experiments.

NASA made significant progress towards its agency priority goal in FY 2016. NASA reached 69 percent occupancy of the ISS at the end of FY 2016, exceeding its FY 2015 occupancy rate of 65 percent. The Agency is on track to meet its agency priority goal in FY 2017.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Increase facility occupancy beyond the FY 2015 baseline.	No API this fiscal year	No API this fiscal year	ISS-13-4 Yellow	ISS 14 4 Green	ISS-15-1 Yellow	ISS 16 1 Green
Planned Future Performance						
For FY 2017: ISS-17-1: By the end of FY 2017, increase the occupancy of the International Space Station's internal and external research facilities to 75 percent.						
For FY 2018: No API this fiscal year						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Performance Goal 1.2.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Maintain capability for six on-orbit crew members.	1.1.1.1 Green	1.1.1.1 Green	1.1.1.1 Green	1.2.2 Green	1.2.2 Yellow	1.2.2 Green
Planned Future Performance						
For FY 2017: 1.2.2: Maintain capability for five or six on-orbit crew members.						
For FY 2018: To be determined.[5]						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					
Data Quality for FY 2018						
Data Source(s): Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC) and the International Space Station (ISS) Program Quarterly Reviews. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The International Space Station (ISS) enables humanity to have an ongoing presence in space, and allows crew members to conduct scientific and technology research that could not be done anywhere else. As NASA continues preparations for the next great era of space exploration, extending humanity's reach beyond low Earth orbit for long-term research and study of the Moon, Mars, asteroids, and other bodies across the solar system, the ISS is being used to conduct medical and microgravity experiments and to test the systems that will be required for long-durations missions.

[5] NASA will set the performance goal for FY 2018 when it releases its *FY 2019 Volume of Integrated Performance*.

NASA maintained a crew of six on board the ISS, except during scheduled crew rotation periods, for the entirety of FY 2016. Crew members representing the United States, Russia, Japan, Canada, and Europe rotated every six months on the Russian Soyuz spacecraft. All of the required resupply flights, logistics, systems, and operational procedures continued to support a safe and effective ISS platform in space.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: In concert with International Partners, maintain a continuous six-crew capability on the International Space Station by coordinating and managing resources, logistics, systems, and operational procedures.	ISS 11 1 Green	ISS 12 1 Green	ISS 13 1 Green	ISS 14 1 Green	ISS-15-2 Yellow	ISS 16 2 Green
Planned Future Performance						
For FY 2017: ISS-17-2: In concert with International Partners, maintain a continuous five- or six-crew capability on the International Space Station by coordinating and managing resources, logistics, systems, and operational procedures.						
For FY 2018: ISS-18-1: In concert with International Partners, maintain a continuous five- or six-crew capability on the International Space Station by coordinating and managing resources, logistics, systems, and operational procedures.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Performance Goal 1.2.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Advance engineering, technology, and science research.	1.1.2.1 Green	1.1.2.1 Green	1.1.2.1 Green	1.2.3 Green	1.2.3 Green	1.2.3 Green
Planned Future Performance						
For FY 2017: 1.2.3: Advance engineering, technology, and science research.						
For FY 2018: To be determined.[6]						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					
Data Quality for FY 2018						
Data Source(s): International Space Station (ISS) Monthly Performance Metrics. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

[6] NASA will set the performance goal for FY 2018 when it releases its *FY 2019 Volume of Integrated Performance*.

FY 2016 Performance Results

During FY 2016, the International Space Station (ISS) supported a robust research and development program, allowing NASA to achieve its planned research objectives to advance engineering, technology, and scientific research.

On March 1, 2016, NASA successfully completed its one-year U.S.-Russian joint human health and performance research project with the return of astronaut Scott Kelly and cosmonaut Mikhail Kornienko to Earth. Kelly and Kornienko, who launched to the station on March 27, 2015, were aboard the ISS for 340 days. This was the longest space mission ever assigned to a NASA astronaut, designed to examine the effects of long-term spaceflight on human physiology. While Kelly was on board the space station, his identical twin brother, retired NASA astronaut Mark Kelly, participated in the study on Earth, allowing NASA to better isolate the deleterious effects of spaceflight on the human body, and to aid in the development of countermeasures for these effects. Scott Kelly retired from NASA effective April 1, 2016, but will continue to participate in the ongoing research related to the one-year mission by providing periodic medical samples and participating in other tests. This research will be invaluable to the preparation for future long-duration spaceflight missions.

On July 12-14, 2016, the American Astronautical Society, in cooperation with NASA and the Center for the Advancement of Science in Space, held its fifth annual ISS Research and Development Conference in San Diego, CA. The conference brought together leaders from industry, academia and government to discuss the latest research and technological breakthroughs in microgravity research, life sciences, materials development, technology development, human health, and remote observation of Earth and its atmosphere. The conference was headlined by Mark and Scott Kelly, who shared their experiences from the one-year study in a panel discussion with keynote speaker Dr. Sanjay Gupta.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the U.S.-Russian joint human health and performance research project on the International Space Station one-year mission.	ERD 11 4 Green	ERD 12 1 Green	ERD 13 1 Green	ERD 14 1 Green	ERD 15 5 Green	ERD 16 5 Green
Planned Future Performance						
For FY 2017: ERD-17-5: Complete the selection and implementation of the contract for the first year of the Translational Research Institute to support the translation of cutting edge research into risk mitigation systems for human exploration missions.						
For FY 2018: No API this fiscal year						
Contributing Theme: Exploration Research and Development	**Contributing Program:** Human Research Program					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Accomplish a minimum of 90 percent of the on-orbit research and technology development objectives.	ISS 11 5 Green	ISS 12 6 Green	ISS 13 3 Green	ISS 14 3 Green	ISS 15 3 Green	ISS 16 3 Green
Planned Future Performance						
For FY 2017: ISS-17-3: Accomplish a minimum of 90 percent of the on-orbit research and technology development objectives.						
For FY 2018: To be determined.[7]						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: ERD-18-5: Perform mixed-field, low-dose rate galactic cosmic ray simulation investigations at the NASA Space Radiation Laboratory to enable better assessment of space radiation health risks for exploration.
Contributing Theme: Exploration Research and Development / **Contributing Program:** Human Research Program

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: ISS-18-8: Initiate in-space demonstration of new technology for improved carbon dioxide removal.
Contributing Theme: International Space Station / **Contributing Program:** International Space Station

[7] NASA will set the annual performance indicator for FY 2018 when it releases its *FY 2019 Volume of Integrated Performance*.

Performance Goal 1.2.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Ensure vital assets are ready, available, and appropriately sized to conduct NASA's Mission.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.2.4 Green	1.2.4 Green	1.2.4 Green
Planned Future Performance						
For FY 2017: 1.2.4: Ensure vital assets are ready, available, and appropriately sized to conduct NASA's Mission.						
For FY 2018: 1.2.3: Ensure vital assets are ready, available, and appropriately sized to conduct NASA's Mission.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Human Space Flight Operations					
Data Quality for FY 2018						
Data Source(s): Center level analysis and schedules. **Verification and Validation:** The Directorate Program Management Council is the governing body for review of this performance goal. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Human Space Flight Operations (HSFO) program supports the training, readiness, and health of crewmembers prior to, during, and after each space flight mission to the International Space Station (ISS). All crews on board the ISS have undergone rigorous preparation, which is critical to mission success. The HSFO program provides astronaut selection and training, and manages all aspects of astronaut crew health, including maintenance of a healthy and productive crew during all phases of space flight missions, implementation of a comprehensive health care program for astronauts, and the prevention and mitigation of negative long-term health consequences of spaceflight. The program also provides expert medical input to program boards, flight rule recommendations, U.S. and international training to both flight and ground crews, medical care guideline requirements for space health care systems, and physical strength conditioning and rehabilitation for crewmembers.

Throughout FY 2016, the astronaut corps was sized appropriately, met all mission needs, and met all health and training standards.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Ensure the astronaut corps meets all mission-related training requirements and mission-related health standards.	No API this fiscal year	No API this fiscal year	No API this fiscal year	SFS 14 7 Green	SFS 15 1 Green	SFS 16 1 Green
Planned Future Performance						
For FY 2017: SFS-17-1: Ensure the astronaut corps meets all mission-related training requirements and mission-related health standards.						
For FY 2018: SFS-18-1: Ensure the astronaut corps meets all mission-related training requirements and mission-related health standards.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Human Space Flight Operations					

Performance Goal 1.2.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Conduct basic and applied biological and physical research to advance and sustain U.S. scientific expertise.	1.1.2.2 Green	1.1.2.2 Green	1.1.2.2 Green	1.2.5 Green	1.2.5 Yellow	1.2.5 Red
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					
Data Quality for FY 2018						
Data Source(s): Documentation for payloads delivered to the International Space Station (ISS) Program; ISS flight manifests; Standing Review Board (SRB) program reports; Center for the Advancement of Science in Space (CASIS) press releases and award documents; and the NASA Task Book bibliographic data, available at https://taskbook.nasaprs.com/Publication/index.cfm?action=bib_search. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** Potential lag time. For peer-reviewed publications, data are gathered throughout the year, but tend to concentrate at the end of the year. Intermediate data are of limited significance. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

During FY 2016, NASA made progress towards its annual performance indicators, demonstrating its focus on conducting basic scientific research aboard the International Space Station (ISS). The following are a few of the major accomplishments in biological and physical research completed in FY 2016:

- NASA launched three physical science research payloads to the ISS.
- The Center for the Advancement of Science in Space (CASIS) released four Requests for Proposals, and made awards to three research projects. The solicitations and awards are intended to expand the use of the ISS by public and private organizations other than NASA.

However, NASA did not complete two planned objectives for FY 2016:

- NASA did not complete the organization of a Science Definition Team for GeneLab. NASA determined that the initial plan was not fully compliant with the Federal Advisory Committee Act. GeneLab is an open access data repository designed to make vast amounts of raw data generated by experiments aboard the ISS available to a worldwide community of scientists and computational researchers.
- NASA did not hold the Cold Atom Laboratory (CAL) Pre-Ship Review (PSR). The PSR was delayed until FY 2017. CAL will be a facility aboard the ISS for the study of ultra-cold quantum gases in microgravity, enabling research in an environment that is inaccessible to Earth-based laboratories.

Performance Improvement Plan

NASA took the following actions to address the issues noted above:

- For GeneLab, NASA developed a new plan that is compliant with the Federal Advisory Committee Act. The NASA Office of the Chief Scientist is reviewing the approach to Agency advisory committees.
- The Cold Atom Laboratory (CAL) is still on track to launch in spring 2017. The schedule slip for the Pre-Ship Review is not expected to have a major impact on the launch schedule.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Organize a Science Definition Team and define the research objectives and requirements for a series of experiments to be conducted within the framework of the GeneLab open science concept and complete the definitions for two experiments.	ERD 11 1 Green	ISS 12 7 Green	ISS 13 6 Green	ISS 14 5 Green	ISS 15 4 Red	ISS 16 10 Red
Planned Future Performance						
For FY 2017: ISS-17-10: Produce at least 13 peer-reviewed publications addressing the critical questions on microbial life in space identified by the National Research Council in the Decadal Survey for Life and Physical Sciences in Space.						
For FY 2018: ISS-18-6: Install and conduct the first scientific investigation in the new Plant Habitat facility, and operate two Vegetable Production System (Veggie) units aboard the International Space Station to conduct research with the Human Research Program on the nutritional and behavioral aspects of growing plants for food in space.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Explanation of Rating

As noted above, NASA did not complete the organization of a Science Definition Team for GeneLab because it determined that the initial plan was not fully compliant with the Federal Advisory Committee Act (FACA). NASA developed a new plan that is compliant with FACA. The NASA Office of the Chief Scientist is reviewing the approach to Agency advisory committees.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Deliver to the International Space Station three physical sciences payloads and conduct successful Cold Atom Laboratory Pre-Ship Review.	ERD 11 3 Green	ISS 12 9 Green	ISS 13 8 Green	ISS 14 6 Green	ISS 15 5 Green	ISS 16 5 Red
Planned Future Performance						
For FY 2017: ISS-17-5: Deliver the Cold Atom Laboratory facility to the International Space Station and initiate operations on orbit, and complete one flight project in combustion research and one flight project in fluid physics or complex fluids research.						
For FY 2018: ERD-18-4: Accomplish new research in the Combustion Integrated Rack through installation and operation of Advanced Combustion via Microgravity Experiments research series; and complete three investigations in colloidal and self-assembling systems in the Fluids Integrated Rack.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Explanation of Rating

NASA did not hold the Cold Atom Laboratory (CAL) Pre-Ship Review (PSR) in FY 2016. The PSR was delayed until FY 2017. CAL is still on track to launch in spring 2017. The schedule slip for the PSR is not expected to have a major impact on the launch schedule.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year.	
For FY 2018: ISS-18-3: Enhance the research capabilities on the International Space Station (ISS) by installing and operating the Cold Atom Laboratory, Life Sciences Glove Box, additional Express Racks, and Bioculture System; and complete operations for Zero Boil Off Tank.	
Contributing Theme: International Space Station	**Contributing Program:** International Space Station

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Through the Center for the Advancement of Science in Space (CASIS) cooperative agreement, release two Requests for Proposal, complete proposal evaluation, and select research projects for International Space Station execution in FY 2016.	No API this fiscal year	No API this fiscal year	No API this fiscal year	ISS 14 7 Green	ISS 15 6 Green	ISS 16 6 Green
Planned Future Performance						
For FY 2017: ISS-17-6: Through the Center for the Advancement of Science in Space (CASIS) cooperative agreement, release two solicitations, complete proposal evaluation, and select research projects for International Space Station execution in FY 2017.						
For FY 2018: ISS-18-4: Through the Center for the Advancement of Science in Space (CASIS) cooperative agreement, meet the goals identified in the annual performance plan to completely use the 50 percent National Laboratory allocation; and develop and execute the sponsored research.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Produce 500 peer-reviewed publications from projects in human research, space biology, and physical sciences.	No API this fiscal year	No API this fiscal year	No API this fiscal year	ISS 14 8 Green	ISS 15 7 Green	ISS 16 7 Green
Planned Future Performance						
For FY 2017: ISS-17-7: Produce 500 peer-reviewed publications from projects in human research, space biology, and physical sciences.						
For FY 2018: To be determined.[8]						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					

Performance Goal 1.2.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Provide cargo transportation to support on-orbit crew members and utilization.	1.1.1.3 Green	1.1.1.3 Green	1.1.1.3 Green	1.2.6 Green	1.2.6 Yellow	1.2.6 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					
Data Quality for FY 2018						
Data Source(s): Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC) and the International Space Station (ISS) Program Quarterly Reviews. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

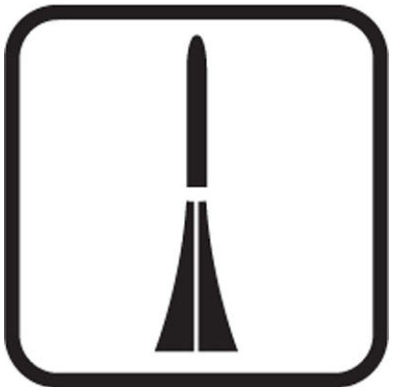
During FY 2016, NASA continued to provide cargo transportation to the International Space Station (ISS), supporting on-orbit crew operations through agreements with foreign partners and U.S. commercial providers. Cargo transportation was provided by the Russian Federation's Progress expendable cargo spacecraft, Orbital ATK's Cygnus vehicle, and the Space Exploration Technologies Corporation's (SpaceX's) Dragon spacecraft.

[8] NASA will set the annual performance indicator for FY 2018 when it releases its *FY 2019 Volume of Integrated Performance*.

In FY 2016, U.S. commercial providers completed four Commercial Resupply Services (CRS) flights delivering cargo to support on-orbit crewmembers:

- On December 6, 2015, Orbital ATK's Cygnus (Orb-4) launched with more than 7,700 pounds of supplies and payloads.
- On March 22, 2016, Orb-6 launched with more than 7,000 pounds of supplies and payloads.
- On April 8, 2016, SpaceX CRS-8 launched with nearly 7,000 pounds of payload and payload resupply.
- On July 18, 2016, CRS-9 launched with nearly 5,000 pounds of supplies and payloads.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete at least three flights, delivering research and logistics hardware to the ISS, by U.S.-developed cargo delivery systems.	No API this fiscal year	ISS 12 3 Green	ISS 13 2 Green	ISS 14 2 Green	ISS-15-8 Yellow	ISS 16 8 Green
Planned Future Performance						
For FY 2017: ISS-17-8: Complete at least three flights, delivering research and logistics hardware to the ISS, by U.S.-developed cargo delivery systems.						
For FY 2018: ISS-18-7: Complete at least three flights, delivering research and logistics hardware to the International Space Station (ISS), by U.S.-developed cargo delivery systems.						
Contributing Theme: International Space Station	**Contributing Program:** International Space Station					



Strategic Objective 1.3

Facilitate and utilize U.S. commercial capabilities to deliver cargo and crew to space.

Lead Office

Human Exploration and Operations Mission Directorate (HEOMD)

Goal Leader

Phil McAlister, Director of Commercial Spaceflight Development, HEOMD

Contributing Programs

Commercial Crew

Budget for Strategic Objective 1.3

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$1,244	–	$732	$173	$36	$36	$36

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and NASA's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Under Strategic Objective 1.3, NASA is supporting the development of U.S. commercial space transportation capabilities to reduce the gap in launching crew and cargo from the United States. In September 2014, NASA awarded Commercial Crew Transportation Capability contracts to two U.S. companies, the Boeing Company (Boeing) and Space Explorations Technologies Corporation (SpaceX), and both partners are making technical and programmatic progress. For example, in January 2016, SpaceX completed a propulsive descent test of its Dragon spacecraft, an important milestone in demonstrating that the spacecraft can safely and accurately return crew to the Earth. Over the next several years, the Agency's critical next steps are to monitor partner progress and milestone completion, working towards full certification, including a crew flight test to the

International Space Station (ISS) with a NASA astronaut. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans that the Agency's current efforts under Strategic Objective 1.3 will lead to the ability to utilize U.S. commercial space transportation capabilities to provide safe, reliable, and cost-effective access to and from low Earth orbit and the ISS for crew and cargo. This ability is critical for NASA's integrated space development and exploration plans. A current challenge for the Commercial Crew Program is that NASA will not complete its agency priority goal associated with this strategic objective before the end of FY 2017. Both commercial providers have delayed some work associated with the goal into FY 2018.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://www.nasa.gov/exploration/commercial/crew/index.html. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 1.3: Facilitate and utilize U.S. commercial capabilities to deliver cargo and crew to space.	
Performance Goal 1.3.1: Facilitate the development of and certify U.S. industry-based crew transportation systems while maintaining competition. (Agency Priority Goal)	Performance Goal 1.3.2: Invest financial and technical resources to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space transportation capabilities.
Annual Performance Indicators	
• CS-16-1: Continue monitoring partner milestone progress based on Commercial Crew transportation Capability (CCtCap) contract content.	• CS-16-2: Continue monitoring partner milestone progress based on agreement content.

Summary of Performance for Strategic Objective 1.3

Performance Goal Ratings for Strategic Objective 1.3, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	2	2	0	0	0
2015	2	2	0	0	0
2014	2	2	0	0	0
2013	1	1	0	0	0
2012	1	1	0	0	0
2011	1	1	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.3, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	2	2	0	0	0
2015	2	2	0	0	0
2014	2	2	0	0	0
2013	1	1	0	0	0
2012	0	0	0	0	0
2011	1	0	1	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.3.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Facilitate the development of and certify U.S. industry-based crew transportation systems while maintaining competition. (Agency Priority Goal)	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.3.1 Green	1.3.1 Green	1.3.1 Green
Planned Future Performance						
For FY 2017: 1.3.1: Facilitate the development of and certify U.S. industry-based crew transportation systems while maintaining competition. (Agency Priority Goal)						
For FY 2018: 1.3.1: Facilitate the development, certification, and operation of U.S. industry-based crew transportation systems while maintaining competition.						
Contributing Theme: Commercial Spaceflight	**Contributing Program:** Commercial Crew					
Data Quality for FY 2018						
Data Source(s): Email(s) and press releases indicating industry partners continue to make progress maturing their transportation system technical and certification/verification efforts. **Verification and Validation:** Review by NASA's Program Management Council and the Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC). **Data Limitations:** Materials provided by NASA's industry partners may include company-proprietary information. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA made significant progress towards its agency priority goal in FY 2016. The NASA Commercial Crew Program is facilitating the development of U.S. commercial crew space transportation capabilities, with the goal of achieving safe, reliable, and cost-effective access to and from low Earth orbit and the International Space Station (ISS). Enabling a U.S. industry-based capability can facilitate the development of a commercial market, providing new high-technology jobs and reducing the cost of human access to space. NASA is working with two commercial partners, the Boeing Company (Boeing) and Space Explorations Technologies Corporation (SpaceX), to complete development and NASA certification for human space transportation systems capable of carrying crews to the International Space Station and other low Earth orbit destinations.

During FY 2016, Boeing and SpaceX made technical and programmatic progress maturing their respective industry-based crew transportation systems. Both partners continued to identify verification items, define requirements closure plans, identify and update hazard reports, and work with NASA to process variances and alternate standards. Boeing installed new training equipment at the Johnson Space Center to simulate aspects of missions aboard the company's CST-100 Starliner spacecraft. The simulators will be used as part of the training for the astronauts who will fly the spacecraft. SpaceX completed its delta Critical Design Review (CDR). The CDR is a significant review that demonstrates that the project design has the ability to meet requirements with appropriate margins and acceptable risk within defined project constraints, including available resources to determine if the design is appropriately mature to continue with the final design and fabrication phase. Both partners have begun manufacturing qualification and flight hardware.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Continue monitoring partner milestone progress based on Commercial Crew transportation Capability (CCtCap) contract content.	CS-11-2 Yellow	No API this fiscal year	CS 13 1 Green	CS 14 1 Green	CS 15 1 Green	CS 16 1 Green
Planned Future Performance						
For FY 2017: CS-17-1: Continue monitoring partner milestone progress toward identifying and closing certification products, in alignment with negotiated contract milestones.						
For FY 2018: CS-18-1: Continue monitoring partner milestone progress toward identifying and closing certification products, in alignment with negotiated contract milestones, including the completion by the Space Exploration Technologies Corporation (SpaceX) of its planned Propulsion Module testing.						
Contributing Theme: Commercial Spaceflight	**Contributing Program:** Commercial Crew					

Performance Goal 1.3.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Invest financial and technical resources to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space transportation capabilities.	1.2.1.1 Green	1.2.1.1 Green	1.2.1.1 Green	1.3.2 Green	1.3.2 Green	1.3.2 Green
Planned Future Performance						
For FY 2017: 1.3.2: Invest financial and technical resources to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space transportation capabilities.						
For FY 2018: 1.3.2: Invest financial and technical resources to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space capabilities.						
Contributing Theme: Commercial Spaceflight	**Contributing Program:** Commercial Crew					
Data Quality for FY 2018						
Data Source(s): Annual report listing Space Transportation's funded and unfunded partnerships. **Verification and Validation:** Review by Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC). **Data Limitations:** Materials provided by NASA's industry partners may include company-proprietary information. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA is working with multiple U.S. companies that are designing and developing commercial low Earth orbit (LEO) and beyond LEO spaceflight capabilities. By supporting these development efforts, NASA is laying the foundation for future commercial spaceflight capabilities that could become available to NASA, other government agencies, and industry customers.

NASA is continuing to invest financial and technical resources within the private sector. NASA's commercial partners continue to make progress completing planned milestones. Blue Origin formally announced their orbital launch vehicle, the New Glenn. The Sierra Nevada Corporation continues preparing their Dream Chaser engineering test article to support their approach and landing test, planned for early calendar year 2017. A test article is hardware built to replicate conditions and behaviors of flight ready versions for ground testing. United Launch Alliance has conducted multiple technical meetings with NASA personnel as it continues to the development of its Vulcan launch vehicle.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Continue monitoring partner milestone progress based on agreement content.	No API this fiscal year	No API this fiscal year	No API this fiscal year	CS 14 5 Green	CS 15 3 Green	CS 16 2 Green
Planned Future Performance						
For FY 2017: CS-17-2: Continue monitoring partner milestone progress based on agreement content.						
For FY 2018: CS-18-2: Continue monitoring partner milestone progress based on agreement content, to include the completion by the Boeing Company of its planned Service Module hot fire launch abort engine test.						
Contributing Theme: Commercial Spaceflight	**Contributing Program:** Commercial Crew					

Strategic Objective 1.4

Understand the Sun and its interactions with Earth and the solar system, including space weather.

Lead Office

Heliophysics Division, Science Mission Directorate (SMD)

Goal Leader

Steven W. Clarke, Director, Heliophysics Division

Contributing Programs

Heliophysics Explorer Program, Heliophysics Research, Living with a Star, Solar Terrestrial Probes

Budget for Strategic Objective 1.4

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$647	–	$678	$688	$693	$698	$698

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has determined that performance toward this strategic objective is making noteworthy progress.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. NASA's Strategic Objective 1.4 is pursued by the Science Mission Directorate (SMD) Heliophysics Division, which seeks to understand the Sun, the vast extended atmosphere of the Sun (called the heliosphere), and planetary environments as a single connected system. The Heliophysics flight program is demonstrating excellent cost and schedule performance, and particularly noteworthy scientific

discoveries were announced in the last year, including key insights into how solar activity affects the Earth and other planets. The critical next steps include continuing the development of the next Heliophysics missions, including the Ionospheric Connection Explorer (ICON), Global-scale Observations of the Limb and Disk (GOLD), Solar Probe Plus (SPP), and the Solar Orbiter. NASA is also an agency member of the Space Weather Operations, Research, and Mitigation Task Force that developed and is implementing the National Space Weather Strategy and National Space Weather Action Plan. This effort will enhance the Nation's space-weather readiness in national preparedness, forecasting, and understanding. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans that the Agency's current efforts under Strategic Objective 1.4 will lead to further understanding of what causes the Sun to vary, how the geospace, planetary space environments, and the heliosphere respond to those variations, and impacts on humanity. Future success for this strategic objective requires maintaining continuity of scientific scope through the Heliophysics System Observatory (HSO), the fleet of spacecraft that operate concurrently, providing continuous observations and connected measurements. Maintaining an adequate mission cadence and balance is therefore critical. Many of the key challenges for the Heliophysics Division are common across all of the SMD divisions (access to space; technology development; project technical, cost, and schedule challenges; and partnerships) and are articulated in the *2014 Science Plan*. In particular, working with international partners presents both a challenge and an opportunity for the Agency.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://science.nasa.gov/heliophysics/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*. Additional information on strategies, challenges, implementation, and program-specific detail is available in the *NASA 2014 Science Plan*.

FY 2016 Performance Measures

Strategic Objective 1.4: Understand the Sun and its interactions with Earth and the solar system, including space weather.			
Performance Goal 1.4.1: Demonstrate progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system.	Performance Goal 1.4.2: Demonstrate progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system.	Performance Goal 1.4.3: Demonstrate progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.	Performance Goal 1.4.4: By December 2017, launch two missions in support of Strategic Objective 1.4.
Annual Performance Indicators			
• HE-16-1: Demonstrate planned progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system.	• HE-16-2: Demonstrate planned progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system.	• HE-16-3: Demonstrate planned progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.	• HE-16-5: Complete Solar Probe Plus System Integration Review (SIR). • HE-16-6: Complete the Ionospheric Connection (ICON) Explorer System Integration Review (SIR). • HE-16-7: Release the next Heliophysics Explorer Announcement of Opportunity (AO). • HE-16-8: Complete Solar Orbiter Collaboration (SOC) Solar Orbiter Heliospheric Imager (SoloHI) and Heavy Ion Sensor (HIS) instrument Pre-Ship Reviews (PSRs).

Summary of Performance for Strategic Objective 1.4

Performance Goal Ratings for Strategic Objective 1.4, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	4	4	0	0	0
2015	4	4	0	0	0
2014	4	4	0	0	0
2013	3	3	0	0	0
2012	3	3	0	0	0
2011	3	3	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.4, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	7	6	1	0	0
2015	6	6	0	0	0
2014	5	5	0	0	0
2013	4	4	0	0	0
2012	3	3	0	0	0
2011	3	3	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.4.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system.	2.2.1.1 Green	2.2.1.1 Green	2.2.1.1 Green	1.4.1 Green	1.4.1 Green	1.4.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Heliophysics Advisory Committee (HPAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Heliophysics Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Heliophysics Subcommittee of the NASA Advisory Council Science Committee determined in August 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

New Look at Sunspot Formation

Sunspots are indicators of solar flares, which can directly impact Earth and humanity's technological infrastructure. New insights on sunspot formation were provided by the combination of data observations from NASA's Solar Dynamics Observatory (SDO), Interface Region Imaging Spectrograph (IRIS), and Hinode missions, and numerical simulations using the NASA Pleiades supercomputer. Magnetic fields inside the Sun contort, coalesce, and eventually bundle into Earth-sized structures that form sunspots on the surface. During coalescence, weakly magnetized plasma is squeezed out, resulting in plasma jets and explosions. Using data and models to understand how sunspots are formed inside the Sun gives researchers crucial information on how they drive eruptive solar flares on the surface.

Wind and ACE Spacecraft Observations Provide Insight on Solar Wind Heating

The heating of the solar atmosphere is fundamentally connected to heating the solar wind, and to how the solar wind accelerates out into space. The solar wind has a low rate of particle collisions, which affects how it heats and accelerates. Long-term datasets from the Wind and Advanced Composition Explorer (ACE) missions enable statistical analysis of distinct plasma processes, such as wave damping, instability, and turbulence, which contribute to the heating of the solar wind. Advances in numerical simulation have allowed researchers to examine individual particle responses within these plasma processes. Wind data have revealed various new particle behaviors, such as how instabilities limit particle temperature ranges. Scientists also found traces of heating processes in ACE data on solar wind, finding that heavy ions appear to be much hotter than solar wind protons and helium. Heliophysics mission data are enabling new and important research into these evolving scientific mysteries around solar wind heating and acceleration.

Explosive Energy Release from Magnetic Fields

Magnetic fields throughout the solar system store, transport, and release energy. Under certain conditions, stored energy is converted explosively into heat and kinetic energy, which is a process known as magnetic reconnection. These physical processes drive magnetic storms at Earth and solar flares and coronal mass ejections on the Sun. Reconnection occurs when oppositely-oriented magnetic fields come into contact, "break" from their original configuration, and subsequently reconnect with the opposing field lines.

For the first time ever, the Magnetospheric Multiscale (MMS) mission has directly observed magnetic reconnection, seeing how the electric field and currents that dissipate the magnetic energy respond. Observations at this small, electron-level scale help scientists understand the processes that contribute to magnetic reconnection in more detail. Using data from SDO and the Solar TErrestrial RElations Observatory (STEREO), scientists were able to observe reconnection in three dimensions: two groups of magnetic loops that gradually approach each other, form an intermediate structure, and then reconnect. SDO and IRIS observations of the Sun identified signatures of high-speed flows and variations within magnetic reconnection events. Scientists now know more about how these signatures may control the rate of energy release, providing deeper insight into magnetic reconnection itself.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Demonstrate planned progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system.	HE 11 1 Green	HE 12 1 Green	HE 13 1 Green	HE 14 1 Green	HE 15 1 Green	HE 16 1 Green
Planned Future Performance						
For FY 2017: HE-17-1: Demonstrate planned progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system.						
For FY 2018: HE-18-1: Demonstrate planned progress in exploring the physical processes in the space environment from the Sun to Earth and throughout the solar system.						
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: HE-17-4: Achieve Magnetospheric Multiscale (MMS) mission success criteria.	
For FY 2018: No API this fiscal year	
Contributing Theme: Heliophysics	**Contributing Program:** Solar Terrestrial Probes

Performance Goal 1.4.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system.	2.2.2.1 Green	2.2.2.1 Green	2.2.2.1 Green	1.4.2 Green	1.4.2 Green	1.4.2 Green

Planned Future Performance	
This performance goal continues through FY 2017 and FY 2018.	
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs
Data Quality for FY 2018	
Data Source(s): On an annual basis, an independent, external expert review panel from the Heliophysics Advisory Committee (HPAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Heliophysics Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.	

FY 2016 Performance Results

The Heliophysics Subcommittee of the NASA Advisory Council Science Committee determined in August 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

New Insights on Solar Activity Affecting Earth and Planets

The constant flow of the solar wind and coronal mass ejections hitting Earth's magnetosphere creates a mixed boundary layer between Earth's magnetic field and interplanetary space known as a bow shock. Observational data from the Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission have shown that certain orientations of the solar wind magnetic field can birth small-scale shocks in the upstream region, which can result in more effective particle acceleration than acceleration from the bow shock alone. These particles, processed internally in the magnetosphere, are re-accelerated by magnetic reconnection, when oppositely-oriented magnetic fields come into contact, break from their original configuration, and subsequently reconnect with the opposing field lines. Observations and numerical simulations of this internal process have revealed that an electrical current system develops ahead of the accelerated particles at what are known as reconnection jets. Such observations improve understanding of how solar energy is transformed into energized particles and electrical currents in space.

Scientists use these observations to model how solar wind behaves at other planets, too. New Horizons mission data revealed that solar wind evolves substantially as it travels from Earth to Pluto. At Pluto, it has been shown to slam as close as roughly 1.5 planet radii above the surface because Pluto does not have a strong magnetic field to fend off the solar wind, and also because, during the Pluto flyby, the solar wind was exceptionally dense. These observations advance considerably space weather prediction capabilities at Earth and at other planetary bodies in the solar system.

Atmospheric Waves Affect Earth's Edge with Space

The Earth's mesosphere, its outermost atmospheric boundary with interplanetary space, is driven by dynamic processes in the troposphere and stratosphere and has been studied using temporal correlations of measurements. A recent study using data from the Aeronomy of Ice in the Mesosphere (AIM) mission revealed that this coupling extends to the spatial properties of the mesosphere. The study analyzed polar mesospheric ice cloud edges and holes to find that they have fractal properties similar to those in turbulence seen in small scale atmospheric gravity waves. These properties are controlled by temperature, humidity, and condensation nuclei fields in the mesosphere and, in turn, connect to tides, gravity waves, and turbulence in the lower atmosphere.

Solar Interactions with the Local Interstellar Medium

As the solar wind moves supersonically outward from the Sun, past the planets, it eventually interacts with the local interstellar medium at the boundary of the solar system. Data from the Interstellar Boundary Explorer (IBEX) mission revealed that energetic neutral atoms (particles with no charge that no longer react to magnetic fields) generated at this boundary seem to be coming from a limited spatial region, described as a "ribbon" in the sky. Simulations and IBEX data have revealed that these neutral hydrogen particles are most likely produced by secondary charge-exchange of the solar wind protons and the dense neutral interstellar medium. These neutrals arrive at Earth unaffected by the interplanetary magnetic field and are generated perpendicular to the interstellar magnetic field. They act as emissaries of the interstellar field's properties. Voyager 1 observations confirm the interstellar field orientation at the ribbon center. Simulations also reconcile discrepancies of the interstellar wind inflow angle between IBEX and Solar TErrestrial RElations Observatory (STEREO) observations. These results from Heliophysics missions and simulations provide a better understanding of the properties of the local interstellar medium and its interaction with the solar wind.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system.	HE 11 4 Green	HE 12 4 Green	HE 13 4 Green	HE 14 4 Green	HE 15 2 Green	HE 16 2 Green
Planned Future Performance						
For FY 2017: HE-17-2: Demonstrate planned progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system.						
For FY 2018: HE-18-2: Demonstrate planned progress in advancing understanding of the connections that link the Sun, Earth and planetary space environments, and the outer reaches of the solar system.						
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: HE-18-6: Achieve the Ionospheric Connection Explorer (ICON) mission success criteria.
Contributing Theme: Heliophysics — **Contributing Program:** Heliophysics Explorer Program

Performance Goal 1.4.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.	2.2.3.1 Green	2.2.3.1 Green	2.2.3.1 Green	1.4.3 Green	1.4.3 Green	1.4.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): On an annual basis, an independent, external expert review panel from the Heliophysics Advisory Committee (HPAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Heliophysics Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

The Heliophysics Subcommittee of the NASA Advisory Council Science Committee determined in August 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Upper Atmosphere at Earth is Getting Colder

An upper atmosphere much different from what humankind has historically experienced is evolving rapidly, as demonstrated by combining longer-term historical data sets with Aeronomy of Ice in the Mesosphere (AIM) mission measurements. Research now shows that the air on the edge of space is getting colder and more humid. Greenhouse gases are beginning to affect the upper atmosphere, as evidenced by at least three long-term observations: (1) the increased number and brightness of polar mesospheric clouds; (2) the continuing decrease of lower thermospheric temperatures, as measured by satellite drag; and (3) the strong correlation between exospheric temperatures and global infrared power radiated from the lower thermosphere.

Solar Wind Stripping Martian Atmosphere

NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) mission has provided new insights into extreme forcing of Mars' upper atmosphere. These results allow new insights into how extreme conditions would affect Earth if its magnetic field were switched off. Large solar flares provide significant heating of Mars' upper atmosphere, but with a faster recovery time than at Earth. Observation of the impact of a coronal mass ejection (CME) with Mars shows that the lack of a magnetic field allows such events to enhance the escape rate to deep space of the tenuous Martian atmosphere. CMEs are violent explosions in which mass and magnetic fields are ejected from the Sun into interplanetary space.

Global Magnetic Field Modeling Improves Understanding of Space Weather Effects

The Van Allen Probes have vastly increased the sampling of the inner magnetosphere, including observations of 65 geomagnetic storm events. Breakthroughs in magnetic field modeling include the first data-derived reconstruction of the global current system deep within the radiation belts. This

increase in observations of the inner magnetosphere has also revealed key drivers of the acceleration of radiation belt electrons, including the influence of kinetic Alfvén waves, which are broadband, low-frequency electromagnetic field fluctuations, on energetic electrons in near-Earth space.

Obtaining accurate data on the electric currents and magnetic fields around Earth is critical for understanding and modeling the adverse effects of space weather. Furthermore, Heliophysics mission data have improved understanding of how Earth's magnetosphere and ionosphere interact, which helps researchers learn how to mitigate electrical impacts to power grids during large geomagnetic storms.

Understanding and Predicting the Trajectories of Solar Energetic Particles

Solar Energetic Particles (SEPs) are a hazard to spacecraft, astronauts, and airline crews. Shocks driven by CMEs are a key SEP acceleration mechanism. Solar TErrestrial RElations Observatory (STEREO) and Advanced Composition Explorer (ACE) observations, along with advances in modeling, have shown that three phenomena, solar wind, shock structures preceding CMEs, and the interconnected magnetic field preceding a CME, can predict SEP arrivals. A survey of 65 interplanetary shocks observed by STEREO was recently completed, with a special emphasis on the foreshock, the region preceding the shock. They found that the foreshock regions exhibit waves in the interplanetary magnetic field and that the foreshocks of CMEs are much larger than those driven by the interactions between fast and slow solar wind streams. This helps to explain the efficiency with which CME shocks accelerate solar energetic particles, and also sheds light on processes occurring at bow shocks preceding planetary magnetospheres.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Demonstrate planned progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.	HE 11 5 Green	HE 12 5 Green	HE 13 5 Green	HE 14 7 Green	HE 15 3 Green	HE 16 3 Green
Planned Future Performance						
For FY 2017: HE-17-3: Demonstrate planned progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.						
For FY 2018: HE-18-3: Demonstrate planned progress in developing the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.						
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs					

Performance Goal 1.4.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
By December 2017, launch two missions in support of Strategic Objective 1.4.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.4.4 Green	1.4.4 Green	1.4.4 Green
Planned Future Performance						
For FY 2017: 1.4.4: By December 2017, launch two missions in support of Strategic Objective 1.4.						
For FY 2018: 1.4.4: By December 2019, launch one mission in support of Strategic Objective 1.4.						
Contributing Theme: Heliophysics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Written explanation of the rating and supporting material from the Science Mission Directorate's (SMD's) Flight Program Review archives. The Deputy Associate Administrator for SMD recommends a rating based on whether the underlying missions are on track to launch during the goal period. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA remains on track to achieve this performance goal with the March 2015 launch of the Magnetospheric Multiscale (MMS) mission, and the planned June 2017 launch of the Ionospheric Connection Explorer (ICON).

ICON is a single spacecraft mission dedicated to exploring the boundary region between Earth and space, called the thermosphere, where ionized plasma and neutral gas collide and interact, causing dramatic variability. The mission will resolve both long-standing and newly emerging questions about the mechanisms that control the daily development of plasma in Earth's space environment. This is the region of space through which radio communications and Global Positioning System (GPS) signals travel, so variations there can result in the distortion or even complete disruption of signals. In August 2016, ICON successfully completed its System Integration Review, which evaluates the readiness of a project and its associated supporting infrastructure to begin system assembly, integration, and testing.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Solar Probe Plus System Integration Review (SIR).	No API this fiscal year	No API this fiscal year	No API this fiscal year	HE 14 6 Green	HE 15 6 Green	HE 16 5 Green
Planned Future Performance						
For FY 2017: HE-17-5: Complete Solar Probe Plus (SPP) Solar Wind Electrons Alphas and Protons (SWEAP), FIELDS, Integrated Science Investigation of the Sun (ISIS) and the Wide-Field Imager for SPP (WISPR) Pre-Ship Reviews (PSRs).						
For FY 2018: HE-18-4: Launch Solar Probe Plus (SPP).						
Contributing Theme: Heliophysics	**Contributing Program:** Living with a Star					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Ionospheric Connection (ICON) Explorer System Integration Review (SIR).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	HE 15 7 Green	HE 16 6 Green
Planned Future Performance						
For FY 2017: HE-17-6: Complete the Ionospheric Connection Explorer (ICON) Pre-Ship Review (PSR).						
For FY 2018: No API this fiscal year						
Contributing Theme: Heliophysics	**Contributing Program:** Heliophysics Explorer Program					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Release the next Heliophysics Explorer Announcement of Opportunity (AO).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	HE 16 7 Green
Planned Future Performance						
For FY 2017: HE-17-7: Complete the Step One selection for the 2016 Heliophysics Small Explorer (SMEX) Announcement of Opportunity.						
For FY 2018: HE-18-5: Release the 2018 Heliophysics Medium Explorer (MIDEX) Announcement of Opportunity.						
Contributing Theme: Heliophysics	**Contributing Program:** Heliophysics Explorer Program					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Solar Orbiter Collaboration (SOC) Solar Orbiter Heliospheric Imager (SoloHI) and Heavy Ion Sensor (HIS) instrument Pre-Ship Reviews (PSRs).	No API this fiscal year	No API this fiscal year	HE 13 6 Green	HE 14 5 Green	HE 15 5 Green	HE-16-8 Yellow
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Heliophysics	**Contributing Program:** Living with a Star					

Explanation of Rating

The Solar Orbiter Collaboration has two U.S.-developed instruments, the Heavy Ion Sensor (HIS) and the Solar Orbiter Heliospheric Imager (SoloHI). The HIS instrument experienced component failures on the High Voltage Power Supply board being delivered by the Institut de Recherche en Astrophysique et Planétologie (IRAP) in France. The problems have been corrected and the board has been integrated into the detector section of the instrument. The SoloHI instrument experienced resource issues, including a test facility flood and the temporary redirection of a subject matter expert contractor to support a higher-priority project. Management has worked through the interruptions.

NASA completed the HIS and SoloHI Pre-Ship Reviews (PSRs) in March 2017. SoloHI will be one of the first instruments completed and shipped to the European Space Agency for integration onto the Solar Orbiter spacecraft. Both of these instruments will meet the European Space Agency's scheduled need dates for integration on Solar Orbiter.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: HE-17-8: Release the Solar Terrestrial Probes-5 (STP-5) Announcement of Opportunity.	
For FY 2018: HE-18-7: Complete the selection for the Solar Terrestrial Probes-5 (STP-5) Announcement of Opportunity.	
Contributing Theme: Heliophysics	**Contributing Program:** Solar Terrestrial Probes

Strategic Objective 1.5

Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere.

Lead Office

Planetary Science Division, Science Mission Directorate (SMD)

Goal Leader

Dr. James Green, Director, Planetary Science Division

Contributing Programs

Discovery, Mars Exploration, New Frontiers, Outer Planets, Planetary Science Research, Technology

Budget for Strategic Objective 1.5

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$1,628	–	$1,929	$1,921	$1,916	$1,911	$1,911

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has determined that performance toward this strategic objective is making noteworthy progress.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. NASA's Strategic Objective 1.5 is pursued by the Science Mission Directorate (SMD) Planetary Science Division, which continues to expand the Agency's knowledge of the solar system. For example, in FY 2016, NASA launched the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx), which will travel to Bennu, a near-Earth asteroid, and bring a small

sample back to Earth for study. The Planetary Science Division launched the OSIRIS-REx mission well below its development cost estimates. Particularly noteworthy scientific discoveries and major accomplishments occurred in the last year, including the production of plutonium, necessary for future deep-space exploration, in the United States for the first time in almost 30 years. The critical next steps include continuing the development of the next Planetary Science missions, such as Mars 2020. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans that the Agency's current efforts under Strategic Objective 1.5 will lead to further understanding of the content, origin, and evolution of the solar system, as well as the potential for life elsewhere. Many of the key challenges for the Planetary Science Division are common across all of the SMD divisions (access to space; technology development; project technical, cost, and schedule challenges; and partnerships) and are articulated in the *2014 Science Plan*. Planetary Science is sustaining extensive intra- and extra-Agency partnerships, and is pursuing efficiencies and informed investments tied to long-term strategic needs.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://solarsystem.nasa.gov/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*. Additional information on strategies, challenges, implementation, and program-specific detail is available in the *NASA 2014 Science Plan*.

FY 2016 Performance Measures

Strategic Objective 1.5: Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere.					
Performance Goal 1.5.1: Demonstrate progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact and evolve.	Performance Goal 1.5.2: Demonstrate progress in exploring and observing the objects in the solar system to understand how they formed and evolve.	Performance Goal 1.5.3: Demonstrate progress in exploring and finding locations where life could have existed or could exist today.	Performance Goal 1.5.4: Demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.	Performance Goal 1.5.5: Demonstrate progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.	Performance Goal 1.5.6: By December 2017, launch at least two missions in support of Strategic Objective 1.5.
Annual Performance Indicators					
• PS-16-1: Demonstrate planned progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact, and evolve.	• PS-16-14: Complete Juno Jupiter orbit insertion. • PS-16-2: Demonstrate planned progress in exploring and observing the objects in the solar system to understand how they formed and evolve.	• PS-16-10: Achieve the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission success criteria. • PS-16-3: Demonstrate planned progress in exploring and finding locations where life could have existed or could exist today.	• PS-16-4: Demonstrate planned progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.	• PS-16-5: Conduct research, involving both U.S. interagency and international cooperation and partnerships, into mitigation techniques and technologies to address the anticipated threat of small body impacts to life on Earth. • PS-16-9: Demonstrate planned progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.	• PS-16-15: Complete Discovery 13 selections. • PS-16-6: Complete the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) Pre-Ship Review (PSR). • PS-16-7: Launch the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission. • PS-16-8: Complete Mars 2020 Mission Confirmation Review.

Summary of Performance for Strategic Objective 1.5

Performance Goal Ratings for Strategic Objective 1.5, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	6	6	0	0	0
2015	6	6	0	0	0
2014	6	6	0	0	0
2013	5	5	0	0	0
2012	5	5	0	0	0
2011	5	5	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.5, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	12	11	0	1	0
2015	9	8	1	0	0
2014	8	8	0	0	0
2013	6	6	0	0	0
2012	6	5	1	0	0
2011	5	5	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.5.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact and evolve.	2.3.1.1 Green	2.3.1.1 Green	2.3.1.1 Green	1.5.1 Green	1.5.1 Green	1.5.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Planetary Science Advisory Committee (PAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Planetary Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Planetary Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance toward the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Pluto's Internal Heat—Evidence from Glaciers and Possible Volcanoes

The New Horizons flyby of Pluto on July 14, 2015, instantaneously changed views of the dwarf planet. Data from New Horizons are revealing Pluto's incredible and unexpected diversity of geological and compositional features. Observations of massive nitrogen, carbon dioxide, and methane-rich glaciers came to the forefront. The New Horizons team theorized that glacier movement may involve heat from inside Pluto, given the "convection cell" appearance and lack of impact craters. Another surprising observation is of a solitary mountain with a depression in the center, reminiscent of central volcanoes with craters. New Horizons instruments revealed that the mountain is made of water ice, and may be where water escaped from the interior to erupt at the surface. These observations make Pluto and other Kuiper Belt objects highly interesting in terms of understanding chemical and physical processes in the outer reaches of the solar system.

MAVEN Characterizes Modern Day Atmospheric Loss at Mars

Past missions have shown that, as Mars evolved, it lost most of its atmosphere, which was thicker, warmer, and relatively humid. With data from the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission, scientists have made major progress in understanding the current loss of atmospheric gases from Mars due to its interaction with the solar wind.

The European Space Agency's Mars Express previously reported that the solar wind can enter the Martian atmosphere and ionize the gas. Ionized particles escape into space, where they may be carried away by the solar wind. MAVEN mission observations have revealed a countervailing return flux of ions in the tail, where the solar wind flows behind Mars, while a concentrated polar plume of ions is being lost to space. By observing both the drivers (energetic solar particles and magnetic field) and the response (the temporal and spatial distribution of ions, electrons, and neutral molecules), a comprehensive picture of atmospheric loss today provides a framework for extrapolating back to early Mars, a time when total solar irradiance was less, but the Sun was brighter in the ultraviolet. Models of the complex interplay at Mars will likely have implications for exoplanet studies, as well.

Cassini Captured a Measurement of Space Weather during a Flyby of Saturn's Moon Titan

NASA's Cassini mission detected changes in Titan's ionosphere that allowed scientists to reconstruct the solar wind at Saturn's distance. Solar wind is a major component of space weather, which is the variable conditions on the Sun, throughout space, and in the Earth's magnetic field and upper atmosphere that can influence the performance of spaceborne and ground-based technological systems and endanger human life or health. Space weather strongly influences the electromagnetic environment around Earth and other solar system bodies, which affects the physical and optical properties of planets in the solar system. This second-hand space weather report, courtesy of Titan, provides the first such measurement so far away from the Sun. Carbonates on Ceres

The typically dark surface of the dwarf planet Ceres is punctuated by areas of much higher albedo, most prominently in the Occator crater. Spectra of these bright areas are consistent with a large amount of sodium carbonate, constituting the most concentrated known extraterrestrial occurrence of carbonate on kilometer-wide scales in the solar system. Researchers suspect that the compounds are the solid residue of the crystallization of brines and solids that reached the surface from below, indicating that fluids may exist at depth on Ceres today.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact, and evolve.	PS 11 1 Green	PS 12 1 Green	PS 13 1 Green	PS 14 1 Green	PS 15 1 Green	PS 16 1 Green
Planned Future Performance						
For FY 2017: PS-17-1: Demonstrate planned progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact, and evolve.						
For FY 2018: PS-18-1: Demonstrate planned progress in advancing the understanding of how the chemical and physical processes in the solar system operate, interact, and evolve.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Performance Goal 1.5.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in exploring and observing the objects in the solar system to understand how they formed and evolve.	2.3.2.1 Green	2.3.2.1 Green	2.3.2.1 Green	1.5.2 Green	1.5.2 Green	1.5.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Planetary Science Advisory Committee (PAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Planetary Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Planetary Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance toward the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Exploration of Dwarf Planet Ceres

New results from NASA's Dawn mission indicate that the gravity field and shape of Ceres is only partially differentiated, with a rocky core, icy shell, and nearly ice-free surface layer. Its surface contains ammoniated clays, suggesting a connection to the outer solar system. Bright regions in fresh craters are deposits rich in sodium carbonate, and water ice has been detected in only a few locations. Ceres appears gravitationally relaxed, implying a mechanically strong outer layer and a weaker interior. Abundant volatiles likely occur at depth, as indicated by features like lobate (i.e., fan-shaped) flows and a possible cryovolcanic dome.

Unraveling the Origin of Lunar Swirls

Using data from the Lunar Reconnaissance Orbiter, scientists have mapped over 100 individual swirling patterns of light and dark across the surface of the Moon, called lunar swirls. Scientists identified two prominent swarms of swirls, one near the equator, and one in the northwest portion of the South Pole-Aitken Basin. The data have enabled characterization of space weathering near the swirls and show that areas within swirls weather more slowly than areas outside of them. A comparison between the distribution of swirls and maps of the magnetic field shows that all swirls are associated with magnetic anomalies.

Explosive Volcanism on Mercury

Observations by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission revealed evidence for explosive volcanism on the innermost planet, but the volatiles responsible were unknown. A combination of MESSENGER X-ray, spectral reflectance, and neutron observations of the largest pyroclastic deposit on Mercury revealed it to be depleted in sulfur and carbon, and enriched in oxidized iron, relative to the rest of the planet's surface. These observations are most consistent with oxidation of sulfides and graphite during magma ascent and the formation of sulfur- and carbon-rich volatiles that were lost during the explosive eruption.

Ice Ages in Recent Geologic Times on Mars

Ice accumulates near Mars's mid-latitude when the poles are tilted more toward the Sun, transferring water from polar ice to mid-latitude cold traps. When the tilt is less, the warmer mid-latitudes lose water to the colder polar regions. NASA's Mars Reconnaissance Orbiter (MRO) has detected a layer of relatively pure ice up to 300 meters thick on top of the north polar cap. Models indicate this is what would be expected if the last Martian ice age ended 400 thousand years ago. Data reveal four such layers in the one-mile thick north polar ice cap, indicating the occurrence of at least four major ice age episodes during the 5-10 million-year lifetime of the current cap.

Enceladus's Subsurface Ocean

Several planetary satellites have shown evidence of subsurface seas, making them interesting for their possible habitability. Scientists have used data from NASA's Cassini mission to determine that Saturn's moon, Enceladus, has a subsurface ocean. Enceladus vigorously vents liquid water and vapor from

fractures within a south polar depression, indicating that it must have a liquid reservoir or active melting. Using measurements of control points across the surface of Enceladus accumulated over seven years, scientists found a forced physical libration (oscillation motion in its orbit) too large to be consistent with Enceladus's core being rigidly connected to its surface. This implies the presence of a global ocean, rather than a localized polar sea.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Juno Jupiter orbit insertion.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	PS 16 14 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in exploring and observing the objects in the solar system to understand how they formed and evolve.	PS 11 4 Green	PS 12 4 Green	PS 13 3 Green	PS 14 4 Green	PS 15 2 Green	PS 16 2 Green
Planned Future Performance						
For FY 2017: PS-17-2: Demonstrate planned progress in exploring and observing the objects in the solar system to understand how they formed and evolve.						
For FY 2018: PS-18-2: Demonstrate planned progress in exploring and observing the objects in the solar system to understand how they formed and evolve.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: PS-18-11: Complete Juno mission success criteria.
Contributing Theme: Planetary Science — **Contributing Program:** New Frontiers

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year	
For FY 2018: PS-18-12: Complete Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) arrival at the Bennu asteroid.	
Contributing Theme: Planetary Science	**Contributing Program:** New Frontiers

Performance Goal 1.5.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in exploring and finding locations where life could have existed or could exist today.	2.3.3.1 Green	2.3.3.1 Green	2.3.3.1 Green	1.5.3 Green	1.5.3 Green	1.5.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Planetary Science Advisory Committee (PAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Planetary Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Planetary Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance toward the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Mass of Early Mars Atmosphere

The search for carbonates on Mars explains how warm and wet ancient Mars might have been, which is key to understanding the conditions under which life might have arisen on the planet. In situ analysis of isotopes by the Curiosity rover, together with a newly understood pathway for loss of carbon through ultraviolet dissociation of carbon dioxide and carbon monoxide in the upper atmosphere of Mars, suggests that much of an early carbon dioxide atmosphere may have been lost to space before the carbon could be sequestered in the Martian crust. A new discovery of high levels of manganese oxides in mineral veins examined by Curiosity suggests that the early Martian atmosphere also contained more oxygen than it does now. While the mass of the early atmosphere remains uncertain, new observations are illuminating the physical processes likely involved in its early evolution.

Venus May Have Been the First Habitable World

A new study by NASA scientists suggests that Venus—a hot, volcanically active planet, with an atmosphere currently consisting primarily of carbon dioxide—may have been the first habitable planet in the solar system. Researchers created a suite of three-dimensional climate simulations using topographic data from the Magellan mission, solar spectral irradiance estimates for 2.9 and 0.715 billion years ago, present day Venus orbital parameters, an ocean volume consistent with current theory and measurements, and an atmospheric composition estimated for early Venus. Using these parameters, scientists found that such a world could have had moderate temperatures if Venus had a rotation period slower than about 16 Earth days, despite an incident solar flux 46-70 percent higher than modern Earth receives. At its current rotation period of 243 days, Venus's climate could have remained habitable until at least 715 million years ago, if it hosted a shallow primordial ocean. These results demonstrate the vital role that rotation and topography play in understanding the climatic history of exoplanetary Venus-like worlds being discovered in the present epoch.

How Friendly is Enceladus's Ocean to Life?

New Cassini data were used to model the ocean water on Enceladus to estimate the acidity or basicity (pH) of its ocean, answering a fundamental question in determining whether Saturn's icy moon Enceladus could support life. Cassini's mass spectra observations of the plume gas indicate that the ocean is a sodium-chloride-carbonate solution with an alkaline pH. The dominance of sodium chloride, or salt, is similar to oceans on Earth, but the dissolved sodium carbonate concentrations mean that the ocean composition is similar to that of soda lakes on Earth. The alkaline pH results from serpentinization, a geochemical fuel that can support both abiotic and biological synthesis of organic molecules, such as those that have been detected in Enceladus's plume from Cassini. The detection of native hydrogen gas in the plume today would indicate current serpentinization, and thus a source of energy for possible life.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Achieve the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission success criteria.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	PS 16 10 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Planetary Science	**Contributing Program:** Mars Exploration					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in exploring and finding locations where life could have existed or could exist today.	PS 11 8 Green	PS 12 7 Green	PS 13 6 Green	PS 14 5 Green	PS 15 3 Green	PS 16 3 Green
Planned Future Performance						
For FY 2017: PS-17-3: Demonstrate planned progress in exploring and finding locations where life could have existed or could exist today.						
For FY 2018: PS-18-3: Demonstrate planned progress in exploring and finding locations where life could have existed or could exist today.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Performance Goal 1.5.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.	2.3.4.1 Green	2.3.4.1 Green	2.3.4.1 Green	1.5.4 Green	1.5.4 Green	1.5.4 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): On an annual basis, an independent, external expert review panel from the Planetary Science Advisory Committee (PAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Planetary Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

The Planetary Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance toward the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Modern Microbial Ecosystems Provide Window to Early Life on Earth

A new study on the growth and structure of microbial reefs known as stromatolites gave a new perspective on these modern features that have a fossil record dating back three billion years. Scientists used three years of data collection to map communities in Shark Bay, Australia. The data revealed features of modern communities that are shared with Precambrian stromatolites, including eight distinct morphological 'provinces,' many of which were previously unknown. In addition to new, large-scale structural features, the study revealed that the microbial communities forming the reefs were different than previously understood, and that rather than trapping and binding particles, minerals like carbonate were actively precipitating in the stromatolites. Fossilized stromatolites hold a record of early life, and early stromatolite-forming microbes produced the atmospheric oxygen that allowed for more complex life to evolve. Modern-day stromatolites are a living laboratory for studying these examples of ancient life.

Honing in on the Great Oxygenation Event

Scientists at the Massachusetts Institute of Technology have identified the date of the Great Oxygenation Event (GOE) on Earth, a period of climate change when oxygen became permanently abundant in the atmosphere and provided a step towards the development of complex life on the planet. The research posits the rapid oxygenation of Earth at 2.33 billion years ago, plus or minus 7 million years, the most narrowed down estimate to date. Scientists found these numbers by analyzing shifts in the sulfur isotope pattern of pyrite in sediment cores from South Africa.

Early Earth's Air Weighed Less than Half of that in Today's Atmosphere

A new paper challenges the idea that the young Earth had a thicker atmosphere. The layers on a 2.7 billion-year-old rock, a stromatolite from Western Australia, show evidence of single-celled, photosynthetic life on the shore of a large lake. The new result suggests that this microbial life thrived despite a

thin atmosphere. The results reverse the commonly accepted idea that the early Earth had a thicker atmosphere to compensate for weaker sunlight. The finding also has implications for which gases were in that atmosphere, and how biology and climate worked on the early planet.

Watching "Jumping Genes" in Action

"Jumping genes" are ubiquitous and central to the origin of life. Every domain of life hosts these sequences of deoxyribonucleic acid (DNA) that can "jump" from one position to another along a chromosome. In fact, nearly half the human genome is made up of jumping genes. Depending on their specific excision and insertion points, jumping genes can interrupt or trigger gene expression, driving genetic mutation and contributing to cell diversification. Scientists at the University of Illinois at Urbana-Champaign have recently observed jumping gene activity in real time within living cells, another step forward in understanding the origin and evolution of life.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Demonstrate planned progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.	PS 11 11 Green	PS 12 11 Green	PS 13 8 Green	PS 14 8 Green	PS 15 4 Green	PS 16 4 Green
Planned Future Performance						
For FY 2017: PS-17-4: Demonstrate planned progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.						
For FY 2018: PS-18-4: Demonstrate planned progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Performance Goal 1.5.5

	FY 2011	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
Demonstrate progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.	2.3.5.1 Green	2.3.5.1 Green	2.3.5.1 Green	1.5.5 Green	1.5.5 Green	1.5.5 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): On an annual basis, an independent, external expert review panel from the Planetary Science Advisory Committee (PAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Planetary Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

The Planetary Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance toward the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

NASA's Planetary Defense Coordination Office

NASA and its partners maintain a watch for near-Earth objects (NEOs), asteroids and comets that pass close to the Earth, as part of an ongoing effort to discover, catalog, and characterize these bodies. NEOs range in size from a few meters to approximately 34 kilometers, with smaller objects being two orders of magnitude more numerous than larger objects.

On January 6, 2016, NASA announced the establishment of its Planetary Defense Coordination Office (PDCO) managed in the Planetary Science Division. NASA's ongoing Near-Earth Object Observations (NEOO) Program was formalized as a research program under the PDCO, which also coordinates NEO observation efforts conducted at ground-based observatories sponsored by the National Science Foundation and space situational awareness facilities of the United States Air Force. In addition to finding, tracking, and characterizing NEOs, NASA's planetary defense goals include developing techniques for deflecting or redirecting, if possible, potentially hazardous objects (PHOs) that are determined to be on an impact course with Earth. In the event that deflection or redirection is not possible, the PDCO is responsible for providing expert input to the Federal Emergency Management Agency for emergency response operations should a PHO be on an impact course or actually impact Earth.

The PDCO is responsible for:

- Ensuring the early detection of PHOs—asteroids and comets whose orbit are predicted to bring them within 0.05 Astronomical Units of Earth, and of a size large enough to reach Earth's surface (i.e., greater than perhaps 30 to 50 meters);
- Tracking and characterizing PHOs and issuing warnings about potential impacts;
- Providing timely and accurate communications about PHOs; and
- Performing as a lead coordination node in U.S. Government planning for response to an actual impact threat.

In FY 2016, asteroid search teams funded by NASA's NEOO Program found another seven asteroids larger than one kilometer in size with orbits that come close to Earth's vicinity. Asteroid search teams also found 1,514 smaller asteroids less than one kilometer in size, along with three additional near-Earth comets. This brings the total known population of NEOs to 14,560 (as of July 2016). The high-precision orbit predictions computed by the Center for Near-Earth Object Studies at NASA's Jet Propulsion Laboratory show that none of these objects is likely to strike Earth in the next century. However, 1,714 small bodies (of which 157 are larger than one kilometer in diameter), with 106 found this year, are in orbits that could become a hazard in the more distant future and warrant continued monitoring.

A Quasi-Moon for Earth

On April 27, 2016, the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) 1 survey telescope on Haleakalā detected a "quasi-moon" of the Earth. This companion is probably a small asteroid between 40 to 100 meters in size. Looking from the Earth, it appears to orbit the planet, yet it actually is in a co-orbit with Earth about the Sun. It never approaches closer than 14 million kilometers, nor ventures farther than 40 million kilometers away. It makes one circuit in 365.93 days.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Conduct research, involving both U.S. interagency and international cooperation and partnerships, into mitigation techniques and technologies to address the anticipated threat of small body impacts to life on Earth.	No API this fiscal year	No API this fiscal year	No API this fiscal year	PS 14 10 Green	PS 15 5 Green	PS 16 5 Green
Planned Future Performance						
For FY 2017: PS-17-5: Conduct research, involving both U.S. interagency and international cooperation and partnerships, into mitigation techniques and technologies to address the anticipated threat of small body impacts to life on Earth.						
For FY 2018: PS-18-5: Conduct research, involving both U.S. interagency and international cooperation and partnerships, into mitigation techniques and technologies to address the anticipated threat of small body impacts to life on Earth.						
Contributing Theme: Planetary Science	**Contributing Program:** Planetary Science Research					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.	No API this fiscal year	No API this fiscal year	No API this fiscal year	PS 14 12 Green	PS 15 9 Green	PS 16 9 Green
Planned Future Performance						
For FY 2017: PS-17-9: Demonstrate planned progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.						
For FY 2018: PS-18-6: Demonstrate planned progress in identifying and characterizing objects in the solar system that pose threats to Earth or offer resources for human exploration.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					

Performance Goal 1.5.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
By December 2017, launch at least two missions in support of Strategic Objective 1.5.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.5.6 Green	1.5.6 Green	1.5.6 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Planetary Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Written explanation of the rating and supporting material from the Science Mission Directorate's (SMD's) Flight Program Review archives. The Deputy Associate Administrator for SMD recommends a rating based on whether the underlying missions are on track to launch during the goal period. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA achieved this performance goal with the successful launch of two Planetary Science missions, including the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft in November 2013 and the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) in September 2016.

MAVEN is investigating Mars's upper atmosphere, ionosphere, and interactions with the Sun and solar wind. Scientists are using the data to determine the role that loss of volatiles (substances that evaporate quickly) from the Mars atmosphere to space has played through time, giving insight into the history of Mars's atmosphere and climate, liquid water, and planetary habitability. MAVEN is exploring how the Sun may have stripped Mars of most of its atmosphere, turning a once possibly habitable planet into a cold and barren desert world. During FY 2016, MAVEN achieved its mission success criteria.

OSIRIS-REx will travel to Bennu, a near-Earth asteroid, and bring a small sample back to Earth for study. The spacecraft will reach its asteroid target in 2018 and return the sample to Earth in 2023. The sample will provide insight into the composition of the very early solar system, the source of organic materials and water that made life possible on Earth, and to better predict the orbits of asteroids that represent collision threats to Earth. OSIRIS-REx completed its Pre-Ship Review (PSR) on May 11, 2016. The PSR is a significant milestone that demonstrates that the flight hardware successfully passed all environmental and performance tests and is ready for shipment to the launch site for final processing prior to launch and mission operations. OSIRIS-REx launched on September 8, 2016, aboard an Atlas V-411 from Cape Canaveral Air Force Station in Florida.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete Discovery 13 selections.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	PS 16 15 Green
Planned Future Performance						
For FY 2017: PS-17-11: Complete down-select for Discovery 13 mission.						
For FY 2018: No API this fiscal year						
Contributing Theme: Planetary Science	**Contributing Program:** Discovery					

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) Pre-Ship Review (PSR).	PS 11 3 Green	PS-12-2 Yellow	PS 13 5 Green	PS 14 2 Green	PS 15 6 Green	PS 16 6 Green
Planned Future Performance						
For FY 2017: PS-17-6: Launch the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission.						
For FY 2018: No API this fiscal year						
Contributing Theme: Planetary Science	**Contributing Program:** New Frontiers					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Launch the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission.	No API this fiscal year	PS 12 3 Green	PS 13 2 Green	PS 14 3 Green	PS 15 7 Green	PS 16 7 Red
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Planetary Science	**Contributing Program:** Discovery					

Explanation of Rating

The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission launch, originally planned for March 2016, was suspended because the mission's most important instrument, the Seismic Experiment for Interior Structure (SEIS), developed a vacuum leak that could not be repaired in time for the 2016 launch opportunity. InSight is now scheduled for launch in May 2018, the next available Mars launch opportunity. (About every 26 months, Mars and Earth reach a position in their respective orbits that offers the best trajectory between the two planets.) On August 31, 2016, the Science Mission Directorate (SMD) Directorate Program Management Council (DPMC) approved the InSight mission launch for May 2018, including the repair plans for SEIS and final assembly of the spacecraft to get the mission to launch.

The repair plan is based on the findings of the failure review board. NASA has taken steps to reduce the implementation risk going forward. NASA's Jet Propulsion Laboratory (JPL), working with the French government's space agency (the Centre National d'Etudes Spatiales, or CNES), realigned the SEIS instrument division of work responsibilities with a new organizational structure. JPL has taken over from CNES the redesign, development, and qualification of the SEIS evacuated container (EC), the structure with the electrical feedthroughs that failed previously. The new development effort is focused on a rigorous test program that fully demonstrates the capability of the newly designed EC at each level of integration—from components to the fully-sealed unit—prior to delivery of the final flight article to CNES. CNES is focused on developing and delivering the key sensors for SEIS, integration of the sensors into the EC, and the final integration of the overall SEIS instrument. Furthermore, additional system level reviews will occur during the course of the instrument integration activity. There has also been an increased exchange of on-site support between JPL and CNES to ensure smooth and continual information flow during the development and test program. NASA will continue to monitor progress in resolving the open issues that led to the delay.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Mars 2020 Mission Confirmation Review.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	PS-15-8 Yellow	PS 16 8 Green
Planned Future Performance						
For FY 2017: PS-17-8: Complete Mars 2020 Critical Design Review (CDR).						
For FY 2018: PS-18-7: Complete Mars 2020 System Integration Review (SIR).						
Contributing Theme: Planetary Science	**Contributing Program:** Mars Exploration					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: PS-17-10: Release New Frontiers 4 Announcement of Opportunity (AO).	
For FY 2018: PS-18-8: Complete New Frontiers 4 Step One Selection.	
Contributing Theme: Planetary Science	**Contributing Program:** New Frontiers

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: PS-17-12: Complete Europa Key Decision Point-B (KDP-B).	
For FY 2018: PS-18-10: Complete Europa Instrument Preliminary Design Reviews (PDRs).	
Contributing Theme: Planetary Science	**Contributing Program:** Outer Planets

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year	
For FY 2018: PS-18-13: Launch the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission.	
Contributing Theme: Planetary Science	**Contributing Program:** Discovery

Strategic Objective 1.6

Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.

Lead Office

Astrophysics Division

Goal Leader

Dr. Paul Hertz, Director, Astrophysics Division

Contributing Programs

Astrophysics Explorer, Astrophysics Research, Cosmic Origins, Exoplanet Exploration, James Webb Space Telescope, Physics of the Cosmos

Budget for Strategic Objective 1.6

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$1,382	–	$1,350	$1,350	$1,350	$1,350	$1,350

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has determined that performance toward this strategic objective is making noteworthy progress.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. NASA's Strategic Objective 1.6 is pursued by the Science Mission Directorate (SMD) Astrophysics Division, which seeks to further understanding of the origin and evolution of the universe, including the search for planets with the potential to harbor life. A number of significant scientific discoveries were announced in the last year, and the Astrophysics Division made outstanding advances on key missions.

For example, the James Webb Space Telescope (Webb) has made remarkable progress as it moves closer to launch. In addition, NASA accelerated the Wide-Field Infrared Survey Telescope (WFIRST) mission, initiating Phase A, the development of mission requirements and architecture, a full year ahead of plan. The Astrophysics Division's critical next steps include continuing the development of the next Astrophysics missions, including Webb and the Transiting Exoplanet Survey Satellite (TESS). Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans that the Agency's current efforts under Strategic Objective 1.6 will lead to further understanding of the universe and how it works, its history, and the continued search for life beyond the solar system. Many of the key challenges for the Astrophysics Division are common across all of the SMD divisions (access to space; technology development; project technical, cost, and schedule challenges; and partnerships) and are articulated in the *2014 Science Plan*. In addition, while Webb is on track and has made tremendous progress, challenges will remain until launch to maintain cost and schedule. Launching Webb in 2018 is one of NASA's agency priority goals. The Astrophysics Division has also faced some recent challenges with non-strategic missions. For example, TESS encountered technical issues with the advanced design of its data handling unit. These issues are being addressed, and NASA does not anticipate an impact to the launch readiness date.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://science.nasa.gov/astrophysics/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*. Additional information on strategies, challenges, implementation, and program-specific detail is available in the *NASA 2014 Science Plan*, as well as the *2013 Astrophysics Roadmap*.

FY 2016 Performance Measures

Strategic Objective 1.6: Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.				
Performance Goal 1.6.1: Launch the James Webb Space Telescope. (Agency Priority Goal)	Performance Goal 1.6.2: Demonstrate progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.	Performance Goal 1.6.3: Demonstrate progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe.	Performance Goal 1.6.4: Demonstrate progress in discovering and studying planets around other stars and exploring whether they could harbor life.	Performance Goal 1.6.5: By December 2018, launch at least one mission in support of Strategic Objective 1.6.
Annual Performance Indicators				
• JWST-16-1: Deliver James Webb Space Telescope (Webb) integrated optical telescope and science instrument module to Goddard Space Flight Center for testing.	• AS-16-1: Demonstrate planned progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.	• AS-16-2: Demonstrate planned progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe. • AS-16-3: Complete commissioning flights for Stratospheric Observatory for Infrared Astronomy (SOFIA) second-generation instrument suite.	• AS-16-5: Demonstrate planned progress in discovering and studying planets around other stars and exploring whether they could harbor life.	• AS-16-4: Complete the Transiting Exoplanet Survey Satellite (TESS) instrument integration and test (I&T). • AS-16-6: Begin Wide-Field Infrared Survey Telescope (WFIRST) mission formulation.

Summary of Performance for Strategic Objective 1.6

Performance Goal Ratings for Strategic Objective 1.6, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	5	5	0	0	0
2015	5	5	0	0	0
2014	5	5	0	0	0
2013	4	4	0	0	0
2012	4	4	0	0	0
2011	4	3	1	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.6, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	7	5	2	0	0
2015	6	6	0	0	0
2014	6	5	1	0	0
2013	5	5	0	0	0
2012	5	4	0	0	1
2011	5	5	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.6.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Launch the James Webb Space Telescope. (Agency Priority Goal)	2.4.2.2 Yellow	2.4.2.2 Green	2.4.2.2 Green	1.6.1 Green	1.6.1 Green	1.6.1 Green
Planned Future Performance						
For FY 2017: 1.6.1: Launch the James Webb Space Telescope. (Agency Priority Goal)						
For FY 2018: 1.6.1: Launch the James Webb Space Telescope.						
Contributing Theme: James Webb Space Telescope	**Contributing Program:** James Webb Space Telescope					
Data Quality for FY 2018						
Data Source(s): Written explanation of the rating and supporting material from the Science Mission Directorate's (SMD's) Flight Program Review archives. The James Webb Space Telescope Program Director recommends a rating based on whether Webb is on track to launch on time. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA is on track to launch the James Webb Space Telescope (Webb) in October 2018, and achieved its FY 2016 annual performance indicator with the integration of the Integrated Science Instrument Module (ISIM) and the Optical Telescope Element (OTE) at the Goddard Space Flight Center (GSFC) on September 28, 2016. Together, the ISIM and OTE form Webb's Optical Telescope and Integrated Science (OTIS) module.

During FY 2016, NASA completed the third and final cryovacuum test of the ISIM at GSFC and the second Optical Ground Support Equipment cryovacuum test at the Johnson Space Center (JSC). Work commenced at JSC on the third and final cryovacuum test prior to the flight OTIS test. This test includes thermal simulators with the pathfinder test backplane to replicate the thermal environment near the sunshield that OTIS will experience.

In addition, NASA completed testing on the flight cryocooler compressor assembly, including end-to-end testing with flight and flight-like components making up the entire cooling system and load. NASA then shipped the compressor assembly to Northrup Grumman Aerospace Systems for integration with the spacecraft bus. After integration, Northrup Grumman shipped the flight spare cryocooler compressor assembly to the Jet Propulsion Laboratory for testing.

In December 2015, NASA completed work on the new Mission Operations Center facilities inside the Space Telescope Science Institute in Baltimore, MD. Development of the flight operations system, which will be installed in the Mission Operations Center, is proceeding on schedule.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Deliver James Webb Space Telescope (Webb) integrated optical telescope and science instrument module to Goddard Space Flight Center for testing.	JWST 11 1 Green	JWST-12-1 White	JWST 13 1 Green	JWST 14 1 Green	JWST 15 1 Green	JWST 16 1 Green
Planned Future Performance						
For FY 2017: JWST-17-1: Complete the testing of the James Webb Space Telescope Optical Telescope Element (OTE) plus Integrated Science Instrument Module (ISIM), known as OTIS.						
For FY 2018: JWST-18-1: Integrate the James Webb Space Telescope Optical Telescope Element (OTE) plus Integrated Science Instrument Module (ISIM), known as OTIS, with the spacecraft and sunshield.						
Contributing Theme: James Webb Space Telescope	**Contributing Program:** James Webb Space Telescope					

Performance Goal 1.6.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.	2.4.1.1 Green	2.4.1.1 Green	2.4.1.1 Green	1.6.2 Green	1.6.2 Green	1.6.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Astrophysics Advisory Committee (APAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Astrophysics Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Astrophysics Subcommittee of the NASA Advisory Council Science Committee determined in July 2016 that NASA remained on track in its annual performance towards the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

NASA's Fermi Satellite Detects First Gamma-ray Pulsar in Another Galaxy

Researchers using NASA's Fermi Gamma-ray Space Telescope have discovered the first gamma-ray pulsar in another galaxy. The object sets a new record for the most luminous gamma-ray pulsar known.

The pulsar lies in the outskirts of the Tarantula Nebula in the Large Magellanic Cloud, a small galaxy that orbits the Milky Way. The Tarantula Nebula is the most complex star-formation region in the galactic neighborhood, identified as a bright source of gamma rays early in the Fermi mission. Astronomers initially attributed this glow to collisions of subatomic particles accelerated in the shock waves produced by supernova explosions. It's now clear that a single pulsar, designated PSR J0540-6919, is responsible for roughly half of the gamma-ray brightness.

When a massive star explodes as a supernova, the star's core may survive as a neutron star, where the mass of half a million Earths is crushed into a magnetized ball no larger than Washington, DC. A young isolated neutron star spins tens of times each second, and its rapidly spinning magnetic field powers beams of radio waves, visible light, X-rays, and gamma rays. If the beams sweep past Earth, a pulsar is observed. Prior to the launch of Fermi in 2008, only seven gamma-ray pulsars were known. To date, the mission has found more than 160.

Andromeda Galaxy Scanned with High-Energy X-ray Vision

NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) captured the best high-energy X-ray view yet of a portion of the Andromeda Galaxy, the closest major galaxy to the Milky Way. The mission observed 40 X-ray binaries, intense sources of X-rays comprised of a black hole or neutron star that feeds off a stellar companion.

The results provide a better understanding of the role of X-ray binaries in the evolution of the universe. These energetic objects may play a critical role in heating the intergalactic gas in which the first galaxies formed.

NASA's Chandra X-ray Observatory obtained crisper images of Andromeda at lower X-ray energies. The combination of Chandra and NuSTAR observations provides a powerful tool for narrowing in on the nature of the X-ray binaries in spiral galaxies.

With NuSTAR's new view of a swath of Andromeda, NASA scientists are working on identifying the fraction of X-ray binaries harboring black holes versus neutron stars. That research will help them understand the population as a whole.

NASA's Fermi Telescope Poised to Pin Down Gravitational Wave Sources

On September 14, 2016, energy waves traveling for more than a billion years gently rattled space-time in Earth's vicinity. The disturbance, produced by a pair of merging black holes, was captured by the Laser Interferometer Gravitational-Wave Observatory (LIGO) facilities in Hanford, WA, and Livingston, LA. This event marked the first-ever detection of gravitational waves and opens a new scientific window on how the universe works.

Less than half a second later, the Gamma-ray Burst Monitor (GBM) on NASA's Fermi Gamma-ray Space Telescope picked up a brief, weak burst of high-energy light consistent with the same part of the sky. Analysis of this burst suggests just a 0.2 percent chance of it simply being random coincidence. Gamma-rays arising from a black hole merger would be a landmark finding because black holes are expected to merge "cleanly," without producing light.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.	AS 11 1 Green	AS 12 1 Green	AS 13 1 Green	AS 14 1 Green	AS 15 1 Green	AS 16 1 Green
Planned Future Performance						
For FY 2017: AS-17-1: Demonstrate planned progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.						
For FY 2018: AS-18-1: Demonstrate planned progress in probing the origin and destiny of the universe, including the nature of black holes, dark energy, dark matter, and gravity.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					

Performance Goal 1.6.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe.	2.4.2.1 Green	2.4.2.1 Green	2.4.2.1 Green	1.6.3 Green	1.6.3 Green	1.6.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): On an annual basis, an independent, external expert review panel from the Astrophysics Advisory Committee (APAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Astrophysics Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

The Astrophysics Subcommittee of the NASA Advisory Council Science Committee determined in July 2016 that NASA remained on track in its annual performance towards the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Hubble Team Breaks Cosmic Distance Record

By pushing NASA's Hubble Space Telescope to its limits, an international team of astronomers has shattered the cosmic distance record by measuring the farthest galaxy ever seen in the universe. This surprisingly bright infant galaxy, named GN-z11, is seen as it was 13.4 billion years in the past, just 400 million years after the Big Bang. GN-z11 is located in the direction of the constellation Ursa Major. The astronomers are viewing GN-z11 at a time when the universe was only three percent of its current age.

This measurement provides strong evidence that some unusual and unexpectedly bright galaxies found earlier in Hubble images are at extraordinary distances. Previously, the team had estimated GN-z11's distance by determining its color through imaging with Hubble and NASA's Spitzer Space Telescope. Now, for the first time for a galaxy at such an extreme distance, the team used Hubble's Wide Field Camera 3 to precisely measure the distance to GN-z11 spectroscopically by splitting the light into its component colors.

This observation takes astronomy into the realm of very distant objects, marking the very early universe, which will be the subject of intense study with the upcoming James Webb Space Telescope, on track for launch in 2018.

NASA's Great Observatories Weigh Massive Young Galaxy Cluster

Astronomers have used data from three of NASA's Great Observatories to make the most detailed study yet of an extremely massive young galaxy cluster. This rare cluster, which is located 10 billion light years from Earth, weighs as much as 500 trillion Suns. This object has important implications for understanding how these megastructures formed and evolved early in the universe.

The galaxy cluster, called IDCS J1426.5+3508 (IDCS 1426 for short), is so far away that the detected light is from when the universe was roughly a quarter of its current age. It is the most massive galaxy cluster detected at such an early age.

Astronomers observed IDCS 1426 using the Hubble Space Telescope and the Keck Observatory to determine its distance. Observations from the Combined Array for Millimeter Wave Astronomy indicated it was extremely massive. New data from the Chandra X-ray Observatory confirm the galaxy cluster mass and show that about 90 percent of the mass of the cluster is in the form of dark matter, a mysterious substance detected only through its gravitational pull on normal matter composed of atoms.

Galaxy clusters are the largest objects in the universe bound together by gravity. Because of their sheer size, it should take several billion years for them to form. The distance of IDCS 1426 means astronomers are observing it when the universe was only 3.8 billion years old, implying that the cluster is seen at a very young age.

The data from Chandra reveal a bright knot of X-rays near the middle of the cluster, but not exactly at its center. This overdense core has been dislodged from the cluster center, possibly by a merger with another developing cluster 500 million years prior. Such a merger would cause the X-ray emitting, hot gas to slosh around like wine in a glass that is tipped from side to side.

The hot gas in the rest of the cluster is very smooth and symmetric. This is another indication that IDCS 1426 formed very rapidly. In addition, astronomers found possible evidence that the amount of elements heavier than hydrogen and helium in the hot gas is unusually low. This suggests that this galaxy cluster might still be in the process of enriching its hot gas with these elements as supernovae create heavier elements and blast them out of individual galaxies.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Demonstrate planned progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe.	AS 11 3 Green	AS 12 3 Green	AS 13 3 Green	AS 14 3 Green	AS 15 2 Green	AS 16 2 Green
Planned Future Performance						
For FY 2017: AS-17-2: Demonstrate planned progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe.						
For FY 2018: AS-18-2: Demonstrate planned progress in exploring the origin and evolution of the galaxies, stars, and planets that make up the universe.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete commissioning flights for Stratospheric Observatory for Infrared Astronomy (SOFIA) second-generation instrument suite.	AS 11 4 Green	AS 12 4 Green	AS 13 4 Green	AS-14-5 Yellow	AS 15 3 Green	AS-16-3 Yellow
Planned Future Performance						
For FY 2017: AS-17-3: Complete Stratospheric Observatory for Infrared Astronomy (SOFIA) third-generation instrument Critical Design Review (CDR).						
For FY 2018: No API this fiscal year						
Contributing Theme: Astrophysics	**Contributing Program:** Cosmic Origins					

Explanation of Rating

The High-resolution Airborne Wideband Camera-plus (HAWC+) instrument development schedule was delayed due to technical issues with the detector development and subsequently with temperature control. As a result, the instrument commissioning flights slipped. NASA completed the HAWC+ commissioning flights in December 2016.

Performance Goal 1.6.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in discovering and studying planets around other stars and exploring whether they could harbor life.	2.4.3.1 Green	2.4.3.1 Green	2.4.3.1 Green	1.6.4 Green	1.6.4 Green	1.6.4 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Astrophysics Advisory Committee (APAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Astrophysics Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Astrophysics Subcommittee of the NASA Advisory Council Science Committee determined in July 2016 that NASA remained on track in its annual performance towards the achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

The Kepler spacecraft's extended mission, called "K2," continues to provide high precision photometric observations of tens of thousands of sources being measured during different observing campaigns of about 80-days duration. K2 has been observing since May 2014 and is currently conducting its 11th observing campaign. K2 has been approved for operation through FY 2018 by the 2016 Astrophysics Senior Review of operating missions.

Recent scientific results include:

- Through September 2016, the number of confirmed exoplanets observed by K2 was 242, and another 391 exoplanet candidates had been identified. In addition to finding exoplanets around bright stars, which facilitate follow-up characterization, the mission continues to find exoplanets in new environments. K2-33b at 5-10 million years old is the youngest fully formed exoplanet detected to date. At the other end of the stellar life cycle, scientists have utilized K2 data to uncover strong evidence of a tiny, rocky object being torn apart as it spirals around a white dwarf star, validating a long-held theory that white dwarfs are capable of cannibalizing possible remnant planets that have survived within a solar system. Other NASA missions, such as the Spitzer Space Telescope and Hubble Space Telescope, are being used to refine the orbital parameters and begin the search for atmospheres of K2 discovered planets in advance of James Webb Space Telescope observations.
- The K2 mission successfully executed a search for microlensing events during its ninth campaign. This is a pathfinder for the Wide Field Infrared Survey Telescope (WFIRST) mission, which will search for exoplanets, as well as study dark matter and dark energy.
- From September 7-20, 2016, K2 observed comet 67P, providing a "big picture" view of the comet during the last month of the Rosetta mission. Ground-based telescopes could not see comet 67P, because the comet's orbit placed it in the sky during daylight hours.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in discovering and studying planets around other stars and exploring whether they could harbor life.	AS 11 5 Green	AS 12 5 Green	AS 13 5 Green	AS 14 6 Green	AS 15 5 Green	AS 16 5 Green
Planned Future Performance						
For FY 2017: AS-17-5: Demonstrate planned progress in discovering and studying planets around other stars and exploring whether they could harbor life.						
For FY 2018: AS-18-4: Demonstrate planned progress in discovering and studying planets around other stars and exploring whether they could harbor life.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					

Performance Goal 1.6.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
By December 2018, launch at least one mission in support of Strategic Objective 1.6.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.6.5 Green	1.6.5 Green	1.6.5 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Astrophysics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Written explanation of the rating and supporting material from the Science Mission Directorate's (SMD's) Flight Program Review archives. The Deputy Associate Administrator for SMD recommends a rating based on whether the underlying mission is on track to launch during the goal period. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

In support of Strategic Objective 1.6, NASA continued work on the Transiting Exoplanet Survey Satellite (TESS), which will use an array of telescopes to perform the first-ever spaceborne all-sky transit survey. TESS will look for exoplanets ranging from Earth-sized to gas giants in orbit around the nearest and brightest stars in the sky. The project's goal is to identify terrestrial planets in the habitable zones of nearby stars. TESS will monitor the brightness of half a million stars, looking for momentary changes in brightness caused when a planet passes, or transits, in front of the star as viewed from Earth.

Completion of TESS instrument integration and test (I&T), originally planned for late FY 2016, was rescheduled for May 2017. This is consistent with the approval in May 2016 by the NASA Human Exploration and Operations Mission Directorate's Flight Planning Board (FPB) of a shift in the mission's launch readiness date from August to December 2017, requested by the Space Exploration Technologies Corporation (SpaceX) to accommodate the replan of the TESS launch vehicle to a Falcon 9 1.2 ("Full Thrust"). Following this shift, the TESS Project Manager made a programmatic decision to allocate an additional portion of available schedule margin to instrument I&T. Subsequently, the FPB approved an additional launch readiness date delay to no earlier than March 2018 to accommodate additional SpaceX launch vehicle certification requirements.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Transiting Exoplanet Survey Satellite (TESS) instrument integration and test (I&T).	No API this fiscal year	No API this fiscal year	No API this fiscal year	AS 14 7 Green	AS 15 4 Green	AS-16-4 Yellow
Planned Future Performance						
For FY 2017: AS-17-4: Complete the Transiting Exoplanet Survey Satellite (TESS) System Integration Review (SIR).						
For FY 2018: AS-18-7: Launch the Transiting Exoplanet Survey Satellite (TESS).						
Contributing Theme: Astrophysics	**Contributing Program:** Astrophysics Explorer					

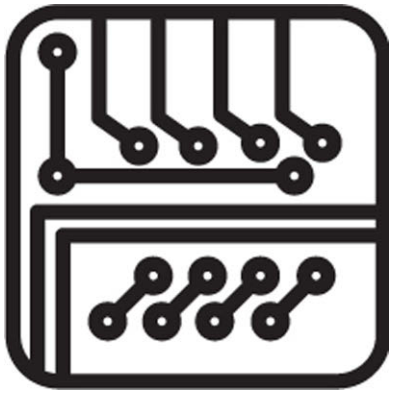
Explanation of Rating

As noted above, completion of Transiting Exoplanet Survey Satellite (TESS) instrument integration and test (I&T), originally planned for late FY 2016, was rescheduled for May 2017. This is consistent with the approval in May 2016 by the NASA Human Exploration and Operations Mission Directorate's Flight Planning Board (FPB) of a shift in the mission's launch readiness date from August to December 2017, requested by the Space Exploration Technologies Corporation (SpaceX) to accommodate the replan of the TESS launch vehicle to a Falcon 9 1.2 ("Full Thrust"). Following this shift, the TESS Project Manager made a programmatic decision to allocate an additional portion of available schedule margin to instrument I&T. Subsequently, the FPB approved an additional launch readiness date delay to no earlier than March 2018 to accommodate additional SpaceX launch vehicle certification requirements.

Prior TESS project technical issues with the data handling unit (DHU) have been mitigated by the parallel development of an alternate data handling unit (ADHU). Accordingly, the TESS project is confident of the availability of a flight unit to support the overall TESS schedule. The DHU interfaces with the satellite's cameras, performs high-speed data processing, communicates with the spacecraft avionics, provides mass data storage, and controls power to the instruments, among other critical functions.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Begin Wide-Field Infrared Survey Telescope (WFIRST) mission formulation.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AS 16 6 Green
Planned Future Performance						
For FY 2017: AS-17-6: Complete Wide-Field Infrared Survey Telescope (WFIRST) System Requirements Review (SRR).						
For FY 2018: AS-18-5: Complete Wide-Field Infrared Survey Telescope (WFIRST) Key Decision Point-B (KDP-B).						
Contributing Theme: Astrophysics	**Contributing Program:** Exoplanet Exploration					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: AS-17-7: Complete the 2016 Astrophysics Medium Explorer (MIDEX) Step One selection.	
For FY 2018: AS-18-6: Complete concept studies for the 2016 Astrophysics Medium Explorer (MIDEX) Announcement of Opportunity.	
Contributing Theme: Astrophysics	**Contributing Program:** Astrophysics Explorer



Strategic Objective 1.7

Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies.

Lead Office

Space Technology Mission Directorate (STMD)

Goal Leader

Dr. Prasun Desai, Deputy Associate Administrator for Management, STMD

Contributing Programs

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR), Space Technology Research and Development

Budget for Strategic Objective 1.7

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$655	–	$647	$647	$647	$647	$647

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Under Strategic Objective 1.7, NASA's Space Technology Mission Directorate (STMD) matures crosscutting and innovative space technologies that benefit the U.S. commercial sector, NASA missions, and other government agencies. STMD is making great strides toward delivering new technologies and capabilities. For example, during FY 2016, STMD tested a prototype solar electric propulsion (SEP) engine at Glenn Research Center, and contracted with Aerojet Rocketdyne, Inc., for the design and development of a high-power SEP flight system. SEP is a critical enabling technology for cost-effective deep space exploration.

Over the next several years, NASA's critical next steps are to continue exploring early stage concepts, advancing promising new technologies, and maturing transformative solutions for flight demonstration. This approach will include continued emphasis on lean, rapid technology development. STMD will also continue to emphasize partnerships within and outside the Agency. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans that the Agency's current efforts under Strategic Objective 1.7 will lead to advancing technology solutions that address NASA mission challenges and other national needs, as well as the market challenges of providing state-of-the-art commercial space products and services that significantly benefit the commercial space sector. However, STMD foresees several challenges and is pursing risk mitigation strategies for these issues.

- This strategic objective has faced historical funding uncertainty, which creates programmatic planning challenges. STMD strives to remain flexible in an uncertain budget environment.
- STMD pursues high-risk technology development. As is expected in such endeavors, STMD experiences challenges and setbacks. STMD continues to respond to budget constraints; cost, schedule, and performance issues; and other factors with both preventive and corrective actions.
- STMD recognizes the opportunity to further improve the integration of activities and technology transition. To increase the probability of transition, STMD is increasing emphasis on Small Business Innovation Research (SBIR) post-Phase II activities, is investing in continuation of promising early stage solutions, and is investing in tipping point technologies that are particularly promising opportunities for the U.S. commercial space sector.
- Access to space is a challenge. To demonstrate new technology capabilities in space, STMD relies on rideshare launch capabilities (i.e., as secondary payloads or hosted payloads). Increasing launch costs and limited availability are challenges.

For more information, please see http://www.nasa.gov/directorates/spacetech/home/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 1.7: Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies.		
Performance Goal 1.7.1: Explore and advance promising early stage solutions to space technology challenges through investment across the U.S. innovation community.	Performance Goal 1.7.2: Advance technologies that offer significant improvement to existing solutions or enable new space science and exploration capabilities.	Performance Goal 1.7.3: Mature new crosscutting space technology capabilities for demonstration.
Annual Performance Indicators		
• ST-16-1: Initiate at least 165 activities to research, study, or develop concepts for new technologies. • ST-16-2: Conduct at least three Centennial Challenges competitions. • ST-16-3: Create seven opportunities for advancement beyond Phase II SBIR/STTR.	• ST-16-4: Complete at least 75 percent of Game Changing Development program milestones, as established at the beginning of the fiscal year.	• ST-16-5: Complete three major milestones for small spacecraft projects to demonstrate game changing or crosscutting technologies in space. • ST-16-6: Complete three major milestones for Technology Demonstration Mission (TDM) technology development projects. • ST-16-7: Select and fly technology payloads from NASA, other government agencies, industry, and academia using flight services procured from at least five different commercial reusable suborbital or parabolic platform providers.

Summary of Performance for Strategic Objective 1.7

Performance Goal Ratings for Strategic Objective 1.7, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	3	3	0	0	0
2015	3	3	0	0	0
2014	3	3	0	0	0
2013	2	2	0	0	0
2012	2	2	0	0	0
2011	2	2	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 1.7, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	7	5	2	0	0
2015	6	5	1	0	0
2014	5	5	0	0	0
2013	5	5	0	0	0
2012	6	6	0	0	0
2011	5	5	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 1.7.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Explore and advance promising early stage solutions to space technology challenges through investment across the U.S. innovation community.	3.1.1.1 Green	3.1.1.1 Green	3.1.1.1 Green	1.7.1 Green	1.7.1 Green	1.7.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Space Technology	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Space Technology Research Grants, NASA Innovative Advanced Concepts, and Center Innovation Fund program documentation and press releases. **Verification and Validation:** Within the Space Technology Mission Directorate (STMD), Strategic Planning and Integration (SPI) coordinates and integrates performance goal and annual performance indicator (PG/API) review and evaluation, working closely with portfolio executives, program executives, and program managers responsible for individual PGs/APIs. For PG 1.7.1, this process includes review of program documentation and press releases for Space Technology Research Grants (STRG), NASA Innovative Advanced Concepts (NIAC), and Center Innovation Fund (CIF). Final ratings and justifications are approved by the SPI Director. During annual program performance status reviews, each program reports applicable PG/API ratings and justification to the STMD Program Management Council. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA is on track to meet this multiyear performance goal as the Agency continues to advance early stage innovation. The Space Technology Mission Directorate (STMD) develops the crosscutting new technologies and capabilities needed by the Agency to achieve its current and future missions. NASA made significant progress in the following areas:

Accelerating Development Through Research Grants

NASA STMD accelerates the development of low technology readiness level space technologies to support future space science and exploration needs. Implementation of this approach includes selection of research grants through competitive solicitations for proposals from accredited U.S. universities. Through NASA Space Technology Research Fellowships (NSTRF), Early Stage Innovations (ESI) awards, and Early Career Faculty (ECF) awards, STMD engages a broad spectrum of academic researchers, from graduate researchers to senior faculty members. In FY 2016, NASA selected:

- 58 NASA Space Technology Research Fellowships;
- 15 Early Stage Innovations awards; and
- Eight Early Career Faculty awards.

More information is available on the Space Technology Research Grants website.

Investing in Innovative and Advanced Concepts

NASA invests in concepts with the potential to transform future aerospace missions, enable new capabilities, or significantly alter and improve current approaches. In FY 2016, NASA:

- Made excellent progress on innovative concept studies selected in prior fiscal years; and
- Selected 21 new innovative concept studies comprising 13 Phase I projects and 8 Phase II projects.

More information is available on the NASA Innovative Advanced Concepts website.

Encouraging Innovation Within NASA's Centers

NASA encourages creativity and innovation within the NASA Centers by supporting low technology readiness level initiatives that leverage Center talent and capability. During FY 2016, NASA selected and conducted 116 Center Innovation Fund (CIF) projects that span:

- All NASA Centers; and
- NASA's 15 Technology Roadmaps.

More information is available on the CIF website.

Incentivizing Innovation Through Cash Prizes

NASA provides cash prize incentives to non-traditional sources for innovations of interest and value to the Agency and the Nation. NASA conducted the following Centennial Challenges competitions during FY 2016:

- Quest Challenge Ground Tournament-2 competition;
- Mars Ascent Vehicle Prize competition; and
- Level 1 and Level 2 challenges for the 2016 Sample Return Robot Challenge.

More information is available on the Centennial Challenges website.

Fostering Innovation at Small Businesses

NASA provides opportunities for small, highly innovative companies and research institutions to contribute to NASA's missions, provide societal benefit, and grow the U.S. economy. The Agency accomplishes this through its Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. The SBIR/STTR programs continue to promote advancement to and beyond Phase II, working closely with internal and external programs to identify and pursue potential collaborations. In FY 2016, NASA created 24 post-Phase II SBIR/STTR opportunities. These opportunities included Phase II-Enhancement contract options to extend SBIR/STTR research and development in partnership with non-SBIR/STTR funding partners. SBIR/STTR post-Phase

II advancement greatly exceeded expectations in FY 2016, especially given the inherent complexities in aligning willing external partners, appropriate technologies, and the right timing.

More information is available on the SBIR/STTR website.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Initiate at least 165 activities to research, study, or develop concepts for new technologies.	ST 11 1 Green	ST 12 1 Green	ST 13 1 Green	ST 14 1 Green	ST 15 1 Green	ST 16 1 Green
Planned Future Performance						
For FY 2017: ST-17-1: Initiate at least 165 activities to research, study, or develop concepts for new technologies.						
For FY 2018: ST-18-1: Initiate at least 165 activities to research, study, or develop concepts for new technologies.						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Conduct at least three Centennial Challenges competitions.	ST 11 2 Green	ST 12 2 Green	No API this fiscal year	No API this fiscal year	ST 15 2 Green	ST 16 2 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Create seven opportunities for advancement beyond Phase II SBIR/STTR.	ST 11 4 Green	ST 12 4 Green	No API this fiscal year	No API this fiscal year	No API this fiscal year	ST 16 3 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Space Technology	**Contributing Program:** SBIR and STTR					

Performance Goal 1.7.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Advance technologies that offer significant improvement to existing solutions or enable new space science and exploration capabilities.	3.2.1.1 Green	3.2.1.1 Green	3.2.1.1 Green	1.7.2 Green	1.7.2 Green	1.7.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					
Data Quality for FY 2018						
Data Source(s): Evidence will include the list of planned fiscal year milestones, along with completion status. **Verification and Validation:** Within the Space Technology Mission Directorate (STMD), Strategic Planning and Integration (SPI) coordinates and integrates performance goal and annual performance indicator (PG/API) review and evaluation, working closely with portfolio executives, program executives and program managers responsible for individual PGs/APIs. For PG 1.7.2, this process includes monthly assessment of milestone progress by Game Changing Development, including presentation of status to STMD leadership. Final ratings and justifications are approved by the SPI Director. During annual program performance status reviews, each program reports applicable PG/API ratings and justification to the STMD Program Management Council. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

During FY 2016, NASA completed 74 percent of its planned Game Changing Development (GCD) program milestones, falling just short of the aggressive 75 percent target it set for its annual performance indicator. However, the Agency is still on track to meet its multiyear performance goal, as the Space Technology Mission Directorate (STMD) continues to deliver improvements to existing capabilities and advance promising new technology solutions.

Improving Existing Capabilities and Advancing Promising New Technology Solutions

In FY 2016, the GCD program continued the advancement of many promising technology solutions. Highlighted accomplishments include:

- Phase Change Heat Exchanger (PCHX): The GCD program successfully matured and launched a self-contained, water-based heat exchanger to the International Space Station. The PCHX was launched on the Space Exploration Technologies Corporation's SpaceX-9 Commercial Resupply Services flight on July 18, 2016. The Phase Change Material Heat Exchanger (PCM HX) project began in 2013 at the Johnson Space Center. It is a collaboration between NASA's GCD program, International Space Station, and Advanced Exploration Systems program; the State of Louisiana; and the Small Business Innovation Research (SBIR) program (UTAS and Mezzo Technologies). Typically, crewed spacecraft use radiators to reject heat, but traditional radiators are not sized to handle the maximum amount of heat rejection, such as during launch, re-entry, and planetary orbits. During these times, a supplemental heat rejection device, such as an evaporator, is used to maintain the full heat rejection requirement of the spacecraft. Evaporators, however, use a consumable, typically water or ammonia. This new type of heat exchanger is self-contained and could help offset heat experienced by Orion and better regulate temperatures.

- Extreme Environment for Solar Power: The GCD program selected four proposals to the NASA Jet Propulsion Laboratory, the Boeing Company of Huntington Beach, and ATK Space Systems of Goleta under the Extreme Environment for Solar Power solicitation. The Extreme Environment for Solar Power project will aim to enhance and enable traditional solar cell and array systems that have been developed with a beginning of life conversion efficiency for intensity and temperature requirements associated with near Earth operation. This project will specifically look at design concepts for space power applications in high radiation and low solar flux environments. Initial contract awards are as much as $400 thousand, providing awardees with funding for nine months of system design, component testing, and analysis. This effort is in collaboration with the Planetary Science Division within NASA's Science Mission Directorate. They are the primary end users. Enhanced LILT (low intensity, low temperature) solar power will allow Planetary Science Division missions to go deeper into the solar system without the complexity and costs associated with nuclear-based solutions.
- High Performance Spaceflight Computing: The GCD program released a Request for Proposals (RFP) entitled, "High Performance Spaceflight Computing (HPSC) Processor Chiplet." The goal of HPSC activities is to develop a significantly improved spaceflight computing capability for NASA missions, addressing the computational performance, energy management, and fault tolerance needs of NASA missions through 2030. The Development Phase of the HPSC project will consist of a preliminary design phase, culminating in a Preliminary Design Review (PDR); a detailed design phase, culminating in a Critical Design Review (CDR); a fabrication phase; and a test and characterization phase. The project duration is baselined at four years. The project will deliver the following products: chiplet software emulator; chiplet simulation models; prototype processor "chiplets," including packaged parts and bare die, which have been functionally tested at ambient temperature; chiplet evaluation boards; and system software as specified in the HPSC Requirements document.
- NICER/SEXTANT: The GCD program successfully delivered the Station Explorer for X-ray Timing and Navigation Technology (SEXTANT). SEXTANT will be demonstrated with the Neutron star Interior Composition ExploreR (NICER) hardware on the International Space Station. In collaboration with the Science Mission Directorate, the project was selected in 2013 as an Explorer Mission of Opportunity. The goal of the NICER/SEXTANT mission will be to investigate pulsars and demonstrate real-time, autonomous spacecraft navigation using pulsars as beacons. The NICER/SEXTANT hardware was delivered to the Kennedy Space Center in the summer of 2016 ahead of a planned FY 2017 launch to the International Space Station.

More information is available on the Game Changing Development website.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete at least 75 percent of Game Changing Development program milestones, as established at the beginning of the fiscal year.	ST 11 7 Green	ST 12 7 Green	ST 13 2 Green	ST 14 2 Green	ST 15 3 Green	ST-16-4 Yellow
Planned Future Performance						
For FY 2017: ST-17-4: Complete at least 75 percent of Game Changing Development program milestones, as established at the beginning of the fiscal year.						
For FY 2018: ST-18-2: Complete at least 75 percent of Game Changing Development program milestones, as established at the beginning of the fiscal year.						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					

Explanation of Rating
In FY 2016, NASA adopted a new annual performance indicator (API) for STMD's Game Changing Development (GCD) program to more accurately reflect the program's performance as related to each project's performance. The GCD program targeted the completion of 75 percent of 85 identified milestones in the advancement of new technologies. The GCD program completed 74 percent of these milestones—just below the 75 percent target—resulting in a yellow rating for FY 2016.

Several adjustments were made to GCD projects throughout FY 2016, including project cancellations. The GCD program is currently evaluating these and other factors to better understand and address FY 2016 performance. As the program gains greater insight into these contributing factors, the GCD program may update this plan throughout the year.

Performance Goal 1.7.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Mature new crosscutting space technology capabilities for demonstration.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	1.7.3 Green	1.7.3 Green	1.7.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					
Data Quality for FY 2018						
Data Source(s): Review reports, Key Decision Points (KDP) decision memoranda, or other relevant milestone documentation. **Verification and Validation:** Within the Space Technology Mission Directorate (STMD), Strategic Planning and Integration (SPI) coordinates and integrates performance goal and annual performance indicator (PG/API) review and evaluation, working closely with portfolio executives, program executives, and program managers responsible for individual PGs/APIs. For PG 1.7.3, this process includes quarterly verification of completion of project Key Decision Points (KDPs) or key associated reviews (e.g., Preliminary Design Reviews, Critical Design Reviews), as defined in governing NASA Procedural Requirements; launches; and significant ground tests or flight operations. Final ratings and justifications are approved by the SPI Director. During annual program performance status reviews, each program reports applicable PG/API ratings and justification to the STMD Program Management Council. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results
NASA is on track to meet this multiyear performance goal as the Agency continues to mature new crosscutting space technology capabilities for demonstration.

Employing the Unique Features of Small Spacecraft

NASA develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration, and space operations. As part of this effort, the Space Technology Mission Directorate (STMD) made significant progress in FY 2016 on small spacecraft demonstration projects, including completion of the following major project lifecycle milestones:

- Integrated Solar Array and Reflectarray Antenna (ISARA) Flight Readiness Review
- CubeSat Proximity Operations Demonstration (CPOD) Flight Readiness Review
- Optical Communications and Sensor Demonstration (OCSD)-2 Flight Readiness Review

More information is available on the Small Spacecraft Technology website.

Maturing Crosscutting Technologies to Flight-Ready Status

Charged with proving revolutionary, crosscutting technologies—ones that could radically advance NASA's Mission in space and reap untold benefits for science and industry here on Earth—STMD seeks to mature laboratory-proven technologies to flight-ready status. In this area, STMD completed the following major milestones for its Technology Demonstration Mission (TDM) projects in FY 2016:

- Restore-L Key Decision Point-A (Key Decision Points are gatekeeping reviews held to determine the readiness of a program or project to progress to the next phase of the life cycle)
- Green Propellant Infusion Mission (GPIM) Pre-Shipment Review
- Evolvable Cryogenics Project (eCryo) Continuation Review
- Solar Electric Propulsion (SEP)/Asteroid Redirect Robotic Mission (ARRM) Key Decision Point-B

More information is available on the Technology Demonstration Missions website.

Providing Flight Opportunities

NASA develops and provides flight opportunities for space technologies to be demonstrated and validated in relevant environments. During FY 2016, STMD flew technology payloads using flight services from four providers:

- UP Aerospace, Inc.
- Zero Gravity Corporation (ZERO-G)
- World View Enterprises, Inc.
- Near Space Corporation

More information is available on the Flight Opportunities website.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete three major milestones for small spacecraft projects to demonstrate game changing or crosscutting technologies in space.	No API this fiscal year	ST 12 9 Green	ST 13 3 Green	ST 14 3 Green	ST 15 4 Green	ST 16 5 Green
Planned Future Performance						
For FY 2017: ST-17-5: Complete three major milestones for small spacecraft projects to demonstrate game changing or crosscutting technologies in space.						
For FY 2018: ST-18-3: Complete three major milestones for small spacecraft projects to demonstrate game changing or crosscutting technologies in space.						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete three major milestones for Technology Demonstration Mission (TDM) technology development projects.	ST 11 10 Green	ST 12 10 Green	ST 13 4 Green	ST 14 4 Green	ST 15 5 Green	ST 16 6 Green
Planned Future Performance						
For FY 2017: ST-17-6: Complete four major milestones for Technology Demonstration Mission (TDM) technology development projects.						
For FY 2018: ST-18-4: Complete four major milestones for Technology Demonstration Mission (TDM) technology development projects.						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Select and fly technology payloads from NASA, other government agencies, industry, and academia using flight services procured from at least five different commercial reusable suborbital or parabolic platform providers.	ST 11 11 Green	ST 12 11 Green	ST 13 5 Green	ST 14 5 Green	ST-15-6 Yellow	ST-16-7 Yellow
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development					

Explanation of Rating

In FY 2016, NASA flew payloads using flight services from four commercial providers (i.e., UP Aerospace, ZERO-G, World View, and Near Space). In addition, Flight Opportunities (FO) funded and was prepared to fly a payload on a Masten Space Systems vehicle. However, this commercial platform was not available to fly the FO payload in FY 2016. This resulted in a yellow rating for this annual performance indicator in FY 2016.

In FY 2017, NASA anticipates flying FO payloads for the first time on Blue Origin's New Shepard and Virgin Galactic's SpaceShipTwo. During FY 2016, FO additionally awarded six collaborations to five different companies under the FY 2015 Announcement of Collaborative Opportunity (ACO). Through these awards, FO encourages and assists the development of future commercial platforms. Also in FY 2016, FO released a small launch vehicle topic through the STMD Tipping Point solicitation. NASA is currently reviewing resulting proposals. FO also continues to solicit additional payloads for future flight campaigns through upcoming solicitations, including the Space Technology Research, Development, Demonstration, and Infusion-2017 (SpaceTech-REDDI-17) umbrella solicitation and a NASA-internal call.

Performance Goal 1.7.4

Does not trend until FY 2017.
Planned Future Performance
For FY 2017 and 2018: 1.7.4: Engage the established commercial sector, emerging aerospace markets, and economic regions to leverage common interests and grow the national economy.
Contributing Theme: Space Technology — **Contributing Program:** Multiple Programs
Data Quality for FY 2018
Data Source(s): External news releases and internal program documents. **Verification and Validation:** Within the Space Technology Mission Directorate (STMD), Strategic Planning and Integration (SPI) coordinates and integrates performance goal and annual performance indicator (PG/API) review and evaluation, working closely with portfolio executives, program executives and program managers responsible for individual PGs/APIs. For PG 1.7.4, this process includes review of external news releases and internal program documents. During annual program performance status reviews, each program reports applicable PG/API ratings and justification to the STMD Program Management Council. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

Annual Performance Indicator
For FY 2016: Does not trend until FY 2017.
Planned Future Performance
For FY 2017: ST-17-2: Conduct at least three prize competitions.
For FY 2018: ST-18-5: Conduct at least three prize competitions.
Contributing Theme: Space Technology — **Contributing Program:** Space Technology Research and Development

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: ST-17-3: Create 10 opportunities for advancement beyond Phase II SBIR/STTR.	
For FY 2018: ST-18-6: Create 15 opportunities for advancement beyond Phase II SBIR/STTR.	
Contributing Theme: Space Technology	**Contributing Program:** SBIR and STTR

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: ST-17-7: Select and fly technology payloads from NASA, other government agencies, industry, and academia using flight services procured from at least five different commercial reusable suborbital or parabolic platform providers.	
For FY 2018: ST-18-7: Select and fly technology payloads from NASA, other government agencies, industry, and academia using flight services procured from at least five different commercial reusable suborbital or parabolic platform providers.	
Contributing Theme: Space Technology	**Contributing Program:** Space Technology Research and Development

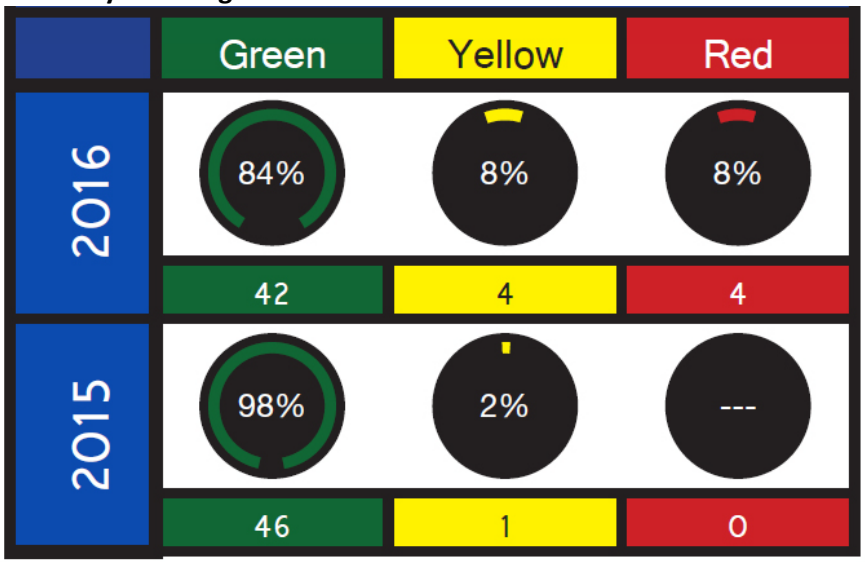
Strategic Goal 2

Advance understanding of Earth
and develop technologies to improve the quality
of life on our home planet.

Strategic Goal 2: Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.			
Strategic Objective 2.1: Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research.	Strategic Objective 2.2: Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet.	Strategic Objective 2.3: Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit.	Strategic Objective 2.4: Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.
FY 2016 Performance Goals			
• 2.1.1: Develop solutions that will advance decision-making ability for improving air traffic management to accommodate future growth in air travel, and for increasing aviation safety under hazardous conditions. • 2.1.2: Demonstrate the ability to reduce sonic booms, enabling future industry innovation in commercial supersonic aircraft. • 2.1.3: Advance airframe and engine technologies to enable the development of future generations of ultra efficient air vehicles that minimize environmental impact. • 2.1.4: Facilitate significant environmental and efficiency improvements through research on alternative jet fuel use and on hybrid gas-electric propulsion system concepts. • 2.1.5: Significantly increase the ability to anticipate and resolve potential safety issues and to predict the health and robustness of aviation systems. • 2.1.6: Support transformation of civil aircraft operations and air traffic management through the development, application, and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of Unmanned Aircraft Systems (UAS) in the National Airspace System, through the development and maturation of technologies and validation of data.	• 2.2.1: Demonstrate progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition. • 2.2.2: Demonstrate progress in improving the capability to predict weather and extreme weather events. • 2.2.3: Demonstrate progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle. • 2.2.4: Demonstrate progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change. • 2.2.5: Demonstrate progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system. • 2.2.6: Demonstrate progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events. • 2.2.7: Further the use of Earth system science research to inform decisions and provide benefits to society. • 2.2.8: By December 2017, launch at least five missions in support of Strategic Objective 2.2.	• 2.3.1: Implement the five-year Strategic Plan to improve the ability to transfer NASA-developed technologies.	• 2.4.1: Assure that students participating in NASA higher education projects are representative of the diversity of the Nation. • 2.4.2: Continue to support STEM educators through the delivery of NASA education content and engagement in educator professional development opportunities. • 2.4.4: Continue to provide opportunities for learners to engage in STEM education through NASA-unique content provided to informal education institutions designed to inspire and educate the public. • 2.4.5: Continue to provide opportunities for learners to engage in STEM education engagement activities that capitalize on NASA-unique assets and content.

Summary of Performance for Strategic Goal 2

Summary of Ratings of All Performance Measures for FY 2016 and 2015



Summary of Ratings for Performance Goals and Annual Performance Indicators by Strategic Objective, FY 2016

Lead	Strategic Objective	Performance Goals					Annual Performance Indicators				
		Total	Green	Yellow	Red	White	Total	Green	Yellow	Red	White
ARMD	2.1	6	6	0	0	0	9	7	2	0	0
SMD	2.2	8	7	1	0	0	16	15	1	0	0
OCT	2.3	1	1	0	0	0	2	2	0	0	0
Education	2.4	4	2	0	2	0	4	2	0	2	0
Total		19	16	1	2	0	31	26	3	2	0
Summary			84%	5%	11%	0%		84%	10%	6%	0%

Strategic Objective 2.1

Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research.

Lead Office

Aeronautics Research Mission Directorate (ARMD)

Goal Leader

Mr. Robert A. Pearce, Deputy Associate Administrator for Strategy, ARMD

Contributing Programs

Advanced Air Vehicles, Airspace Operations and Safety, Integrated Aviation Systems, Transformative Aeronautics Concepts

Budget for Strategic Objective 2.1

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$639	–	$624	$624	$624	$624	$624

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Under Strategic Objective 2.1, NASA's Aeronautics Research Mission Directorate (ARMD) advances aeronautics research along six Strategic Thrusts, which are research areas guiding ARMD's response to global trends affecting aviation:

- Strategic Thrust 1: Safe, Efficient Growth in Global Operations
- Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft
- Strategic Thrust 3: Ultra-Efficient Commercial Vehicles
- Strategic Thrust 4: Transition to Low-Carbon Propulsion

- Strategic Thrust 5: Real-Time System-Wide Safety Assurance
- Strategic Thrust 6: Assured Autonomy for Aviation Transformation

This strategic direction is described in ARMD's Strategic Implementation Plan, released in 2015, which provides a hierarchy of Outcomes, Research Themes, and Technical Challenges for each of the six Strategic Thrusts. The 2016 NASA Strategic Review found that ARMD's progress towards its strategic Outcomes and direction has been on track in the few years since it began implementing the new framework. External reports have been positive regarding the research portfolio and new strategic direction. Over the next several years, NASA's critical next steps are to continue contributing to the six new Strategic Thrusts through the completion of the Technical Challenges in partnership with the aviation community.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. There are no known significant events or issues that would prevent ARMD from achieving the strategic objective.

For more information, please see http://www.aeronautics.nasa.gov/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 2.1: Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research.					
Performance Goal 2.1.1: Develop solutions that will advance decision-making ability for improving air traffic management to accommodate future growth in air travel, and for increasing aviation safety under hazardous conditions.	Performance Goal 2.1.2: Demonstrate the ability to reduce sonic booms, enabling future industry innovation in commercial supersonic aircraft.	Performance Goal 2.1.3: Advance airframe and engine technologies to enable the development of future generations of ultra efficient air vehicles that minimize environmental impact.	Performance Goal 2.1.4: Facilitate significant environmental and efficiency improvements through research on alternative jet fuel use and on hybrid gas-electric propulsion system concepts.	Performance Goal 2.1.5: Significantly increase the ability to anticipate and resolve potential safety issues and to predict the health and robustness of aviation systems.	Performance Goal 2.1.6: Support transformation of civil aircraft operations and air traffic management through the development, application, and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of Unmanned Aircraft Systems (UAS) in the National Airspace System, through the development and maturation of technologies and validation of data.
Annual Performance Indicators					
• AR-16-1: Develop an integrated Concept of Operations (ConOps) to reduce take-off time variability, thereby decreasing delays, aircraft wait time, and fuel usage, and conduct a simulation to demonstrate technologies that support the integrated ConOps.	• AR-16-2: Complete Low Boom Flight Demonstration (LBFD) Concept Refinement Studies.	• AR-16-3: Quantify the drag reduction benefit of boundary layer ingestion for a representative aircraft configuration. • AR-16-4: Complete Phase I activities and create a plan for Phase II to enable the project to reduce the timeline for development and certification of advanced composite structures.	• AR-16-5: Develop a detailed conceptual design of a hybrid gas-electric propulsion system for a B737-class aircraft and assess its overall vehicle-level benefits in terms of noise, emissions, and energy consumption. • AR-16-6: Establish a process for originating, proposing, and selecting feasibility assessment research activities for the Convergent Aeronautics Solutions (CAS) Project.	• AR-16-7: Mature the safety risk assessment tools to validate and demonstrate safety metrics for real-time system-wide safety assurance.	• AR-16-8: Deliver data, analysis, and recommendations based on integrated simulation and flight test series with simulated traffic or live vehicles to the RTCA Special Committee on Minimum Operational Performance Standards (MOPS) for Unmanned Aircraft Systems to support development of the final MOPS. • AR-16-9: Complete Unmanned Aircraft Systems Traffic Management initial prototype to enable safe and efficient low altitude airspace operations and conduct initial tests.

Summary of Performance for Strategic Objective 2.1

Performance Goal Ratings for Strategic Objective 2.1, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	6	6	0	0	0
2015	6	6	0	0	0
2014	6	6	0	0	0
2013	4	4	0	0	0
2012	4	4	0	0	0
2011	4	4	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 2.1, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	9	7	2	0	0
2015	4	4	0	0	0
2014	6	5	1	0	0
2013	3	3	0	0	0
2012	4	4	0	0	0
2011	3	3	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 2.1.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Develop solutions that will advance decision-making ability for improving air traffic management to accommodate future growth in air travel, and for increasing aviation safety under hazardous conditions.	4.1.2.1 Green	4.1.2.1 Green	4.1.2.1 Green	2.1.1 Green	2.1.1 Green	2.1.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Aeronautics	**Contributing Program:** Airspace Operations and Safety					
Data Quality for FY 2018						
Data Source(s): Execution of a series of demonstrations of NASA-developed concepts and technologies; demonstration data, including available aircraft and system performance metrics, and controller and pilot workload and acceptance data; demonstration reports and technical publications that include data analyses, conclusions, and any recommendations from the demonstration participants. **Verification and Validation:** Measure rating reviewed and approved quarterly by the Program Director and Aeronautics Research Mission Directorate (ARMD) Associate Administrator (AA). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

During FY 2016, NASA contributed specific research and technology that will advance decision-making ability for improving air traffic management (ATM) to accommodate future growth in air travel, and for increasing aviation safety under hazardous conditions as part of the continued development of the Next Generation Air Transportation System (NextGen).

NASA continued development of an avionics suite for a major in-flight demonstration planned for early 2017 of a Flight Deck Interval Management (FIM) system, which is a key component of the Agency's ATM Technology Demonstration-1 (ATD-1) research designed to make airport arrivals more efficient. FIM is a cockpit-based system that combines NASA-developed software with commercially available off-the-shelf hardware. FIM connects to existing avionics to offer pilots a more efficient way to approach an airport for landing by safely decreasing the time between each touchdown.

NASA also made progress with ATM Technology Demonstration-2 (ATD-2), an initiative that provides coordinated aircraft surface movement schedules to air traffic managers working the airport ramp, control tower, terminal area, and air route centers. ATD-2 provides tools to make better decisions about how to reduce congestion, helping to ensure the aviation system is able to safely absorb the more than four billion additional passengers that are estimated to be traveling globally during the next 20 years. To that end, an aeronautical research laboratory was opened in June 2016 at the Charlotte Douglas International Airport. An initial Engineering Shadow Evaluation of ATD-2 surface management tools was conducted and two Phase 1 Engineering Shadow Evaluations were completed at the lab late in FY 2016. The initial Operational Shadow Evaluation is scheduled in the first quarter of FY 2017.

In FY 2016, NASA completed an initial Concept of Use document for the first phase of an Integrated Arrival/Departure/Surface (IADS) baseline

demonstration, which is part of the ATD-2 project. ATD-2 seeks to improve efficiencies in scheduling arrivals, departures, and runway and surface operations. The Concept of Use document was matured following four rounds of review and involved addressing 571 comments from stakeholders.

NASA also helped deliver and train personnel on an ATM tool at American Airlines' Integrated Operations Center in Fort Worth, Texas. The National Airspace System Constraint Evaluation and Notification Tool, or NASCENT, enables airline flight coordinators to call out adjustments in a flight's trajectory in real time, particularly to avoid bad weather. At the heart of the technology is NASA-developed software called Dynamic Weather Routes, which continuously and automatically analyzes aircraft flight paths in the National Airspace System to find opportunities for time- and fuel-saving corrections to avoid bad weather. Route corrections are simple reroutes like those typically used in today's operations. In support of advancing NASA's contributions to improving the Nation's ATM systems, the Agency hosted industry and government members of the Federal Aviation Administration's (FAA's) Flow Evaluation Team at NASA's North Texas Research Station (NTX) during the first quarter of FY 2016. The gathering included discussion and demonstrations of the Precision Departure Release Capability and Dynamic Weather Routes tools, which have been turned over to the FAA. The meeting is but one example of how NASA constantly strives to improve partner coordination, which also facilitates transfer of NASA's technology research successes to industry and the FAA.

Also in FY 2016, NASA's Aeronautics Research Mission Directorate completed a roadmap from today through 2035 and beyond that defines epochs, outcomes, and research themes for safe, efficient growth in global operations. The Thrust 1 roadmap identified five strategies involving NextGen, Unmanned Aircraft Systems integration, revolutionary ATM concepts integration, safety needs, and tools for testing future concepts. The roadmap remains open for continued vetting by stakeholders, the aviation community, and the general public.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Develop an integrated Concept of Operations (ConOps) to reduce take-off time variability, thereby decreasing delays, aircraft wait time, and fuel usage, and conduct a simulation to demonstrate technologies that support the integrated ConOps.	AR 11 4 Green	AR 12 6 Green	No API this fiscal year	AR 14 4 Green	AR 15 1 Green	AR 16 1 Green
Planned Future Performance						
For FY 2017: AR-17-1: Conduct Shadow Mode assessment of departure metering prototypes in the field.						
For FY 2018: AR-18-1: Demonstrate the Integrated Demand Management (IDM) concept to coordinate management of traffic demand and flight trajectories across multiple constraints, resulting in improved arrival operations in the New York City metroplex airspace.						
Contributing Theme: Aeronautics	**Contributing Program:** Airspace Operations and Safety					

Performance Goal 2.1.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate the ability to reduce sonic booms, enabling future industry innovation in commercial supersonic aircraft.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	2.1.2 Green	2.1.2 Green	2.1.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Aeronautics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Successful completion and reports for Project Key Decision Points and Life Cycle Reviews. Plans and approvals for Initial Community Response. **Verification and Validation:** Measure rating reviewed and approved quarterly by the Program Director and Aeronautics Research Mission Directorate (ARMD) Associate Administrator (AA). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The return of supersonic passenger air travel within the National Airspace System took a major leap forward during FY 2016 with NASA's completion of Concept Refinement Studies and award of a contract for the preliminary design of a "low boom" flight demonstration (LBFD) concept. Work on the concept is expected to lead to the potential design, construction, and flight of an LBFD X-plane.

The primary goal is to design and then fly a piloted test aircraft that can fly at supersonic speeds, creating a quieter supersonic "heartbeat"—a soft thump, rather than the disruptive boom currently associated with supersonic flight.

In addition to the completion of the Concept Refinement Studies, another step towards maturing the LBFD concept was the validation of the Low Sonic Boom Design Tools in FY 2016. This helped pave the way for awarding a contract that will lead to a Preliminary Design Review (PDR) for LBFD in FY 2017. The contract was awarded to a team led by Lockheed Martin Aeronautics Company of Palmdale, CA, and is being executed as a task under the Basic and Applied Aerospace Research and Technology contract at NASA's Langley Research Center in Hampton, VA.

In close collaboration with NASA, the Lockheed-led team will develop baseline aircraft requirements and a preliminary aircraft design, with supporting documentation for concept formulation and project planning. In the months since the contract award, the team has worked to define the high-level systems requirements and to begin to flow those requirements into the more detailed aircraft and subsystem requirements. An aircraft System Requirements Review was successfully completed, leading to the first release of the preliminary design geometry. The details of this geometry are being used to fabricate scale models that will be tested in wind tunnels in 2017 to validate the performance of the design. The team will continue to develop and validate the preliminary design through the remainder of 2016 and into the first half of 2017. The effort will conclude with the PDR early next summer.

In parallel with the demonstration design, NASA led efforts continued to improve the understanding of how the supersonic acoustic signature from a future quiet aircraft will interact with the atmosphere as it travels from the aircraft to the ground and, once reaching the ground, how it is perceived by people, both indoors and outdoors. Models of human response, and structural response that creates indoor acoustics leading to human response, have been improved and tested in NASA's unique simulation facilities. NASA also initiated a new effort to plan for future tests that will collect data on people's response to supersonic overflight in actual communities. NASA continues to work with the international standards and regulatory communities, including the International Civil Aviation Organization and Federal Aviation Administration, to ensure that the results of NASA's work will support the ongoing efforts to develop certification standards for supersonic aircraft. Jet noise during takeoff and landing also is a concern for future supersonic aircraft. In FY 2016, NASA completed a key Technical Challenge in this area by developing tools and technologies needed to help these propulsion systems meet noise standards. Comprehensive testing in ground facilities was conducted to validate the technologies. The overall goal of this research is to reassess and replace current noise certification standards, which are preventing overland supersonic flight due to unacceptable noise in older supersonic technologies.

Also in FY 2016, NASA's Aeronautics Research Mission Directorate completed a roadmap from today through 2035 and beyond that guides the development of innovative technologies in support of reintroducing commercial supersonic aircraft to the National Airspace System. The Thrust 2 roadmap calls for near-term demonstration of supersonic flight without disruptive sonic boom noise and delivering scientifically valid data on community response to U.S. and international standard and regulatory organizations. The roadmap remains open for continued vetting by stakeholders, the aviation community, and the general public.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Complete Low Boom Flight Demonstration (LBFD) Concept Refinement Studies.	AR 11 8 Green	AR 12 10 Green	AR 13 5 Green	AR 14 12 Green	AR 15 2 Green	AR 16 2 Green
Planned Future Performance						
For FY 2017: AR-17-2: Complete Low-Boom Flight Demonstration (LBFD) Aircraft Preliminary Design Review (PDR).						
For FY 2018: AR-18-2: Award the Low-Boom Flight Demonstration (LBFD) Aircraft Design, Build, and Initial Test Contract.						
Contributing Theme: Aeronautics	**Contributing Program:** Advanced Air Vehicles					

Performance Goal 2.1.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Advance airframe and engine technologies to enable the development of future generations of ultra efficient air vehicles that minimize environmental impact.	4.1.3.1 Green	4.1.3.1 Green	4.1.3.1 Green	2.1.3 Green	2.1.3 Green	2.1.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Aeronautics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): NASA publications (e.g., Technical Memoranda, Contractor Reports) and/or presentations and test reports. **Verification and Validation:** Measure rating reviewed and approved quarterly by the Program Director and Aeronautics Research Mission Directorate (ARMD) Associate Administrator (AA). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

During FY 2016, NASA continued to support world-class research aimed at developing future aircraft that could reduce fuel burn by 50 percent, landing and take-off (LTO) nitric oxide and nitrogen dioxide (NO_x) emissions by 75 percent, and noise to nearly one-half of today's regulatory limits.

One promising technology that could help realize these goals is boundary layer ingestion (BLI). This is where the jet engines are mounted on top of the fuselage at the rear of the aircraft in a manner that enables the air flowing over the aircraft to enter the engine and join with the jet exhaust, resulting in improvement in engine efficiency. During a review in the first quarter of FY 2016 of wind tunnel and computational fluid dynamics (CFD) simulations performed on a representative BLI-equipped aircraft—namely the D8 series "double bubble" aircraft design under investigation by a team led by the Massachusetts Institute of Technology—the drag reduction benefits of BLI were evaluated. The consensus of the review panel was that all milestones showing those benefits were realized. Additional studies of the D8 concept featuring BLI are planned for early FY 2017.

In FY 2016, a variety of research efforts were initiated or completed by NASA to design, build, and fly a variety of flight demonstration vehicles, also known as "X-planes." For example, a transonic truss-braced wing (TTBW) high-speed performance test was conducted in the NASA Ames Research Center's 11- by 11-Foot Transonic Wind Tunnel Facility. These tests, in addition to other advanced technologies for this TTBW concept, show the potential of the concept to improve fuel burn by greater than 50 percent. NASA also initiated a preliminary design of key aspects for the double bubble configuration. This work will help better understand how the airframe can be tested to show the tremendous benefits of this configuration.

Many of the ultra-efficient commercial vehicles proposed for development require ever-more-advanced composite structures. NASA continued to develop and test these structures in FY 2016 by supporting the methods, tools, and processes associated with today's composite structure requirements. Important steps were taken to develop computational tools in order to reliably predict the strength and life of composite structures, reducing design cycle time and testing efforts during the development and certification processes. Key tests were conducted to obtain detailed data that will be critical for

validating these computational tools. Another area of key progress was in the area of testing methods to help determine if damage exists in a composites structure. Enabling future ultra-efficient vertical lift capabilities is also an important aspect of Thrust 3. In FY 2016, NASA helped achieve significant success in demonstrating a variable-speed power-turbine (VSPT) system, working closely with industry and the U.S. Army. NASA and its partners completed the design, fabrication, and testing of a VSPT component that exceeded the design goals over a defined operating speed range. This technology will enable fuel-efficient commercial vertical lift concepts with flight speed validation for insertion in the Next Generation Air Transportation System (NextGen) airspace.

Also in FY 2016, NASA's Aeronautics Research Mission Directorate (ARMD) completed Thrust 3 roadmaps that will guide research of innovative technologies in support of developing ultra-efficient commercial vehicles and subsonic transports, including vertical lift, which are more economical and use less fuel, reduce emissions, and fly more quietly. This included defining epochs, outcomes, and research themes derived from ARMD's Strategic Implementation Plan. The Thrust 3 roadmaps remain open for continued vetting by stakeholders, the aviation community, and the general public.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Quantify the drag reduction benefit of boundary layer ingestion for a representative aircraft configuration.	AR 11 6 Green	AR 12 8 Green	AR 13 4 Green	AR 14 5 Green	No API this fiscal year	AR 16 3 Green
Planned Future Performance						
For FY 2017: AR-17-3: Design, fabricate, and test an engine inlet-fan configuration that withstands the flow distortions arising from boundary layer ingestion and demonstrates vehicle-level fuel-burn benefit through minimal impact on fan performance and stability.						
For FY 2018: AR-18-3: Design, fabricate, and test a high aspect ratio wing box employing tow-steered composites and demonstrate vehicle-level fuel-burn benefit through aeroelastic-tailored structural design.						
Contributing Theme: Aeronautics	**Contributing Program:** Advanced Air Vehicles					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Phase I activities and create a plan for Phase II to enable the project to reduce the timeline for development and certification of advanced composite structures.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AR-14-9 Yellow	No API this fiscal year	AR-16-4 Yellow
Planned Future Performance						
For FY 2017: AR-17-4: Successfully complete Phase-2 Authority to Proceed (ATP) Review (i.e., Key Decision Point-D [KDP-D]), mature the down-selected tools and methodologies according to Phase-2 KDP success criteria, and fabricate key element or component-level validation test articles.						
For FY 2018: No API this fiscal year						
Contributing Theme: Aeronautics	**Contributing Program:** Advanced Air Vehicles					

Explanation of Rating
Completion of Phase I activities and planning for Phase II were delayed to 1st quarter FY 2017.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: AR-17-6: Complete Critical Design Review (CDR) of the X-57 Maxwell aircraft.	
For FY 2018: AR-18-6: Demonstrate novel landing gear porous fairing and wheel cavity treatments that reduce the airframe component of aircraft noise by at least 1.5 decibels (dB).	
Contributing Theme: Aeronautics	**Contributing Program:** Integrated Aviation Systems

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: AR-17-7: Demonstrate advanced high-temperature engine materials for high-pressure turbine components, enabling reduced cooling and thereby lower engine fuel burn.	
For FY 2018: AR-18-7: Complete detailed experimental measurements in the wing-body junction region of an aircraft to enable better computational tools for prediction of future air vehicle designs.	
Contributing Theme: Aeronautics	**Contributing Program:** Transformative Aeronautics Concepts

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: AR-17-8: Demonstrate a two-speed drive system that achieves a reduction in helicopter rotor revolutions per minute (RPM).	
For FY 2018: AR-18-8: Demonstration of a multidisciplinary design analysis and optimization (MDAO) process for the conceptual design of vertical lift vehicles.	
Contributing Theme: Aeronautics	**Contributing Program:** Advanced Air Vehicles

Performance Goal 2.1.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Facilitate significant environmental and efficiency improvements through research on alternative jet fuel use and on hybrid gas-electric propulsion system concepts.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	2.1.4 Green	2.1.4 Green	2.1.4 Green
Planned Future Performance						
For FY 2017: 2.1.4: Facilitate significant environmental and efficiency improvements through research on alternative jet fuel use and on hybrid gas-electric propulsion system concepts.						
For FY 2018: 2.1.4: Facilitate significant environmental and efficiency improvements through research on alternative jet fuel use, and on hybrid gas-electric propulsion system concepts.						
Contributing Theme: Aeronautics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): NASA publications (e.g., Technical Memoranda, Contractor Reports) and/or presentations and test reports. **Verification and Validation:** Measure rating reviewed and approved quarterly by the Program Director and Aeronautics Research Mission Directorate (ARMD) Associate Administrator (AA). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

During FY 2016, NASA continued its investigations into the use of alternative fuels for commercial jet airliners, as well as development of all-electric or hybrid gas-electric propulsion systems that could enable low or nearly no carbon emission propulsion.

On the heels of the successful Alternative-Fuel Effects on Contrails and Cruise Emissions (ACCESS-2) flight experiment flown back in 2014, critical data analysis has continued to aid in the development of cleaner alternative aviation fuels. Data from the ACCESS-2 flight experiment has enabled new research to be investigated in the area of alternative fuels, focusing on reducing additive or aromatic compound effects during ground engine demonstrations. NASA, working in collaboration with the German Aerospace Center (DLR), supplied several key measurement systems for the DLR's Emissions and Climate Impacts of Alternative Aviation Fuels (ECLIF) experiments during the first quarter of FY 2016. Under this activity, NASA researchers placed sampling inlets roughly 100 feet (30 meters) behind a parked DLR Airbus 320 and measured engine soot emissions. Data were acquired at five different thrust settings as the engines burned eight different types of conventional and alternative fuels that contained varying amounts of aromatic compounds and/or sulfur impurities. These data will be used to better interpret in-flight measurements made by DLR aboard their Falcon 20 chase aircraft and to develop and verify models that predict cruise emissions from ground-based engine certification measurements.

Industry-led studies, complemented by NASA's internal concept assessments of a hybrid gas-electric propulsion system for a Boeing 737-class aircraft, have confirmed that it is feasible to achieve overall vehicle-level benefits—including reduced noise, emissions, and energy consumption—using a hybrid

system, which uses batteries in conjunction with gas turbine propulsion. This enabled NASA to complete in FY 2016 a detailed conceptual design for such an aircraft.

In addition, NASA in FY 2016 continued investigating the potential of an advanced turboelectric concept employing an aft electric motor to re-energize the plane's boundary layer. These new concepts will be used to establish key performance parameters for in-depth design work and maturation to enable components such as lightweight electrical systems and machines. Concurrently, work on superconducting designs for larger, 300 passenger aircraft have been reformulated to concentrate on key enabling components, specifically wire and coil designs, and also to fully understand the fundamental loss mechanisms that have been inhibiting this technology for aerospace turbogenerator applications.

Also during FY 2016, NASA re-designated a planned all-electric research aircraft, part of NASA's ongoing Scalable Convergent Electric Propulsion Technology and Operations Research (SCEPTOR) project, as the X-57 Maxwell, the Agency's first numbered X-plane in more than a decade. The general aviation-sized airplane will be a highly-modified Tecnam P2006T featuring a high-aspect ratio wing that sports 12 small, electrically-driven propellers on its leading edge, and two slightly larger motors on the wingtips. During 2016, the aircraft fuselage was delivered to a NASA contractor for inspections and modifications, which will include adding a new wing and the total of 14 electric motors.

Also in FY 2016, NASA's Aeronautics Research Mission Directorate completed a roadmap from today through 2035 and beyond that guides the research of innovative technologies to enable low-carbon emissions through use of both alternate jet fuels with lower life-cycle carbon footprints, and alternative propulsion systems, such as hybrid-electric or all-electric. The Thrust 4 roadmap remains open for continued vetting by stakeholders, the aviation community, and the general public.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Develop a detailed conceptual design of a hybrid gas-electric propulsion system for a B737-class aircraft and assess its overall vehicle-level benefits in terms of noise, emissions, and energy consumption.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AR 14 13 Green	AR 15 4 Green	AR 16 5 Green
Planned Future Performance						
For FY 2017: AR-17-5: Design and fabricate a megawatt-class fully superconducting electric machine with advanced stator design and demonstrate its capability for at least 750 kilowatt rated power.						
For FY 2018: AR-18-5: Design, build, and test key ambient-temperature electric aircraft powertrain components that achieve specific performance parameters necessary for large commercial applications.						
Contributing Theme: Aeronautics	**Contributing Program:** Advanced Air Vehicles					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Establish a process for originating, proposing, and selecting feasibility assessment research activities for the Convergent Aeronautics Solutions (CAS) Project.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AR 16 6 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Aeronautics	**Contributing Program:** Transformative Aeronautics Concepts					

Performance Goal 2.1.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Significantly increase the ability to anticipate and resolve potential safety issues and to predict the health and robustness of aviation systems.	4.1.1.1 Green	4.1.1.1 Green	4.1.1.1 Green	2.1.5 Green	2.1.5 Green	2.1.5 Green
Planned Future Performance						
For FY 2017 and 2018: 2.1.5: Significantly increase the ability to anticipate and resolve potential safety issues, and to predict the health and robustness of aviation systems.						
Contributing Theme: Aeronautics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): Assured tools that improve the accuracy of real-time detection, diagnosis, and prediction of hazardous states and the impact of these states on system safety. Demonstration, benefits analysis, and transition of new real-time system-wide safety technologies. **Verification and Validation:** Measure rating reviewed and approved quarterly by the Program Director and Aeronautics Research Mission Directorate (ARMD) Associate Administrator (AA). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

During FY 2016, NASA worked to mature new safety risk assessment tools that can validate and demonstrate safety metrics for real-time, system-wide safety assurance.

Two directed studies were completed and final reports submitted in April 2016. These studies, conducted by Crown Consulting, Inc. and the Science Applications International Corporation (SAIC), supported articulation of NASA's Real-time System-wide Safety Assurance (RSSA) vision and research plan by identifying a set of safety metrics for evaluating safety risk and contributing candidate roadmaps for system-wide safety technology development to

enable RSSA. Both study teams validated their approach and metrics using a team of subject matter experts.

An internal NASA team also began conducting studies to validate safety assessment tools related to hazards in the airspace using historical aviation data. Preliminary results were presented at the American Institute of Aeronautics and Astronautics Aviation Technology, Integration, and Operations Conference in June 2016.

Also in FY 2016, NASA's Aeronautics Research Mission Directorate (ARMD) completed a Thrust 5 roadmap from today through 2035 and beyond that guides research of innovative technologies to enable real-time, system-wide safety assurance. Elements of this roadmap include design, development, training, operation, and maintenance. The Thrust 5 roadmap remains open for continued vetting by stakeholders, the aviation community, and the general public.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Mature the safety risk assessment tools to validate and demonstrate safety metrics for real-time system-wide safety assurance.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AR 16 7 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Aeronautics	**Contributing Program:** Airspace Operations and Safety					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: AR-17-10: Develop technologies and training processes that mitigate the problems and contributing factors that lead to flight crew loss of airplane state awareness.	
For FY 2018: No API this fiscal year	
Contributing Theme: Aeronautics	**Contributing Program:** Airspace Operations and Safety

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year	
For FY 2018: AR-18-4: Develop initial tools for identifying, measuring, and monitoring safety margins with initial components for evolution of real-time system-wide capability.	
Contributing Theme: Aeronautics	**Contributing Program:** Airspace Operations and Safety

Performance Goal 2.1.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Support transformation of civil aircraft operations and air traffic management through the development, application, and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of Unmanned Aircraft Systems (UAS) in the National Airspace System, through the development and maturation of technologies and validation of data.	4.2.1.1 Green	4.2.1.1 Green	4.2.1.1 Green	2.1.6 Green	2.1.6 Green	2.1.6 Green
Planned Future Performance						
For FY 2017: 2.1.6: Support transformation of civil aircraft operations and air traffic management through the development, application and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of Unmanned Aircraft Systems (UAS) in the National Airspace System, through the development and maturation of technologies and validation of data.						
For FY 2018: 2.1.6: Support transformation of civil aircraft operations and air traffic management through the development, application, and validation of advanced autonomy and automation technologies, including addressing critical barriers to future routine access of Unmanned Aircraft Systems (UAS) in the National Airspace System, through the development and maturation of technologies and validation through demonstration.						
Contributing Theme: Aeronautics	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): An unmanned aircraft system (UAS) traffic management (UTM) Technology Capability Level (TCL) research assessment and related documentation. **Verification and Validation:** Measure rating reviewed and approved quarterly by the Program Director and Aeronautics Research Mission Directorate (ARMD) Associate Administrator (AA). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

Ever-increasing levels of automation and autonomy are transforming aviation. Safe integration of Unmanned Aircraft Systems (UAS)—commonly called drones—into the National Airspace System (NAS) requires research in multiple areas, including communications, human-machine interfaces, sense-and-avoid, and separation assurance. NASA's aeronautical innovators addressed each of these areas during FY 2016 with a particular emphasis on developing a UAS Traffic Management (UTM) concept to handle the growing number of small drones taking to the skies.

In FY 2016, NASA successfully demonstrated rural operations of a UTM concept, integrating operator platforms, vehicle performance, and ground infrastructure. This was in support of meeting the goals for Technology Capability Level One (TCL1), the first of four defined levels that address different operational UAS environments, each of which requires its own development of proposed uses, software, procedures, and policies to enable safe operation. Following a TCL1 demonstration at a single site late in 2015, a national campaign involving six geographically diverse Federal Aviation Administration (FAA) UAS test sites was conducted in April 2016. NASA, the FAA, and industry partners participating in eight different states simultaneously flew 22 drones to assess rural operations of NASA's UTM research platform. The next level, TCL2, which is intended to demonstrate applications that operate beyond visual line of sight of the operator in sparsely populated areas, was successfully demonstrated during the first quarter of FY 2017. TCL3 and TCL4, which together further expand the UAS operating envelope, are planned for demonstrations in calendar years 2018 and 2019.

In FY 2016, NASA also delivered its contribution to a set of UAS Minimum Operating Performance Standards (MOPS) data, analysis, and recommendations to the Radio Technical Commission for Aeronautics (RTCA) Special Committee 228 on MOPS for UAS. Based on a series of flight test and other activities, this first series of MOPS addresses standards for Detect and Avoid (DAA) and Command and Control (C2) solutions for UAS operating in a specific segment of airspace. A C2 MOPS was presented to the RTCA in July, while a DAA MOPS entered a final review and comment period late in FY 2016.

Also in FY 2016, NASA's Aeronautics Research Mission Directorate (ARMD) completed a roadmap from today through 2035 and beyond that guides research of innovative technologies to enable autonomous systems that employ highly intelligent machines to maximize the benefits of aviation to society. The goal is that anyone can safely fly any time, and anywhere, while sharing the sky with 1,000 times more vehicles, many flying in close proximity to people and property—all without harming the environment. The Thrust 6 roadmap remains open for continued vetting by stakeholders, the aviation community, and the general public.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Deliver data, analysis, and recommendations based on integrated simulation and flight test series with simulated traffic or live vehicles to the RTCA Special Committee on Minimum Operational Performance Standards (MOPS) for Unmanned Aircraft Systems to support development of the final MOPS.	No API this fiscal year	AR 12 13 Green	AR 13 7 Green	AR 14 8 Green	AR 15 7 Green	AR-16-8 Yellow
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Aeronautics	**Contributing Program:** Integrated Aviation Systems					

Explanation of Rating
NASA completed Flight Test Series 4, but did not fully complete Flight Test Series 3. However, all data required for the successful completion of the requirement were provided to the Radio Technical Commission for Aeronautics (RTCA) Special Committee 228 through the project's other research activities.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Unmanned Aircraft Systems Traffic Management initial prototype to enable safe and efficient low altitude airspace operations and conduct initial tests.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AR 16 9 Green
Planned Future Performance						
For FY 2017: AR-17-9: Deliver the second build of an Unmanned Aircraft System Traffic Management (UTM) Technology Capability Level (TCL) demonstration to assess increased density and contingency management in low-altitude airspace.						
For FY 2018: AR-18-9: Deliver the third Unmanned Aircraft System Traffic Management (UTM) Technology Capability Level (TCL) demonstration to enable beyond visual line-of-sight operations in suburban settings in a live, virtual constructive environment.						
Contributing Theme: Aeronautics	**Contributing Program:** Airspace Operations and Safety					

Strategic Objective 2.2

Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet.

Lead Office

Earth Science Division, Science Mission Directorate (SMD)

Goal Leader

Dr. Michael Freilich, Director, Earth Science Division

Contributing Programs

Applied Sciences, Earth Science Multi-Mission Operations, Earth Science Research, Earth Science Technology, Earth System Science Pathfinder, Earth Systematic Missions

Budget for Strategic Objective 2.2

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$1,927	–	$1,754	$1,769	$1,769	$1,769	$1,769

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has determined that performance toward this strategic objective is making noteworthy progress.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. NASA's Strategic Objective 2.2 is pursued by the Science Mission Directorate (SMD) Earth Science Division, which seeks to develop a scientific understanding of the Earth's system and its response to natural or human-induced changes, and to improve

prediction of climate, weather, and natural hazards. Particularly noteworthy scientific discoveries and major accomplishments occurred in the last year, including the launch of the Cyclone Global Navigation Satellite System (CYGNSS) mission in December 2016. CYGNSS will use eight microsatellites to measure wind speeds over the Earth's oceans, increasing the ability of scientists to understand and predict hurricanes. The 2016 Strategic Review also noted that the Earth Science Division is playing a leading role in:

- Partnering with and providing support for other federal agencies.
- Initiating innovative flight programs (such as using the International Space Station, Venture Class Launch Services, small-sat constellations, and CubeSat-based technology demonstration flights).
- Leading major international collaborations with non-traditional partners for major flight missions, such as the NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) mission.

NASA's critical next steps include continuing the development of several missions, such as the Ice, Cloud, and land Elevation Satellite (ICESat)-2, Gravity Recovery and Climate Experiment Follow-On (GRACE-FO), and Surface Water and Ocean Topography (SWOT) mission. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. In 10 years, NASA plans that the Agency's current efforts under Strategic Objective 2.2 will lead to further understanding of Earth as a system to meet the challenges of environmental change, as well as continued improvement of life on Earth. Many of the key challenges for the Earth Science Division are common across all of the SMD divisions (access to space; technology development; project technical, cost, and schedule challenges; and partnerships) and are articulated in the *2014 Science Plan*. The Earth Science Division is pursuing several opportunities to mitigate or address challenges, such as international partnerships, developing new and innovative ways of making Earth observations via the Earth Venture solicitations, utilizing the International Space Station as a platform for observations, and continuing to make technology investments through the Earth Science Technology Program.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://science.nasa.gov/earth-science/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*. Additional information on strategies, challenges, implementation, and program-specific detail is available in the *NASA 2014 Science Plan*.

FY 2016 Performance Measures

Strategic Objective 2.2: Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet.							
Performance Goal 2.2.1: Demonstrate progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition.	Performance Goal 2.2.2: Demonstrate progress in improving the capability to predict weather and extreme weather events.	Performance Goal 2.2.3: Demonstrate progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle.	Performance Goal 2.2.4: Demonstrate progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change.	Performance Goal 2.2.5: Demonstrate progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.	Performance Goal 2.2.6: Demonstrate progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.	Performance Goal 2.2.7: Further the use of Earth system science research to inform decisions and provide benefits to society.	Performance Goal 2.2.8: By December 2017, launch at least five missions in support of Strategic Objective 2.2.
Annual Performance Indicators							
• ES-16-1: Demonstrate planned progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition.	• ES-16-2: Demonstrate planned progress in improving the capability to predict weather and extreme weather events.	• ES-16-3: Demonstrate planned progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle.	• ES-16-4: Demonstrate planned progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change. • ES-16-6: Achieve Soil Moisture Active Passive (SMAP) mission success criteria.	• ES-16-7: Demonstrate planned progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.	• ES-16-8: Demonstrate planned progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.	• ES-16-10: Maintain a high level of customer satisfaction, as measured by exceeding the most recently available Federal Government average rating of the American Customer Satisfaction Index. • ES-16-9: Advance at least 40 percent of Earth science applications projects one Applications Readiness Level.	• ES-16-11: Complete Cyclone Global Navigation Satellite System (CYGNSS/EV-2) Unit 1 thermal vacuum test. • ES-16-13: Complete Ice, Cloud, and Land Elevation Satellite (ICESat)-2 Mission Operations Center (MOC) final release. • ES-16-14: Complete the Surface Water and Ocean Topography (SWOT) mission Preliminary Design Review (PDR). • ES-16-15: Complete the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission instrument deliveries to integration and test (I&T). • ES-16-16: Complete NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) High Capacity Data Storage Subsystem Preliminary Design Review (PDR). • ES-16-18: Complete Earth Venture Instrument (EVI)-3 selections. • ES-16-19: Complete the Landsat 9 Mission Definition Review (MDR).

Summary of Performance for Strategic Objective 2.2

Performance Goal Ratings for Strategic Objective 2.2, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	8	7	1	0	0
2015	8	8	0	0	0
2014	8	8	0	0	0
2013	7	7	0	0	0
2012	7	7	0	0	0
2011	7	7	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 2.2, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	16	15	1	0	0
2015	12	12	0	0	0
2014	11	10	1	0	0
2013	10	9	1	0	0
2012	9	8	1	0	0
2011	9	8	1	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 2.2.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition.	2.1.1.1 Green	2.1.1.1 Green	2.1.1.1 Green	2.2.1 Green	2.2.1 Green	2.2.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Earth Science Advisory Committee (ESAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Earth Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Earth Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

In July 2016, the United Nations World Climate Research Programme released a report on carbon tetrachloride (CCl_4) emissions. The report answers questions related to the global budget of CCl_4, an important ozone-depleting substance, closing the gap between emissions reported to the United Nations Environment Programme's ozone secretariat and those estimated from atmospheric observations. NASA-funded scientists participated as authors and editors of this report. A different study, based on chemistry climate model simulations, reported that hydrofluorocarbons (HFCs) will increasingly impact the global atmosphere through 2050. HFCs are strong greenhouse gases that directly contribute to global warming. HFCs increase tropospheric and stratospheric temperatures, thereby enhancing ozone-destroying catalytic cycles and modifying the atmospheric circulation. These changes lead to a weak depletion of stratospheric ozone. Simulations with the NASA Goddard Space Flight Center 2-D model showed that HFC-125, a type of HFC used in fire suppression systems, will be the most significant contributor to HFC-related atmospheric change in 2050.

Researchers analyzed publicly-available hydrogen chloride, water vapor, and ozone data from the Global Ozone Chemistry And Related trace gas Data records for the Stratosphere (GOZCARDS) project, hosted by the Goddard Earth Science Data and Information Services Center. The GOZCARDS dataset is a

global, long-term, commonly-formatted Earth system data record, based on high-quality measurements from several NASA satellite instruments and from the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) on the Canadian Space Agency's SCISAT-1 spacecraft. This dataset will be especially useful to the study of ozone depletion and recovery.

Emissions of nitrogen oxides, which act as indirect greenhouse gases, decreased over North America during the 2005-2010 period, due to federal, state, and local air quality policies. However, the expected resulting decrease in tropospheric ozone was partially offset by increased downwelling from the stratosphere and increased transport of pollution from China. In particular, a recent study reported that the transport of ozone and its precursors from China had offset about 43 percent of the 0.42 Dobson unit (DU) reduction in tropospheric ozone over the western United States that was expected between 2005 and 2010. Unlike stratospheric ozone, which makes Earth habitable by absorbing ultraviolet (UV) radiation, tropospheric (i.e., ground-level) ozone is a pollutant that can be harmful to human health.

With the use of satellite retrievals and surface observations of atmospheric methane, researchers found that U.S. methane emissions increased by more than 30 percent over the 2002-2014 period. The trend was found to be largest in the central part of the country, but it could not be readily attributed to any specific source type. They concluded that these "top-down" derived emissions were far greater than those estimated from the "bottom-up" approach that computes emissions as the product of activity rates.

Scientists used the Hyperion imaging spectrometer onboard the NASA Earth Observing (EO)-1 satellite to successfully detect methane emissions from the accidental release at the Aliso Canyon gas storage facility near Porter Ranch, CA, during the winter of 2015-2016, achieving the first orbital attribution of methane to a single anthropogenic super-emitter. These orbital observations were consistent with measurements by NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) flying onboard a NASA Lockheed ER-2 aircraft.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition.	ES 11 1 Green	ES 12 1 Green	ES 13 1 Green	ES 14 1 Green	ES 15 1 Green	ES 16 1 Green
Planned Future Performance						
For FY 2017: ES-17-1: Demonstrate planned progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition.						
For FY 2018: ES-18-1: Demonstrate planned progress in advancing the understanding of changes in Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Performance Goal 2.2.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in improving the capability to predict weather and extreme weather events.	2.1.2.1 Green	2.1.2.1 Green	2.1.2.1 Green	2.2.2 Green	2.2.2 Green	2.2.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Earth Science Advisory Committee (ESAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Earth Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Earth Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

During FY 2016, NASA-sponsored research continued to provide new insights into weather and extreme-weather events via the utilization of data obtained from a variety of satellite platforms, including the Geostationary Operational Environmental Satellites (GOES), Tropical Rainfall Measuring Mission (TRMM), Global Precipitation Measurement (GPM), Aqua, Terra, Suomi National Polar-orbiting Partnership (NPP), CloudSat, and Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), as well as a field campaign.

Up to now, cloud- and precipitation-affected satellite observed radiances have been excluded from use in most atmospheric data assimilation systems, mostly because of deficiencies in existing methodologies to assimilate these data effectively. The availability of GPM mission data allowed NASA scientists to implement several key extensions of modeling and assimilation schemes. The new "all-sky" conditions (i.e., in clear, cloudy, and precipitating environments) assimilation has undergone extensive testing in the current Goddard Earth Observing System Model, Version 5 (GEOS-5), and shows improvement on mean skill scores and forecasts of individual hurricanes.

Observations of precipitation in mountainous terrain were collected during the GPM-sponsored Olympic Mountain Experiment (OLYMPEX) held

November 2015-January 2016 in the Olympic Mountains in Washington (https://pmm.nasa.gov/OLYMPEX). OLYMPEX was one of the most comprehensive campaigns for GPM for validating rain and snow measurements in mid-latitude frontal systems moving from ocean to coast to mountains. OLYMPEX observations will be used to investigate the optimal use of precipitation GPM observations in a range of hydrologic, weather forecasting, and climate process studies and products.

TRMM data for the period 1998-2013, which coincides with the global warming hiatus, allowed researchers to investigate changes in daily precipitation extremes. Results show a change in probability distribution functions of local precipitation events (LPEs) during this period consistent with previous global warming studies, indicating increasing contrast between wet and dry extremes, with more intense LPEs, and more dry (no rain) days globally. Analyses for land and ocean separately reveal more complex and nuanced changes over land, characterized by a strong positive trend (an increase of 12.0 percent per decade) in the frequency of extreme LPEs over the Northern Hemisphere extratropics during the wet season, but a negative global trend (a decrease of 6.6 percent per decade) during the dry season. A significant global drying trend (3.2 percent per decade) over land was also found during the dry season. Regions of pronounced increased dry events include the western and central United States, northeastern Asia, and southern Europe and the Mediterranean.

Landslide inventories are critical to support investigations of where and when landslides have occurred and may occur in the future; however, there is little information on the historical occurrence of landslides at the global scale. In FY 2015, NASA scientists updated the first publicly-available global landslide catalog (GLC), which is based on media reports, online databases, and other sources. NASA researchers then began comparing reported landslide events with precipitation estimates from TRMM to evaluate the co-occurrence of extreme precipitation and landslide activity. Of the 3,550 points considered in a subset of the GLC, approximately 60 percent of the reported landslides had daily precipitation exceeding the 95th percentile of precipitation calculated over a 14-year TRMM record for the same location.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Demonstrate planned progress in improving the capability to predict weather and extreme weather events.	ES 11 5 Green	ES 12 4 Green	ES 13 3 Green	ES 14 3 Green	ES 15 2 Green	ES 16 2 Green
Planned Future Performance						
For FY 2017: ES-17-2: Demonstrate planned progress in improving the capability to predict weather and extreme weather events.						
For FY 2018: ES-18-2: Demonstrate planned progress in improving the capability to predict weather and extreme weather events.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: ES-17-6: Achieve the Cyclone Global Navigation Satellite System (CYGNSS) mission success criteria.	
For FY 2018: No API this fiscal year	
Contributing Theme: Earth Science	**Contributing Program:** Earth System Science Pathfinder

Performance Goal 2.2.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle.	2.1.3.1 Green	2.1.3.1 Green	2.1.3.1 Green	2.2.3 Green	2.2.3 Green	2.2.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Earth Science Advisory Committee (ESAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Earth Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Earth Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Earth's physical climate is changing, and there are measurable impacts on Earth's biogeochemistry and ecosystems. Researchers used model inputs from a variety of process-based biophysical models to examine the net balance of the three major greenhouse gases—carbon dioxide, methane, and nitrous

oxide—which revealed that human-induced emissions of methane and nitrous oxide overwhelmingly surpass the ability of the land to absorb carbon dioxide emissions.

High-resolution lidar-derived biomass maps provided a valuable bottom-up reference to improve the analysis and interpretation of large-scale maps produced in carbon monitoring systems. A global gridded data product of agricultural carbon budgets was developed, including crop- and animal-based food intake, crop biofuels, crop residues left on-field and used as feed, crop byproducts used as feed, livestock grazing, additions to food reserves, and food supply chain losses and waste.

Researchers used the Normalized Difference Vegetation Index (NDVI) dataset to constrain estimates of net biome production (NBP) over Europe between 1982 and 2012. The NDVI uses remote sensors to assess the density of vegetation in a geographic area. The research revealed links to anomalies in heat and water transport controlled by interactions between the North Atlantic Oscillation and the East Atlantic Pattern. These results suggest that human alterations of land cover and management practices over the past century have resulted in a substantial increase of carbon exported from the land to the ocean.

The Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) airborne campaign continued to elucidate the seasonal dynamics and environmental controls of methane emissions in the Alaskan Arctic and boreal ecosystems. Research over the past year showed that methane emissions after snowfall are greater than summer emissions in Arctic Alaska, and that methane emissions in upland tundra are greater than in wetland tundra.

Field-based isotopic black carbon (i.e., light-absorbing carbon) from wildfires was analyzed and compared to measurements from an aerosol network and predicted concentrations from an atmospheric transport model, which showed that fires were the dominant contributor to variability in carbonaceous aerosol mass in interior Alaska during the summer. Carbonaceous aerosols make up a large but variable fraction of atmospheric aerosol, and consist of black carbon and organic compounds that may be emitted from biomass burning, fossil fuel combustion, and industrial processes.

Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) data were combined in a land model to assess the impact of urbanization on U.S. surface climate. For cities built within forests, daytime urban land surface temperature is much higher than that of vegetated lands. With a small areal extent, urbanization has been found to have significant effects on surface energy, water, and carbon budgets, revealing an uneven impact on surface climate that should inform policy options for improving urban growth, including heat mitigation and carbon sequestration.

Terrestrial and aquatic ecosystems respond to climate variability and change, including impacts on species distribution and biodiversity. Researchers combined crowdsourced (e.g., citizen science) in situ data with satellite imagery and models to develop dynamic distribution models for bird species, showing how birds can adapt their migratory strategies to changing land cover along their routes.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle.	ES 11 7 Green	ES 12 6 Green	ES 13 5 Green	ES 14 6 Green	ES 15 3 Green	ES 16 3 Green
Planned Future Performance						
For FY 2017: ES-17-3: Demonstrate planned progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle.						
For FY 2018: ES-18-3: Demonstrate planned progress in detecting and predicting changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2017.
Planned Future Performance
For FY 2017: ES-17-12: Achieve the Orbiting Carbon Observatory (OCO)-2 mission success criteria.
For FY 2018: No API this fiscal year
Contributing Theme: Earth Science — **Contributing Program:** Earth System Science Pathfinder

Performance Goal 2.2.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change.	2.1.4.1 Green	2.1.4.1 Green	2.1.4.1 Green	2.2.4 Green	2.2.4 Green	2.2.4 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): On an annual basis, an independent, external expert review panel from the Earth Science Advisory Committee (ESAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Earth Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

The Earth Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

NASA's Water and Energy Cycle focus area continues to improve the understanding of the water cycle by developing tools that contribute to a better evaluation of the global water cycle budget and improved assessment of water quality, both of which can help enable improved water resource management.

In a recent study, scientists used Gravity Recovery and Climate Experiment (GRACE) mission data, along with Global Land Data Assimilation Systems outputs, to quantify the extended major drought over eastern Brazil. Another study demonstrated that intensified water cycle extremes are linked to strengthened El Niño Southern Oscillation (ENSO) teleconnections, which modulate California's climate not only through ENSO's warm and cold phases, but also through its precursor patterns.

Researchers used a variety of satellite data sources and modeling tools to show that between 2002 and 2014, climate variability resulted in an additional 3,200 gigatons of water stored on land. This gain of the amount of water stored on land partially offsets the contributions to sea level rise, for example by melting ice sheets and glaciers, to slow the rate of overall sea level rise by approximately 0.71 millimeters per year.

Scientists also helped recreate past snow water equivalent values in the Sierra Nevada Mountains, while combining very high resolution Landsat snow mapping with a mesoscale model via data assimilation. The results showed that 2015 was an extremely dry year. The 2015 conditions, occurring on top of three previous drought years, led to the highest accumulated snowpack deficit over the 65 years analyzed.

A seminal paper described the Airborne Snow Observatory (ASO), a project combining an airborne coupled imaging spectrometer, a scanning lidar, and distributed snow modeling for measuring snow spectral and broadband albedos (i.e., the proportion of solar energy reflected from Earth back into space) and snow depth. ASO has been providing weekly information over the past four years to hydrological scientists and resource managers for a few basins in California.

In a recent study, researchers analyzed Coupled Model Intercomparison Project Phase 5 (CMIP5) model runs during 1990-2000 and 2090-2100, and compared them to a dataset built from modern observations, to evaluate and explain how the water cycle might intensify over the coming century and what the results of this intensification may be. Using regional projections, the study also elucidated changes in regions influential to the large-scale ocean circulation. These revealed export of atmospheric moisture from the tropical Americas in the Atlantic to the Pacific Ocean.

Researchers used in-situ and satellite data to review the surface temperature of 235 lakes, on six continents, and discovered that more than half of the world's freshwater supply is threatened by rising water temperatures. They found that lakes are warming at an average of 0.34 degrees Celsius each decade, which is a larger rate than seen in either the ocean or the atmosphere. The study projected that warming lakes will produce 4 percent more methane per decade and over the next century, and that lake algal bloom outbreaks may increase by 20 percent.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change.	ES 11 9 Green	ES 12 8 Green	ES 13 7 Green	ES 14 7 Green	ES 15 4 Green	ES 16 4 Green
Planned Future Performance						
For FY 2017: ES-17-4: Demonstrate planned progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change.						
For FY 2018: ES-18-4: Demonstrate planned progress in enabling better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Achieve Soil Moisture Active Passive (SMAP) mission success criteria.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ES-16-6 Yellow
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions					

Explanation of Rating
The Soil Moisture Active Passive (SMAP) observatory met its science objectives, but only partially met its mission success criteria. NASA's assessment for the performance of SMAP is a yellow rating.

The SMAP spacecraft carries two instruments, an active radar and a passive radiometer, designed to provide concurrent, complementary measurements of the amount of moisture in the soil, and to determine whether the ground is frozen or thawed in colder areas of the world. SMAP began routine operations on May 11, 2015. To meet the minimum success criteria, SMAP needed to collect global, space-based measurements for at least six months. Due to an anomaly involving its high-power amplifier, the radar stopped transmitting on July 7, 2015, so measurements were collected for only 1.9 months. This falls approximately four months short of the duration defined in the minimum success criteria. However, due to its late winter launch, and the early validation of soil moisture data, SMAP observed the seasonal phenomena needed for mission success. The science objectives were met, but the criteria as written were only partially met.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: ES-17-17: Achieve the Global Precipitation Measurement (GPM) mission success criteria.	
For FY 2018: No API this fiscal year	
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions

Performance Goal 2.2.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.	2.1.5.1 Green	2.1.5.1 Green	2.1.5.1 Green	2.2.5 Green	2.2.5 Green	2.2.5 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): On an annual basis, an independent, external expert review panel from the Earth Science Advisory Committee (ESAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Earth Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

The Earth Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

The NASA Climate Variability and Change (CVC) focus area continues to increase knowledge of global climate and sea level on seasonal to decadal time scales, through its three constituent programs: Cryospheric Sciences; Physical Oceanography; and Modeling, Analysis, and Prediction (MAP). Together, these programs collect and assess satellite, aircraft, and ground-based observations of sea ice, glaciers, ice sheets, and the global ocean, and integrate them into comprehensive, interactive Earth system models. Highlights of research conducted in the past year are summarized below.

The loss of Arctic sea ice has emerged as a leading signal of global warming. The September 2015 seasonal minimum extent was the fourth lowest on record, and reinforces the long-term downward trend. The nine lowest September sea ice extents in the satellite record have all occurred in the last nine years. In stark contrast with Arctic sea ice, sea ice around Antarctica has reached a record maximum extent in each of the last three years, with maximum extent recorded in October 2015.

The processes controlling ice loss from the Greenland ice sheet continue to be the subject of intense focus. Multi-beam echo sounding observations revealed that marine-terminating glaciers are grounded deeper below sea level than previously measured, and undercut by warm, salty Atlantic water, which enhances iceberg calving (i.e., the breaking off of chunks of ice at the edge of a glacier). This impacts ice front stability and, in turn, glacier mass balance. Researchers used ice-penetrating radar and a subglacial flow model to show that the connectivity of different regions influences how glacier velocity responds to variations in surface melting.

Ice shelves represent a critical, climate-sensitive interface between the Antarctic ice sheet and the global ocean. Researchers used satellite observations and a polar-adapted regional climate model to assess the twenty-first-century evolution of surface melt across Antarctica under intermediate and high emissions climate scenarios. Both scenarios yield a doubling of Antarctic-wide melt by 2050, and under the high emissions scenario, melt on several ice shelves approaches or surpasses intensities historically associated with ice shelf collapse by 2100.

Global mean sea level has been rising at a rate of approximately 3.4 millimeters per year since 1993, based on sea surface heights measured by the TOPEX/Poseidon, Jason-1, and Ocean Surface Topography Mission (OSTM)/Jason-2 satellites. This represents an acceleration from pre-industrial times. The annual rate has roughly equal contributions from ocean warming, melting of ice sheets, and melting of mountain glaciers. Temporal and regional variations in this rate can exceed the global mean rate due to a combination of factors, including variations in the water cycle and interannual and decadal variations of wind forcing of the ocean and ocean circulation.

Studies of ocean salinity have blossomed in the last decade with the advent of the Argo profiling float program, the European Space Agency's Soil Moisture Ocean Salinity (SMOS) satellite, and NASA's Aquarius and Soil Moisture Active Passive (SMAP) satellite missions. Water evaporating from the ocean sustains precipitation on land, a process that leaves an imprint on sea surface salinity. Researchers found that springtime sea surface salinity in the subtropical North Atlantic Ocean is a useful predictor of terrestrial precipitation during the summer monsoon in Africa, and also outweighs the leading sea surface temperature modes in predicting summer precipitation in the U.S. Midwest.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Demonstrate planned progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.	ES 11 11 Green	ES 12 10 Green	ES 13 9 Green	ES 14 9 Green	ES 15 7 Green	ES 16 7 Green
Planned Future Performance						
For FY 2017: ES-17-7: Demonstrate planned progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.						
For FY 2018: ES-18-5: Demonstrate planned progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: ES-17-5: Produce three consistent indicators of critical Earth system parameters based on data from NASA research satellites (either on their own or in conjunction with non-NASA satellites) to help document long-term Earth system evolution. Indicators will cover time scales appropriate for climate variability and change studies.	
For FY 2018: No API this fiscal year	
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs

Performance Goal 2.2.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Demonstrate progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.	2.1.6.1 Green	2.1.6.1 Green	2.1.6.1 Green	2.2.6 Green	2.2.6 Green	2.2.6 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): On an annual basis, an independent, external expert review panel from the Earth Science Advisory Committee (ESAC) evaluates scientific progress relative to the current Science Plan and assigns a rating to the annual performance indicator that supports this performance goal. Their findings are available online at https://science.nasa.gov/researchers/nac/science-advisory-committees/. The Earth Science Division Director recommends a rating for the performance goal based on the findings of the review panel and other significant factors, if applicable. Ratings are reviewed by the Deputy Associate Administrator for Research within NASA's Science Mission Directorate (SMD), with any issues being resolved by the Associate Administrator for SMD. **Verification and Validation:** Review of the ratings and supporting material from the external expert review panel, along with a written explanation of any other significant factors considered in arriving at the rating, if applicable. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The Earth Science Subcommittee of the NASA Advisory Council Science Committee determined in September 2016 that NASA remained on track in its annual performance supporting achievement of this performance goal. Below are examples of the scientific progress reported in FY 2016.

Earth Surface and Interior (ESI) focus area investigators continued to advance understanding of interactions between hydraulic systems and solid-Earth deformation. Researchers used Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) data acquired in June 2009 and July 2012 to measure ongoing subsidence near New Orleans, LA. Primary drivers of subsidence were identified as groundwater withdrawal and surficial drainage and dewatering activities, with high subsidence rates also observed around some major industrial facilities and due to shallow compaction in highly localized areas. UAVSAR also captured subsidence in California's Sacramento-San Joaquin Delta. The study measured subsidence rates across Sherman Island averaging 1.3 centimeters per year, with a systematic uncertainty of 0.3 centimeters per year, consistent with previous measurements at electric transmission line towers. Results have important implications for maintaining a reliable water supply for the state of California and protecting the Delta ecosystem.

The dynamics of the mantle and core fundamentally drive the evolution of the Earth's shape, orientation and rotation, plate motions, and deformation. Two studies investigated processes acting on polar motion. The first analyzed space geodetic and satellite gravimetric data for the period 2003-2015 to

show that all of the main features of polar motion are explained by global-scale continent-ocean mass transport, especially changes in terrestrial water storage (TWS) and the global cryosphere. The second showed that Global Positioning System (GPS)-based observations of diurnal and semidiurnal variations in polar motion were most consistent with the recent models for ocean tide effects together with libration effects (i.e., the oscillation of the Moon relative to Earth). The results suggest revisiting model recommendations for adoption by the International Earth Rotation Service.

California's unprecedented drought is having a profound impact on landslides. Recent research assessed 98 deep-seated, slow-moving landslides in northern California using analysis of aerial photographs, satellite interferometry, and satellite pixel tracking to measure earthflow velocities spanning 1944-2015. Landslide and earthflow velocities reached a historical low in the 2012-2015 drought, but their deceleration began at the turn of the century in response to a longer-term moisture deficit. The analysis implies depth-dependent sensitivity of earthflows to climate forcing, with thicker earthflows reflecting longer-term climate trends and thinner earthflows exhibiting less systematic velocity variations. In a follow up study, the researchers assessed how landslides shape terrain in response to tectonic uplift of the northern California Coast Ranges. They found that landslide erosion rates mapped from aerial imagery are consistent with modeled uplift and exhumation, while hill slope gradient is invariant across the region, suggesting that landslides accommodate uplift, as predicted by the threshold slope model. The Slumgullion landslide in Colorado is 3.9 kilometers long and moves persistently at rates approaching 2 centimeters per day. Researchers collected UAVSAR imagery over Slumgullion and developed a new approach to resolve a three-dimensional deformation field across the length of the landslide. The approach was validated with GPS data and then was used to resolve the average landslide thickness and spatially coherent deforming regions within the slide. Researchers were able to relate velocity to rheological parameters and found that the landslide has a viscoplastic rheology (i.e., the land shifts only when it is placed under a sufficient level of stress).

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Demonstrate planned progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.	ES 11 15 Green	ES 12 14 Green	ES 13 11 Green	ES 14 11 Green	ES 15 8 Green	ES 16 8 Green
Planned Future Performance						
For FY 2017: ES-17-8: Demonstrate planned progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.						
For FY 2018: ES-18-6: Demonstrate planned progress in characterizing the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Performance Goal 2.2.7

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Further the use of Earth system science research to inform decisions and provide benefits to society.	2.1.7.1 Green	2.1.7.1 Green	2.1.7.1 Green	2.2.7 Green	2.2.7 Green	2.2.7 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					
Data Quality for FY 2018						
Data Source(s): NASA Applied Sciences Program's Annual Report, CFI Group report, and other documentation, as appropriate. The Director of the NASA Applied Sciences Program recommends a rating after reviewing progress toward the performance goal. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's Applied Sciences Program (ASP) enables innovative and practical uses of Earth observations by businesses, governments, and nonprofits to inform their decisions and actions. The enhanced decision-making made possible by ASP projects improves quality of life and strengthens the economy. Following are some examples from FY 2016:

- The National Oceanic and Atmospheric Administration (NOAA) began applying an Evaporative Stress Index (ESI) operationally. ESI shows the beginning of a drought two-to-four weeks before plant stress shows up in current drought indicators, giving farmers considerable added lead time to offset the effects of drought.
- Conservation International expanded its Firecast application, enabling uses of NASA data to provide near-real-time fire information to localities and regional managers, helping them manage protected forest and endangered species.
- The Pakistan Council of Research in Water Resources began using NASA Gravity Recovery and Climate Experiment (GRACE) data to monitor groundwater storage in the Indus Basin, achieving the first-ever basin-wide view of water resources and enabling more equitable management of water resources in the region.
- Based on work with the NASA Air Quality Applied Sciences Team, the U.S. Environmental Protection Agency (EPA), California air districts, and western states used NASA Earth science data to quantify ozone entering from outside the U.S. and impacts on meeting air quality standards for public health.
- The National Drought Mitigation Center began using improved wetness and drought indicators based on NASA GRACE terrestrial water storage data, providing valuable information on groundwater and deep soil moisture conditions that are used by water resources managers, drought specialists, and agricultural interests.

In addition, NASA used the vantage point of space to support the response to numerous national and international disasters. For example:

- NASA supported the response to Mississippi River flooding, enabling uses of data from Earth Observing (EO)-1, Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (GPM/IMERG), Sentinel-1A, Advanced Land Observing Satellite (ALOS)-2, Constellation of Small Satellites for Mediterranean basin Observation (COSMO)-SkyMed, and Moderate Resolution Imaging Spectroradiometer (MODIS). NASA people and products supported strategic guidance daily on flood- and water-index maps, visualization and decision tools, inundation assessments, and damage proxy maps.
- NASA supported the response to the Fort McMurray fires, including MODIS and Visible Infrared Imaging Radiometer Suite (VIIRS) imagery to pinpoint active fires, assess post-fire burn severity, model hydrologic processes for rapid remediation actions, and help prioritize watersheds to concentrate post-fire treatment areas and save resources and significant mitigation costs.
- NASA data from EO-1, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Landsat, and Shuttle Radar Topography Mission (SRTM) supported an official decision in Nepal to lower the level of a dangerous glacial lake after the massive 2015 Nepal earthquake, averting the risk of a flood.
- NASA supported the response to the historic rainfall and flooding in Louisiana. NASA provided data from GPM/IMERG and VIIRS showing estimates of rainfall and flood maps, as well as products used for determining power outages, as a means of mapping impact zones for planning by the Federal Emergency Management Agency (FEMA) and state emergency managers.

Of the 77 projects tracked, ASP advanced 44 projects, or 57 percent, at least one application readiness level, an index used to track the maturity level of projects, from basic research through development, transition, and operational deployment.

The DEVELOP program, an endeavor for young professionals to apply Earth science data, included over 350 people in 82 projects. NASA's training endeavor on remote sensing for professionals conducted 18 virtual and in-person trainings, which reached over 3,000 people, including people in all 50 U.S. states and over 100 countries. The SERVIR program (managed jointly with the U.S. Agency for International Development) launched a new regional hub in Western Africa to enhance uses of Earth observations for decision-making and environmental monitoring.

ASP also engaged the applications community to expand knowledge about NASA's Earth science missions and in planning for upcoming satellites. The Tropospheric Emissions: Monitoring of Pollution (TEMPO) and NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) missions held applications workshops, Surface Water Ocean Topography (SWOT) held an applications plenary and conducted an applications user survey, GRACE finalized an applications plan, and Ice, Cloud, and Land Elevation Satellite (ICESat)-2 expanded its number of Early Adopters to apply the data and information.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Maintain a high level of customer satisfaction, as measured by exceeding the most recently available Federal Government average rating of the American Customer Satisfaction Index.	ES 11 18 Green	ES 12 17 Green	ES 13 14 Green	ES 14 14 Green	ES 15 10 Green	ES 16 10 Green
Planned Future Performance						
For FY 2017: ES-17-10: Maintain high level of customer satisfaction, as measured by exceeding the most recently available Federal Government average rating of the American Customer Satisfaction Index.						
For FY 2018: ES-18-8: Maintain high level of customer satisfaction, as measured by exceeding the most recently available Federal Government average rating of the American Customer Satisfaction Index.						
Contributing Theme: Earth Science	**Contributing Program:** Earth Science Multi-Mission Operations					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Advance at least 40 percent of Earth science applications projects one Applications Readiness Level.	ES 11 16 Green	ES 12 15 Green	ES 13 12 Green	ES 14 12 Green	ES 15 9 Green	ES 16 9 Green
Planned Future Performance						
For FY 2017: ES-17-9: Advance at least 40 percent of Earth science applications projects one Applications Readiness Level.						
For FY 2018: ES-18-7: Advance at least 40 percent of Earth science applications projects one Applications Readiness Level.						
Contributing Theme: Earth Science	**Contributing Program:** Applied Sciences					

Performance Goal 2.2.8

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
By December 2017, launch at least five missions in support of Strategic Objective 2.2.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	2.2.8 Green	2.2.8 Green	2.2.8 Yellow
Planned Future Performance						
For FY 2017: 2.2.8: By December 2017, launch at least five missions in support of Strategic Objective 2.2.						
For FY 2018: 2.2.8: By December 2021, launch at least two missions in support of Strategic Objective 2.2.						
Contributing Theme: Earth Science	**Contributing Program:** Multiple Programs					

Data Quality for FY 2018
Data Source(s): Written explanation of the rating and supporting material from the Science Mission Directorate's (SMD's) Flight Program Review archives. The Deputy Associate Administrator for SMD recommends a rating based on whether the underlying missions are on track to launch during the goal period. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

Through FY 2016, NASA launched three missions in support of this performance goal, including the joint NASA-Japanese Aerospace Exploration Agency (JAXA) Global Precipitation Measurement (GPM) mission in February 2014, the Orbiting Carbon Observatory (OCO)-2 in July 2014, and the Soil Moisture Active Passive (SMAP) mission in January 2015.

During FY 2016, NASA completed a thermal vacuum test of the Cyclone Global Navigation Satellite System (CYGNSS) mission. CYGNSS, which launched in December 2016, will use eight microsatellites to make accurate measurements of ocean surface winds in and near the eye of the storm throughout the lifecycle of tropical cyclones, typhoons, and hurricanes, with the goal of improving hurricane forecasting. The thermal vacuum simulates the harsh environment of space, cycling through the extreme hot and cold temperatures the microsatellites will face in orbit, and is designed to test how well the spacecraft will operate under "flight-like" conditions.

The Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) replanned to support a December 8, 2017, launch readiness date. Launch services are being contributed by the German Research Centre for Geosciences (GFZ), NASA's foreign partner for the mission. GFZ has entered into a ride-share agreement with Iridium Communications for a launch on an Iridium-provided Space Exploration Technologies Corporation (SpaceX) Falcon 9 during a launch period beginning in December 2017 through February 2018. This launch period is codified in a contract between Iridium and SpaceX. With the successful return to flight of Falcon 9 in January 2016, it is anticipated that the actual launch date for GRACE-FO will be established by Iridium and GFZ within this launch period, dependent on the SpaceX Falcon 9 Iridium launch manifest.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Cyclone Global Navigation Satellite System (CYGNSS/EV-2) Unit 1 thermal vacuum test.	No API this fiscal year	No API this fiscal year	ES 13 2 Green	ES 14 5 Green	ES 15 11 Green	ES 16 11 Green
Planned Future Performance						
For FY 2017: ES-17-11: Launch Cyclone Global Navigation Satellite System (CYGNSS).						
For FY 2018: No API this fiscal year						
Contributing Theme: Earth Science	**Contributing Program:** Earth System Science Pathfinder					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Ice, Cloud, and Land Elevation Satellite (ICESat)-2 Mission Operations Center (MOC) final release.	ES-11-14 Yellow	ES-12-13 Yellow	ES-13-10 Yellow	ES-14-10 Yellow	ES 15 13 Green	ES 16 13 Green
Planned Future Performance						
For FY 2017: ES-17-13: Complete Ice, Cloud, and Land Elevation Satellite (ICESat)-2 Pre-Ship Review (PSR).						
For FY 2018: ES-18-17: Launch the Ice, Cloud, and Land Elevation Satellite (ICESat)-2.						
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Surface Water and Ocean Topography (SWOT) mission Preliminary Design Review (PDR).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ES 15 14 Green	ES 16 14 Green
Planned Future Performance						
For FY 2017: ES-17-14: Complete the Surface Water and Ocean Topography (SWOT) Ka-band Radar Interferometer (KaRIN) instrument Critical Design Review (CDR).						
For FY 2018: ES-18-11: Complete the Surface Water and Ocean Topography (SWOT) mission Critical Design Review (CDR).						
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission instrument deliveries to integration and test (I&T).	No API this fiscal year	No API this fiscal year	No API this fiscal year	ES 14 18 Green	ES 15 15 Green	ES 16 15 Green
Planned Future Performance						
For FY 2017: ES-17-15: Complete the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission Pre-Ship Review (PSR).						
For FY 2018: ES-18-16: Launch the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission.						
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) High Capacity Data Storage Subsystem Preliminary Design Review (PDR).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ES 16 16 Green
Planned Future Performance						
For FY 2017: ES-17-16: Complete NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) Antenna-Reflector Critical Design Review (CDR).						
For FY 2018: ES-18-10: Complete NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) L-Band SAR Instrument Critical Design Review (CDR).						
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete Earth Venture Instrument (EVI)-3 selections.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ES 16 18 Green
Planned Future Performance						
For FY 2017: ES-17-18: Complete the Earth Venture Instrument (EVI)-4 selection.						
For FY 2018: ES-18-14: Release Earth Venture Instrument (EVI)-5 Announcement of Opportunity.						
Contributing Theme: Earth Science	**Contributing Program:** Earth System Science Pathfinder					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Landsat 9 Mission Definition Review (MDR).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ES 16 19 Green
Planned Future Performance						
For FY 2017: ES-17-19: Complete the Landsat 9 Thermal Infrared Sensor (TIRS)-2 instrument Critical Design Review.						
For FY 2018: ES-18-9: Complete the Landsat 9 Critical Design Review (CDR).						
Contributing Theme: Earth Science	**Contributing Program:** Earth Systematic Missions					

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year	
For FY 2018: ES-18-15: Complete the Earth Venture Suborbital (EVS)-3 selection.	
Contributing Theme: Earth Science	**Contributing Program:** Earth System Science Pathfinder

Strategic Objective 2.3

Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit.

Lead Office

Office of the Chief Technologist (OCT)

Goal Leader

Douglas Terrier, Acting Chief Technologist, OCT

Contributing Programs

Agency Technology and Innovation

Budget for Strategic Objective 2.3

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$31	–	$32	$32	$32	$32	$32

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Under Strategic Objective 2.3, NASA's Office of the Chief Technologist (OCT) provides the strategy and leadership that guide NASA's technology development and open innovation activities. OCT had a number of significant accomplishments in FY 2016. For example, in May 2016, NASA released dozens of formerly-patented Agency technologies into the public domain, making them freely available for commercial use. The technologies include advanced manufacturing processes, sensors, propulsion methods, rocket nozzles, thrusters, aircraft wing designs, and improved rocket safety and performance concepts. In addition, the Asteroid Data Hunter Challenge, initiated in FY 2014, has improved the detection of asteroids in the main asteroid belt by approximately 15 percent. The Asteroid Data Hunter Challenge tasked citizen scientists with developing

improved algorithms that can be used to identify asteroids, and NASA developed and released free software for amateur use. NASA also produced its draft FY 2016 Annual Technology Report, which documents a dozen examples of technology infusions across NASA Centers and mission directorates. This includes the delivery of additive manufacturing capability to the International Space Station; development and testing of a new generation of batteries for the future extravehicular suit as part of its portable life support system; and development of a new heat shield system, designed to protect a mission to the Sun.

Effective in late FY 2016, NASA restructured OCT and the Space Technology Mission Directorate (STMD) to better align functions with roles and responsibilities. Beginning in FY 2017, the technology transfer activities previously reported under Strategic Objective 2.3 will be reported under Strategic Objective 1.7. NASA will discontinue reporting under Strategic Objective 2.3 in FY 2017.

For more information, please see http://www.nasa.gov/offices/oct/home/index.html. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 2.3: Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit.
Performance Goal 2.3.1: Implement the five-year Strategic Plan to improve the ability to transfer NASA-developed technologies.
Annual Performance Indicators
• ST-16-8: Streamline, augment, and automate intellectual property and license portfolio management through a licensee monitoring system. • ST-16-9: Develop an initiative to encourage and track infusion of NASA-developed technology into NASA missions, and pilot the initiative at three or more NASA Centers.

Summary of Performance for Strategic Objective 2.3

Performance Goal Ratings for Strategic Objective 2.3, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	1	1	0	0	0
2015	1	1	0	0	0
2014	1	1	0	0	0
2013	0	0	0	0	0
2012	1	1	0	0	0
2011	1	1	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 2.3, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	2	2	0	0	0
2015	1	1	0	0	0
2014	1	1	0	0	0
2013	0	0	0	0	0
2012	1	1	0	0	0
2011	1	1	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 2.3.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Implement the five-year Strategic Plan to improve the ability to transfer NASA-developed technologies.	3.4.1.2 Green	3.4.1.2 Green	No PG this fiscal year	2.3.1 Green	2.3.1 Green	2.3.1 Green
Planned Future Performance						
This performance goal does not continue past FY 2016.						
Contributing Theme: Space Technologies	**Contributing Program:** Agency Technology and Innovation					

FY 2016 Performance Results
NASA met its performance goal in FY 2016. During the fiscal year, NASA made significant enhancements to its licensee monitoring system. NASA streamlined and standardized the licensing process and application templates across its Centers, and then wrote requirements for the design of a new system that will allow for maximum automation of this common process. The system asks licensees a series of common-sense questions, rather than requiring them to fill out a complicated and jargon-heavy application form. The new system, called ATLAS (Automated Technology Licensing Application System), is on schedule to be soft launched in fall 2016, with full adoption by the end of calendar year 2016.

In addition, NASA produced a draft FY 2016 Annual Technology Report, which contains a dozen documented technology infusions from six Centers (Glenn Research Center, Goddard Space Flight Center, Johnson Space Center, Langley Research Center, Marshall Space Flight Center, and Stennis Space Center), the Jet Propulsion Laboratory, and three Mission Directorates (Human Exploration and Operations, Science, and Space Technology). These technology infusions include an additive manufacturing capability delivered to the International Space Station, which offers an elegant solution for sustainability and affordability for long-term exploration missions; a new generation of batteries, which was developed and is being tested with the future extravehicular suit as part of the portable life support system; and a new heat shield system, which is being developed to protect a mission to the Sun.

NASA's technology transfer efforts also support the Lab-To-Market cross-agency priority goal.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Streamline, augment, and automate intellectual property and license portfolio management through a licensee monitoring system.	ST 11 14 Green	ST 12 14 Green	No API this fiscal year	ST 14 8 Green	ST 15 7 Green	ST 16 8 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Space Technologies	**Contributing Program:** Agency Technology and Innovation					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Develop an initiative to encourage and track infusion of NASA-developed technology into NASA missions, and pilot the initiative at three or more NASA Centers.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	ST 16 9 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Space Technologies	**Contributing Program:** Agency Technology and Innovation					

Strategic Objective 2.4

Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.

Lead Office

Office of Education

Goal Leader

Dr. Roosevelt Johnson, Deputy Associate Administrator for Education

Contributing Programs

Aerospace Research and Career Development, STEM Education Accountability

Budget for Strategic Objective 2.4

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$115	–	$37	$ –	$ –	$ –	$ –

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

The NASA Office of Education is proposed for elimination in the FY 2018 President's Budget Request. While output data (e.g., number of people funded, number of papers generated, number of events supported) have been tracked, outcome-related data demonstrating program effectiveness have been insufficient to assess the impact of the overall Office of Education portfolio.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Strategic Objective 2.4 covers NASA's Office of Education, which helps advance the Nation's science, technology, engineering, and mathematics (STEM) education and workforce pipeline by working collaboratively with other agencies to engage students,

teachers, and faculty in NASA's missions and unique assets. Specific performance measures can be found in the FY 2017 Annual Performance Plan in the performance goal and annual performance indicator tables below.

The Strategic Review addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. The Office of Education experienced recent setbacks when it missed several of its performance goals and annual performance indicators reported in FY 2016. (The Office of Education reports data on the academic calendar, so the FY 2016 ratings are based on data from the 2014-2015 academic calendar.) The Office of Education is revising the reporting methodologies used for some of its performance metrics to focus on the outcome-oriented activities identified in the *NASA Education Implementation Plan: 2015-2017*.

For more information, please see http://www.nasa.gov/offices/education/about/index.html. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 2.4: Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.			
Performance Goal 2.4.1: Assure that students participating in NASA higher education projects are representative of the diversity of the Nation.	Performance Goal 2.4.2: Continue to support STEM educators through the delivery of NASA education content and engagement in educator professional development opportunities.	Performance Goal 2.4.4: Continue to provide opportunities for learners to engage in STEM education through NASA-unique content provided to informal education institutions designed to inspire and educate the public.	Performance Goal 2.4.5: Continue to provide opportunities for learners to engage in STEM education engagement activities that capitalize on NASA-unique assets and content.
Annual Performance Indicators			
• ED-16-1: Provide significant, direct student awards in higher education to (1) students across all institutional categories and levels (as defined by the U.S. Department of Education); (2) racially or ethnically underrepresented students, (3) women, and (4) persons with disabilities at percentages that meet or exceed the national enrolled percentages for these populations, as determined by the most recent, publicly available data from the U.S. Department of Education's National Center for Education Statistics for a minimum of two of the four categories.	• ED-16-2: Engage with at least 80,000 educators in NASA-supported professional development, research, and internships that use NASA-unique STEM content.	• ED-16-4: Maintain the NASA Museum Alliance and/or other STEM education strategic partnerships in no fewer than 30 states, U.S. territories, and/or the District of Columbia.	• ED-16-5: Engage with at least 750,000 elementary and secondary students in NASA STEM activities.

Summary of Performance for Strategic Objective 2.4

Performance Goal Ratings for Strategic Objective 2.4, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	4	2	0	2	0
2015	4	4	0	0	0
2014	4	4	0	0	0
2013	4	2	0	0	2
2012	4	3	1	0	0
2011	4	4	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 2.4, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	4	2	0	2	0
2015	4	4	0	0	0
2014	4	4	0	0	0
2013	2	1	0	0	1
2012	3	2	0	1	0
2011	3	2	1	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 2.4.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Assure that students participating in NASA higher education projects are representative of the diversity of the Nation.	5.1.2.1 Green	5.1.2.1 Yellow	5.1.2.1 White	2.4.1 Green	2.4.1 Green	2.4.1 Green
Planned Future Performance						
For FY 2017: 2.4.1: Assure that students participating in NASA higher education investments are representative of the diversity of the Nation.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					
Data Quality for FY 2017						
Data Source(s): Student profile and award records from the Office of Education Performance Measurement (OEPM) System and reports from the National Center for Education Statistics. **Verification and Validation:** NASA Education staff review the data collected using the Office of Education Performance Measurement (OEPM) System and conduct a comparative analysis with Department of Education data to determine whether goals have been met. The measure rating is reviewed and approved by the Deputy Associate Administrator for NASA Education. **Data Limitations:** There is a data lag. Academic calendars do not coincide with the federal fiscal year calendar. In order to ensure accurate data collection and reporting, NASA Education uses prior year data (e.g., in FY 2017, NASA Education reports on FY 2016 data) to meet performance reporting requirements. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's performance in diversity is examined across ethnicity, race, gender, and disability status. NASA Education is on target to complete this performance goal, having provided 3,708 significant, direct student awards in higher education to students across all institutional categories and levels in FY 2015.* The FY 2015 population of significant awardees also exceeded the national science, technology, engineering, and mathematics (STEM) enrollment percentages for the demographic categories of racially and ethnically underrepresented student participants and women.

NASA student participants receiving significant awards attend institutions that represent all institutional categories (Historically Black Colleges and Universities, Predominantly White Institutions, Predominantly Black Institutions, Tribal Colleges and Universities, and Hispanic-Serving Institutions) and levels (at least two but less than four years, and four or more years), as defined by the U.S. Department of Education. NASA Education provided 29.0 percent of its significant awards to racially and ethnically underrepresented student participants, compared to 18.6 percent for the national average. Additionally, NASA Education provided 40.3 percent of its significant awards to women, compared to a 39.5 national enrollment percentage for women. However, NASA is below the national enrollment percentage for persons with disabilities. NASA provided 1.5 percent of its awards to persons with disabilities, compared to 11 percent for the national average.

Due to various awards still completing their award period, NASA is roughly on par with national STEM averages, rather than exceeding national STEM averages in certain diversity areas.

NASA Education's efforts also support the STEM Education cross-agency priority goal.

*Note: NASA Education rates this performance goal using data reported on the academic calendar. The FY 2016 rating is based on data from the 2014-2015 academic calendar.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Provide significant, direct student awards in higher education to (1) students across all institutional categories and levels (as defined by the U.S. Department of Education); (2) racially or ethnically underrepresented students, (3) women, and (4) persons with disabilities at percentages that meet or exceed the national enrolled percentages for these populations, as determined by the most recent, publicly available data from the U.S. Department of Education's National Center for Education Statistics for a minimum of two of the four categories.	ED-11-1 Yellow	ED 12 1 Red	ED-13-1 White	ED 14 1 Green	ED 15 1 Green	ED 16 1 Green
Planned Future Performance						
For FY 2017: ED-17-1: Provide significant, direct student awards in higher education to (1) students across all institutional categories and levels (as defined by the U.S. Department of Education), (2) racially or ethnically underrepresented students, (3) women, and (4) persons with disabilities at percentages that meet or exceed the national enrolled percentages for these populations, as determined by the most recent, publicly available data from the U.S. Department of Education's National Center for Education Statistics for a minimum of two of the four categories.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					

Performance Goal 2.4.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Continue to support STEM educators through the delivery of NASA education content and engagement in educator professional development opportunities.	6.1.1.1 Green	6.1.1.1 Green	6.1.1.1 White	2.4.2 Green	2.4.2 Green	2.4.2 Red
Planned Future Performance						
This performance goal continues through FY 2017.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					

Data Quality for FY 2017
Data Source(s): Project activity data from the Office of Education Performance Measurement (OEPM) System. **Verification and Validation:** NASA Education staff review the data collected using the Office of Education Performance Measurement (OEPM) System to determine whether goals have been met. The measure rating is reviewed and approved by the Deputy Associate Administrator for NASA Education. **Data Limitations:** There is a data lag. Academic calendars do not coincide with the federal fiscal year calendar. In order to ensure accurate data collection and reporting, NASA Education uses prior year data (e.g., in FY 2017, NASA Education reports on FY 2016 data) to meet performance reporting requirements. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

Through NASA Education, 49,952 educators have participated in NASA-supported activities. This number includes 2,419 pre-service and 38,726 in-service K-12 educators, 5,476 informal educators, and 3,331 higher education faculty. NASA did not achieve its goal to serve 80,000 educators in FY 2015.*

The *NASA Education Implementation Plan: 2015-2017* describes NASA's Educator Professional Development (EPD) activities, which are designed to provide high-quality science, technology, engineering, and mathematics (STEM) content and hands-on learning experiences to educators. These efforts are organized into four integrated delivery mechanisms:

- Face to Face Institute provides face-to-face interactions at NASA facilities, conducted through a single delivery model and implemented uniformly across all NASA Centers and facilities. It leverages the content specific to each Center or facility, at grade-appropriate levels based on specific audiences, for a minimum of 40 contact hours.
- Partner-Delivered EPD provides a uniform set of standards for partners to adhere to when developing or offering EPD in concert with NASA. The purpose of Partner-Delivered EPD is to increase the number of geographically dispersed participants engaged in NASA Educator EPD offerings.
- Online EPD provides a uniform set of standards for designing, planning, and implementing online learning opportunities for educators. Online EPD includes synchronous and asynchronous virtual learning opportunities that enhance and extend the breadth, depth, and reach of NASA's EPD training, content, and resources, using a variety of electronic delivery tools.
- Community-Requested EPD provides NASA Centers and the Jet Propulsion Laboratory the flexibility to meet and respond to the EPD needs of their surrounding communities on a case-by-case basis throughout the year, using a set of uniform guidelines to the greatest extent possible.

NASA Education's efforts also support the STEM Education cross-agency priority goal.

*Note: NASA Education rates this performance goal using data reported on the academic calendar. The FY 2016 rating is based on data from the 2014-2015 academic calendar.

Performance Improvement Plan

As noted above, during FY 2015, 49,952 educators participated in NASA-supported activities, which fell short of NASA's goal to serve 80,000 educators. NASA Education failed to achieve its performance goal primarily due to the sunsetting of national projects and the conclusion of one-year special project initiatives.

In FY 2017, NASA Education is revising its methodology for reporting on this performance goal. The previous targets and results have included educators who visited NASA exhibit booths or downloaded NASA materials from the NASA Education website. To be consistent with the *NASA Education Implementation Plan: 2015-2017*, NASA is limiting the definition of Educator Professional Development (EPD) activities to include only those educators who receive professional development through one of the four approved EPD delivery mechanisms (i.e., face-to-face, partner-delivered, online, and community-requested activities).

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Engage with at least 80,000 educators in NASA-supported professional development, research, and internships that use NASA-unique STEM content.	No API this fiscal year	No API this fiscal year	No API this fiscal year	ED 14 6 Green	ED 15 2 Green	ED 16 2 Red
Planned Future Performance						
For FY 2017: ED-17-2: Engage with at least 10,000 educators in NASA educator professional development through face-to-face, online, partner-delivered, and community-requested activities.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					

Explanation of Rating

As noted above, during FY 2015, 49,952 educators participated in NASA-supported activities, which fell short of NASA's goal to serve 80,000 educators. NASA Education failed to achieve its annual performance indicator primarily due to the sunsetting of national projects and the conclusion of one-year special project initiatives.

Performance Goal 2.4.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Continue to provide opportunities for learners to engage in STEM education through NASA-unique content provided to informal education institutions designed to inspire and educate the public.	6.4.1.1 Green	6.4.1.1 Green	6.4.1.1 Green	2.4.4 Green	2.4.4 Green	2.4.4 Green
Planned Future Performance						
This performance goal continues through FY 2017.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					

Data Quality for FY 2017
Data Source(s): Project activity and affiliate/partner network data from the Office of Education Performance Measurement (OEPM) System. **Verification and Validation:** NASA Education staff review the data collected using the Office of Education Performance Measurement (OEPM) System to determine whether goals have been met. The measure rating is reviewed and approved by the Deputy Associate Administrator for NASA Education. **Data Limitations:** There is a data lag. Academic calendars do not coincide with the federal fiscal year calendar. In order to ensure accurate data collection and reporting, NASA Education uses prior year data (e.g., in FY 2017, NASA Education reports on FY 2016 data) to meet performance reporting requirements. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

NASA is on target to achieve this performance goal by providing NASA-unique content through different education institutions. NASA Education supports a diverse portfolio of programs that enhance education efforts on space exploration, aeronautics, space science, Earth science, and microgravity research. These partnerships, maintained through the NASA Museum Alliance, result in strategic collaboration between science, technology, engineering, and mathematics (STEM) formal and informal education providers, such as science centers, planetariums, museums, aquariums, zoos, nature centers, parks and observatories, federal and non-federal NASA Visitor Centers and affiliates, and Challenger Centers. The Museum Alliance, which has 648 organizations in 52 U.S. states and territories, extended an existing, free-of-charge NASA STEM content facilitation membership service to youth-serving efforts throughout the United States.

NASA Education's efforts also support the STEM Education cross-agency priority goal.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Maintain the NASA Museum Alliance and/or other STEM education strategic partnerships in no fewer than 30 states, U.S. territories, and/or the District of Columbia.	ED 11 9 Green	ED 12 9 Green	ED 13 5 Green	ED 14 5 Green	ED 15 4 Green	ED 16 4 Green
Planned Future Performance						
For FY 2017: ED-17-4: Support informal education institutions, including youth-serving organizations, to use NASA-unique content in no fewer than 40 states, U.S. Territories and/or the District of Columbia.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					

Performance Goal 2.4.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Continue to provide opportunities for learners to engage in STEM education engagement activities that capitalize on NASA-unique assets and content.	6.1.2.2 Green	6.1.2.2 Green	6.1.2.2 Green	2.4.5 Green	2.4.5 Green	2.4.5 Red
Planned Future Performance						
This performance goal continues through FY 2017.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					
Data Quality for FY 2017						
Data Source(s): Project activity data from the Office of Education Performance Measurement (OEPM) System. **Verification and Validation:** NASA Education staff review the data collected using the Office of Education Performance Measurement (OEPM) System to determine whether goals have been met. The measure rating is reviewed and approved by the Deputy Associate Administrator for NASA Education. **Data Limitations:** There is a data lag. Academic calendars do not coincide with the federal fiscal year calendar. In order to ensure accurate data collection and reporting, NASA Education uses prior year data (e.g., in FY 2017, NASA Education reports on FY 2016 data) to meet performance reporting requirements. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

In FY 2015, NASA Education reached 632,922 elementary and secondary students in NASA science, technology, engineering, and mathematics (STEM) engagement activities. This figure includes 249,445 elementary students, 335,450 middle school students, and 48,027 high school students. NASA did not achieve its goal to reach 750,000 elementary and secondary students in FY 2015.*

The STEM engagement events leveraged NASA-unique resources, personnel, content, and facilities. Interactive events included experiential learning opportunities for youth at NASA Centers or events at NASA Education partner facilities with NASA content, design challenges with live mentoring from NASA scientists and engineers, professional development opportunities for the Nation's K-12 STEM educators, and other opportunities.

NASA Education's efforts support the STEM Education cross-agency priority goal.

*Note: NASA Education rates this performance goal using data reported on the academic calendar. The FY 2016 rating is based on data from the 2014-2015 academic calendar.

Performance Improvement Plan

As noted above, during FY 2015, 632,922 elementary and secondary students participated in NASA science, technology, engineering, and mathematics (STEM) engagement activities, which fell short of NASA's goal to reach 750,000 students. NASA Education failed to meet its target due to the sunsetting of national projects and the conclusion of one-year special projects initiatives.

In FY 2017, NASA Education is revising its methodology for reporting on this performance goal. NASA will begin using the draft Federal Coordination in STEM Education (FC-STEM) framework definition of "authentic STEM experiences." An authentic STEM experience is an experience inside or outside of school designed to engage learners directly or indirectly with practitioners and in developmentally-appropriate practices from the STEM disciplines that promote real-world understanding. STEM engagement experiential learning opportunities and STEM challenges meet the authentic STEM experience definition. Many public engagement activities reported to-date would most likely not meet the authentic STEM experience definition.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Engage with at least 750,000 elementary and secondary students in NASA STEM activities.	ED 11 5 Green	ED 12 5 Green	No API this fiscal year	ED 14 8 Green	ED 15 5 Green	ED 16 5 Red
Planned Future Performance						
For FY 2017: ED-17-5: Provide NASA STEM engagement to at least 50,000 elementary, secondary, and higher education students through authentic STEM experiences.						
Contributing Theme: Education	**Contributing Program:** Multiple Programs					

Explanation of Rating

As noted above, during FY 2015, 632,922 elementary and secondary students participated in NASA science, technology, engineering, and mathematics (STEM) engagement activities, which fell short of NASA's goal to reach 750,000 students. NASA Education failed to meet its target due to the sunsetting of national projects and the conclusion of one-year special projects initiatives.

Performance Goal 2.4.6

Does not trend until FY 2017.
Planned Future Performance
For FY 2017: 2.4.6: Ensure that grantees and cooperative agreement awardees conduct independent evaluations, providing evidence for the effectiveness of NASA STEM education investments.
Contributing Theme: Education / **Contributing Program:** Multiple Programs

Data Quality for FY 2017
Data Source(s): Project activity data from the Office of Education Performance Measurement (OEPM) System. **Verification and Validation:** NASA Education staff review the data collected using the Office of Education Performance Measurement (OEPM) System to determine whether goals have been met. The measure rating is reviewed and approved by the Deputy Associate Administrator for NASA Education. **Data Limitations:** There is a data lag. Academic calendars do not coincide with the federal fiscal year calendar. In order to ensure accurate data collection and reporting, NASA Education uses prior year data (e.g., in FY 2017, NASA Education reports on FY 2016 data) to meet performance reporting requirements. Data are sufficiently accurate for their intended use.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2017.	
Planned Future Performance	
For FY 2017: ED-17-3: Ensure that at least 30 percent of grantees and cooperative agreement awardees conduct independent evaluations and report to NASA on their evaluation activities.	
Contributing Theme: Education	**Contributing Program:** Multiple Programs

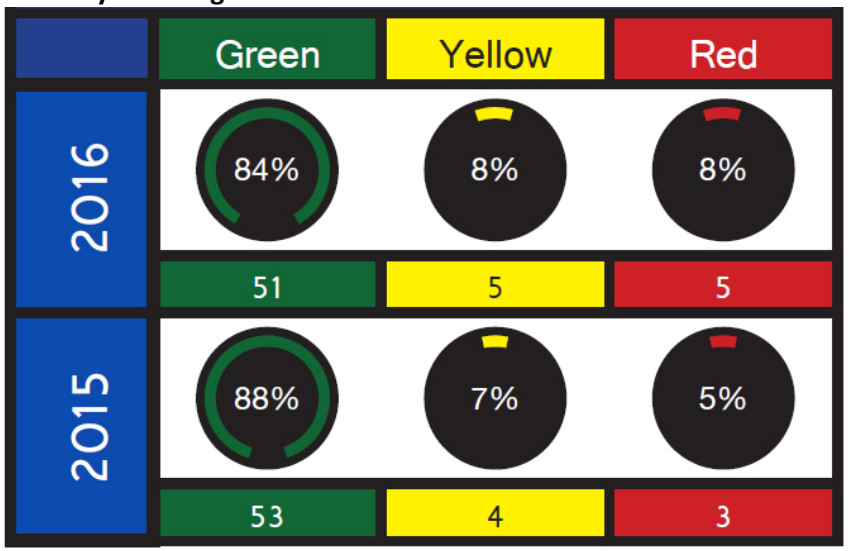
Strategic Goal 3

Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.

Strategic Goal 3: Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.			
Strategic Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions.	Strategic Objective 3.2: Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's Mission.	Strategic Objective 3.3: Provide secure, effective, and affordable information technologies and services that enable NASA's Mission.	Strategic Objective 3.4: Ensure effective management of NASA programs and operations to complete the mission safely and successfully.
FY 2016 Performance Goals			
• 3.1.1: Define and build diverse workforce skills and competencies needed for the Agency's mission. • 3.1.2: Advance a workplace environment that affords equal employment opportunities (EEO) to all employees and takes proactive diversity and inclusion (D&I) efforts. • 3.1.3: Promote equal opportunity compliance and encourage best practices among NASA grant recipient institutions. • 3.1.4: Between 2012 and 2016, support the demolition and elimination of obsolete and unneeded facilities. • 3.1.5: Manage coordination of NASA's international and interagency activities in conjunction with the NASA mission directorates. • 3.1.6: Achieve savings for the Agency through acquisition reforms. • 3.1.7: Ensure that NASA continues progress towards implementing statutory or Executive Order targets and goals reflected in its annual Sustainability Plan. • 3.1.8: Enhance reach and effectiveness of programs and projects that engage the public. • 3.1.9: Manage coordination of advisory committees' (NASA Advisory Council and Aerospace Safety Advisory Panel) recommendations to the NASA Administrator. • 3.1.10: Between 2016 and 2017, demonstrate increased facility reliability by reducing spending on unscheduled maintenance by two percent annually.	• 3.2.1: Review the current state of the NASA test capabilities, known test requirements and test requests, and revise the Master Plan as needed. • 3.2.2: Complete Launch Services Program (LSP) objectives for all NASA-managed expendable launches. • 3.2.3: Maintain a minimum of 95 percent delivery of the Space Communications network services that support NASA and other customers' mission success. • 3.2.5: Replace aging Deep Space Network (DSN) 70-meter antenna at Canberra Deep Space Communications Complex (CDSCC). • 3.2.6: Prioritize and complete launch and range complex modernization studies and projects to sustain government and commercial capabilities at the Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). • 3.2.7: Ensure the strategic availability and maintenance of facilities that are necessary to meet the long-term needs and requirements of the Agency.	• 3.3.1: Enhance NASA's information security posture through implementation of automated security and privacy tools and technologies. • 3.3.5: By 2017, operate as a single NASA enterprise network and effectively utilize the bandwidth of the Communications Services Office (CSO) backbone for both corporate and mission data, enabling more efficient use of available capacity while improving performance with no degradation to mission services. • 3.3.6: Enhance NASA's data management through open data actions, research and development data access, and new data modeling and technologies. • 3.3.7: Increase the adoption of technologies and services such as cloud computing throughout NASA's infrastructure and mission, leveraging savings from solutions such as reduced capital expenditures from not owning hardware, benefits from new technology capabilities, and increased computing flexibility available with "pay as you go" services. • 3.3.8: By 2017, increase Agency business systems performance and efficiency by upgrading NASA's business systems infrastructure and modernizing business applications with no degradation to business services.	• 3.4.1: Assure the safety and health of NASA's activities and reduce damage to assets through the development, implementation, and oversight of Agency-wide safety, reliability, maintainability, quality assurance, and health and medical policies and procedures. • 3.4.2: Implement the policies, procedures and oversight to continuously improve the probability of technical and programmatic mission success.

Summary of Performance for Strategic Goal 3

Summary of Ratings of All Performance Measures for FY 2016 and 2015



Summary of Ratings for Performance Goals and Annual Performance Indicators by Strategic Objective, FY 2016

Lead	Strategic Objective	Performance Goals					Annual Performance Indicators				
		Total	Green	Yellow	Red	White	Total	Green	Yellow	Red	White
MSD	3.1	10	7	2	1	0	17	14	2	1	0
HEOMD	3.2	6	6	0	0	0	7	7	0	0	0
MSD	3.3	5	3	1	1	0	9	7	0	2	0
MSD	3.4	2	2	0	0	0	5	5	0	0	0
Total		23	18	3	2	0	38	33	2	3	0
Summary			78%	13%	9%	0%		87%	5%	8%	0%

Strategic Objective 3.1

Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions.

Lead Office

Mission Support Directorate

Goal Leader

Krista C. Paquin, Associate Administrator, Mission Support

Contributing Programs

Agency Management, Center Management and Operations, Institutional Construction of Facilities, Environmental Compliance and Restoration, Space Shuttle Program

Budget for Strategic Objective 3.1

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$2,712	–	$2,737	$2,782	$2,782	$2,782	$2,782

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has highlighted this strategic objective as a focus area for improvement for three consecutive fiscal years.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Strategic Objective 3.1 covers NASA's workforce and institutional capabilities.

Key successes over the past three fiscal years:

NASA has had several recent successes within this portfolio of activities, including success in diversity and equal opportunity, workforce satisfaction and engagement, communications, and sustainability and energy usage. Over the past five years, NASA has seen increases in the percentages of its workforce who are women, individuals with disabilities, and racial/ethnic minorities, including African-Americans, Asian American and Pacific Islanders, and Hispanics. For the sixth consecutive year, NASA was ranked as the top large agency for innovation and, for the fifth consecutive year, as the Best Place to Work in the Federal Government. In addition, for three consecutive years NASA has met or exceeded its targets for the demolition of obsolete and unneeded facilities.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities.

Key challenges over the past three fiscal years:

Despite the successes noted above, challenges remain within Strategic Objective 3.1, particularly related to NASA's institutional base. Continued attention and resources are needed to address risks associated with deferred maintenance, aging infrastructure, and environmental compliance. In 10 years, a part of NASA's vision for success for this strategic objective is for NASA's institutional capabilities to enable the Agency to provide the day-to-day operations required to support and achieve its missions. However, about 83 percent of NASA's infrastructure and facilities are currently beyond their constructed design life. Aging infrastructure from the Apollo era is costly to maintain and, in some cases, poses risk to mission operations. In FY 2016, NASA noted that unscheduled maintenance continues to grow, which is more costly than planned maintenance and can directly impact mission activities.

Performance Improvement Recommendations/Next Steps:

Over the next several years, NASA's critical steps under this strategic objective include investing in projects that reduce energy costs, demolishing unneeded infrastructure, renewing and consolidating facilities, continuing to use targeted outreach and recruitment efforts, focusing on activities that impact workforce innovation, and using current and emerging communications technologies, platforms, and methods to reach increasingly broader and more diverse audiences. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

To address challenges associated with aging infrastructure, NASA is aggressively managing its facility portfolio to consolidate and modernize into fewer, more efficient and sustainable facilities. NASA has achieved some success in consolidating facilities, reducing energy costs, and demolishing unneeded infrastructure and will continue to use these strategies to manage its facilities portfolio. Additionally, NASA will continue to prioritize and triage maintenance and repair work to prevent or minimize facility failures and impacts to missions. A few examples of these efforts include the following:

- NASA is increasing its inventory of sustainable buildings and awarding more Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs), which enable energy service companies and utility companies to finance energy projects that NASA repays over time from avoided utility costs. In 2016, NASA added two Leadership in Energy & Environmental Design (LEED)-certified buildings to its portfolio, with a

combined area of more than 21,000 gross square feet. In addition, a building that was LEED-certified in 2015 obtained a "2 Green Globes" certification from the Green Building Initiative in 2016. This 153,000 gross square foot building is the first NASA building to attain multiple sustainable facility systems ratings.

- NASA has adopted a facilities maintenance and operation philosophy to support its mission by proactively pursuing and adopting the safest, most cost-effective blend of reliability centered maintenance (RCM) techniques, sustainability practices, and safety procedures and other best practices to provide safe, sustainable, efficient, and reliable facilities. Funding for RCM and condition based maintenance (CBM) was set aside within the maintenance funding when available for Centers over the past few years, to invest in technology advancements that allow Centers to better manage maintenance resources.
- NASA is moving forward with its Facilities Business Services Assessment that identified areas for improved management of the Agency's portfolio. A key recommendation from the Assessment included the development of an Agency Master Plan that identifies facility priorities over a 20-year timeframe and will assist NASA Center Master Plans in meeting Agency goals and missions. Other recommendations include improved processes to facilitate divestment, limit in-grant investments, and a revised methodology for prioritizing capital investments and repairs across the Agency. The Assessment also recommended improvements in operations and maintenance that call for improving standards for level of maintenance and more focused investment on CBM and RCM to maximize maintenance investments and optimize maintenance cycles for core critical assets.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General. More information is available in the "Management Challenges" section in Part 2.

For more information, please see http://msd.hq.nasa.gov/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions.									
Performance Goals									
Performance Goal 3.1.1: Define and build diverse workforce skills and competencies needed for the Agency's mission.	Performance Goal 3.1.2: Advance a workplace environment that affords equal employment opportunities (EEO) to all employees and takes proactive diversity and inclusion (D&I) efforts.	Performance Goal 3.1.3: Promote equal opportunity compliance and encourage best practices among NASA grant recipient institutions.	Performance Goal 3.1.4: Between 2012 and 2016, support the demolition and elimination of obsolete and unneeded facilities.	Performance Goal 3.1.5: Manage coordination of NASA's international and interagency activities in conjunction with the NASA mission directorates.	Performance Goal 3.1.6: Achieve savings for the Agency through acquisition reforms.	Performance Goal 3.1.7: Ensure that NASA continues progress towards implementing statutory or Executive Order targets and goals reflected in its annual Sustainability Plan.	Performance Goal 3.1.8: Enhance reach and effectiveness of programs and projects that engage the public.	Performance Goal 3.1.9: Manage coordination of advisory committees' (NASA Advisory Council and Aerospace Safety Advisory Panel) recommendations to the NASA Administrator.	Performance Goal 3.1.10: Between 2016 and 2017, demonstrate increased facility reliability by reducing spending on unscheduled maintenance by two percent annually.

FY 2016 Performance Measures (Continued)

Strategic Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions.									
Annual Performance Indicators									
• AMO-16-1: Sustain NASA's Innovation Score, as measured by the Innovation-related questions of the Employee Viewpoint Survey (EVS), by taking actions such as refining and updating human capital policies, programs, and systems to support and encourage innovation to meet NASA's missions.	• AMO-16-2: Sustain three programs and processes designed to proactively prevent discrimination, as outlined in the Model EEO Agency Plan. AMO-16-3: Issue and begin implementation of the NASA Diversity and Inclusion Strategic Implementation Plan FY 2016 to FY 2019.	• AMO-16-4: Continue to conduct civil rights compliance assessments at a minimum of two STEM or STEM-related programs that receive NASA funding; and broaden the scope of civil rights technical assistance to NASA grantees through the MissionSTEM website, focused on grantee civil rights requirements and promising practices for grantee compliance and diversity and inclusion.	• COF-16-1: Initiate the demolition or disposal of five facilities or structures during 2016 to reduce the Agency's footprint.	• AMO-16-6: Implement the Agency-wide export control training program plan. • AMO-16-7: Negotiate and conclude international and interagency agreements with foreign and domestic partners in support of NASA missions.	• AMO-16-8: Achieve savings through effective use of both Federal-level and Agency-level strategic sourcing approaches. • AMO-16-9: Achieve savings through increased contract efficiencies and reduced transaction costs in NASA procurements.	• AMO-16-10: Reduce energy intensity (energy consumption per gross square feet, or Btu/gsf) to meet the target set by the Office of Management and Budget for FY 2016 in the Sustainability and Energy Scorecard. • AMO-16-11: Meet sustainable building inventory target (percentage of gross square footage of inventory meeting guiding principles) set by the Office of Management and Budget for FY 2016 in the Sustainability and Energy Scorecard. • AMO-16-12: Ensure that a percentage of electricity consumed is generated from renewable energy sources, to meet the target set by the Office of Management and Budget for FY 2016 in the Sustainability and Energy Scorecard.	• AMO-16-13: Use current and emerging communications technologies, platforms, and methods to reach increasingly broad and diverse audiences. • AMO-16-14: Develop a set of metrics by which to assess the reach and effectiveness of activities in the communications portfolio. • AMO-16-24: Develop a toolkit (clearinghouse) of NASA communications products to share with NASA's communications professionals and employees to help ensure that consistent and current content is utilized in communicating the Agency's results to the public.	• AMO-16-15: Provide NASA responses to advisory committees' recommendations made formally to the NASA Administrator.	• AMO-16-5: Reduce spending on unscheduled maintenance (out of total maintenance spending) by at least two percentage points.

Summary of Performance for Strategic Objective 3.1

Performance Goal Ratings for Strategic Objective 3.1, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	10	7	2	1	0
2015	9	7	2	0	0
2014	9	9	0	0	0
2013	7	7	0	0	0
2012	6	6	0	0	0
2011	6	6	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 3.1, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	17	14	2	1	0
2015	15	13	2	0	0
2014	15	13	2	0	0
2013	8	8	0	0	0
2012	8	8	0	0	0
2011	8	6	2	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 3.1.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Define and build diverse workforce skills and competencies needed for the Agency's mission.	5.1.1.1 Green	5.1.1.1 Green	5.1.1.1 Green	3.1.1 Green	3.1.1 Green	3.1.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					
Data Quality for FY 2018						
Data Source(s): Federal Employee Viewpoint Survey Innovation Index. Publically available from the Office of Personnel Management and Partnership for Public Service. **Verification and Validation:** Review trends from the 2011 baseline. Monitor focus areas that drive innovation, including recognizing/rewarding innovative performance, engaging/connecting the workforce, and building model supervisors and leaders, through additional indices in the Federal Employee Viewpoint Survey. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use and are generally available late in the 4th quarter of the fiscal year.						

FY 2016 Performance Results

NASA is continuing its efforts to instill a culture of innovation in its workforce by recognizing and rewarding innovative performance; engaging and connecting the workforce to make it easy for employees to collaborate, network, and innovate; and creating an environment in which leaders view developing innovative employees as a productive and vital use of their time.

- Recognizing and rewarding performance: NASA continues the annual NASA Innovation Awards (started in 2014) to recognize, encourage, and celebrate a spirit of innovative behavior. There are two categories of awards, the Lean Forward; Fail Smart Award and the Champion of Innovation Award, and the NASA workforce selects the winner in each category. In FY 2016, innovation has received greater focus, with the Deputy Administrator serving as the Agency champion. The NASA FIRST (Foundations of Influence, Relationships, Success, and Teamwork) leadership program planned an Innovation Day for November 1, 2016.
- Engaging and connecting: NASA is working to create a workplace where geography is inconsequential and Agency work can be conducted anywhere and anytime by putting information, data, and tools at the fingertips of those individuals who need it. For example, NASA has made great improvements in effective virtual collaboration. NASA continues to expand the use of its telework program, which allows employees to perform their duties from home or another approved worksite.
- Growing leaders: NASA ensures that first-line supervisors appreciate the importance of developing innovative employees. NASA infuses its leadership values into potential leaders early in their careers through Agency-level and Center-level leadership development programs. These programs have a heavy emphasis on personal effectiveness, relating to others, and self-reflection. According to the annual Federal Employee Viewpoint Survey (FEVS), which is administered by the Office of Personnel Management, NASA is ranked as one of the top agencies in effective leadership.

NASA demonstrated its commitment to workforce innovation by increasing its Innovation Index score from 79.5 percent in FY 2015 to 81.0 percent as determined through the FEVS. Through the survey, NASA's employees expressed their opinions about their workplace environment and opportunities. The Innovation Index score is derived from the results on three questions measuring the extent to which an individual employee feels encouraged and motivated to improve personal performance and deliver superior results, and six questions centered on the workplace environment, from employee recognition for superior work to opportunities to demonstrate value and creative practices.

Visit http://nasapeople.nasa.gov/ for more information.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Sustain NASA's Innovation Score, as measured by the Innovation-related questions of the Employee Viewpoint Survey (EVS), by taking actions such as refining and updating human capital policies, programs, and systems to support and encourage innovation to meet NASA's missions.	AMO-11-1 Yellow	AMO 12 1 Green	AMO 13 1 Green	AMO 14 1 Green	AMO 15 1 Green	AMO 16 1 Green
Planned Future Performance						
For FY 2017: AMO-17-1: Sustain NASA's Innovation Score, as measured by the Innovation-related questions of the Employee Viewpoint Survey (EVS), by taking actions such as refining and updating human capital policies, programs, and systems to support and encourage innovation to meet NASA's missions.						
For FY 2018: AMO-18-1: Sustain NASA's Innovation Score, as measured by the Innovation-related questions of the Employee Viewpoint Survey (EVS), by taking actions such as refining and updating human capital policies, programs, and systems to support and encourage innovation to meet NASA's missions.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Performance Goal 3.1.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Advance a workplace environment that affords equal employment opportunities (EEO) to all employees and takes proactive diversity and inclusion (D&I) efforts.	5.1.1.5 Green	5.1.1.5 Green	5.1.1.5 Green	3.1.2 Green	3.1.2 Green	3.1.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Data Quality for FY 2018
Data Source(s): NASA Model Equal Employment Opportunity Agency Plan, Strategic Management Council, Diversity and Inclusion Strategic Partnership meetings, and Baseline Performance Review reporting. **Verification and Validation:** Assessment of the NASA Model Equal Employment Opportunity Agency Plan and NASA Diversity and Inclusion Strategic Implementation Plan. **Data Limitations:** Slight lag time in data reporting, particularly at the end of the fiscal year. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

NASA continues to make progress toward this performance goal by implementing equal employment opportunity (EEO) programs and processes to proactively prevent discrimination and resolve issues and concerns as promptly and efficiently as possible. Examples include alternative dispute resolution (ADR) in the EEO complaints process, reasonable accommodations for individuals with disabilities, and the Anti-Harassment Program. Each of these programs and processes has been furthered in FY 2016 through concrete steps, such as innovative education and awareness opportunities and technical assistance to employee practitioners.

Using 2012 as a baseline, NASA achieved positive rates of change in the employment participation rates of underrepresented EEO groups. Specifically, between 2012 and 2016, NASA increased the percentage of individuals with disabilities in its workforce by 11 percent. NASA also increased the percentage of women, African-Americans, Asian American and Pacific Islanders, and Hispanics in senior-level General Schedule (GS) positions (i.e., GS-14 and GS-15 positions) and in the Senior Executive Service. NASA increased the percentage of women in senior-level positions by 3 percent, African Americans by 14 percent, Asian American and Pacific Islanders by 1 percent, and Hispanics by 7 percent. More information is available at NASA's Office of Diversity and Equal Opportunity website at http://odeo.hq.nasa.gov/.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Sustain three programs and processes designed to proactively prevent discrimination, as outlined in the Model EEO Agency Plan.	AMO-11-7 Yellow	AMO 12 7 Green	AMO 13 2 Green	AMO 14 2 Green	AMO 15 2 Green	AMO 16 2 Green
Planned Future Performance						
For FY 2017: AMO-17-2: Sustain three programs and processes designed to proactively prevent discrimination, as outlined in the Model EEO Agency Plan.						
For FY 2018: AMO-18-2: Sustain three programs and processes designed to proactively prevent discrimination, as outlined in the Model EEO Agency Plan.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Issue and begin implementation of the NASA Diversity and Inclusion Strategic Implementation Plan FY 2016 to FY 2019.	AMO 11 8 Green	AMO 12 8 Green	AMO 13 3 Green	AMO 14 3 Green	AMO 15 3 Green	AMO 16 3 Green
Planned Future Performance						
For FY 2017: AMO-17-3: Continue implementation of the NASA Diversity and Inclusion Strategic Implementation Plan FY 2016 to FY 2019.						
For FY 2018: AMO-18-3: Continue implementation of the NASA Diversity and Inclusion Strategic Implementation Plan FY 2016 to FY 2019.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Performance Goal 3.1.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Promote equal opportunity compliance and encourage best practices among NASA grant recipient institutions.	6.1.3.1 Green	6.1.3.1 Green	6.1.3.1 Green	3.1.3 Green	3.1.3 Green	3.1.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					
Data Quality for FY 2018						
Data Source(s): Executive Order 12250 Report and Implementation Plan; Office of Diversity and Equal Opportunity (ODEO) External Compliance Tracking System; and NASA usage statistics for missionstem.hq.nasa.gov. **Verification and Validation:** Review compliance with NASA Policy Directive 2081.1A and NASA Procedural Requirements 2081.1A. **Data Limitations:** Potential lag time. The program assesses grantee institutional compliance with federal civil rights requirements. If there is non-compliance, it can take months or years to achieve compliance. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA has established a vigorous civil rights compliance review program for its grantee institutions, and a robust technical assistance effort centered on its MissionSTEM website. MissionSTEM is designed to highlight both compliance requirements under the civil rights laws and the many promising practices of NASA grant recipients and stakeholder organizations for creating greater diversity and inclusion in the science, technology, engineering, and mathematics (STEM) fields. NASA continues to post fresh content, both written and video, to MissionSTEM on a regular basis, and continues to see increases in MissionSTEM usage based on data analytics. For the first time in FY 2016, the Agency brought together hundreds of its grantees to discuss equal opportunity and diversity in STEM at a MissionSTEM summit, conducted at NASA Headquarters in August 2016.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Continue to conduct civil rights compliance assessments at a minimum of two STEM or STEM-related programs that receive NASA funding; and broaden the scope of civil rights technical assistance to NASA grantees through the MissionSTEM website, focused on grantee civil rights requirements and promising practices for grantee compliance and diversity and inclusion.	AMO 11 19 Green	AMO 12 19 Green	AMO 13 11 Green	AMO 14 10 Green	AMO 15 4 Green	AMO 16 4 Green
Planned Future Performance						
For FY 2017: AMO-17-4: Continue to conduct civil rights compliance assessments at a minimum of two STEM or STEM-related programs that receive NASA funding; and broaden the scope of civil rights technical assistance to NASA grantees through the MissionSTEM website, focused on grantee civil rights requirements and promising practices for grantee compliance and diversity and inclusion.						
For FY 2018: AMO-18-4: Continue to conduct civil rights compliance assessments at a minimum of two STEM or STEM-related programs that receive NASA funding; and broaden the scope of civil rights technical assistance to NASA grantees through the MissionSTEM website, focused on grantee civil rights requirements and promising practices for grantee compliance and diversity and inclusion.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Performance Goal 3.1.4

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Between 2012 and 2016, support the demolition and elimination of obsolete and unneeded facilities.	5.2.3.1 Green	5.2.3.1 Green	5.2.3.1 Green	3.1.4 Green	3.1.4 Green	3.1.4 Green
Planned Future Performance						
For FY 2017: 3.1.4: Between 2012 and 2017, support the demolition and elimination of obsolete and unneeded facilities.						
For FY 2018: 3.1.4: Between 2012 and 2018, support the demolition and elimination of obsolete and unneeded facilities.						
Contributing Theme: Construction of Facilities	**Contributing Program:** Institutional CoF					
Data Quality for FY 2018						
Data Source(s): Quarterly budget and excess property reports. **Verification and Validation:** Review of the documentation listed under Data Source. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA has a demolition program to eliminate obsolete, unneeded infrastructure in order to improve efficiency and eliminate safety and environmental risks. The program, which been in operation for over a decade, is an important part of NASA's efforts to reduce its infrastructure and operating costs. NASA's Office of Strategic Infrastructure continues to evaluate unused and unneeded facilities on a regular basis, and has made progress toward reducing the Agency's overall footprint through demolition.

In each year from FY 2012 through 2016, NASA met or exceeded its target of demolishing five buildings per year. In FY 2016, NASA awarded the following key demolition contracts:

- B-16 Complex at the Goddard Space Flight Center;
- Headquarters Building and Central Instrumentation Facility at the Kennedy Space Center;
- Hypersonic CF4 Tunnel Complex at the Langley Research Center; and
- Buildings Test Complex Shop, Multi-Purpose Office and Training Facility, and Complex Potable Water Well Pump House at the Stennis Space Center.

NASA identifies facilities for demolition through special studies, which determine if the facility is required for current or future missions. Facilities that no longer are needed are included in a five-year demolition plan that sets project schedules based on last need (both mission and date), annual costs avoided if the facility is demolished, potential liability, and project execution factors. Facilities included in the five-year plan occasionally are adjusted due to consultation with states on historic properties, changes in operational schedules, environmental remediation, funding profiles, local market forces, and the value of recycled materials.

More information is available at NASA's Office of Strategic Infrastructure website.

Annual Performance Indicator	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
For FY 2016: Initiate the demolition or disposal of five facilities or structures during 2016 to reduce the Agency's footprint.	COF 11 1 Green	COF 12 1 Green	COF 13 1 Green	COF 14 1 Green	COF 15 1 Green	COF 16 1 Green
Planned Future Performance						
For FY 2017: COF-17-1: Initiate the demolition or disposal of five facilities or structures during 2017 to reduce the Agency's footprint.						
For FY 2018: COF-18-1: Initiate the demolition or disposal of five facilities or structures during 2018 to reduce the Agency's footprint.						
Contributing Theme: Construction of Facilities	**Contributing Program:** Institutional CoF					

Performance Goal 3.1.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Manage coordination of NASA's international and interagency activities in conjunction with the NASA mission directorates.	5.5.2.1 Green	5.5.2.1 Green	5.5.2.1 Green	3.1.5 Green	3.1.5 Green	3.1.5 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					
Data Quality for FY 2018						
Data Source(s): NASA Headquarters Mission Directorate Reviews. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's Office of International and Interagency Relations (OIIR) provides executive leadership and coordination for all of NASA's international activities and partnerships, and for policy interactions between NASA and other U.S. Executive Branch offices and agencies. OIIR serves as the principal Agency liaison with the National Security Council, the Office of Science and Technology Policy, the Department of State, and the Department of Defense. OIIR also directs NASA's international relations; negotiates cooperative and reimbursable agreements with foreign space partners; provides management oversight and staff support of NASA's advisory committees, commissions, and panels; and manages the NASA Export Control Program and foreign travel.

In FY 2016, OIIR produced 12 monthly reports on the management of 766 active international agreements with 127 countries and the management of 950 interagency agreements with 50 agencies. OIIR concluded 119 new agreements with 27 countries and international organizations, and had an additional 96 agreements in development.

In addition, OIIR implemented an Agency-wide export control training program plan to provide instruction on the new regulations resulting from the Export Control Reform Initiative. This training includes export control regulations affecting NASA programs and best practices for facilitating execution of international programs. Specifically, OIIR sponsored onsite, face-to-face training for Center Export Administrators at all NASA Centers, including the Goddard Institute for Space Studies, Independent Verification and Validation (IV&V) Facility, White Sands Test Facility, and Wallops Flight facility; sponsored a general export control awareness training for all NASA Headquarters employees in December 2015; held export control briefings on the new regulations during all-hands sessions at the Goddard Space Flight Center, Ames Research Center, and Kennedy Space Center (KSC); held a day-long export control seminar and the annual NASA Export Control Program Review at the Johnson Space Center in March 2016; and provided export control program support to the International Program Management Training course at KSC in July 2016. NASA posted export control training online learning materials to its internal career training and development website, and an export control awareness training video to YouTube.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Implement the Agency-wide export control training program plan.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 26 Green	AMO 15 6 Green	AMO 16 6 Green
Planned Future Performance						
For FY 2017: AMO-17-6: Implement the Agency-wide export control training program.						
For FY 2018: AMO-18-11: Implement the Agency-wide export control training program by facilitating at least 10 training sessions across the Agency.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Negotiate and conclude international and interagency agreements with foreign and domestic partners in support of NASA missions.	AMO 11 18 Green	AMO 12 18 Green	AMO 13 10 Green	AMO 14 9 Green	AMO 15 7 Green	AMO 16 7 Green
Planned Future Performance						
For FY 2017: AMO-17-7: Negotiate and conclude international and interagency agreements with foreign and domestic partners in support of NASA missions.						
For FY 2018: AMO-18-12: Negotiate and conclude at least 80 international and interagency agreements with foreign and domestic partners in support of NASA missions.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Performance Goal 3.1.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Achieve savings for the Agency through acquisition reforms.	No PG this fiscal year	No PG this fiscal year	5.2.4.1 Green	3.1.6 Green	3.1.6 Green	3.1.6 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Data Quality for FY 2018
Data Source(s): NASA Strategic Sourcing Plan, Master Buy Plan Database, and Federal Procurement Data System. **Verification and Validation:** Review compliance with the Office of Management and Budget Strategic Sourcing Policy, NASA Policy Directive 1000.5B, Federal Acquisition Regulation (FAR), and the NASA FAR Supplement. **Data Limitations:** Contract data availability from the Federal Procurement Data System and Federal Strategic Sourcing Initiative data collection systems lags the reporting cycle. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

NASA is on track to achieve this performance goal through its effective use of strategic sourcing strategies, both at the federal and Agency level. NASA's procurement efforts support the Category Management cross-agency priority goal, which focuses on streamlining the acquisition process.

Of the 10 strategic sourcing initiatives NASA identified for FY 2016, 9 (90 percent) achieved cost savings or avoidance. Some significant examples are summarized below:

- Solutions for Enterprise-Wide Procurement (SEWP) V is a multi-award, government-wide acquisition contract that negotiates cost avoidance and savings through leveraged purchases, reduced fees for utilization, and decreased price per unit (compared to current, higher market prices). For FY 2016, the total negotiated cost avoidance and savings combined for SEWP V was approximately $4.75 million, an amount that reflects an adjustment to account for the administrative cost of running the program.
- Office Supplies Third Generation (OS3) is a purchasing channel solution that helps federal customers achieve savings on their office supply purchases, while also supporting the Nation's small businesses. NASA increased its use of OS3 by approximately 62 percent in FY 2016, resulting in cost savings and avoidance of roughly $70 thousand.
- The Enterprise License Management Team (ELMT) is an Agency-based, strategic sourcing effort to consolidate software licenses across the Agency. ELMT continues to identify and add additional software to its inventory, which increases NASA's buying power by lowering the price per unit. ELMT achieved an estimated cost savings and avoidance of $34.6 million in FY 2016.
- The Synergy Achieving Consolidated Operations and Maintenance (SACOM) contract consolidates base operations support for the Michoud Assembly Facility and the Stennis Space Center. The SACOM procurement achieved cost savings and avoidance—an estimated $24 million in FY 2016—by providing business at a reduced cost over previous prices paid.
- NASA's Information Technology (IT) Infrastructure Integration Program (I3P) is transforming NASA's IT infrastructure services from a Center-based model to an enterprise-based management and provisioning model. I3P achieved an estimated $24.4 million in savings in FY 2016, representing negotiated cost avoidance and savings and fee avoidance for five of the six contracts that comprise the I3P activities.

NASA also achieved savings through increased contract efficiencies and reduced transaction costs in its procurements. NASA achieved this through reduced contract lead times, using less complex evaluation procedures, reducing the number task orders, consolidating software licenses, and reducing the number of non-competed actions.

Of the eight contract efficiency initiatives NASA identified for FY 2016, seven (87.5 percent) were effective. A couple significant examples are summarized below:

- NASA exercised the option on a reverse auctioning contract with FedBid, Inc., conducting about $152 thousand of small purchases resulting in $37 thousand of cost savings and avoidance. This equates to roughly a 25 percent savings on the transactions, an increase over the average savings rate of 15 percent in FY 2015.
- The NASA Shared Services Center (NSSC), which consolidates and standardizes business activities from across the Agency, was re-competed in FY 2016. While the previous contract was cost plus award fee, the new contract is predominantly firm fixed price. NASA achieved a savings of $13.5 million due to the competition.

More information is available at the Office of Procurement website.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Achieve savings through effective use of both Federal-level and Agency-level strategic sourcing approaches.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 30 Green	AMO 15 8 Green	AMO 16 8 Green
Planned Future Performance						
For FY 2017: AMO-17-8: Achieve savings through effective use of both Federal-level and Agency-level strategic sourcing approaches.						
For FY 2018: AMO-18-9: Achieve savings in at least 70 percent of identified procurement initiatives through effective use of both Federal-level and Agency-level strategic sourcing approaches.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Achieve savings through increased contract efficiencies and reduced transaction costs in NASA procurements.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO-14-8 Yellow	AMO-15-9 Yellow	AMO 16 9 Green
Planned Future Performance						
For FY 2017: AMO-17-9: Achieve savings through increased contract efficiencies and reduced transaction costs in NASA procurements.						
For FY 2018: AMO-18-10: Achieve savings in at least 70 percent of identified procurement initiatives through increased contract efficiencies and reduced transaction costs in NASA procurements.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Performance Goal 3.1.7

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Ensure that NASA continues progress towards implementing statutory or Executive Order targets and goals reflected in its annual Sustainability Plan.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.1.7 Green	3.1.7 Yellow	3.1.7 Yellow
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					
Data Quality for FY 2018						
Data Source(s): Annual external reporting to the Department of Energy, Office of Management and Budget (OMB), and Council on Environmental Quality via the Energy-Greenhouse Gas Workbook; OMB Scorecard on Sustainability/Energy; and Strategic Sustainability Performance Plan. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** Lag time. Preliminary data are available in October or November after the end of the fiscal year, but final data typically are not available until January. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA has a sustainability policy to execute its mission without compromising the planet's resources, so that future generations can meet their needs. Sustainability also involves taking action now to provide a future where the environment and living conditions are protected and enhanced. In implementing sustainability practices, NASA manages risks to its mission, the environment, and local communities. To this end, NASA seeks to use public funds efficiently and effectively, promote the health of the planet, and operate in a way that benefits its neighbors. More information is available in the *2016 Strategic Sustainability Performance Plan (SSPP)*.

In July 2016, the Office of Management and Budget (OMB) released the January 2016 Scorecard on Sustainability/Energy. The OMB Scorecard shows data for the prior year. NASA continues to devote significant effort and focus toward meeting its sustainability goals, and received green ratings in five out of seven metrics on the scorecard. Since NASA was slightly below target for one of its annual performance indicators (see first bullet below), the Office of Strategic Infrastructure rated this performance goal yellow for FY 2016. Following were some of NASA's key sustainability activities as reported on the scorecard:

- NASA reduced its energy consumption per gross square feet (Btu/GSF) by 27 percent, receiving a yellow rating on the scorecard. The energy intensity goal contains an inherent conflict between the competing goals of reducing the Agency's footprint (GSF) and reducing its energy intensity (Btu/GSF). Although demolishing or mothballing facilities based upon mission requirements reduces overall energy usage, the resulting reduction in overall square footage raises the energy usage per square foot. Additional challenges this year included colder than average weather conditions, and a need to utilize natural gas at times, rather than landfill gas. Landfill gas is considered a renewable energy source, which does not count towards this metric.

- NASA increased its inventory of sustainable buildings to 19.7 percent, measured by GSF, meeting its multiyear goal. In FY 2015, NASA added six buildings, with a combined area of more than 547,000 GSF, to its portfolio of buildings meeting the Guiding Principles for High Performance and Sustainable Buildings. One facility received Leadership in Energy and Environmental Design (LEED) gold certification, and the other five received LEED silver certifications.
- NASA met its renewable energy goal, with 10.5 percent of electricity coming from renewable sources. NASA follows an Agency-wide strategy that emphasizes identifying large projects that can make a significant difference for the Agency, in addition to initiating smaller projects at each Center. Centers are trying to bundle solar projects with larger facility upgrades or energy conservation measures to reduce payback periods. For example, NASA completed a feasibility study for a solar plant installation at one facility and awarded a contract for a 1.6 megawatt (MW) solar installation, which will provide renewable power for a groundwater remediation system, reducing energy costs over a long period of time and providing energy security for critical facilities.

NASA's sustainability efforts support the Climate Change cross-agency priority goal.

More information is available at NASA's Office of Strategic Infrastructure website.

Performance Improvement Plan

In support of Executive Order (EO) 13693, which introduced new sustainability requirements, NASA is developing an Agency-wide Energy Strategic Investment Plan. This plan will assess opportunities and inform decision-making regarding the achievement of the aggressive energy reduction, renewable energy, and greenhouse gas goals of EO 13693, as well as reduce the energy risks to NASA's mission. The plan will also be used to select energy projects for funding, and to highlight opportunities for using third-party financing, including energy savings performance contracts and utility energy service contracts.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Reduce energy intensity (energy consumption per gross square feet, or Btu/gsf) to meet the target set by the Office of Management and Budget for FY 2016 in the Sustainability and Energy Scorecard.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO-14-20 Yellow	AMO-15-10 Yellow	AMO-16-10 Yellow
Planned Future Performance						
For FY 2017: AMO-17-10: Reduce energy intensity (energy consumption per gross square feet, or Btu/gsf) to meet the target set by the Office of Management and Budget for FY 2017 in the Sustainability and Energy Scorecard.						
For FY 2018: AMO-18-5: Reduce energy intensity (energy consumption per gross square feet, or Btu/gsf) to meet the target set by the Office of Management and Budget for FY 2018 in the Sustainability and Energy Scorecard.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Explanation of Rating

NASA will continue to partner with utility companies and energy service companies to implement projects and conduct assessments and audits leading to proposals for potential additional projects. NASA plans to install combined heat and power systems at three candidate Centers, depending on the results of feasibility studies, to increase energy efficiency, reduce greenhouse gas emissions, and improve energy security. Executive Order 13693 provides for weather normalization calculations, using the Energy Star Portfolio Manager, which will reduce the impact of colder or warmer than average weather conditions on calculations of energy intensity.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Meet sustainable building inventory target (percentage of gross square footage of inventory meeting guiding principles) set by the Office of Management and Budget for FY 2016 in the Sustainability and Energy Scorecard.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 21 Green	AMO 15 11 Green	AMO 16 11 Green
Planned Future Performance						
For FY 2017: AMO-17-11: Meet sustainable building inventory target (percentage of gross square footage of inventory meeting guiding principles) set by the Office of Management and Budget for FY 2017 in the Sustainability and Energy Scorecard.						
For FY 2018: AMO-18-6: Meet sustainable building inventory target (percentage of gross square footage of inventory meeting guiding principles) set by the Office of Management and Budget for FY 2018 in the Sustainability and Energy Scorecard.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Ensure that a percentage of electricity consumed is generated from renewable energy sources, to meet the target set by the Office of Management and Budget for FY 2016 in the Sustainability and Energy Scorecard.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 22 Green	AMO 15 12 Green	AMO 16 12 Green
Planned Future Performance						
For FY 2017: AMO-17-12: Ensure that a percentage of electricity consumed is generated from renewable energy sources, to meet the target set by the Office of Management and Budget for FY 2017 in the Sustainability and Energy Scorecard.						
For FY 2018: AMO-18-7: Ensure that a percentage of electricity consumed is generated from renewable energy sources, to meet the target set by the Office of Management and Budget for FY 2018 in the Sustainability and Energy Scorecard.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Performance Goal 3.1.8

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Enhance reach and effectiveness of programs and projects that engage the public.	6.4.2.1 Green	6.4.2.1 Green	6.4.2.1 Green	3.1.8 Green	3.1.8 Yellow	3.1.8 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					
Data Quality for FY 2018						
Data Source(s): Specific to each platform or communications tool, with contributions from programs, mission directorates, functional offices, and field centers. Includes after-event reports, lessons-learned documentation, media monitoring, and/or media metrics. **Verification and Validation:** Review of the documentation listed under Data Sources. Rating determined by the Associate Administrator for the Office of Communications. **Data Limitations:** Constrained by legal limitations on collecting information on the public. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's public website customer satisfaction scores are among the highest in the Federal Government, and traffic to the site is consistently high, averaging about 10 million visits per month as of September 2016. NASA has the most followers in the Federal Government on Instagram, Twitter, Facebook, and Google+. The Agency's flagship social media accounts reach a total of 56.6 million people, and there are 117.9 million followers across all of the Agency's accounts. NASA's Twitter account is the 67th most followed account, averaging 525 thousand new followers per month and 315 million impressions on tweets per month. NASA's Facebook account averages 383 thousand new likes per month on the page and 158.7 million impressions per month on page posts. Instagram averages 908 thousand new followers per month and 323 thousand likes per photograph posted. NASA's Tumblr is the Agency's most-read blog, with almost 270 thousand subscribers and more than 995 thousand readers. NASA's Office of Communications has a process for approving new social media accounts that continues to be a useful mechanism to ensure both the quality and cost-effectiveness of the Agency's investments in this area.

The Office of Communications continues to assess new social media tools and techniques to engage both science attentive and non-traditional audiences, and in FY 2016 launched an official presence on Snapchat, whose over 665 thousand followers are predominantly teens and young adults. The Office of Communications has also taken advantage of new tools from existing platforms, such as Facebook's Live broadcast tool, to deepen the engagement with social media followers on NASA's Facebook pages. For example, the Agency now routinely streams NASA Television coverage of mission milestones, such as launches, using Facebook Live. This allows NASA to reach hundreds of thousands of new viewers through Facebook.

The Office of Communications has enhanced its planning for social media activities to coincide with the priority events selected by the Agency's Communications Coordinating Council, with planning for messages, tactics, and actions for Level 1, Level 2, and Level 3 (indicating Agency level of effort) events being evaluated to leverage new tools and features. Employees have access to a Communications Toolkit via an internal website that is updated regularly with new content and integrated with a limited-access cloud storage account that enables interested external partners and stakeholders to

access selected content. Increasingly, metrics are collected, reported, analyzed, and applied to decision-making regarding content and operations on NASA.gov, Agency social media accounts, and in other communications functions.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Use current and emerging communications technologies, platforms, and methods to reach increasingly broad and diverse audiences.	AMO 11 21 Green	AMO 12 21 Green	AMO 13 13 Green	AMO 14 13 Green	AMO 15 13 Green	AMO 16 13 Green
Planned Future Performance						
For FY 2017: AMO-17-13: Use current and emerging communications technologies, platforms, and methods to reach increasingly broad and diverse audiences.						
For FY 2018: AMO-18-14: Add at least one new communications technology, platform, or tool to facilitate and improve cross-Agency communications collaboration and to reach increasingly broad and diverse audiences.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Develop a set of metrics by which to assess the reach and effectiveness of activities in the communications portfolio.	AMO 11 22 Green	AMO 12 22 Green	AMO 13 14 Green	AMO 14 28 Green	AMO 15 14 Green	AMO 16 14 Green
Planned Future Performance						
For FY 2017: AMO-17-14: Increase cross-Agency participation in a program of metrics by which to assess the reach and effectiveness, and articulate the value, of activities in the Agency's communications portfolio.						
For FY 2018: AMO-18-15: Increase cross-Agency participation in a program of metrics by which to assess the reach and effectiveness, and articulate the value, of activities in the Agency's communications portfolio.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Develop a toolkit (clearinghouse) of NASA communications products to share with NASA's communications professionals and employees to help ensure that consistent and current content is utilized in communicating the Agency's results to the public.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 16 24 Green
Planned Future Performance						
For FY 2017: AMO-17-24: Implement and maintain a toolkit (clearinghouse) of NASA communications products to share with NASA's communications professionals and employees to help ensure that consistent and current content is utilized in communicating the Agency's results to the public.						
For FY 2018: AMO-18-16: Maintain, grow, and promote a toolkit (clearinghouse) of NASA communications products to share with NASA's communications professionals and employees to help ensure that consistent and current content is utilized in communicating the Agency's results to the public.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: AMO-18-17: Strengthen strategic communications planning by improving alignment of Agency-wide communications activities with both Office of Communications and NASA strategic goals and objectives, including established processes of communications activities prioritization and campaign teams for execution.
Contributing Theme: Agency Management and Operations / **Contributing Program:** Agency Management

Performance Goal 3.1.9

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Manage coordination of advisory committees' (NASA Advisory Council and Aerospace Safety Advisory Panel) recommendations to the NASA Administrator.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.1.9 Green	3.1.9 Green	3.1.9 Yellow
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Data Quality for FY 2018
Data Source(s): Aerospace Safety Advisory Panel Annual Report to Congress. **Verification and Validation:** Review compliance with NASA Policy Directive 1150.11A. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

In addition to its work with international and interagency partners, the Office of International and Interagency Relations (OIIR) supports NASA's advisory committees, including the NASA Advisory Council (NAC), which provides advice and makes recommendations to NASA on Agency programs, policies, plans, financial controls, and other matters; and the Aerospace Safety Advisory Panel (ASAP), which evaluates NASA's safety performance and advises the Agency on ways to improve that performance. During FY 2016, OIIR coordinated NASA's responses to three recommendations from the NAC and two recommendations from the ASAP. While NASA responded to all three NAC recommendations within 90 days, the coordination of NASA's responses to the two ASAP recommendations took longer than 90 days. Additional time was needed to reach agreement on the responses internally within NASA.

OIIR also led the Agency-wide management oversight and legal compliance for NASA's six Federal Advisory Committee Act (FACA) committees; and directly planned and executed 17 NAC and ASAP meetings, including three NAC meetings, four ASAP quarterly meetings, and 10 ASAP insight meetings. OIIR also assisted with the coordination and release of the *ASAP Annual Report for 2015*.

Performance Improvement Plan

As noted above, NASA responded to three of five recommendations from the NAC and ASAP within 90 days.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Provide NASA responses to advisory committees' recommendations made formally to the NASA Administrator.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 27 Green	AMO 15 15 Green	AMO-16-15 Yellow
Planned Future Performance						
For FY 2017: AMO-17-15: Provide NASA responses to advisory committees' recommendations made formally to the NASA Administrator.						
For FY 2018: AMO-18-13: Provide NASA responses to advisory committees' recommendations made formally to the NASA Administrator.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Explanation of Rating

As noted above, NASA responded to three of five recommendations from the NASA Advisory Council (NAC) and Aerospace Safety Advisory Panel (ASAP) within 90 days.

Performance Goal 3.1.10

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Between 2016 and 2017, demonstrate increased facility reliability by reducing spending on unscheduled maintenance by two percent annually.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.1.10 Red
Planned Future Performance						
For FY 2017: 3.1.10: Between 2016 and 2017, demonstrate increased facility reliability by reducing spending on unscheduled maintenance by two percent annually.						
For FY 2018: 3.1.10: Between 2016 and 2018, demonstrate increased facility reliability by reducing spending on unscheduled maintenance by two percent annually.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					
Data Quality for FY 2018						
Data Source(s): Systems Application Products (SAP) and NASA Center work plans. **Verification and Validation:** Review of the documentation listed under Data Source. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

For FY 2016, NASA's ratio of the cost of unscheduled maintenance to the total cost of maintenance was approximately 35 percent. This is an increase over the 2015 ratio, which was 31.54 percent. The Agency's deferred maintenance continues to grow, which further drives up unplanned maintenance.

NASA performs scheduled maintenance on its equipment to keep it in good operating condition. When equipment fails, NASA must perform unscheduled maintenance to repair it. The percentage of unscheduled maintenance spending to total maintenance spending is an indicator of the overall condition of equipment; i.e., the higher the percentage, the poorer the condition. When these percentages are high, it indicates that equipment is not reliable, and unplanned failures and outages become more frequent, which can interrupt or delay direct mission activities, such as testing and manufacturing. This issue is exacerbated by the age of NASA's infrastructure. About 83 percent of NASA's infrastructure and facilities are currently beyond their constructed design life. However, with appropriate spending on maintenance, NASA can rebuild, repair, and, in some cases, replace the old, unreliable equipment. Unscheduled maintenance is significantly more expensive than scheduled maintenance. It can cost up to three times more to repair or replace equipment after it has failed, rather than keeping it in good working order. Due to funding prioritization, NASA has deferred planned maintenance spending, which in some instances has led to an increase in unscheduled maintenance.

More information is available at NASA's Office of Strategic Infrastructure website.

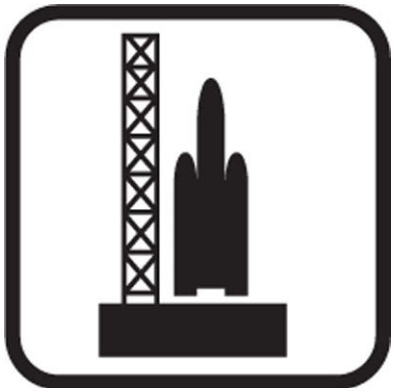
Performance Improvement Plan

Maintenance costs are increasing at an average rate of about three percent per year. With the current level of funding, the Agency's deferred maintenance continues to grow, which further drives up unplanned maintenance. NASA will continue to implement best maintenance practices and demolish unneeded facilities, but these efforts alone may not be enough to improve performance.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Reduce spending on unscheduled maintenance (out of total maintenance spending) by at least two percentage points.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 16 5 Red
Planned Future Performance						
For FY 2017: AMO-17-5: Reduce spending on unscheduled maintenance (out of total maintenance spending) by at least two percentage points.						
For FY 2018: AMO-18-8: Reduce spending on unscheduled maintenance (out of total maintenance spending) by at least two percentage points.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency Management					

Explanation of Rating

There is a direct, inversely proportional relationship between the percentage of unplanned maintenance and the amount of money spent on maintenance (the less spent on maintenance, the higher the ratio of unplanned maintenance to total maintenance).



Strategic Objective 3.2

Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's Mission.

Lead Office

Human Exploration and Operations Mission Directorate (HEOMD)

Goal Leader

Greg Williams, Deputy Associate Administrator for Policy and Plans, HEOMD

Contributing Programs

21st Century Space Launch Complex, Exploration Construction of Facilities (CoF), Launch Services, Rocket Propulsion Test, Space Communications and Navigation, Space Operations CoF, Strategic Capabilities Assets Program

Budget for Strategic Objective 3.2

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$914	–	$850	$744	$740	$749	$778

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Under Strategic Objective 3.2, multiple NASA programs provide critical services and strategic technical programmatic capabilities for the Agency. Recent examples of progress include the successful launches of missions such as Jason-3 and the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) via the Launch Services Program (LSP), the completion of the second new 34-meter deep-space antenna at Canberra, and the completion by the Rocket Propulsion Test (RPT) program of approximately 20 percent more tests in FY 2016 than the previous year. Over the next several years, NASA's critical next steps are to provide valuable propulsion data to the Space

Launch System and Orion programs as they prepare for Exploration Missions 1 and 2, and to continue to successfully launch the assigned NASA and civil sector robotic missions plus acquire new launch services for future NASA missions. Specific performance metrics for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. The NASA 2016 Strategic Review noted that several challenges noted in previous Strategic Reviews are being managed and mitigated. However, the Strategic Capabilities Assets Program (SCAP) is maintaining a portfolio of aging facilities, many over 40 years old, and planning and initiating the next-generation Tracking and Data Relay System is a major area of forward work for the Agency.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General and the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 3.2: Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's Mission.					
Performance Goal 3.2.1: Review the current state of the NASA test capabilities, known test requirements and test requests, and revise the Master Plan as needed.	Performance Goal 3.2.2: Complete Launch Services Program (LSP) objectives for all NASA-managed expendable launches.	Performance Goal 3.2.3: Maintain a minimum of 95 percent delivery of the Space Communications network services that support NASA and other customers' mission success.	Performance Goal 3.2.5: Replace aging Deep Space Network (DSN) 70-meter antenna at Canberra Deep Space Communications Complex (CDSCC).	Performance Goal 3.2.6: Prioritize and complete launch and range complex modernization studies and projects to sustain government and commercial capabilities at the Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS).	Performance Goal 3.2.7: Ensure the strategic availability and maintenance of facilities that are necessary to meet the long-term needs and requirements of the Agency.
Annual Performance Indicators					
• SFS-16-2: Sustain 90 percent availability of test facilities to support NASA and other customers' planned test requirements.	• SFS-16-3: Sustain a 100 percent success rate with the successful launch of NASA-managed expendable launches as identified on the Launch Services Flight Planning Board manifest. • SFS-16-4: Complete acquisitions on time for NASA-managed expendable launches.	• SFS-16-5: Complete the development of the Tracking and Data Relay Satellite (TDRS)-M Spacecraft and prepare it for storage.	• SFS-16-7: Initiate installation of electronics at Canberra Deep Space Communications Complex (CDSCC) for Deep Space Station (DSS)-36.	• ESD-16-4: Complete a study of the Crawlerway, which will include an assessment of updated loads on Leg B, sampling (boring) data analysis, and development of a conditioning plan.	• SC-16-1: Achieve a minimum of 80 percent overall availability of Strategic Capabilities Assets Program (SCAP) portfolio of assets that are necessary to meet the long-term needs and requirements of the Agency.

Summary of Performance for Strategic Objective 3.2

Performance Goal Ratings for Strategic Objective 3.2, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	6	6	0	0	0
2015	6	6	0	0	0
2014	6	6	0	0	0
2013	5	5	0	0	0
2012	5	5	0	0	0
2011	5	5	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 3.2, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	7	7	0	0	0
2015	7	7	0	0	0
2014	7	7	0	0	0
2013	4	4	0	0	0
2012	4	4	0	0	0
2011	4	3	1	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 3.2.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Review the current state of the NASA test capabilities, known test requirements and test requests, and revise the Master Plan as needed.	5.3.1.1 Green	5.3.1.1 Green	5.3.1.1 Green	3.2.1 Green	3.2.1 Green	3.2.1 Green
Planned Future Performance						
For FY 2017: 3.2.1: Review the current state of the NASA test capabilities, known test requirements and test requests, and revise the Master Plan as needed.						
For FY 2018: 3.2.1: Review the current state of the NASA test capabilities, known test requirements, and test requests, and ensure their availability to meet the Nation's needs.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Rocket Propulsion Test					
Data Quality for FY 2018						
Data Source(s): Rocket Propulsion Test (RPT) staff presentations at quarterly Directorate Program Management Council (DPMC) and Program Management Review (PMR) meetings. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's Rocket Propulsion Test (RPT) program is responsible for managing and sustaining the Agency's facilities for ground testing rocket engines. It works both to advance new test technologies and to reduce propulsion test costs. The RPT program prioritizes its limited resources to sustain its core test capabilities and meet customer test requirements. In addition, the RPT program is NASA's representative on the National Rocket Propulsion Test Alliance (NRPTA), which was established between NASA and the Department of Defense in 1998. The NRPTA helps shape the Federal Government's rocket propulsion test capabilities to better meet national test needs through intra- and interagency cooperation, and recommends solutions to provide the best overall value to taxpayers.

The RPT program continually monitors the state of its test capabilities, known test requirements, and test requests. NASA uses weekly Rocket Propulsion Test Management Board (RPTMB) teleconferences and semi-annual Program Manager Reviews to monitor the condition and operational state of all facilities, and work solutions as needed. The RPTMB also tracks current test activities, requirements for upcoming tests, and requests for future testing. The Master Plan is current in relation to the Program Commitment Agreement and the current state of the program's infrastructure. In FY 2016, the RPT program performed 540 tests totaling 152,388 seconds, while maintaining 99.4 percent test stand availability. This accomplishment represents a roughly 20 percent increase in testing and a 50 percent reduction in test facility related delays from FY 2015.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Sustain 90 percent availability of test facilities to support NASA and other customers' planned test requirements.	SFS 11 1 Green	SFS 12 1 Green	SFS 13 1 Green	SFS 14 1 Green	SFS 15 2 Green	SFS 16 2 Green
Planned Future Performance						
For FY 2017: SFS-17-2: Sustain 90 percent availability of test facilities to support NASA and other customers' planned test requirements.						
For FY 2018: SFS-18-2: Sustain 90 percent availability of test facilities to support NASA and other customers' planned test requirements.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Rocket Propulsion Test					

Performance Goal 3.2.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Complete Launch Services Program (LSP) objectives for all NASA-managed expendable launches.	5.4.1.1 Green	5.4.1.1 Green	5.4.1.1 Green	3.2.2 Green	3.2.2 Green	3.2.2 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Launch Services					
Data Quality for FY 2018						
Data Source(s): LSP Mission Success Metric 0773, which is updated at the end of each fiscal year; and link(s) to mission press release(s). **Verification and Validation:** Review of the documentation listed under Data Sources by the Human Exploration and Operations Mission Directorate Launch Services Office, Director; and Launch Services Program (LSP) Program Planning Office. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's Launch Services Program (LSP) is responsible for the acquisition and management of commercial, expendable launch vehicle missions. LSP provides safe, reliable, cost-effective, and on-schedule launch services to NASA and NASA-sponsored payloads. LSP oversees all aspects of launch services, including launch vehicle engineering and manufacturing, launch operations and countdown management, and quality and mission assurance.

LSP sustained a 100 percent success rate for FY 2016 with the successful launch of Jason-3 and the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) mission. Jason-3 launched on January 17, 2016, aboard a Falcon 9 v1.1 from Vandenberg Air Force Base in California. The OSIRIS-REx mission launched on September 8, 2016, aboard an Atlas V-411 from Cape Canaveral Air Force Station in Florida. OSIRIS-REx was the last LSP mission manifested to fly in FY 2016.

LSP successfully completed all acquisitions scheduled for award in FY 2016 on-time, and met customer requirements, with the award of one new acquisition approach and two launch service awards:

- On October 14, 2015, NASA announced the award of multiple Venture Class Launch Services (VCLS) contracts to provide small satellites (SmallSats)—also called CubeSats, microsatellites, or nanosatellites—access to low Earth orbit. Rocket Lab's Electron launch vehicle (VCLS-E) is scheduled for launch in June 2017, Virgin Galactic's LauncherOne launch vehicle (VCLS-L) for launch in December 2017, and Firefly's Alpha launch vehicle (VCLS-A) for launch in March 2018.
- On October 30, 2015, NASA announced the Tracking and Relay Satellite (TDRS)-M launch service award to United Launch Services LLC of Centennial, Colorado, to provide launch services for the Agency's TDRS-M mission. TDRS-M will launch in August 2017 aboard an Atlas V-401 rocket from Space Launch Complex 41 at Cape Canaveral Air Force Station (CCAFS) in Florida.
- On August 25, 2016, NASA announced the Mars 2020 launch service award to United Launch Services LLC of Centennial, Colorado. Mars 2020 will launch in July 2020 aboard an Atlas V-541 rocket from CCAFS in Florida.

In addition, LSP is actively performing Launch Service Task Order evaluations and competitions for the Surface Water and Ocean Topography (SWOT) and Joint Polar Satellite System (JPSS)-2 missions.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Sustain a 100 percent success rate with the successful launch of NASA-managed expendable launches as identified on the Launch Services Flight Planning Board manifest.	SFS-11-2 Yellow	SFS 12 2 Green	SFS 13 2 Green	SFS 14 2 Green	SFS 15 3 Green	SFS 16 3 Green
Planned Future Performance						
For FY 2017: SFS-17-3: Sustain a 100 percent success rate with the successful launch of NASA-managed expendable launches as identified on the Launch Services Flight Planning Board manifest.						
For FY 2018: SFS-18-3: Sustain a 100 percent success rate with the successful launch of NASA-managed expendable launches as identified each fiscal year on the Launch Services Flight Planning Board manifest.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Launch Services					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete acquisitions on time for NASA-managed expendable launches.	No API this fiscal year	No API this fiscal year	No API this fiscal year	SFS 14 3 Green	SFS 15 4 Green	SFS 16 4 Green
Planned Future Performance						
For FY 2017: SFS-17-4: Complete acquisitions on time for NASA-managed expendable launches.						
For FY 2018: SFS-18-4: Complete acquisitions on time for NASA-managed expendable launches.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Launch Services					

Performance Goal 3.2.3

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Maintain a minimum of 95 percent delivery of the Space Communications network services that support NASA and other customers' mission success.	5.4.3.1 Green	5.4.3.1 Green	5.4.3.1 Green	3.2.3 Green	3.2.3 Green	3.2.3 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Space Communications and Navigation					
Data Quality for FY 2018						
Data Source(s): NASA-internal presentation charts and link(s) to external press releases. **Verification and Validation:** Review of the documentation listed under Data Sources by the Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC) and at the Baseline Performance Review (BPR). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The NASA Space Communications and Navigation (SCaN) program is responsible for Agency-wide operations, management, and development of all NASA space communications capabilities and enabling technology. The SCaN program manages and directs the ground-based facilities and services for three networks, including the Deep Space Network (DSN), Near Earth Network (NEN), and Space Network (SN), which span the globe and support over 100 space missions. The Space Network consists of a constellation of geosynchronous (Earth-orbiting) satellites named the Tracking Data Relay Satellite (TDRS) system, ground systems that operate as a relay system between satellites, satellites in low Earth orbit above 73 kilometers, and ground facilities.

The Space Network maintains near-continuous communications with the International Space Station (ISS), the Hubble Space Telescope, and other satellites beyond low Earth orbit, and supports resupply missions to the ISS. SCaN's three Networks are operated 24 hours a day, seven days a week, 365 days per year. During FY 2016, the Space Network, Near Earth Network, and Deep Space Network each exceeded their requirement of 95 percent delivery

of network services, achieving an actual service delivery of 99.9, 99.6 and 98.6 percent respectively. The three networks are frequently able to exceed their 95 percent delivery requirement, often by achieving over 98 percent proficiency.

In addition, the TDRS-M spacecraft was prepared for and moved to storage according to plan. The replenishment of the TDRS fleet will help to ensure that NASA's Space Network is able to continue to provide around-the-clock, high throughput communications services to NASA's missions, including the ISS. TDRS-M is planned for launch in August 2017.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the development of the Tracking and Data Relay Satellite (TDRS)-M Spacecraft and prepare it for storage.	SFS 11 5 Green	SFS 12 5 Green	SFS 13 4 Green	SFS 14 4 Green	SFS 15 5 Green	SFS 16 5 Green
Planned Future Performance						
For FY 2017: SFS-17-5: Maintain a minimum of 95 percent delivery of the Space Communications network services that support NASA and other customers' mission success.						
For FY 2018: SFS-18-5: Demonstrate Initial Operating Capability of the Tracking and Data Relay Satellite (TDRS)-M spacecraft.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Space Communications and Navigation					

Performance Goal 3.2.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Replace aging Deep Space Network (DSN) 70-meter antenna at Canberra Deep Space Communications Complex (CDSCC).	5.4.3.3 Green	5.4.3.3 Green	5.4.3.3 Green	3.2.5 Green	3.2.5 Green	3.2.5 Green
Planned Future Performance						
For FY 2017: 3.2.5: Replace aging Deep Space Network (DSN) 70-meter antenna at Canberra Deep Space Communications Complex (CDSCC).						
For FY 2018: 3.2.4: Replace aging Deep Space Network (DSN) infrastructure.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Space Communications and Navigation					
Data Quality for FY 2018						
Data Source(s): NASA-internal presentation charts and link(s) to external press releases. **Verification and Validation:** Review of the documentation listed under Data Sources by the Human Exploration and Operations Mission Directorate (HEOMD) Directorate Program Management Council (DPMC) and at the Baseline Performance Review (BPR). **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA's Space Communications and Navigation (SCaN) program manages the Deep Space Network, which is an international network of antennas that supports interplanetary spacecraft missions, space-based telescopes, and some select Earth-orbiting science missions. The Deep Space Network comprises three facilities, the Canberra Deep Space Communications Complex (CDSCC) in Australia; the Goldstone Deep Space Communications Complex in Fort Irwin, CA; and the Madrid Deep Space Communications Complex in Spain. The Deep Space Network supports NASA and non-NASA missions that explore the furthest points of the solar system.

To meet ongoing demand for deep space communication services, SCaN is replacing its aging Deep Space Station (DSS) 70-meter antennas with a new generation of 34-meter antennas. Four 34-meter antennas are being arrayed in order to provide functionally similar capabilities to the 70-meter antenna at the CDSCC, which is over 40 years old. SCaN completed two new 34-meter antennas, DSS-35 and DSS-36, at the Canberra Deep Space Communications Complex. The two new antennas can be arrayed with the existing two 34-meter antennas to provide redundancy and eliminate the critical dependence on the old 70-meter antenna.

In FY 2016, NASA initiated the installation of electronics at CDSCC for DSS-36 according to plan. NASA achieved initial operational status of DSS-36 in early FY 2017.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Initiate installation of electronics at Canberra Deep Space Communications Complex (CDSCC) for Deep Space Station (DSS)-36.	SFS 11 7 Green	SFS 12 7 Green	SFS 13 6 Green	SFS 14 6 Green	SFS 15 7 Green	SFS 16 7 Green
Planned Future Performance						
For FY 2017: SFS-17-7: Achieve initial operational status of Deep Space Station (DSS)-36 at Canberra Deep Space Communications Complex (CDSCC).						
For FY 2018: SFS-18-6: Continue the Deep Space Network Aperture Enhancement Project (DAEP) at the Madrid Deep Space Communications Complex (MDSCC) by completing the pedestal construction of both Deep Space Station (DSS)-56 and DSS-53 by the end of FY 2018.						
Contributing Theme: Space and Flight Support	**Contributing Program:** Space Communications and Navigation					

Performance Goal 3.2.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Prioritize and complete launch and range complex modernization studies and projects to sustain government and commercial capabilities at the Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS).	5.4.2.1 Green	5.4.2.1 Green	5.4.2.1 Green	3.2.6 Green	3.2.6 Green	3.2.6 Green
Planned Future Performance						
This performance goal does not continue past FY 2016.						
Contributing Theme: Space and Flight Support	**Contributing Program:** 21st Century Space Launch Complex					

FY 2016 Performance Results

The 21st Century Space Launch Complex (21CSLC) initiative within the Ground Systems Development and Operations (GSDO) program is modernizing the launch and range complex at the Kennedy Space Center (KSC), Cape Canaveral Air Force Station, and Wallops Flight Facility. The enhanced complexes will facilitate multiple launches of different vehicle types from different companies carrying both humans and cargo to space in a cost-effective and timely manner. Other important projects include enhancements to the range, payload processing capabilities, and environmental clean-up activities. Beneficiaries of this work include current and future NASA programs, other U.S. government agencies, and commercial industry.

The 21CSLC initiative was extended by one year, and will conclude at the end of FY 2017. During FY 2016, the 21CSLC initiative completed a number of planned projects and activities, including the replacement of old, deteriorating cable ducts that provide critical communication connections between KSC and the Eastern Range; the completion of the facility design for the eventual replacement of the converter compressor facility, which supplies gaseous nitrogen and helium to processing and launch sites across the Florida Range; and the completion of a variety of range telemetry upgrades.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete a study of the Crawlerway, which will include an assessment of updated loads on Leg B, sampling (boring) data analysis, and development of a conditioning plan.	No API this fiscal year	No API this fiscal year	No API this fiscal year	ESD 14 4 Green	ESD 15 4 Green	ESD 16 4 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Space and Flight Support	**Contributing Program:** 21st Century Space Launch Complex					

Performance Goal 3.2.7

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Ensure the strategic availability and maintenance of facilities that are necessary to meet the long-term needs and requirements of the Agency.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.2.7 Green	3.2.7 Green	3.2.7 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Strategic Capabilities Assets Program					
Data Quality for FY 2018						
Data Source(s): Quarterly program reviews of the Space Environments Testing Management Office (SETMO) **Verification and Validation:** Assessment Space Environments Testing Management Office (SETMO) by staff at the quarterly program reviews. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

The NASA Strategic Capabilities Assets Program (SCAP) ensures that essential Agency test facilities are maintained in a state of readiness. SCAP maintains the skilled workforce and performs essential preventive maintenance to ensure that NASA's key capabilities and critical assets will continue to be available in the future to support the missions that require them; to ensure that capabilities include the right mix of the facilities, equipment, core competencies, and skilled staff; and to identify and prioritize NASA's essential assets, and implement strategic investment decisions to sustain, enhance, replace, modify, or dispose of them based on NASA and national needs. Core capabilities supported within SCAP include thermal vacuum chambers, simulators, and the Arc Jet Complex.

SCAP asset capabilities continue to be available for programs and projects with no major impacts to critical programs and projects milestones. The overall availability for SCAP assets for FY 2016 was 98.2 percent.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Achieve a minimum of 80 percent overall availability of Strategic Capabilities Assets Program (SCAP) portfolio of assets that are necessary to meet the long-term needs and requirements of the Agency.	No API this fiscal year	No API this fiscal year	No API this fiscal year	SC 14 1 Green	SC 15 1 Green	SC 16 1 Green
Planned Future Performance						
For FY 2017: SC-17-1: Achieve a minimum of 90 percent overall availability of Space Environment Testing Management Office (SETMO) portfolio of assets which are necessary to meet the long-term needs and requirements of the Agency.						
For FY 2018: SC-18-1: Achieve a minimum of 90 percent overall availability of Space Environment Testing Management Office (SETMO) portfolio of assets, which are necessary to meet the long-term needs and requirements of the Agency.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Strategic Capabilities Assets Program					

Strategic Objective 3.3

Provide secure, effective, and affordable information technologies and services that enable NASA's Mission.

Lead Office

Office of the Chief Information Officer

Goal Leader

Reneé Wynn, Chief Information Officer

Contributing Programs

Agency IT Services

Budget for Strategic Objective 3.3

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$220	–	$278	$248	$248	$248	$248

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

NASA, in consultation with the Office of Management and Budget, has highlighted this strategic objective as a focus area for improvement.

Through the Strategic Review and the Agency's other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. The Agency Information Technology (IT) Services program falls under Strategic Objective 3.3, managed by the Office of the Chief Information Officer (OCIO). During the 2016 Strategic Review, NASA found that OCIO is on track for several performance metrics. Specific performance measures for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans in the performance goal and annual performance indicator tables below.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. The 2015 Strategic Review assessment showed that NASA has the opportunity for significant strategic improvement. Since that time, OCIO's IT Business Services Assessment implementation plan was approved in March 2016. Once executed, the plan will lay the foundation for NASA's IT transformation, including completion of the three actions from the 2015 Strategic Review:

- Managing IT as a program.
- Implementing an integrated risk management approach.
- Implementing a portfolio management capability.

While these positive steps will lay the foundation for NASA's IT transformation, the 2016 Strategic Review noted that challenges remain from previous assessments. No single entity has had insight, authority, and oversight for NASA's overall IT requirements, budget, resources, acquisition, and results, thus OCIO is experiencing difficulties establishing a holistic approach to mitigate resource risks by using data to drive better purchasing of hardware and software and to enable proper cybersecurity mitigation planning and risk reduction. To address this challenge, NASA appointed a team in 2016 to analyze NASA's IT portfolio budget estimate, spend, and resources and make recommendations to improve the comprehensiveness and quality of the IT portfolio characterization. Leveraging the findings and recommendations from this team, NASA is in the process of formulating an IT portfolio management approach. As a separate challenge, NASA did not meet the Cybersecurity cross-agency priority (CAP) goal for strong authentication. Strategies going forward include working with other Federal agencies to acquire and implement Personal Identity Verification (PIV) solutions.

This strategic objective has been identified as a management challenge by the NASA Office of Inspector General. More information is available in the "Management Challenges" section in Part 2.

For more information, please see https://www.nasa.gov/offices/ocio/home/. Highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 3.3: Provide secure, effective, and affordable information technologies and services that enable NASA's Mission.				
Performance Goal 3.3.1: Enhance NASA's information security posture through implementation of automated security and privacy tools and technologies.	Performance Goal 3.3.5: By 2017, operate as a single NASA enterprise network and effectively utilize the bandwidth of the Communications Services Office (CSO) backbone for both corporate and mission data, enabling more efficient use of available capacity while improving performance with no degradation to mission services.	Performance Goal 3.3.6: Enhance NASA's data management through open data actions, research and development data access, and new data modeling and technologies.	Performance Goal 3.3.7: Increase the adoption of technologies and services such as cloud computing throughout NASA's infrastructure and mission, leveraging savings from solutions such as reduced capital expenditures from not owning hardware, benefits from new technology capabilities, and increased computing flexibility available with "pay as you go" services.	Performance Goal 3.3.8: By 2017, increase Agency business systems performance and efficiency by upgrading NASA's business systems infrastructure and modernizing business applications with no degradation to business services.
Annual Performance Indicators				
• AMO-16-17: Plan and implement Continuous Diagnostics and Mitigation (CDM) Phase 1 tools and technologies into the NASA environment. • AMO-16-25: Increase the security of NASA's information operations by implementing the FY 2016 target cross-agency priority cybersecurity capabilities, including Information Security Continuous Monitoring (ISCM); Identity, Credential, and Access Management (ICAM); and anti-phishing and malware defense.	• AMO-16-26: Complete the Consolidated Network Operations System (CNOS) project.	• AMO-16-27: Provide information architecture to manage NASA's data more efficiently. • AMO-16-28: Enable access to NASA R&D data and publications by securely integrating with shared hosting and data infrastructure.	• AMO-16-29: Onboard two significant communities into the cloud in FY 2016. • AMO-16-30: Implement at least one new technology solution that improves efficiency and the effectiveness of end user service delivery to NASA's workforce.	• AMO-16-31: Complete the Phase-3 Operations Readiness Review (ORR) of the NASA Aircraft Management Information System–Logistic Upgrade (NAMIS-LU). • AMO-16-32: Complete the NASA Enterprise Applications Competency Center (NEACC) release 16.1, a significant business systems upgrade.

Summary of Performance for Strategic Objective 3.3

Performance Goal Ratings for Strategic Objective 3.3, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	5	3	1	1	0
2015	4	4	0	0	0
2014	1	0	1	0	0
2013	0	0	0	0	0
2012	0	0	0	0	0
2011	0	0	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 3.3, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	9	7	0	2	0
2015	5	4	0	1	0
2014	1	1	0	0	0
2013	0	0	0	0	0
2012	0	0	0	0	0
2011	0	0	0	0	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 3.3.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Enhance NASA's information security posture through implementation of automated security and privacy tools and technologies.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.3.1 Yellow	3.3.1 Green	3.3.1 Red
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					
Data Quality for FY 2018						
Data Source(s): Federal Information Security Management Act (FISMA) reporting metrics and NASA-internal reports. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results
NASA's Office of the Chief Information Officer (OCIO) efforts support the Cybersecurity cross-agency priority goal.

NASA's anti-phishing effort improved substantially due to the implementation of incoming email traffic filters. The Agency also completed the implementation of the Intrusion Prevention System (IPS), which reduced the overall number of systems placed at risk by external actors.

NASA's Continuous Diagnostics and Mitigation (CDM) project team completed requirements gathering. NASA's ability to meet continuous monitoring targets remain dependent on CDM Phase 1 implementation, which started in November 2016. CDM is used to identify cybersecurity risks on an ongoing basis, prioritize risks based upon potential impacts, and enable cybersecurity personnel to mitigate the most significant problems first. Even after full implementation of CDM, NASA will require additional mitigations in order to gain full visibility into software and hardware requirements.

Issues have delayed the Agency's implementation of the CDM capability and the ability to meet Federal strong authentication targets using Personal Identity Verification (PIV). The preliminary design review took place in November 2016. NASA's deployment of its CDM Initial Operating Capability is underway.

NASA did not meet the Office of Management and Budget's (OMB's) 85 percent PIV strong authentication target for non-privileged user access in FY 2016. The schedule delay for reaching 85 percent compliance is due in part to issues with an operating system upgrade required for a segment of NASA users and the migration of the upgraded machines to the PIV solution. NASA has not identified a PIV solution for another operating system and user segment, contributing to the overall delay with meeting OMB's PIV target.

Performance Improvement Plan
NASA will collaborate with DHS regarding the dependencies on DHS and the integrator to implement CDM in NASA's environment.

NASA's ability to maintain PIV compliance for unprivileged users depends on two activities:

- A timely operating system upgrade for a segment of NASA users and migration of the upgraded machines to the PIV solution, which is being planned.
- Identification and implementation of a PIV solution for the remaining segment of NASA users.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Plan and implement Continuous Diagnostics and Mitigation (CDM) Phase 1 tools and technologies into the NASA environment.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 17 Green	AMO 15 16 Green	AMO 16 17 Red
Planned Future Performance						
For FY 2017: AMO-17-17: Plan and implement Continuous Diagnostics and Mitigation (CDM) Phase 2 tools and technologies into the NASA environment.						
For FY 2018: No API this fiscal year						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Explanation of Rating
NASA will collaborate with DHS regarding the dependencies on DHS and the integrator to implement CDM in NASA's environment.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Increase the security of NASA's information operations by implementing the FY 2016 target cross-agency priority cybersecurity capabilities, including Information Security Continuous Monitoring (ISCM); Identity, Credential, and Access Management (ICAM); and anti-phishing and malware defense.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 15 25 Green	AMO 16 25 Red
Planned Future Performance						
For FY 2017: AMO-17-25: Increase the security of NASA's information operations by implementing the FY 2017 target cross-agency priority cybersecurity capabilities, including Information Security Continuous Monitoring (ISCM); Identity, Credential, and Access Management (ICAM); and anti-phishing and malware defense.						
For FY 2018: AMO-18-18: Attain 95 percent Personal Identity Verification (PIV) authentication for non-privileged access in FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Explanation of Rating

NASA's ability to maintain PIV compliance for unprivileged users depends on two activities:

- A timely operating system upgrade for a segment of NASA users and migration of the upgraded machines to the PIV solution, which is being planned.
- Identification and implementation of a PIV solution for the remaining segment of NASA users.

Annual Performance Indicator	
For FY 2016: Does not trend until FY 2018.	
Planned Future Performance	
For FY 2017: No API this fiscal year	
For FY 2018: AMO-18-19: Attain Hardware and Software Asset Management of 95 percent in FY 2018.	
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services

Performance Goal 3.3.5

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
By 2017, operate as a single NASA enterprise network and effectively utilize the bandwidth of the Communications Services Office (CSO) backbone for both corporate and mission data, enabling more efficient use of available capacity while improving performance with no degradation to mission services.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.3.5 Green	3.3.5 Yellow
Planned Future Performance						
This performance goal continues through FY 2017.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

FY 2016 Performance Results

NASA continues to make progress toward achieving this performance goal. The Agency completed the Mission Next Generation Architecture (MNGA) project in the second quarter of FY 2016. MNGA implements the new mission network architecture required to support emerging and upcoming mission concepts and requirements while reducing cost and improving service delivery. NASA has also made significant progress in migrating mission customers to the new mission network in the Mission Backbone Transition (MBT), thus allowing the decommissioning of several high cost mission circuits.

In addition, NASA completed the Consolidated Network Operations Services (CNOS) project in the second quarter of FY 2016. CNOS transitioned the Agency from a Center-based network management and provisioning model to an enterprise-based model that standardizes network operations processes and procedures.

NASA also transferred funding for the NASA Integrated Communication Services (NICS) and Networx contracts to the Agency Office of the Chief Information Officer (OCIO) to fund enterprise communication services, such as local area networks, voice, and cable plant services. This funding transfer realigns the agency funding and technical direction for implementation and also restructures the process by which communications services priorities are established.

However, two related projects, External Border Protection (EBPro) and Enterprise Internal Border-Network Access Control (EIB-NAC), have made significant progress but are facing cost risk and schedule delays due to issues with establishing the enterprise IT security governance for these services. An effective governance process will provide NASA with the structure to make efficient decisions and provide accountability for IT security operations.

The Agency deployed EBPro Unified Threat Management (UTM) next generation firewalls and Virtual Private Network (VPN) appliances at NASA's Trusted Internet Connections (TICs). NASA completed this activity in preparation for establishment of a secure enterprise perimeter and transition of the Center Web Content Filter and Center VPN systems to the enterprise devices for consistent application of security policies. NASA will define and implement enterprise web content filters, firewall rulesets, and VPN policies in FY 2017 and 2018.

NASA installed EIB-NAC appliances in all NASA Center corporate networks. These appliances are gathering hardware asset management information and traffic logs in a cloud-based data warehouse for use by NASA's incident response teams. The Agency is defining policies to admit computing resources onto NASA's internal network and will implement policy enforcement using the EIB-NAC appliances in FY 2018.

Performance Improvement Plan
NASA is working to develop enterprise IT security governance processes and procedures to manage the internal and external network border. The Agency is also assessing a potential scope change for the internal border project to facilitate incremental delivery of the capabilities in phases.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Consolidated Network Operations System (CNOS) project.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 15 26 Red	AMO 16 26 Green
Planned Future Performance						
For FY 2017: AMO-17-26: Complete the Mission Backbone Transition (MBT) project.						
For FY 2018: No API this fiscal year.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Performance Goal 3.3.6

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Enhance NASA's data management through open data actions, research and development data access, and new data modeling and technologies.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.3.6 Green	3.3.6 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					
Data Quality for FY 2018						
Data Source(s): NASA-internal reports on enterprise wide data tools. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA continues to make progress toward achieving this performance goal. The Office of the Chief Information Officer's (OCIO's) efforts also support the Open Data cross-agency priority goal.

NASA provides over 32,000 open datasets on data.nasa.gov and 50 machine-readable Application Programming Interfaces are available at data.nasa.gov. More than 1,300 citizen applications are using these open data resources, driven in large part by the International Space Apps Challenge. During the challenge, participants from across the globe collaborated and engaged with publicly-available data to design innovative solutions for global challenges. 241 NASA Open Source software projects are listed on code.nasa.gov.

NASA updated the guidance for its information architecture and completed the data architecture for Exploration Medical Capability (ExMC) project. The Agency started the second phase of its Extravehicular Activity (EVA) data project to fully implement a data management tool and migrated and analyzed 17 terabytes of exploration suit data from the International Space Station (ISS). NASA is working on a data architecture assessment for the Scientific and Technical Information (STI) program.

NASA completed the first two phases of the PubMed Central (PMC) initiative for peer-reviewed manuscripts. Phase 1 established the process and system for civil servants to deposit manuscripts, and Phase 2 implemented system availability for grantees and contractors to deposit manuscripts. Phase 3 is on schedule and focuses on extracting digital metadata and developing requirements. NASA chose to use the National Institutes of Health (NIH) PMC system for manuscript deposits and the first peer-reviewed manuscript was deposited in October 2015.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Provide information architecture to manage NASA's data more efficiently.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 15 27 Green	AMO 16 27 Green
Planned Future Performance						
For FY 2017: AMO-17-27: Enable customers to utilize information architecture to drive opportunities for new insights using NASA data.						
For FY 2018: AMO-18-20: Provide analysis of needed enterprise-wide data tools in FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Enable access to NASA R&D data and publications by securely integrating with shared hosting and data infrastructure.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 16 28 Green
Planned Future Performance						
For FY 2017: AMO-17-28: Expand availability of R&D data and publications through secure use of shared hosting and data infrastructure.						
For FY 2018: No API this fiscal year						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Performance Goal 3.3.7

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Increase the adoption of technologies and services such as cloud computing throughout NASA's infrastructure and mission, leveraging savings from solutions such as reduced capital expenditures from not owning hardware, benefits from new technology capabilities, and increased computing flexibility available with "pay as you go" services.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.3.7 Green	3.3.7 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Data Quality for FY 2018
Data Source(s): Office of the Chief Information Officer (OCIO) governance processes, including the IT Program Management Board and Program/Project Management Reviews, as well as other NASA-internal reports. **Verification and Validation:** Review of the documentation listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.

FY 2016 Performance Results

NASA continues to make progress toward achieving this performance goal. NASA's Cloud Computing Service Office completed the onboarding of two more new significant communities to the cloud during FY 2016. The first community is the Advanced Information Systems Technology (AIST) element of the Earth Science program at the Goddard Space Flight Center (GSFC). The second community is the Headquarters Information Technology and Communications Division (HQ-ITCD).

NASA implemented an improved Product Catalog and started the Device Refresh Process, including an automated workflow, in the first quarter of FY 2016 for end users through the Agency Consolidated End-user Services (ACES) contract. Registration for Mobile Device Management (MDM) also began in the first quarter of FY 2016.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Onboard two significant communities into the cloud in FY 2016.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 15 29 Green	AMO 16 29 Green
Planned Future Performance						
For FY 2017: AMO-17-29: Onboard two significant communities into the cloud in FY 2017.						
For FY 2018: No API this fiscal year						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Implement at least one new technology solution that improves efficiency and the effectiveness of end user service delivery to NASA's workforce.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 16 30 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: AMO-18-21: Complete analysis and restructuring of NASA's IT portfolio in FY 2018.
Contributing Theme: Agency Management and Operations / **Contributing Program:** Agency IT Services

Annual Performance Indicator
For FY 2016: Does not trend until FY 2018.
Planned Future Performance
For FY 2017: No API this fiscal year
For FY 2018: AMO-18-22: Identify $50 million of NASA-wide cost avoidance and cost savings by the end of FY 2018.
Contributing Theme: Agency Management and Operations / **Contributing Program:** Agency IT Services

Performance Goal 3.3.8

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
By 2017, increase Agency business systems performance and efficiency by upgrading NASA's business systems infrastructure and modernizing business applications with no degradation to business services.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.3.8 Green
Planned Future Performance						
This performance goal continues through FY 2017.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

FY 2016 Performance Results

NASA is making progress on this performance goal. NASA completed the Agency Applications Office (formerly the NASA Enterprise Applications Competency Center) Release 16.1 in November 2015 as the last part of the Financial Processing cutover between fiscal years 2015 and 2016.

NASA is also on track to implement the NASA Aircraft Management Information System–Logistic Upgrade (NAMIS-LU). This project will update the existing logistics module by replacing the outdated programming platform with an industry standard. NASA successfully held the Phase 3 Operational Readiness Review (ORR) for NAMIS-LU in 2016 as planned, and will complete the roll-out of NAMIS-LU in FY 2017.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the Phase-3 Operations Readiness Review (ORR) of the NASA Aircraft Management Information System–Logistic Upgrade (NAMIS-LU).	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 16 31 Green
Planned Future Performance						
For FY 2017: AMO-17-31: Complete the NASA Aircraft Management Information System – Logistic Upgrade (NAMIS-LU) project.						
For FY 2018: No API this fiscal year						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Complete the NASA Enterprise Applications Competency Center (NEACC) release 16.1, a significant business systems upgrade.	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 16 32 Green
Planned Future Performance						
For FY 2017: No API this fiscal year						
For FY 2018: No API this fiscal year						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Agency IT Services					

Annual Performance Indicator
For FY 2016: Does not trend until FY 2017.
Planned Future Performance
For FY 2017: AMO-17-18: Complete the Contract Management Transformation (CMT) project.
For FY 2018: No API this fiscal year
Contributing Theme: Agency Management and Operations / **Contributing Program:** Agency IT Services

Strategic Objective 3.4

Ensure effective management of NASA programs and operations to complete the mission safely and successfully.

Lead Office

Office of Safety and Mission Assurance (OSMA); Office of the Chief Engineer (OCE); and Office of the Chief Health and Medical Officer (OCHMO).

Goal Leader

Hal Bell, Deputy Chief, Safety and Mission Assurance

Contributing Programs

Safety and Mission Success

Budget for Strategic Objective 3.4

Budget Authority (in $ millions)	Actual FY 2016	Enacted FY 2017	Requested FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021	Notional FY 2022
Total Budget	$176	–	$171	$171	$171	$171	$171

Note: For explanation of budget table, please see the "How to Read the Strategic Objective Information" section in the introduction to Part 3.

Progress Update

Through the Strategic Review and our other performance management processes, NASA reviews recent accomplishments and near-term plans for the Agency's strategic objectives and programs. Program elements managed by the Office of the Chief Engineer, Office of Safety and Mission Assurance, and the Office of the Chief Health and Medical Officer, along with the corresponding Technical Authorities, fall under Strategic Objective 3.4. These program elements together are more broadly referred to as "Safety and Mission Success." These programs work to protect the health and safety of the NASA workforce and improve the likelihood that NASA's programs, projects, and operations are completed safely and successfully. During the 2016 Strategic

Review, NASA found no major changes from the 2015 Strategic Review assessment, and performance metrics for Safety and Mission Success (SMS) are all on track. In the near-term future, SMS will continue to ensure effective management of NASA programs and operations to complete the mission safely and successfully. Specific performance metrics for the next two years can be found in the FY 2017 and FY 2018 Annual Performance Plans.

The Strategic Review also addresses long-term strategic outcomes, alignment, and key management challenges for each strategic objective, as well as across NASA's portfolio of activities. A challenge for this strategic objective is that NASA's mission requires working in many unforgiving environments, including the upper atmosphere, low Earth orbit, and deep space. SMS works to ensure mission safety and success given these environmental challenges, but faces resource constraints. Threats to the successful performance of this strategic objective includes the Agency's ability to assess the deteriorating Micrometeoroid and Orbital Debris (MMOD) environment. Millions of man-made and naturally occurring objects orbiting around Earth at hypervelocity speeds increase the potential for collisions that could seriously damage satellites or spacecraft, or pose a catastrophic threat to crews during intra- or extra-vehicular operations. With increasing reliance on commercial partners, key to these concerns is NASA's ability to apply advanced assurance and risk analysis techniques and tools to keep current with emergent technologies, such as applied in additive manufacturing, commercial-grade parts, and model-based systems engineering. Other areas of concern for SMS disciplines include aviation safety, human factors, and rapid advancement of software design and applications.

This strategic objective has been identified as a management challenge by the Government Accountability Office. More information is available in the "Management Challenges" section in Part 2.

For more information, highlighted achievements during FY 2016 are detailed in the *FY 2016 Agency Financial Report*. Information on the strategies for achieving this strategic objective can be found in the *NASA 2014 Strategic Plan*.

FY 2016 Performance Measures

Strategic Objective 3.4: Ensure effective management of NASA programs and operations to complete the mission safely and successfully.	
Performance Goal 3.4.1: Assure the safety and health of NASA's activities and reduce damage to assets through the development, implementation, and oversight of Agency-wide safety, reliability, maintainability, quality assurance, and health and medical policies and procedures.	Performance Goal 3.4.2: Implement the policies, procedures and oversight to continuously improve the probability of technical and programmatic mission success.
Annual Performance Indicators	
• AMO-16-19: Assure zero fatalities or permanent disabling injuries to the public resulting from NASA activities during FY 2016. • AMO-16-20: Maintain a Total Case Rate and Lost Time Case Rate that meets or exceeds the goals of the President's Protecting Our Workers and Ensuring Reemployment (POWER) initiative. • AMO-16-21: Reduce damage to NASA assets (excluding launched flight hardware) in FY 2016 to a level less than the historical annual average.	• AMO-16-22: Ensure 100 percent of Category 1 and 2 projects use Agency Safety and Mission Success policy, procedures, and independent assessments focused on both technical and programmatic mission success. • AMO-16-23: Ensure that 100 percent of the engineering and programmatic workforce has access to the standards and knowledge base needed to maintain and build their skills.

Summary of Performance for Strategic Objective 3.4

Performance Goal Ratings for Strategic Objective 3.4, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	2	2	0	0	0
2015	2	2	0	0	0
2014	2	2	0	0	0
2013	1	1	0	0	0
2012	1	1	0	0	0
2011	1	1	0	0	0

Annual Performance Indicator Ratings for Strategic Objective 3.4, FY 2011 through FY 2016

Fiscal Year	Total	Green	Yellow	Red	White
2016	5	5	0	0	0
2015	5	5	0	0	0
2014	5	5	0	0	0
2013	3	3	0	0	0
2012	3	3	0	0	0
2011	3	1	0	2	0

Past fiscal years do not include annual performance indicators that do not trend to the current fiscal year annual performance indicators.

Performance Goal 3.4.1

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Assure the safety and health of NASA's activities and reduce damage to assets through the development, implementation, and oversight of Agency-wide safety, reliability, maintainability, quality assurance, and health and medical policies and procedures.	5.2.1.1 Green	5.2.1.1 Green	5.2.1.1 Green	3.4.1 Green	3.4.1 Green	3.4.1 Green
Planned Future Performance						
This performance goal continues through FY 2017 and FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					
Data Quality for FY 2018						
Data Source(s): NASA Mishap Information System (NMIS). **Verification and Validation:** Quarterly review of the data listed under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA assured the continued safety and health of its activities and reduced the damage to its assets in FY 2016. This was demonstrated by the following:

- There were no fatalities or permanent disabling injuries to the public from NASA activities.
- NASA's Total Case Rate and Lost Time Case Rate were under the injury/illness goals established in the Protecting Our Workers and Ensuring Reemployment (POWER) initiative. Under the POWER initiative, an agency must have total and lost time injury rates at least one percent below its prior year rates. If an agency has a rate of one injury or illness per 100 employees per year or less, no further reductions are required. NASA was significantly under one injury/illness per year, with an FY 2016 Total Case Rate of 0.23 percent, and a Lost Time Case Rate of 0.06 percent.
- The non-mission failure damage costs were significantly below the five-year running average. In FY 2016, NASA's non-mission failure damage costs were $2.0 million and its five-year running average is $2.3 million, below the target of $6.5 million.

NASA takes significant effort to understand and mitigate risk and continues to anticipate achieving a green rating for this performance goal.

NASA's strategy to achieve this performance goal is based upon the integration of both its program portfolio and mission support activities, while utilizing its strong governance structure, risk analysis, and business practices. At the core of the Agency's preventive approach to achieve safety, health, and mission success are:

- Active engagement with NASA programs and institutions to advise, advocate, and ensure safety and mission success;
- Routine on-site inspections and regular self-audits to ensure compliance with mandatory regulations, Agency policies, industry standards, and best practices;
- Robust knowledge management and communities of practice that capture and inculcate lessons learned into future missions;

- Multi-faceted training and development programs to ensure that the Safety and Mission Success workforce has the necessary skills and capabilities; and
- Comprehensive review processes to identify and mitigate risks and analyze and understand failures when they occur.

This strategy and practice provides a systematic approach to support safety and mission success.

More Safety and Mission Success information is available on NASA's websites for the Office of the Chief Engineer, Office of the Chief Health and Medical Officer, Office of Safety and Mission Assurance, and Independent Verification and Validation (IV&V) Program.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Assure zero fatalities or permanent disabling injuries to the public resulting from NASA activities during FY 2016.	AMO 11 9 Green	AMO 12 9 Green	AMO 13 4 Green	AMO 14 4 Green	AMO 15 19 Green	AMO 16 19 Green
Planned Future Performance						
For FY 2017: AMO-17-19: Assure zero fatalities or permanent disabling injuries to the public resulting from NASA activities during FY 2017.						
For FY 2018: AMO-18-25: Assure zero fatalities or permanent disabling injuries to the public resulting from NASA activities during FY 2018.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Maintain a Total Case Rate and Lost Time Case Rate that meets or exceeds the goals of the President's Protecting Our Workers and Ensuring Reemployment (POWER) initiative.	AMO 11 10 Red	AMO 12 10 Green	AMO 13 5 Green	AMO 14 5 Green	AMO 15 20 Green	AMO 16 20 Green
Planned Future Performance						
For FY 2017: AMO-17-20: Maintain a Total Case Rate and Lost Time Case Rate that meets or exceeds the goals of the Administration.						
For FY 2018: AMO-18-26: Maintain a Total Case Rate and Lost Time Case Rate that meets or exceeds the goals of the Administration.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Reduce damage to NASA assets (excluding launched flight hardware) in FY 2016 to a level less than the historical annual average.	AMO 11 11 Red	AMO 12 11 Green	AMO 13 6 Green	AMO 14 6 Green	AMO 15 21 Green	AMO 16 21 Green
Planned Future Performance						
For FY 2017: AMO-17-21: Reduce damage to NASA assets (excluding launched flight hardware) by two percent per year through FY 2017, compared to an FY 2010 baseline (in real dollars).						
For FY 2018: AMO-18-27: Reduce damage to NASA assets (excluding launched flight hardware) by two percent per year through FY 2018, compared to an FY 2010 baseline (in real dollars).						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					

Performance Goal 3.4.2

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Implement the policies, procedures and oversight to continuously improve the probability of technical and programmatic mission success.	No PG this fiscal year	No PG this fiscal year	No PG this fiscal year	3.4.2 Green	3.4.2 Green	3.4.2 Green
Planned Future Performance						
For FY 2017: 3.4.2: Implement the policies, procedures and oversight to continuously improve the probability of technical and programmatic mission success.						
For FY 2018: 3.4.2: Implement the policies, procedures, and oversight to continuously improve the probability of technical and programmatic mission success.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					
Data Quality for FY 2018						
Data Source(s): Baseline Performance Review (BPR) meetings. **Verification and Validation:** Quarterly reviews noted under Data Sources. **Data Limitations:** None identified. Data are sufficiently accurate for their intended use.						

FY 2016 Performance Results

NASA is implementing the policies, procedures, and oversight necessary to continuously improve the probability of technical and programmatic mission success. Projects are assigned to Category 1, 2, or 3 based on the estimated lifecycle costs and priority level. During FY 2016, 100 percent of Category 1 and 2 projects complied with Safety and Mission Success policies and procedures. Specifically, all Category 1 and 2 projects that conducted lifecycle reviews were also subject to independent assessments; all Category 1 and 2 projects either were executing to an approved plan, or were in an approved

rebaseline planning cycle; and the NASA Engineering and Safety Center had the capability and capacity to accept all requested assessments of Category 1 and 2 projects. In addition, the entire engineering and programmatic workforce had access to the standards and knowledge base necessary to achieve or maintain their project manager certification requirements. There are no anticipated potential risks that could affect achievement of the performance goal in FY 2017.

More Safety and Mission Success information is available on NASA's websites for the Office of the Chief Engineer, Office of the Chief Health and Medical Officer, Office of Safety and Mission Assurance, and Independent Verification and Validation (IV&V) Program.

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Ensure 100 percent of Category 1 and 2 projects use Agency Safety and Mission Success policy, procedures, and independent assessments focused on both technical and programmatic mission success.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 15 Green	AMO 15 22 Green	AMO 16 22 Green
Planned Future Performance						
For FY 2017: AMO-17-22: Ensure 100 percent of Category 1 and 2 projects use Agency Safety and Mission Success policy, procedures and independent assessments focused on both technical and programmatic mission success.						
For FY 2018: AMO-18-28: Ensure 100 percent of Category 1 and 2 projects use Agency Safety and Mission Success policy, procedures and independent assessments focused on both technical and programmatic mission success.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					

Annual Performance Indicator	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
For FY 2016: Ensure that 100 percent of the engineering and programmatic workforce has access to the standards and knowledge base needed to maintain and build their skills.	No API this fiscal year	No API this fiscal year	No API this fiscal year	AMO 14 16 Green	AMO 15 23 Green	AMO 16 23 Green
Planned Future Performance						
For FY 2017: AMO-17-23: Ensure that 100 percent of the engineering and programmatic workforce has access to the standards and knowledge base needed to maintain and build their skills.						
For FY 2018: AMO-18-29: Ensure that 100 percent of the engineering and programmatic workforce has access to the standards and knowledge base needed to maintain and build their skills.						
Contributing Theme: Agency Management and Operations	**Contributing Program:** Safety and Mission Success					

Part 4: Supporting Information

Changes to the FY 2017 Performance Plan

Each fiscal year, NASA's budget request to Congress contains an Annual Performance Plan (APP) that aligns with the funds requested. Changes to a performance plan are generally reflected in the next year's budget request, if the changes are known before the request is sent to Congress. If a change occurs after, then it is reflected in the APP. NASA updates measures in the APP when the final appropriation differs from the amount requested, or if congressional or executive direction places a different emphasis on programs relative to what was initially requested. Additionally, the dynamic nature of research and development can lead to shifting priorities. This may result in NASA no longer pursuing activities originally identified in the APP or placing greater emphasis on other activities.

NASA's policy has been to allow one of the following actions if programs are impacted by congressional budget action via an appropriations or authorization law or executive direction places a different emphasis on programs:

- Eliminate the performance measure (do not rate the performance measure);
- Change the targeted performance (rate at the new target); or
- Move the measure to the next year's APP (do not rate until the following year).

If priorities have shifted due to the dynamic nature of research and development, and the activity is no longer pursued, NASA generally retains the measure and does not reduce the target, but rather reflects this via a white rating. If emphasis is shifted onto a program for which there was no measure, NASA may choose to add a measure and rate it, to reflect the priority of that activity. Details on NASA's approach to rating measures and setting criteria are in the "Performance Management at NASA" section.

FY 2017 Performance Plan Update

NASA submitted the FY 2017 Performance Plan with its FY 2017 President's Budget Request in February 2016. Since then, NASA reviewed and updated the FY 2017 measures in light of the contents of the FY 2018 President's Budget Request, in consultation with the Office of Management and Budget. Additionally, NASA has revised the plan to address typographical errors and other minor inaccuracies.

This list shows all measures that have been updated.

Strategic Goal 1: Expand the frontiers of knowledge, capability, and opportunity in space.

1.2.5: ISS-17-10: Produce at least 13 peer-reviewed publications addressing the critical questions on microbial life in space identified by the National Research Council in the Decadal Survey for Life and Physical Sciences in Space.

1.2.5: ISS-17-6: Through the Center for the Advancement of Science in Space (CASIS) cooperative agreement, release two solicitations, complete proposal evaluation, and select research projects for International Space Station execution in FY 2017.

1.4.4: HE-17-6: Complete the Ionospheric Connection Explorer (ICON) Pre-Ship Review (PSR).

1.4.4: HE-17-7: Complete the Step One selection for the 2016 Heliophysics Small Explorer (SMEX) Announcement of Opportunity.

1.4.4: HE-17-8: Release the Solar Terrestrial Probes-5 (STP-5) Announcement of Opportunity.

1.5.6: PS-17-12: Complete Europa Key Decision Point-B (KDP-B).

1.6.5: AS-17-4: Complete the Transiting Exoplanet Survey Satellite (TESS) System Integration Review (SIR).

1.6.5: AS-17-6: Complete Wide-Field Infrared Survey Telescope (WFIRST) System Requirements Review (SRR).

1.6.5: AS-17-7: Complete the 2017 Astrophysics Medium Explorer (MIDEX) Step One selection.

1.7.4: Engage the established commercial sector, emerging aerospace markets, and economic regions to leverage common interests and grow the national economy.

1.7.4: ST-17-2: Conduct at least three prize competitions.

1.7.4: ST-17-3: Create 10 opportunities for advancement beyond Phase II SBIR/STTR.

1.7.4: ST-17-7: Select and fly technology payloads from NASA, other government agencies, industry, and academia using flight services procured from at least five different commercial reusable suborbital or parabolic platform providers.

Strategic Goal 2: Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.

2.1.2: AR-17-2: Complete Low-Boom Flight Demonstration (LBFD) Aircraft Preliminary Design Review (PDR).

2.1.3: AR-17-6: Complete Critical Design Review (CDR) of the X-57 Maxwell aircraft.

2.1.6: AR-17-9: Deliver the second build of an Unmanned Aircraft System Traffic Management (UTM) Technology Capability Level (TCL) demonstration to assess increased density and contingency management in low-altitude airspace.

2.2.8: ES-17-14: Complete the Surface Water and Ocean Topography (SWOT) Ka-band Radar Interferometer (KaRIN) instrument Critical Design Review (CDR).

2.2.8: ES-17-16: Complete NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) Antenna-Reflector Critical Design Review (CDR).

2.2.8: ES-17-18: Complete the Earth Venture Instrument (EVI)-4 selection.

2.4.1: Assure that students participating in NASA higher education investments are representative of the diversity of the Nation.

2.4.2: ED-17-2: Engage with at least 10,000 educators in NASA educator professional development through face-to-face, online, partner-delivered, and community-requested activities.

2.4.4: ED-17-4: Support informal education institutions, including youth-serving organizations, to use NASA-unique content in no fewer than 40 states, U.S. Territories and/or the District of Columbia.

2.4.5: ED-17-5: Provide NASA STEM engagement to at least 50,000 elementary, secondary, and higher education students through authentic STEM experiences.

2.4.6: Ensure that grantees and cooperative agreement awardees conduct independent evaluations, providing evidence for the effectiveness of NASA STEM education investments.

2.4.6: ED-17-3: Ensure that at least 30 percent of grantees and cooperative agreement awardees conduct independent evaluations and report to NASA on their evaluation activities.

Strategic Goal 3: Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.

3.1.8: AMO-17-14: Increase cross-Agency participation in a program of metrics by which to assess the reach and effectiveness, and articulate the value, of activities in the Agency's communications portfolio.

3.2.7: SC-17-1: Achieve a minimum of 90 percent overall availability of Space Environment Testing Management Office (SETMO) portfolio of assets which are necessary to meet the long-term needs and requirements of the Agency.

3.4.1: AMO-17-20: Maintain a Total Case Rate and Lost Time Case Rate that meets or exceeds the goals of the Administration.

3.4.1: AMO-17-21: Reduce damage to NASA assets (excluding launched flight hardware) by two percent per year through FY 2017, compared to an FY 2010 baseline (in real dollars).

This list shows all measures that have been removed.

Strategic Goal 2: Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.

2.3.1: Facilitate and track NASA technology infusion, internal success stories, and technology transfer.

2.3.1: ST-17-8: Develop, launch, and migrate all Agency licensing activities to an online patent licensing portal.

2.3.1: ST-17-9: Execute an initiative across seven Centers to encourage and track infusion (use) of NASA-developed technology by NASA missions and other NASA user groups.

Image Captions and Credits

Part 1

Former NASA astronaut Scott Kelly speaks about his historic 340-day mission, referred to as the One-Year mission, aboard the International Space Station during an event at the U.S. Capitol Visitor Center, May 25, 2016, in Washington, DC. Credit: B. Ingalls/NASA

This image of a sunlit part of Jupiter and its swirling atmosphere was created by a citizen scientist (Alex Mai) using data from Juno's JunoCam instrument. Credit: NASA/JPL-Caltech/SwRI/MSSS/A. Mai

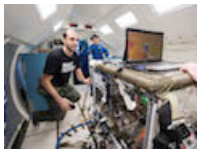
In FY 2016, NASA awarded six-month contracts to four companies, who will each define the technical approach, schedule, and cost for one or more large-scale, subsonic X-plane concepts. These concepts are in support of NASA's ultra-efficient subsonic transport research goals. This photo shows Boeing's truss-braced wing concept during testing at the NASA Ames Research Center's Unitary Plan Wind Tunnel. Credit: The Boeing Company

Showcased at the center of this NASA–European Space Agency (ESA) Hubble Space Telescope image is an emission-line star known as IRAS 12196-6300. Located just under 2,300 light-years from Earth, this star displays prominent emission lines, meaning that the star's light, dispersed into a spectrum, shows up as a rainbow of colors marked with a characteristic pattern of dark and bright lines. The characteristics of these lines, when compared to the "fingerprints" left by particular atoms and molecules, can be used to reveal IRAS 12196-6300's chemical composition. Credit: ESA/Hubble/NASA; Acknowledgment: J. Schmidt

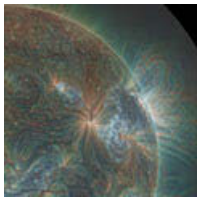
The Juno team (shown here at the Jet Propulsion Laboratory) celebrates after receiving confirmation from the spacecraft that it had successfully completed engine burn and entered Jupiter's orbit on July 4, 2016. The spacecraft had to pass a tricky obstacle to successfully enter orbit—Jupiter's magnetosphere, which is the largest structure in the solar system. To get the best possible data, and to avoid as much radiation as possible from the magnetosphere, Juno entered a polar orbit close to the planet, but not so close that it would risk impact. In this sweet spot, between Jupiter and the danger zone, the spacecraft should function for at least a year. Credit: A. Gemignani/NASA

Part 2

A United Launch Alliance Atlas V rocket with Orbital ATK's Cygnus cargo spacecraft on top stands at the launch pad at Space Launch Complex 41, Cape Canaveral Air Force Station, Florida on December 3, 2015. The launch of Cygnus on the CRS-4 resupply mission to the International Space Station was scheduled for December 3, but was scrubbed due to poor weather. Credit: ULA



The Space Technology Mission Directorate's Flight Opportunities program allows businesses and academia to demonstrate new technologies of interest to NASA on parabolic aircraft, high-altitude balloons or suborbital launch vehicles. In this photo, a team tests in a weightless environment aboard an aircraft in November 2015. Credit: J. Blair/NASA

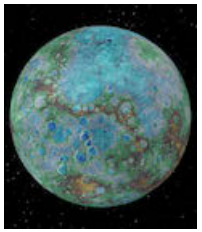


This combination of three wavelengths of light from NASA's Solar Dynamics Observatory shows one of the multiple jets that led to a series of slow coronal puffs on January 17, 2013. The light has been colorized in red, green, and blue. Credit: Alzate/SDO

Katherine Johnson shares some smiles with NASA astronaut Leland Melvin. Johnson was one of the African-American women whose mathematical skills were critical to the early U.S. space program, as depicted in the motion picture "Hidden Figures." Referred to as a human computer, she did complex number crunching. She calculated the trajectory for Alan Shepherd's first mission in 1961, and went on to do the calculations for the first Moon landing in 1969. Credit: K. Johnson

Part 3

In early 2016, NASA tested a new instrument, called the CO_2 Sounder Lidar, during aircraft flights over California and Nevada. Developers for the instrument took this photograph during the field campaign. Engineers and scientists from NASA's Goddard Space Flight Center analyzed the data collected during the flight. Credit: NASA



In September 2016, NASA revealed that images obtained by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft found previously undetected small fault scarps, cliff-like landforms that resemble stair steps. These scarps are small enough that scientists believe they must be geologically young. This means Mercury is still contracting and that Earth is not the only tectonically active planet in our solar system, as previously thought. Credits: NASA/JHUAPL/Carnegie Institution of Washington/USGS/Arizona State University

NASA astronaut Terry Virts tweeted this photo to his followers after completing a series of spacewalks with his partner astronaut Barry "Butch" Wilmore. They were preparing the International Space Station for docking with U.S. commercial spacecraft that are currently in development. In his tweet, Virts wrote: "Mission Accomplished - 3 #spacewalks, 800' of cable, 4 antennas, 3 laser reflectors, 1 greased robotic arm." Credit: NASA

This photo shows a prototype 13-kilowatt Hall thruster during testing at NASA's Glenn Research Center in Cleveland. This prototype demonstrated the technology readiness needed for industry to continue the development of high-power solar electric propulsion into a flight-qualified system. An advanced electric propulsion system could potentially increase spaceflight transportation fuel efficiency by 10 times over current chemical propulsion technology and more than double thrust capability compared to current electric propulsion technology. Credit: NASA

This photo shows the second and final qualification motor (QM-2) test for the Space Launch System's booster, conducted on June 28, 2016, at Orbital ATK Propulsion Systems' test facilities in Promontory, Utah. The booster was tested at a cold motor conditioning target of 40 degrees Fahrenheit, which is the colder end of its accepted propellant temperature range. When ignited, temperatures inside the booster reached nearly 6,000 degrees. Credit: B. Ingalls/NASA

Strategic Goal 1

At the Michoud Assembly Facility, welders inside a large liquid hydrogen tank for NASA's Space Launch System plug holes left after the tank was assembled. Credit: S. Seipel/MAF/NASA

The NASA Juno spacecraft's JunoCam instrument obtained this view of Juno's north polar region on August 27, 2016, two hours before the spacecraft made its closest approach. Unlike the equatorial region's familiar structure of belts and zones, the poles are mottled with rotating storms of various sizes, similar to giant versions of terrestrial hurricanes. Jupiter's poles have not been seen from this perspective since the Pioneer 11 spacecraft flew by the planet in 1974. Credit: NASA/JPL-Caltech/SwRI/MSSS

NASA astronauts Jeff Williams (shown here) and Kate Rubins installed a new international docking adapter on August 19, 2016, during an almost six hour-long spacewalk. Japanese astronaut Takuya Onishi assisted the duo from inside the International Space Station. Credit: NASA

BisonSat, which was launched in early FY 2016, was an Earth science mission that demonstrated the acquisition of 100-meter or better resolution visible light imagery of Earth using passive magnetic stabilization from a CubeSat. BisonSat was the first CubeSat designed, built, tested, and operated by tribal college students. Credit: Salish Kootenai College

Strategic Goal 2

At the end of FY 2016, a Boeing engineer Stephen Provost checks out a blended wing body model before a wind tunnel test run at NASA Langley. The test is part of an effort to develop a series of greener, quieter, faster X-planes. Credit: D.C. Bowman/NASA

A NASA staff member talks to a young visitor at the 2014 USA Science and Engineering Festival about how NASA measures global precipitation. Held April 15-17, 2016, in Washington, DC, the festival allowed visitors to take virtual reality walks on other planets, snap a selfie in a spacesuit, and enjoy several other interactive activities, as well as talk to experts about a variety of topics, including rockets, robots, X-Planes (experimental aircraft) and deep-space exploration. Credit: A. Gemignani/NASA

An analysis of satellite data showed that at 1.60 million square miles (4.14 million square kilometers), the 2016 Arctic sea ice minimum extent effectively tied with 2007 for the second lowest yearly minimum in the satellite record. Since satellites began monitoring sea ice in 1978, researchers have observed a steep decline in the average extent of Arctic sea ice for every month of the year. Credits: NASA Goddard's Scientific Visualization Studio/C. Starr

NASA's rodent habitat, developed at Ames Research Center serves as a home away from home for mice on the International Space Station. When the final Space Shuttle launched in 2011, it carried mice treated with a sclerostin antibody under development by Amgen, of Thousand Oaks, CA. NASA is interested in the company's work to help protect astronauts' bone health, but the research also has benefits for people suffering from osteoporosis here on Earth. Credit: NASA

Strategic Goal 3

On September 8, 2016, the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission launched from Cape Canaveral Air Force Station, FL, aboard an Atlas V rocket. The spacecraft is traveling to collect samples from asteroid Bennu, which may contain the molecular precursors to the origins of life. Credit: ULA

Participants of NASA's Langley Research Center's Social Media Event prepare to photograph the Water Test Drop of the Orion Ground Test Article on August 25, 2016. For the test, engineers plunged a mockup of the Orion spacecraft into a 20-foot-deep basin to simulate an ocean splashdown. Prior to the test, the media participants received overviews and a poolside update on the tests. Credit: NASA

A demolition crew take apart one of the spheres that comprised the Thermal Structures Laboratory at NASA's Langley Research Center. Every year NASA works to get rid of unneeded facilities or repurpose unused facilities to support new missions. Credit: NASA

Space Communications and Navigation (SCaN) celebrated its 10th anniversary in 2016. Created on May 16, 2006, SCaN serves as the program office for all of NASA's space communications activities. This photograph shows NASA's newest Deep Space Network antenna, Deep Space Station 35 in Canberra, Australia. NASA's Deep Space Network, Near Earth Network, and Space Network, all managed by SCaN, provide communication and tracking services to hundreds of NASA and non-NASA missions. Credit: Canberra Deep Space Communication Complex/NASA

Part 4

Researchers at NASA's Armstrong Flight Research are using a unique test stand to understand the intricacies of how electric motor systems work before the first electric propulsion X-planes fly, such as the X-57. Made of steel and aluminum, the 13.5-foot tall Airvolt test stand (shown here with Yohan Lin, Airvolt integration lead) is one of the newest tools in NASA's approach to explore the use of electric propulsion on future aircraft. The goal of using this technology is to burn less fuel, while reducing emissions and noise. Credit: L. Hughes/NASA

On August 18, 2016, NASA engineers conducted a development test of the RS-25 rocket engine at the modified B-2 test stand at NASA's Stennis Space Center. The RS-25 will help power the core stage of the Space Launch System (SLS) rocket. Credit: NASA

Antenna AS-3, in the foreground, and AS-1, in the background, are part of NASA's Near Earth Network (NEN), based out of Goddard Space Flight Center. Both antennas are at the Alaska Satellite Facility operated by the University of Alaska, Fairbanks. The NEN serves as a conduit for information from spacecraft in low Earth orbits, geosynchronous orbits, and lunar orbits. Credit: NASA

A member of the Expedition 44 crew took this photo from the International Space Station (ISS) while looking out at the night sky over the remote reaches of the central equatorial Pacific Ocean. The ISS was passing over the island nation of Kiribati at the time, about 1,600 miles south of Hawaii. The photo has been enhanced to improve contrast. The brightest light in the image is a lightning flash that illuminated a large mass of clouds. The flash reflected off the shiny solar arrays of the ISS and back to the camera. The curvature of Earth is illuminated by a variety of airglow layers in orange, green, and red. Credit: NASA

In September 2016, NASA completed welding on the largest piece of the core stage that will provide the fuel for the first flight of the Space Launch System. Standing more than 130 feet tall, the liquid hydrogen tank is the largest cryogenic fuel tank for a rocket in the world. Credit: S. Seipel/MAF/NASA