NASA OFFICE OF INSPECTOR GENERAL

SUITE 8U37, 300 E ST SW
WASHINGTON, D.C. 20546-0001

November 6, 2017

TO: Robert M. Lightfoot Jr.
Acting Administrator

SUBJECT: NASA's 2017 Top Management and Performance Challenges

Dear Acting Administrator Lightfoot,

As required by the Reports Consolidation Act of 2000, this annual report provides our views of the top management and performance challenges facing NASA for inclusion in the 2017 Agency Financial Report. We previously provided a draft copy of this document to NASA officials and considered all comments received when finalizing our report.

Similar to past years, in deciding whether to identify an issue as a top challenge we considered its significance in relation to NASA's mission; its susceptibility to fraud, waste, and abuse; whether the underlying causes are systemic in nature; and the Agency's progress in addressing the challenge. Not surprisingly, given the importance and scope of the issues, this year's list includes many of the same challenges discussed in previous reports.

Looking to 2018, we organized the top management and performance challenges facing NASA under the following topics:

- Deep Space Exploration
- NASA's Science Portfolio
- Information Technology Governance and Security
- Aging Infrastructure and Facilities
- Contracting and Grants

During the coming year, the Office of Inspector General plans to conduct audits and investigations that focus on NASA's continuing efforts to meet these and other challenges.

Sincerely,

Paul K. Martin
Inspector General

Enclosure – 1

NASA's Top Management and Performance Challenges, November 2017

This annual report provides the Office of Inspector General's (OIG) independent assessment of the top management and performance challenges facing NASA, which we organize under the following topics:

- Deep Space Exploration
- NASA's Science Portfolio
- Information Technology Governance and Security
- Aging Infrastructure and Facilities
- Contracting and Grants

In deciding whether to identify an issue as a top challenge, we considered its significance in relation to NASA's mission; whether its underlying causes are systemic in nature; and its susceptibility to fraud, waste, and abuse. Identification of an issue as a "top challenge" does not necessarily denote significant deficiencies or lack of attention on the part of NASA. Rather, all of these issues are long-standing and inherently difficult challenges central to the Agency's mission and, as such, will remain challenges for years. Consequently, these issues require consistent, focused attention from NASA management and engagement on the part of Congress and the public.

That said, this year we removed "Ensuring the Continued Efficacy of the Space Communications Networks" as a top management challenge because of the progress made in addressing the issues we identified in a series of audit reports over the past few years.[1] Otherwise, the challenges described in this report correspond to those we identified in our November 2016 report and, like previous years, are not listed in priority order.

Deep Space Exploration

NASA's long-term objective for its human exploration program is a crewed surface mission to Mars in the late 2030s or early 2040s. To meet this goal, the Agency must develop more sophisticated rockets, capsules, and related hardware, manage the aging International Space Station (ISS or Station) to maximize its use as a test-bed for research and development of new technologies, and mitigate human health risks of extended space travel – all within the constraints of a static budget profile. In the near-

[1] NASA OIG, "NASA's Management of Electromagnetic Spectrum" (IG-17-012, March 9, 2017); "NASA's Management of the Near Earth Network" (IG-16-014, March 17, 2016); "NASA's Management of the Deep Space Network" (IG-15-013, March 26, 2015); and "Space Communications and Navigation: NASA's Management of the Space Network" (IG-14-018, April 29, 2014).

term, 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 critical to achieving NASA's human exploration goals beyond low Earth orbit. However, the first unmanned flight of the integrated SLS, Orion, and GSDO systems on Exploration Mission-1 (EM-1) – initially planned for 2016 and currently scheduled for no earlier than October 2019 – and the first crewed flight, Exploration Mission-2 (EM-2) – planned for no earlier than August 2021 – face significant challenges to meet their launch dates.

In the long term, NASA's plans beyond EM-2 for achieving a crewed Mars surface mission in the late 2030s or early 2040s remain high level, serving as more of a strategic framework than a detailed operational plan. For example, the Agency's current Journey to Mars framework lacks objectives; does not identify key system requirements other than SLS, Orion, GSDO, and a Deep Space Gateway; and does not suggest target mission dates for crewed orbits of Mars or planet surface landings.[2] If the Agency is to reach its goal of sending humans to Mars in the late 2030s or early 2040s, significant development work on key systems – such as a deep space habitat, in-space transportation, and Mars landing and ascent vehicles – must be accomplished in the 2020s. In addition, NASA will need to begin developing more detailed cost estimates for its Mars exploration program after EM-2 to ensure the commitment from Congress and other stakeholders exists to fund an exploration effort of this magnitude over the next several decades. Finally, NASA's decision whether to continue spending $3–$4 billion annually to maintain the ISS after 2024 – roughly a third of its exploration budget – will affect its funding profile for human exploration efforts in the 2020s, and therefore has significant implications for the Agency's Mars plans.

Space Launch System

The SLS is a heavy lift launch vehicle that uses liquid propellant and a pair of five-segment solid boosters to transport cargo and crew into space for missions beyond Earth's orbit into deep space. NASA is using the Space Shuttle's RS-25 engines to power the SLS core stage and is designing the vehicle with an evolvable architecture that can be tailored to accommodate longer and more ambitious missions. Initial versions will be capable of lifting 70 metric tons to low Earth orbit and will use a modified Delta IV upper stage to propel Orion on a trajectory around the Moon during EM-1. Later versions of the SLS will include a more powerful upper stage and advanced rocket boosters with a capability to lift 130 metric tons to low Earth orbit and 41 metric tons to Mars.

We reported in April 2017 that the SLS Program faced several technical challenges leading up to the EM-1 launch that negatively affected its schedule margin.[3] As a result of these challenges, NASA subsequently announced a schedule delay for the EM-1 mission from November 2018 to no earlier than October 2019. Even though the SLS Program factored in a schedule margin of 11 months to allow time to address any unexpected technical issues or other factors, testing has been delayed from October 2017 until December 2018 because of welding issues with the SLS core stage tanks and damage from a February 2017 tornado at Michoud Assembly Facility. Notwithstanding the 1-year launch delay, testing and delivery of the core stage remains on the critical path with little schedule margin available to manage problems that may arise during the integration and test phase before an integrated SLS/Orion launch. The late completion of the core stage is a critical schedule issue in meeting the EM-1 launch date.

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[2] Deep Space Gateway, which will consist of a small space habitat, docking station, and propulsion system, is intended for operation near the Moon and will serve as a testing platform and staging point for deep space missions.

[3] NASA OIG, "NASA's Plans for Human Exploration Beyond Low Earth Orbit" (IG-17-017, April 13, 2017).

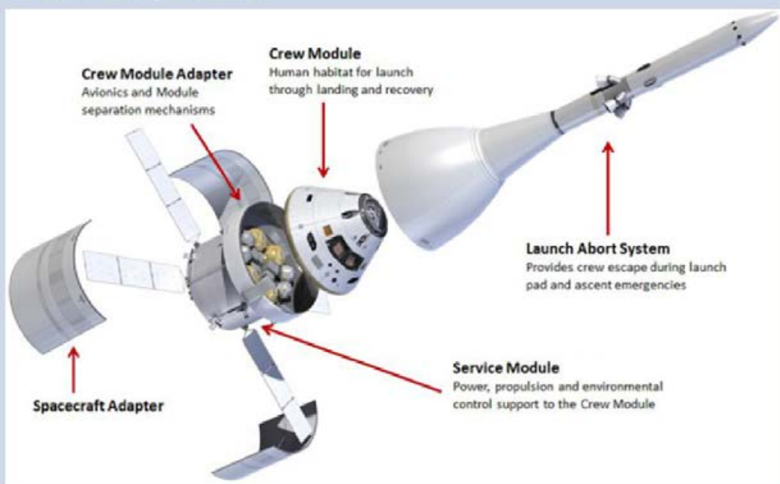
The rising cost of the SLS Program also presents challenges for NASA given the program may exceed its $9.7 billion budget commitment. The Agency plans to spend roughly $2 billion a year on SLS development but has minimal monetary reserves to address any technical challenges that may arise for EM-1 or EM-2. According to guidance developed at Marshall Space Flight Center (Marshall), the standard monetary reserve for a program such as the SLS should be between 10 and 30 percent during development.[4] The SLS Program did not carry any program reserves in fiscal year (FY) 2015 and only $25 million in FY 2016 – approximately 1 percent of its development budget. Moving forward, the SLS Program plans to carry only minimal reserves through 2030, which in our view is unlikely to be sufficient to enable NASA to address issues that may arise during development and testing.

Prior to the EM-2 flight, NASA will make a major upgrade in the SLS configuration by integrating the Exploration Upper Stage (EUS) as the spacecraft's new upper stage. This will increase SLS capability from 70 to 105 metric tons of cargo to low Earth orbit. However, in addition to integration and testing changes needed to accommodate the new upper stage, the height and weight of the SLS will increase, so changes to the ground processing infrastructure and mobile launcher will be necessary. In addition, a new tank will need to be fabricated and installed at the launch pad to provide the additional fuel required by the EUS.

Orion Multi-Purpose Crew Vehicle

The Orion capsule – which will be mounted atop the SLS and serve as the crew vehicle for up to four astronauts – has four major components: a crew module; a service module; a spacecraft adapter that connects the vehicle to the rocket; and a launch abort system. NASA began developing Orion in 2006 as part of the Agency's former deep space exploration effort known as the Constellation Program and had spent about $5.7 billion on the effort when Constellation was cancelled in 2010. Since then, NASA has spent more than $1 billion annually, or about 6 percent of its overall budget, on the Orion Program. In 2016, we estimated the Agency will have devoted approximately $17 billion in funding for all Orion activities, including Constellation Program funding, by the time the spacecraft makes its first crewed flight on EM-2.[5]

Orion Components



Source: NASA (artist's rendering).

[4] Marshall Procedural Requirements (MPR) 7120.1.

[5] NASA OIG, "NASA's Management of the Orion Multi-Purpose Crew Vehicle Program" (IG-16-029, September 6, 2016).

The biggest challenge facing Orion for EM-1 is delivery of the European Service Module, which is integral to the overall service module. In September 2016, we reported that the service module had undergone design changes and as a result would be delivered to NASA at least 5 but possibly up to 10 months later than originally planned.[6] The module has been further delayed and is now scheduled to be delivered in February 2018. Because the new Orion service module differs from the module flown during the first Orion test flight in December 2014, assembly, integration, and processing of the new module may delay transfer of Orion to the GSDO Program for integration with the SLS. Consequently, delivery, test, and integration of the service module is another critical schedule issue to meet the current EM-1 launch date.

Looking ahead to EM-2, one of the key challenges NASA faces is ensuring the Orion capsule's Environmental Control and Life Support System functions properly. NASA is testing portions of this critical life support system on the ISS and on Earth, and will fly substantial parts of the system (such as thermal control pumps, heat exchangers, radiators, gas containment and delivery systems, and cabin pressurization controls) on EM-1. However, the first flight test of the complete Environmental Control and Life Support System will be during EM-2 with crew aboard. The Aerospace Safety Advisory Panel, an advisory committee that reports to NASA and Congress on safety issues, expressed concern in its 2015 and 2016 annual reports about the lack of flight testing before EM-2, suggesting the mission remain in low Earth orbit until NASA gains more confidence the life support systems are performing properly.[7] The Advisory Panel acknowledged in its 2016 annual report that NASA had selected a mission profile in which the crew spends its first 24 hours in an elliptical high Earth orbit to check the Environmental Control and Life Support System and other systems for possible malfunction.

Like SLS, the Orion Program has less than 1 percent in monetary reserves leading up to EM-1, much less than the recommended 10 to 30 percent.[8] Although NASA expects to increase Orion's reserves for EM-2 to a more appropriate level beginning in 2019 and 2020, the impact of the delay in EM-1's launch date to no earlier than October 2019 on Orion's overall funding profile remains unclear.

Ground Systems Development and Operations Program

NASA's GSDO Program is modifying infrastructure at Kennedy Space Center (Kennedy) formerly used by the Space Shuttle Program to launch the combined SLS/Orion, including refurbishing the crawler transporter that will transport the SLS to the launch pad and modifying the mobile launcher and tower (originally built for the Constellation Program's Ares I rocket), the Vehicle Assembly Building (VAB), and Launch Pad 39B.

In 2015 and 2017, we reported that modifications to the VAB and mobile launcher needed to support SLS have left GSDO with only 1 month of schedule margin to address any further issues that arise.[9] Similarly, the Government Accountability Office (GAO) reported in July 2016 that although the Program is making progress in modifying facilities and equipment to support SLS and Orion, it is encountering

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6 IG-16-029.

7 Aerospace Safety Advisory Panel, "Annual Report for 2015," January 13, 2016, and "Annual Report for 2016," January 11, 2017.

8 MPR 7120.1.

9 IG-17-017; NASA OIG, "NASA's Launch Support and Infrastructure Modernization: Assessment of the Ground Systems Needed to Launch SLS and Orion" (IG-15-012, March 18, 2015).

technical challenges that require additional time and money, which in turn has reduced cost and schedule reserves, threatening the EM-1 launch readiness date.[10] Although the delay in the launch date may have mitigated some of these concerns, development of software needed to launch SLS and Orion remains a concern.

In a March 2016 audit, we reported that the GDSO Program's software, known as the Spaceport Command and Control System (SCCS), had significantly exceeded its initial cost and schedule estimates.[11] SCCS is a software system that will control pumps, motors, valves, power supplies, and other ground equipment; record and retrieve data from systems before and during launch; and monitor the health and status of spacecraft as they prepare for and during launch. In 2016, we reported that, compared to FY 2012 projections, development costs had increased approximately 77 percent to $207.4 million and the release of a fully operational version had slipped by 14 months from July 2016 to September 2017 for an EM-1 launch in November 2018. Given that the launch date has slipped to no earlier than October 2019, GSDO is in the process of extending the SCCS completion date to align with the new launch date.

Furthermore, GSDO will not be able to complete all necessary software validation and verification efforts until SLS and Orion complete development, testing, and delivery of their software. Delivery of Orion software is the third most critical task, schedule-wise, to meeting the current EM-1 launch date of no earlier than October 2019.

Finally, after EM-1 is launched GSDO will need to make additional modifications to Kennedy's launch infrastructure to prepare for EM-2. Among other issues, the Program has identified a budget shortfall associated with EUS upgrades that will need to be addressed.[12]

International Space Station

A significant amount of research aboard the ISS is related to understanding and mitigating the health and performance risks associated with human space travel such as protecting against bone loss and eyesight degeneration and testing new technologies to overcome challenges associated with preventing, diagnosing, and treating medical conditions during long-duration exploration missions. In November 2015, NASA formally extended the life of the Station through 2024, ensuring this unique facility, which has operated in low Earth orbit for almost 20 years, remains available to support research into the development of new exploration technologies and ways to mitigate the dangers posed by space travel.[13] Despite the extension, in October 2015, we reported NASA will not have enough time to mitigate several known human space flight risks for future deep space missions.[14] Accordingly, the Agency needs to prioritize its research to address the most important risks in the time available while also ensuring a spacecraft originally designed and tested for a 15-year life span will continue to operate safely and as economically as possible.

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[10] GAO, "NASA Human Space Exploration: Opportunity Nears to Reassess Launch Vehicle and Ground Systems Cost and Schedule" (GAO-16-612, July 27, 2016).

[11] NASA OIG, "Audit of the Spaceport Command and Control System" (IG-16-015, March 28, 2016).

[12] IG-17-017.

[13] In 2009, NASA asked The Boeing Company, the primary ISS contractor, to examine the feasibility of extending Station operations until 2028. Boeing has completed a significant portion of the hardware analysis and its review is expected to be complete by June 2018.

[14] NASA OIG, "NASA'S Efforts to Manage Health and Human Performance Risks for Space Exploration," (IG-16-003, October 29, 2015).

While the amount of research being conducted on the ISS has increased over the past 8 years, several factors continue to limit full utilization. In particular, until a seventh crew member is brought onboard, NASA will not be in a position to maximize the amount of crew time dedicated to research on the Station.[15] Moreover, the launch failures of two commercial resupply missions – an Orbital ATK (Orbital) mission in October 2014 and a Space Exploration Technologies Corporation (SpaceX) mission in June 2015 – led to compressed launch schedules in FYs 2016 and 2017.

International Space Station

Source: NASA.

The United States has invested more than $87 billion in the ISS over the last 24 years, and the Station continues to account for a significant portion of NASA's annual budget.[16] In FY 2016, NASA's cost to operate the Station – including on-orbit vehicle operations, research, crew transportation, and cargo resupply missions – was almost $3 billion, with the Agency projecting these costs will increase to approximately $3.5 billion in the 2020s. Balancing the need for continued ISS research to mitigate human exploration risks with the need to construct the key exploration hardware systems required for reaching Mars will challenge the Agency's budgeting process well into the next decade.

Commercial Transportation to the International Space Station

From 1998 through 2011, NASA primarily relied on the Space Shuttle to construct the ISS and ferry astronauts and materials to the Station. With the Shuttle's retirement in 2011, NASA began relying on European and Japanese spacecraft to ferry cargo and the Russian Soyuz to transport crew while partnering with U.S. corporations to develop privately owned and operated cargo and crew transportation systems. Unlike the Shuttle, NASA does not own these systems but rather purchases flights from the companies to carry NASA supplies and crew to the ISS. Both cargo and crew contractors have faced delays and setbacks – two failed cargo missions lost critical ISS cargo and impacted resupply schedules – and crew vehicle development delays have pushed back the first demonstration flights from 2016 to 2018.

[15] Although the ISS is capable of supporting a seven-person crew, currently only six individuals can be on Station at one time. The Russian Soyuz capsule, currently the only vehicle transporting astronauts to the Station, has a three-person capacity and only two Soyuz capsules can be attached to the Station simultaneously for evacuation in the event of an emergency.

[16] This figure includes $30.7 billion for 37 supporting Space Shuttle flights.

Cargo Resupply

Between 2006 and 2008, NASA entered into a series of funded Space Act Agreements with Orbital, SpaceX, and other private companies to stimulate development of space flight systems capable of transporting cargo to the ISS.[17] In 2008, while development efforts were still underway, NASA awarded fixed-price contracts valued at $1.9 billion and $1.6 billion to Orbital and SpaceX, respectively, for a series of resupply missions to the ISS known as Commercial Resupply Services (CRS-1) contracts. NASA selected two companies to ensure redundancy if one was unable to perform. The contracted services include delivery of supplies and equipment (upmass) to the Station and, depending on the mission, return of equipment and experiments to Earth or disposal of waste (downmass).[18]

Both Orbital and SpaceX experienced launch failures during their CRS-1 missions. In October 2014, Orbital's third delivery mission failed during lift-off, causing the vehicle to crash near the launch pad and destroying the company's Antares rocket and Cygnus spacecraft as well as $51 million of cargo aboard. The mishap also caused $15 million in damage to the Virginia Commercial Space Flight Authority's launch pad and supporting facilities at NASA's Wallops Flight Facility on Virginia's Eastern Shore. Following an investigation and acceptance by NASA of the company's Return to Flight Plan, Orbital resumed resupply missions in December 2015 and, as of September 2017, has completed four successful missions since returning to flight.

Similarly, in June 2015 SpaceX's seventh resupply mission (SPX-7) exploded shortly after takeoff from Cape Canaveral Air Force Station in Florida, resulting in the total loss of $118 million in cargo. Like Orbital, SpaceX suspended resupply missions until completion of an investigation and acceptance by NASA of a Return to Flight Plan.[19] SpaceX resumed resupply missions in April 2016 and completed two successful cargo flights for NASA when, on September 1, 2016, a Falcon 9 rocket exploded as it was being prepared for a static fire test, destroying the rocket and its commercial satellite payload and damaging the launch pad, which the company leases from the Air Force.[20] Although this was not a NASA mission, because of its contracts with SpaceX to deliver cargo and eventually crew to the ISS, NASA needed to understand the cause of the mishap and ensure the company took appropriate steps to prevent similar incidents in the future. SpaceX resumed resupply missions in February 2017 and, as of September 2017, has completed five successful cargo missions since returning to flight.

In September 2015, we examined the effects of the Orbital failure on ISS resupply, finding Orbital's Return to Flight Plan contained technical and operational risks.[21] Specifically, we found the company's plan to drop one of its five remaining previously scheduled resupply flights and carry the promised cargo in four missions may have disadvantaged NASA by decreasing the Agency's flexibility in choosing the type and size of cargo Orbital transports to the ISS.

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[17] NASA bartered with the Japan Aerospace Exploration Agency for cargo transportation on Japan's H-II Transfer Vehicle and can place a small amount of upmass on the Russian space agency's Progress cargo vehicle. In the past, NASA sent cargo to the ISS on the European Space Agency's Automated Transfer Vehicle, which made its final delivery in July 2014.

[18] The SpaceX capsule returns intact and therefore can carry experiments and other cargo back to Earth. In contrast, Orbital's capsule burns up upon reentry to Earth's atmosphere and therefore removes only waste from the Station.

[19] In addition to the Orbital and SpaceX failures, two Russian Progress cargo missions failed to reach the ISS in April 2015 and December 2016.

[20] A static fire test involves a full propellant loading sequence, launch countdown and engine ignition operations, and testing of the launch pad's high-volume water deluge system.

[21] NASA OIG, "NASA's Response to Orbital's October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (IG-15-023, September 17, 2015).

In June 2016, we issued a similar examination of the SpaceX cargo failure.[22] We found the loss of SPX-7 and the shift of SpaceX's eighth resupply mission into 2016 resulted in approximately 3.48 metric tons of pressurized cargo scheduled for delivery in FY 2015 not arriving on the Station. NASA absorbed this loss by placing additional upmass on two other SpaceX missions, a Japanese cargo flight, and six Russian flights, thereby reducing the total upmass shortfall from 3.48 to 2.63 metric tons.

The most significant item lost during the SPX-7 mishap was a Docking Adapter necessary to support upcoming commercial crew missions. Although NASA had planned to have two adapters installed on the Station before the first "crewed" commercial crew demonstration mission scheduled for June 2018, it is now likely there will be only one installed in time for this mission. Having only one adapter means that a commercial crew vehicle will not be able to dock with the ISS if technical issues arise with the single available docking port. ISS Program officials told us they plan to have the second adapter installed before regular commercial crew rotations begin in late 2018.

Our report also examined the Agency's risk management approach and found that it differs between commercially-procured resupply services and traditional NASA-owned missions. For CRS missions, the ISS Program does not provide a risk rating for each launch, and this process may not provide NASA management with sufficient information concerning actual launch risks. Finally, we noted NASA had no official, coordinated, and consistent mishap investigation policy for commercial resupply launches, which could affect its ability to determine the root cause of a launch failure and ensure corrective actions are implemented. Based on this finding, NASA reviewed its mishap investigation policies and is in the process of updating the process for commercial launches with NASA payloads.

In January 2016, NASA awarded follow-on cargo resupply contracts known as CRS-2 to Orbital, SpaceX, and the Sierra Nevada Corporation (Sierra Nevada). NASA is expected to order a minimum of six missions from each provider at fixed prices with specified cargo amounts and performance dates based on the Station's needs. Challenges going forward include both fiscal and technical risks and NASA's need to manage similar but separate contracts with each company. In addition, NASA needs to complete certifications of all spacecraft prior to approving them for approach and mating with the ISS. Specifically, Orbital is planning on using upgraded versions of the Cygnus capsule and Antares rocket; SpaceX plans to use a modified Dragon capsule and may reuse Falcon 9 rockets, subject to NASA's approval; and Sierra Nevada is developing its delivery vehicle – the Dream Chaser spacecraft – and has yet to prove its flight worthiness.

Crew Transportation

Since the Space Shuttle Program ended in July 2011, the United States has lacked a domestic capability to transport crew to the ISS, instead relying on the Russian Federal Space Agency (Roscosmos) to ferry astronauts at prices up to $82 million per astronaut. The goal of the Commercial Crew Program is to enable domestically provided safe, reliable, and cost-effective crew transportation to and from the ISS and low Earth orbit. Although NASA has spent approximately $4 billion on the Commercial Crew Program, progress toward that goal has been slower than expected.

[22] NASA OIG, "NASA's Response to SpaceX's June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (IG-16-025, June 28, 2016).

Boeing's Launch Site at Cape Canaveral Air Force Station

Source: NASA.

NASA's efforts to facilitate the development of a commercial crew transportation capability began in earnest in February 2010. However, it was not until September 2014 that the final phase of the effort began and NASA awarded SpaceX and The Boeing Company (Boeing) firm-fixed-price contracts to complete development of their crew transportation systems and, assuming they met the Agency's safety and performance requirements, receive certification to begin flying astronauts to the ISS.

In September 2016, we reported that the Commercial Crew Program continues to face multiple challenges that will likely delay the first routine flight carrying NASA astronauts to the ISS until late 2018 – more than 3 years after NASA's original 2015 goal.[23] While past funding shortfalls contributed to the delay, technical challenges with the contractors' spacecraft designs are now driving schedule slippages. For Boeing, these include issues related to the effects of vibrations from intense sound waves generated during launch and challenges regarding vehicle mass. For SpaceX, delays resulted from a change in capsule design to enable a water-based rather than ground-based landing and related concerns that the capsule would take on excessive water.

Moreover, both companies must satisfy NASA's safety review process to ensure they meet Agency requirements for "human rating" their vehicles. As part of the certification process, Boeing and SpaceX conduct safety reviews and report to NASA on potential hazards and how they plan to mitigate these risks. We found significant delays in NASA's evaluation and approval of these hazard reports and related requests for variances from NASA requirements that increase the risk that costly redesign work may be required late in development, further delaying vehicle certification.

SpaceX Launch Site at Kennedy Space Center

Source: SpaceX.

Given delays in the Commercial Crew Program, NASA extended its contract with the Russian Space Agency for astronaut transportation through 2018 at a cost of $490 million for six seats, or $82 million each, and entered into a new agreement to purchase flights from Boeing to the ISS on the Soyuz vehicle.[24] If the Commercial Crew Program experiences additional delays, NASA may need to buy additional seats from Russia to ensure a continued U.S. presence on the ISS.

[23] NASA OIG, "NASA's Commercial Crew Program: Update of Development and Certification Efforts" (IG-16-028, September 1, 2016).

[24] Boeing received the Soyuz flight opportunities as part of a legal settlement with the Russian company Energia, which manufactures the Soyuz spacecraft and has the legal rights to sell seats and associated services.

NASA's Science Portfolio

With a budget that has averaged about $5.3 billion a year over the past 5 years, NASA's Science Mission Directorate focuses on answering questions related to the origins and destiny of the universe; the Sun and its effects on Earth and the rest of the solar system; the Earth's climate; the history of the solar system; and the potential for life elsewhere. In doing so, the Directorate manages about 125 flight projects in various phases of development and operations and funds research drawn from the data provided by these projects.

The selection and balance of NASA's science missions is heavily influenced by stakeholders external to the Agency, including the President, Congress, the science community, and, to a lesser extent, other Federal and international agencies. The President and Congress provide direction through the budgeting and appropriation processes, which has a strong influence on the composition and overall balance of the Agency's science portfolio. The science community – as represented by the National Research Council (NRC) – establishes mission priorities based on a broad consensus within various science research disciplines.[25] These priorities are set forth in the NRC's decadal surveys on the subject matter areas encompassed by the Science Mission Directorate's four divisions: Astrophysics, Earth Science, Heliophysics, and Planetary Science. Each survey lists the NRC's recommendations by priority (e.g., the 2007 Earth Science Decadal Survey grouped missions by Tier 1 through Tier 3, with Tier 1 being the highest priority).[26] Managing differing priorities from numerous stakeholders and funding changes on a year-to-year basis (which we described as "funding instability" in a September 2012 report) can lead to inefficiencies, resulting in cost increases and schedule delays that can have a cascading effect on NASA's entire science portfolio.[27]

On a macro scale, the changing priorities of a new President and Congress, and results of the annual appropriation process, tend to create challenges managing a science portfolio with projects that take many years to develop and launch. For example, in FY 2017 NASA anticipated that the FY 2018 budget for Earth Science and Planetary Science would be $1.99 billion and $1.44 billion, respectively. However, the Presidential Budget Request for FY 2018 included $1.75 billion for Earth Science and $1.93 billion for Planetary Science. Specific changes to the portfolio include the proposed cancellation of five Earth Science missions, including one that was a high priority in the 2007 Earth Science Decadal Survey, one that was to launch to the ISS next year, and one that would have funded NASA instruments on an operational National Oceanic and Atmospheric Administration (NOAA) satellite – each of which we described in a November 2016 report on NASA's Earth Science portfolio.[28] To further complicate management of the portfolio, in July 2017 both Houses of Congress provided differing direction with regard to the balance of Earth Science and Planetary Science missions, with the Senate explicitly directing money to four of the projects marked for cancellation by the President. We described the

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[25] The NRC is the research arm of the National Academy of Sciences, the National Academy of Engineering, and the National Academy of Medicine, and issues reports to help improve public policy, understanding, and education in matters of science, technology, and health.

[26] NRC, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," 2007.

[27] NASA OIG, "NASA's Challenges to Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012).

[28] NASA OIG, "NASA's Earth Science Mission Portfolio" (IG-17-003, November 2, 2016). The five missions are Pre-Aerosol, Clouds, and ocean Ecosystem; Orbiting Carbon Observatory 3; Radiation Budget Instrument; Climate Absolute Radiance and Refractivity Observatory Pathfinder; and two instruments on the Deep Space Climate Observatory.

negative effects of this "on again, off again" funding and policy direction in a July 2014 report on NASA's Stratospheric Observatory for Infrared Astronomy.[29]

Mars Exploration Rover Opportunity

Source: NASA (artist's rendering).

Further challenging efficient management of the science portfolio are sometimes conflicting and fluid stakeholder priorities. The Mars Exploration Program has been a centerpiece of the Planetary Science Division for decades. This year, Mars Odyssey and Mars Reconnaissance Orbiter surpassed 16 and 11 years, respectively, far exceeding their planned operational lifespans while sending back photographs, science data, and acting as relays for surface rovers.[30] The Mars Exploration Rover, Opportunity, continues to send back data after nearly 14 years operating on the Martian surface. The Mars Science Laboratory rover, Curiosity, recently celebrated its fifth anniversary on the Red Planet in August 2017 after a challenging development period.[31] In January 2017, we reported on the challenges facing the Program's next rover, Mars 2020, which NASA designed to collect soil samples for storage on the planet's surface.[32] The Mars 2020 mission is the highest priority flagship mission of the most recent Planetary Decadal Survey and was described as the first of three missions to return Martian soil samples to Earth.[33] However, NASA has no follow-on Mars mission planned after the 2020 launch, rover or orbiter, as exploration of the outer planets has emerged as a higher priority in recent years.

For example, the 2011 Planetary Decadal Survey described an orbiter mission to Europa, an icy moon of Jupiter, as the second highest priority flagship mission. Although the NRC specifically warned against a mission with costs that would cause unacceptable programmatic imbalance and elimination of other important missions, since FY 2014 Congress has appropriated $500 million more to a Europa mission than NASA requested, and consistently directed specific mission elements – a lander to the surface of Europa – that both NASA and the NRC have said would be prohibitively expensive. As currently designed, the mission would cost approximately $3.1 billion to develop and launch by 2022. If Congress insists on inclusion of a lander, the additional mission costs would certainly impact the overall Science Mission Directorate portfolio.

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29 NASA OIG, "SOFIA: NASA's Stratospheric Observatory for Infrared Astronomy" (IG-14-022, July 9, 2014).

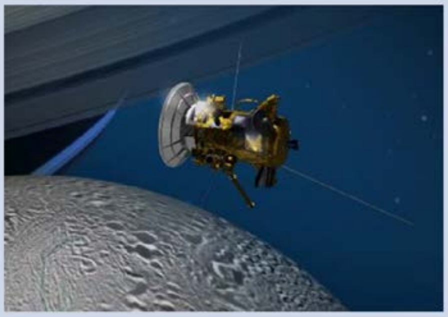
30 Mars Odyssey launched in April 2001 and arrived at Mars in October 2001. The Mars Reconnaissance Orbiter launched in August 2005 and arrived at Mars in March 2006.

31 Opportunity was launched in July 2003 and landed on Mars in January 2004. Curiosity launched in November 2011 and landed in August 2012. Our report, "NASA's Management of the Mars Science Laboratory Project" (IG-11-019, June 8, 2011), reported on the challenges project managers faced that led to 2-year launch delay and cost increase of $969 million.

32 NASA OIG, "NASA's Mars 2020 Project" (IG-17-009, January 30, 2017).

33 NRC, "Vision and Voyages for Planetary Science in the Decade 2013-2022," 2011.

Cassini Space Probe



Source: NASA (artist's rendering).

In spite of these ongoing challenges, NASA has had many operational and developmental successes in the past few years. For example, in July 2015, New Horizons made a close pass of Pluto, revealing unexpected details; in February 2017, the 14-year-old Spitzer Space Telescope discovered seven Earth-size planets around a single star – setting the record for greatest number of habitable-zone planets found around a single star outside our solar system; in September 2017, Cassini completed 13 years of investigating Saturn, making numerous discoveries, including water emanating from the icy moon, Enceladus; and the Solar and Heliospheric Observatory will turn 22 in December 2017, having provided early alert space weather observations and enabled discovery of more than 3,000 comets – an unanticipated capability when it was launched.[34] In addition, NASA launched the Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) in September 2016 approximately 20 percent under budget and launched the Cyclone Global Navigation Satellite System (CYGNSS) in December 2016, 5 months early and approximately 15 percent under budget.[35]

Several of NASA's recent developmental successes are partially attributable to the implementation of tools that help improve the fidelity of the Agency's cost and schedule estimates, such as a requirement that projects exceeding $250 million conduct a Joint Cost and Schedule Confidence Level (JCL) assessment. However, as we discussed in a September 2015 report, the JCL process has inherent limitations in that, like any estimating practice, it does not fully address all of the root causes of NASA's project management challenges such as funding instability, underestimation of technical complexity, and to a lesser extent overly optimistic expectations.[36] In fact, the projects discussed below are some of NASA's largest science projects currently in development and are continuing to face the same project management challenges discussed in our September 2012 report as well as the challenges we highlighted in a May 2016 report regarding NASA's work with international partners.[37] Each of the projects implemented JCL; all but one – Parker Solar Probe – have experienced schedule delays and cost increases and are due to be launched in the coming year. Overcoming these challenges and launching these projects on schedule at their baseline costs is vital to NASA effectively managing its science portfolio.

[34] New Horizons was launched in January 2006. Spitzer Space Telescope was launched in August 2003 and trails the Earth in an orbit around the Sun. Cassini was launched in October 1997 and arrived at Saturn in July 2004. The Solar and Heliospheric Observatory was launched in December 1995 and orbits around the First Lagrangian Point, about 1 million miles from the Earth toward the Sun.

[35] OSIRIS-REx is designed to study and obtain a sample of surface material from the asteroid Bennu and return it to Earth in 2023. CYGNSS is designed to facilitate better weather forecasting by measuring ocean surface winds throughout the life cycle of tropical storms and hurricanes.

[36] NASA OIG, "Audit of NASA's Joint Cost and Schedule Confidence Level Process" (IG-15-024, September 29, 2015).

[37] NASA OIG, "NASA's International Partnerships: Capabilities, Benefits, and Challenges" (IG-16-020, May 5, 2016); IG-12-021.

Ice, Cloud, and land Elevation Satellite-2

Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) is a satellite mission designed to collect data on ice sheets and track changes in glaciers and sea ice, which will allow scientists to see where ice is flowing, melting, or growing and to investigate the global impacts – such as sea level rise – of these changes. Although the NRC recommended the mission in its 2007 Earth Science Decadal Survey with a suggested launch in 2013, NASA baselined ICESat-2 in December 2012 with a life-cycle cost of $860 million and a launch date of May 2017.[38] However, managers underestimated the technical complexity of building the satellite's sole instrument – the Advanced Topographic Laser Altimeter System (ATLAS) – and therefore significantly understated the mission's cost and schedule. In May 2014, NASA revised the baseline to reflect a $1.06 billion life-cycle cost and a planned launch date in June 2018. Funds to cover this 24 percent cost increase were drawn from other projects in the Earth Science Division portfolio.

ICESat-2

Source: NASA (artist's rendering).

Although last year the Project appeared to be making good progress toward an early or on-schedule launch of this revised date, development was negatively impacted in July 2016 when one of the two flight lasers manufactured for the ATLAS instrument failed during thermal vacuum testing. Consequently, the Project will not launch earlier than September 2018, 3 months later than the revised baseline date, and costs may increase to support the additional work.

Interior Exploration using Seismic Investigations Geodesy and Heat Transport

Interior Exploration using Seismic Investigations Geodesy and Heat Transport (InSight) is NASA's next Mars lander mission, designed to investigate the crust, deep interior, and tectonic activity of Mars to better understand how rocky planets like Earth and Mars formed. Using a German-built penetrating "mole," the lander will pound a probe 16 feet into the Martian crust to take thermal measurements while a French-built seismometer will attempt to sense and measure "Marsquakes." However, a leak discovered in the seismometer in November 2015 caused NASA to delay its planned March 2016 launch for 26 months and increased Project life-cycle costs $154 million to $829 million.

InSight Mars Lander

Source: NASA.

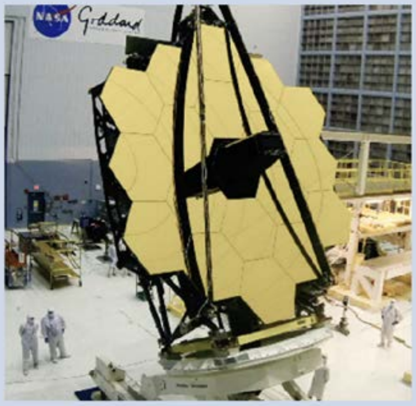
In July 2017, InSight was still experiencing delays with its seismometer, was troubleshooting unexpected technical issues with the penetrating mole, and was developing mitigation strategies to address degradation of parachute

[38] This baseline cost was approximately $75 million higher than initial estimates because NASA had to procure a separate launch vehicle when its plan to share the cost of a launch vehicle with a U.S. Air Force payload did not materialize.

strength found in testing – all of which eroded schedule and cost reserves. As of September 2017, the seismometer instrument and mole had been delivered and installed on the spacecraft, managers concluded that the parachute strength was within the performance margin, and the Project was on schedule for launch in May 2018.

James Webb Space Telescope

James Webb Space Telescope



Source: NASA.

The successor to the Hubble Space Telescope, the James Webb Space Telescope (JWST) is designed to help understand the origin of the first stars and galaxies in the universe, the evolution of stars, the formation of stellar systems, and the nature of celestial objects in our solar system. The 2001 Astrophysics Decadal Survey identified JWST as its top priority for that decade.[39] Early cost and schedule estimates – ranging from $1 billion to $3.5 billion, with an expected launch date between 2007 and 2011 – proved overly optimistic, and following a change in the launch vehicle and other revisions in 2005, NASA estimated life-cycle costs at $4.5 billion with a launch date in 2013. Soon after, a review team found the 2013 launch date unachievable. Consequently, in 2009 NASA rebaselined JWST with a life-cycle cost estimate of $4.9 billion and a June 2014 launch date. However, it soon became clear that neither the new cost estimate nor the 2014 launch date were attainable. Subsequently, NASA restructured the JWST Project and in September 2011 established a revised baseline life-cycle cost estimate of $8.84 billion and an October 2018 launch date.

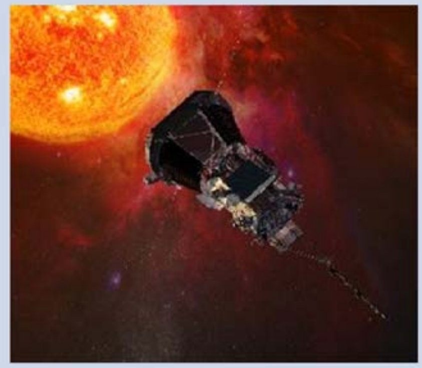
JWST has made significant progress in integration and testing, including installation of all five sunshield membranes and environmental testing of the optical telescope and science instrument module. Although the Project remains within its revised baseline cost and schedule, some integration and test activities have taken longer than expected, which is likely to consume available cost and schedule reserves. While not completely unexpected at this point in a project's life cycle, the schedule margin has fallen below what was planned, increasing costs have resulted in a smaller-than-planned funding reserve, and issues were identified with integration and testing of the spacecraft bus and sunshield. In late September 2017, the Agency delayed the JWST launch to no earlier than March 30, 2019, and the project will need to tap into JWST budget reserves to remain within the Agency's cost cap.

[39] NRC, "Astronomy and Astrophysics in the New Millennium," 2001. At the time, JWST was referred to as the Next Generation Space Telescope.

Parker Solar Probe

The $1.6 billion Parker Solar Probe mission is designed to orbit the Sun closer than any other spacecraft while investigating the Sun's corona or outer atmosphere. The mission will sample plasma and the coronal magnetic field in the region that heats the solar atmosphere and accelerates the solar wind to provide insights into coronal heating and the origin and evolution of the solar wind – questions posed in the 2003 and 2013 Heliophysics Decadal Surveys.[40] The mission will also provide a better understanding of the radiation environment in which future space explorers will work and live.

Parker Solar Probe



Source: NASA (artist's rendering).

The Parker Solar Probe has a 20-day launch window that opens on July 31, 2018. Development delays and testing failures with instruments and spacecraft subsystems required the use of schedule reserve and funding from Headquarters-held reserves. As late as August 2017, two instruments critical to the mission meeting its primary science objectives were experiencing development delays and testing failures. As the Project begins spacecraft-level environmental testing, solving any remaining technical issues in time to meet the launch window is imperative if NASA is to avoid a minimum 10-month launch delay.

Information Technology Governance and Security

Information Technology (IT) plays an integral role in every facet of Agency operations, and hundreds of thousands of individuals – from NASA personnel to members of academia to the public – rely on NASA IT systems every day. In 2017, NASA spent approximately $1.4 billion (7.6 percent) of it $18.5 billion budget on IT investments. The Agency's portfolio of IT assets includes approximately 500 information systems used to control spacecraft, collect and process scientific data, and enable NASA personnel to collaborate with colleagues around the world.

For more than 10 years, the OIG has identified securing NASA's IT systems and data as a top management challenge. Over the last 7 years, we have issued 24 audit reports containing over 119 recommendations designed to improve NASA's IT governance and IT security efforts. Although the Agency has made progress in this area, we remain concerned about the state of the Agency's IT governance, its acquisition of IT systems, cybersecurity vulnerabilities, IT security incident detection and handling capabilities, continuous monitoring tools, cloud-computing services, and web application security.

[40] NRC, "The Sun to the Earth – and Beyond: A Decadal Research Strategy in Solar and Space Physics," 2003, and "Solar and Space Physics: A Science for a Technological Society," 2013.

Information Technology Governance

Effective IT governance must balance compliance, cost, risk, security, and mission success to meet the Agency's strategic goals and the needs of external stakeholders. However, for more than 2 decades NASA has struggled to implement an effective IT governance approach that appropriately aligns authority and responsibility commensurate with the Agency's overall mission.

In a June 2013 audit, we examined whether NASA's Office of the Chief Information Officer (OCIO) had the organizational, budgetary, and regulatory framework needed to effectively meet the Agency's varied missions.[41] We found the decentralized nature of NASA's operations and its longstanding culture of autonomy hindered its ability to implement effective IT governance. Specifically, the Chief Information Officer (CIO) had limited visibility and control over a majority of the Agency's IT investments, operated in an organizational structure that marginalized the authority of the position, and could not enforce security measures across NASA's computer networks. Moreover, the IT governance structure in place at the time was overly complex, did not function effectively, and operated under a decentralized model that relegated decision making about critical IT issues to numerous individuals across the Agency, leaving such decisions outside the purview of the CIO. As a result, NASA's IT governance model weakened accountability and did not ensure that IT assets across the Agency were cost effective or secure.

Given the criticality of these issues, we reexamined the Agency's reform efforts and in an October 2017 follow-on audit report found a continued lack of progress in improving the Agency's IT governance, casting doubt on the OCIO's ability to effectively oversee the $1.4 billion the Agency spends annually on IT.[42] Specifically, the CIO continues to have limited visibility into IT investments across NASA and the process the Agency developed to correct those shortcomings is flawed. Moreover, the OCIO continues its decade-long struggle to establish an effective enterprise architecture. While the OCIO has made changes to its three senior advisory boards over the past few years, these boards have yet to make strategic decisions that substantively impact how IT at NASA is managed. Consequently, slow implementation of the OCIO's revised IT governance structure has left many Agency IT officials operating under the previous inefficient and ineffective framework, and as of July 2017 the OCIO had not finalized the roles and responsibilities for IT management at NASA. Further, lingering confusion regarding security roles coupled with poor IT inventory practices negatively impacts NASA's security posture. Finally, the OCIO continues to have limited influence over IT management within the Mission Directorates and at Centers due to the autonomous nature of NASA's operations and its lack of credibility on IT issues in the eyes of many of its customers. Moving forward, NASA needs to redouble its efforts to create and sustain a system of IT governance and operation that provides secure and efficient IT systems for Agency employees, contractors, and the public.

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[41] NASA OIG, "NASA's Information Technology Governance" (IG-13-015, June 5, 2013).

[42] NASA OIG, "NASA's Efforts to Improve the Agency's Information Technology Governance" (IG-18-002, October 19, 2017).

Securing Information Technology Systems and Data

NASA manages approximately 1,200 publicly accessible web applications, or about half of all publicly accessible, non-military Federal Government websites.[43] The Agency's vast connectivity with educational institutions, research facilities, and other outside organizations offers cybercriminals a larger target than most other Government agencies and presents unique IT security challenges.

NASA must ensure that its IT systems and associated components are safeguarded, assessed, and monitored to protect against inevitable attacks. Over the past 2 years, NASA reported more than 3,000 computer security incidents related to malicious software on or unauthorized access to Agency computers. These incidents included individuals testing their skills to break into NASA systems, well-organized criminal enterprises hacking for profit, and intrusions that may have been sponsored by foreign intelligence services seeking to further their countries' objectives. To protect against these incidents, NASA recently completed a series of initiatives, including:

- expanding network penetration testing and incident response assessments;
- deploying intrusion detection systems across mission, corporate, and research networks;
- increasing web application security scanning;
- implementing intrusion prevention systems;
- expanding anti-phishing exercises Agency-wide; and
- implementing anti-exploitation software to reduce potential incidents.

While these actions improve NASA's security posture, the Agency has yet to develop an Agency-wide risk management process specific to information security. Furthermore, in April 2016 we reported that although NASA has made progress in meeting requirements in support of an Agency-wide information security program, it has not fully implemented key management controls essential to managing that program.[44] Specifically, NASA lacked an Agency-wide risk management framework for information security and an information security architecture. This situation is further complicated by high personnel turnover in the Agency's OCIO – specifically, the CIO and Senior Agency Information Security Officer roles – resulting in a lack of continuity and effective program planning.

NASA's efforts to incorporate a greater use of cloud computing also challenges the Agency's IT security posture. While cloud computing offers the potential for significant cost savings through faster deployment of computing resources, a decreased need to buy hardware or build data centers, and enhanced collaboration capabilities, the move to a cloud-computing environment poses operational and IT security risks such as limited controls over the management of critical or sensitive data within the cloud environment. In 2013, we reported that the Agency's IT governance and risk management practices were impeding NASA from fully realizing the benefits of cloud computing and potentially

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[43] In 2014, we examined NASA's efforts to assess vulnerabilities on its publicly accessible web applications and mitigate the most severe vulnerabilities before hackers exploit them. NASA OIG, "Security of NASA's Publicly Accessible Web Applications" (IG-14-023, July 10, 2014). Although the OCIO and Center IT security officials have reduced NASA's web presence by eliminating some unused and duplicative web applications, the Agency's remaining publicly accessible web applications continue to present a significant target for hackers.

[44] NASA OIG, "Review of NASA's Information Security Program" (IG-16-016, April 14, 2016).

placed at risk its information stored in the cloud.[45] In February 2017, we reexamined NASA's efforts and found that while NASA has made improvements since the 2013 report, continuing weaknesses in its governance and risk management processes have prevented the Agency from fully realizing the benefits of cloud computing and continue to leave Agency information stored in cloud environments at unnecessary risk.[46] Specifically, we found cloud services in use by NASA that lacked IT security authorizations to operate and system security plans, and cloud services using contracts that lacked provisions intended to address key business and IT security risks associated with cloud environments. As NASA continues to move more data to the cloud, the Agency's OCIO is challenged to strengthen its risk management and governance practices to safeguard this information.

Advancements in technology have enabled NASA to move away from isolated, manually controlled operational technology (OT) systems to an environment in which physical processes are controlled with sophisticated and interconnected IT equipment. As more devices become "smart" through wireless connectivity, OT systems that once required hands-on manipulation, such as adjusting a valve or flipping a switch can now be controlled remotely. Many of these OT systems are part of the Agency's critical infrastructure used to test rocket propulsion systems, control and communicate with spacecraft, and operate ground support facilities, or are associated with electrical power, heating and cooling systems, and other supporting infrastructure. While the convergence of IT and OT can lead to cost savings and other efficiencies, it also means OT systems are potentially vulnerable to the same types of security challenges more common to IT systems, including malicious hacking.

In February 2017, we issued a report critical of the Agency's ability to protect systems that contain OT components.[47] Specifically, NASA had no complete inventory of systems that incorporated OT, and this shortcoming resulted in those systems lacking comprehensive IT security controls. In addition, we found that NASA's policies did not distinguish OT from IT, and the Agency did not offer training focused on protecting OT systems. As a result, NASA was not well-positioned to meet the security demands of an evolving OT environment and was assuming unnecessary risk for critical Agency systems and facilities with OT components. Further, because we found Centers implementing inconsistent security practices, we questioned the overall efficacy of NASA's process for identifying its critical infrastructure. Finally, inadequate guidance and oversight, coupled with insufficient funding and record keeping, limit the visibility and insight into NASA's critical infrastructure protection processes and ultimately impair the Agency's ability to protect its vital assets.

In the past several years, we also identified IT security deficiencies in NASA's Space Communication and Navigation Program that operates the networks that provide communications, navigation, and transmission of scientific data to space flight missions. In March 2016, we found the Near Earth Network was at increased risk of compromise due to operators deviating from required elements of Federal and Agency cyber and physical security risk management policies.[48] Similarly, in a March 2015 report on the Deep Space Network, we found that NASA's Security Operations Center (SOC) was not adequately integrated into the Jet Propulsion Laboratory's (JPL) computer network operations resulting in a lack of oversight for some JPL systems because the two organizations had not agreed on plans for

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45 NASA OIG, "NASA's Progress in Adopting Cloud-Computing Technologies" (IG-13-021, July 29, 2013).

46 NASA OIG, "Security of NASA's Cloud Computing Services" (IG-17-010, February 7, 2017).

47 NASA OIG, "Industrial Control System Security Within NASA's Critical and Supporting Infrastructure" (IG-17-011, February 8, 2017).

48 IG-16-014.

comprehensive monitoring.[49] As a result, NASA lacked the ability to monitor a large portion of JPL network traffic for suspicious activity, provide timely assistance in the event of an incident, and ensure its information systems and data are fully protected. In response to the reports' recommendations, the Agency said it has improved SOC oversight at JPL. To check on its progress, in March 2017 we initiated an audit to assess the SOC's capability, workload, and resource management as well as continuity of operations.

In addition to our audit work, the OIG continues to expend substantial resources investigating IT security issues, including breaches of NASA IT networks. The OIG recently arrested a former NASA contract employee indicted for illegally accessing and attempting to damage NASA systems. During the course of another cyber investigation, the OIG found NASA was not sufficiently protecting sensitive export-controlled software and, acting on OIG recommendations, subsequently improved its internal controls.

Aging Infrastructure and Facilities

NASA controls approximately 5,000 buildings and structures with an estimated replacement value of at least $34 billion, making the Agency one of the largest property holders in the Federal Government. However, more than 80 percent of the Agency's facilities are 40 or more years old and are beyond their design life. While NASA strives to keep these facilities operational – and when not operational, in sufficient condition so they do not pose a safety hazard – the Agency has not been able to fully fund required maintenance for its facilities for many years, with NASA estimating its deferred maintenance costs at $2.4 billion in 2016. The Agency faces ongoing operational challenges in this area as it juggles a long history of decentralized governance, intense political interest in its Centers and their real property assets, and the likelihood of flat or reduced budgets.

Test Stand 4693

Source: NASA.

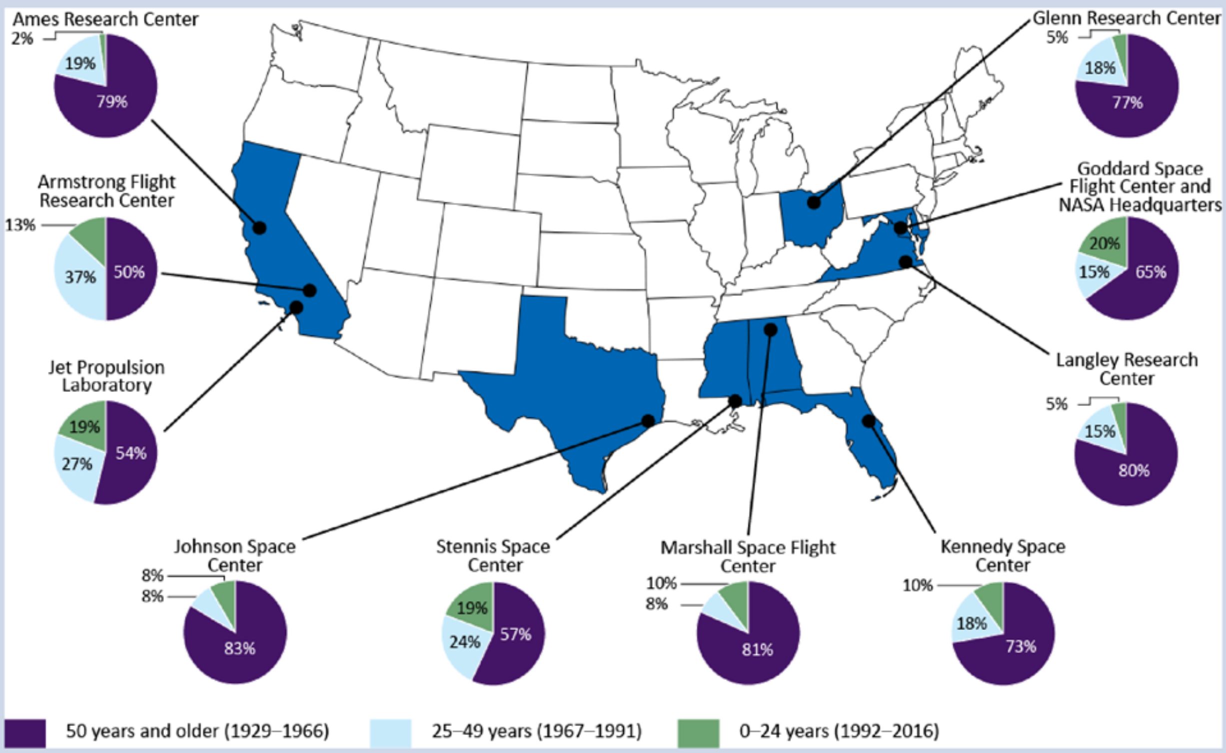
Over the last 7 years, the OIG has dedicated substantial resources – issuing 16 audit reports – examining NASA's infrastructure challenges. In doing so, we assessed a variety of issues including NASA's efforts to "right-size" its workforce, facilities, and other supporting assets; the construction of new assets such as test stands at Marshall Space Flight Center; NASA's plans for underused test facilities at Plum Brook Station in Ohio; management of its Pressure Vessels and Pressurized Systems and Explosive Safety Programs; the Agency's environmental remediation efforts; and NASA's efforts to reduce unneeded infrastructure and facilities. Common themes throughout all of these reviews are slow implementation of corrective actions, inconsistent implementation of Agency policies, and a need for stronger life-cycle cost considerations in facility construction decisions.

NASA established the Technical Capabilities Assessment Team (TCAT) in June 2012 to assess the Agency's technical capabilities (including infrastructure and personnel resources) and make recommendations for investing in, consolidating, or eliminating capabilities based on mission

[49] IG-15-013. The SOC provides an Agency-wide single point-of-contact for information security incidents and continuously monitors computer network traffic entering and leaving NASA Centers.

requirements.[50] In our April 2017 review of the undertaking, we found that after more than 4 years the Agency has yet to make many concrete decisions about its technical capabilities – for example, to consolidate or dispose of assets.[51] Rather, most decisions have been iterative steps on the path to making actual determinations about technical capabilities, leaving us concerned that the Agency's efforts have been slow to produce meaningful results. Moreover, NASA's assessments of its capabilities did not consistently include information needed to make informed decisions, including mission needs or facility usage data, analyses to determine gaps or overlaps, recommendations to achieve cost savings, or firm timeframes for completing actions. The Agency must be willing to make difficult decisions to invest, divest, or consolidate unneeded infrastructure; effectively communicate those decisions to stakeholders; and withstand the inevitable pressures from Federal, state, and local officials to retain capabilities and structures "just in case."

NASA's Aging Facilities



Source: NASA OIG analysis of Agency data (some percentages sum to greater or less than 100 because of rounding).

In another example, in May 2017, we reported on NASA's construction of two test stands at Marshall Space Flight Center and found that inadequate planning for the effort ultimately increased costs.[52] NASA built two test stands to test the liquid hydrogen and liquid oxygen tanks from the core stage of the SLS rocket. To meet schedule commitments, test stand design and construction began before tank

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[50] To institutionalize capability management into its annual planning and budgeting processes, NASA replaced TCAT with the Capability Leadership Model (CLM) in 2015. CLM is designed to advance NASA's technical capabilities to meet long-term missions, optimize deployment of capabilities across its major facilities, and transition capabilities no longer needed.

[51] NASA OIG, "NASA's Efforts to 'Rightsize' its Workforce, Facilities, and Other Supporting Assets" (IG-17-015, March 21, 2017).

[52] NASA OIG, "Construction of Test Stands 4693 and 4697 at Marshall Space Flight Center" (IG-17-021, May 17, 2017).

design was finalized. In addition, NASA paid the contractor a premium of $7.6 million for the additional labor needed to work around-the-clock to meet the ambitious schedule. Subsequently, when the project's requirements matured, NASA needed an additional $20.3 million to make modifications to the original test stand designs. In addition, because NASA failed to establish adequate funding reserves to cover these increased costs, project officials had to secure $35.5 million in additional funding over the planned budget. Finally, NASA did not adequately consider alternative locations before selecting Marshall as the site for the new test stands and therefore cannot be sure it made the most cost effective decision.

Contracting and Grants

Approximately 76 percent of NASA's $18.5 billion FY 2016 budget was spent on contracts to procure goods and services, and the Agency awarded an additional $974 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 agreed-upon goals. The OIG seeks to assist NASA in these efforts by examining Agency-wide procurement and grant-making processes; auditing individual contracts, grants, and cooperative agreements; and investigating potential misuse of Agency contract and grant funds. Additionally, we monitor the impact of contracts and grants awarded to assist NASA in accomplishing its aeronautics, exploration, and science missions as well as to provide support-type functions in areas like information technology. While many project management and IT reviews are highlighted elsewhere in this report, we discuss below several underlying issues that correlate directly to the Agency's contracting and grant challenges.

During the past year, the OIG continued to uncover fraud and misconduct related to NASA contracts. For example, as the result of an investigation conducted by the NASA OIG and several other agencies, a Nevada aerospace company agreed to pay $14.9 million to settle allegations it violated the Federal False Claims Act by knowingly misclassifying costs, causing Government agencies to pay inflated overhead rates. Further, in January 2017 a Los Angeles contractor was sentenced to 2 years of imprisonment after being found guilty for conspiring to provide $42,590 in illegal gratuities to approximately 70 Government purchase cardholders, which yielded an estimated $3 million in return business for the contractor's company.

Given NASA's continued reliance on contractors to provide essential services, the Agency will remain susceptible to contract fraud schemes, including collusion among bidders, employers, and contractors; corrupt payments in the form of bribes and kickbacks; bid manipulation; failure to meet contractual specifications; substitution of products or materials of lesser quality than specified in the contract; use of counterfeit, defective, or used parts; submission of false, inflated, or duplicate invoices; false claims regarding a contractor's abilities or level of experience; and conflicts of interest. To assist in identifying such issues, in 2015 the OIG established an Advanced Data Analytics Program that uses statistical and mathematical techniques to gather, analyze, and interpret Agency and open-source data to assist investigative and audit staff in identifying, among other issues, contract, grant, and procurement fraud.

Over the years, we have consistently reported on the Agency's challenges in effectively executing its contract and grant functions and we continue to track open recommendations related to prior award fee, contract management, and service contract audit findings. For example, two programmatic and policy-based recommendations remain open from our May 2016 report on NASA's $1.9 billion Engineering Services Contract at Kennedy that found the size and scope of the Center's agreement with

Vencore, the prime contractor, made managing the contract particularly challenging.[53] Specifically, costs and tasks were not clearly defined, some managers overseeing the contract lacked appropriate expertise, and several tasks performed by Vencore on a cost-reimbursable basis appeared more suitable to a fixed-price arrangement.[54] Moreover, NASA limited its ability to evaluate Vencore's performance by including generic milestones and deliverables in several task orders, and the Agency employed evaluation standards that did not align with the Federal Acquisition Regulation or the contract's award-fee plan. As a result, NASA's evaluations of the contractor's performance did not consistently support the award-fee scores assigned and we questioned more than $450,000 in award-fee payments. These challenges relating to managing award-fee contracts mirrored similar concerns we raised in previous reports, and we continue to work with the Agency to ensure our recommendations are addressed to improve contract management.[55]

More recently, in an April 2017 report we questioned NASA's management of the contracts used to develop new spacesuits.[56] Specifically, in 2011 Johnson Space Center officials recommended terminating a contract for a spacesuit development project associated with the cancelled Constellation Program. However, rather than end the contract, NASA paid the contractor $80.8 million between 2011 and 2016 for spacesuit technology development despite parallel development activities being conducted elsewhere in the Agency. Consequently, NASA has spent nearly $200 million to develop spacesuit technologies, though the Agency remains years away from having a flight-ready spacesuit suitable for use on future exploration missions.

NASA also awards millions of dollars in grants and cooperative agreements annually to facilitate research and fund scholarships, fellowships, and stipends to students and teachers, as well as research by educational institutions or other nonprofit organizations. The Agency faces the ongoing challenge of ensuring grant and cooperative agreement funds are administered appropriately and that recipients are accomplishing agreed-upon goals. We continue to conduct audits and investigations to assist NASA in meeting this challenge. For example, in our June 2015 report on NASA's cooperative agreements awarded to the Wise County Clerk of Circuit Court (Wise County), we found that although Wise County satisfied the overall performance goals and objectives of its cooperative agreements with NASA, substantial deficiencies existed in the County's management of award funds that resulted in recovery of unallowable costs and cost avoidance totaling $208,808.[57] In another audit report on NASA's grant awards to the Philadelphia College Opportunity Resources for Education (CORE), we found that CORE charged $60,511 in unallocable or unallowable expenditures and failed to maintain appropriate time and attendance documentation to support personnel charges totaling $156,409, among other control

[53] NASA OIG, "Audit of NASA's Engineering Services Contract at Kennedy Space Center" (IG-16-017, May 5, 2016).

[54] In a cost-reimbursement contract, NASA reimburses contractors for allowable costs they incur producing or delivering the contracted goods or services. Cost-type contracts pose a financial risk to the procuring agency because they do not promise delivery of a good or service at a set price. An award fee is money a contractor may earn in whole or in part by meeting or exceeding predetermined performance criteria.

[55] NASA OIG, "Audit of NASA's Management of International Space Station Operations and Maintenance Contracts" (IG-15-021, July 15, 2015); "Extending the Operational Life of the International Space Station Until 2024" (IG-14-031, September 18, 2014); and "NASA's Use of Award-fee Contracts" (IG-14-003, November 19, 2013).

[56] NASA OIG, "NASA's Management and Development of Spacesuits" (IG-17-018, April 26, 2017).

[57] NASA OIG, "Audit of NASA's Cooperative Agreements Awarded to Wise County Circuit Court" (IG-15-022, July 16, 2015). The cooperative agreements were awarded in support of the Agency's DEVELOP National Program, a capacity building program that seeks to address environmental management and public policy issues through interdisciplinary research projects that apply NASA Earth observations to community concerns around the globe.

deficiencies identified.[58] In another audit, we found that NASA's poor internal controls resulted in the Texas Space Grant Consortium, led by the University of Texas at Austin, inappropriately awarded scholarships to students who were not U.S. citizens and failed to adequately track required cost matching.[59] We continue to monitor the Agency's status in addressing open recommendations related to our grant and cooperative agreement audits.

Similarly, our Office of Investigations is actively helping the Agency prevent and make recoveries from grant fraud and abuse. Over the past 5 years, the OIG has conducted 25 grant fraud investigations resulting in 8 indictments, 5 prosecutions, $638,783 in direct recoveries to NASA, $2.9 million in civil settlements, 2 suspensions, and 7 debarments. In one case, an investigation of fraud committed by Educational Advancement Alliance, Inc., (EAA) and its president ended in the convictions of its president, former Pennsylvania Congressman Chaka Fattah, and several associates.[60] The organization received a series of Federal grants, including a $1.8 million grant from NASA to promote science, technology, engineering, and mathematics education. The investigation revealed that EAA improperly used $100,000 of the NASA grant to pay a campaign debt on former Congressman Fattah's behalf. In June 2016, a Federal jury convicted the Congressman and his associates of taking part in a racketeering conspiracy by misappropriating Federal, charitable, and campaign funds. In December 2016, the Congressman was sentenced to 10-years' imprisonment while the company president was sentenced to 2-years' imprisonment.

[58] NASA OIG, "Audit of NASA Grants Awarded to the Philadelphia College Opportunity Resources for Education" (IG-12-018, July 26, 2012). CORE is a not-for-profit organization that provides college scholarships to high school seniors.

[59] NASA OIG, "Audit of NASA Space Grant Awarded to the University of Texas at Austin" (IG-16-013, February 18, 2016). In 2010, NASA awarded a $3.36 million grant to the University of Texas at Austin for educational training to increase interest in science, technology, engineering, and mathematics.

[60] NASA OIG assisted the Federal Bureau of Investigation and Internal Revenue Service in the investigation.

Appendix A. Management's Comments

National Aeronautics and Space Administration
Office of the Administrator
Washington, DC 20546-0001

October 31, 2017

TO: Inspector General

FROM: Acting Administrator

SUBJECT: Agency Response to Office of Inspector General Report, "NASA's 2017 Top Management and Performance Challenges"

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General's (OIG) report entitled, "NASA's 2017 Top Management and Performance Challenges."

The audits and investigations conducted by your office provide NASA's leadership and management with valuable contributions to the collective effort to provide oversight and gain insight into NASA's broad portfolio of programs, projects, and mission support activities with which it is entrusted. The efforts expended by your office during this past year have furthered the cause of providing the taxpayer with maximum value for each dollar invested in NASA's wide-ranging, ambitious, and challenging portfolio. As an Agency, we continue to aggressively pursue the mitigation and remediation of findings related to the audit recommendations issued by your office, including those which form the underpinnings of your observations as cited in your 2017 Top Management and Performance Challenges Letter.

While we fundamentally agree that the five areas outlined in your 2017 letter constitute significant challenges for the Agency, we would like to highlight the following mitigation and remediation efforts that have either been taken, or are underway, which we believe further demonstrate NASA's commitment in addressing its most significant management and performance challenges:

1. Deep Space Exploration

Space Launch System, Orion, and Ground Systems Development Program:

The predominance of Orion, Space Launch System (SLS), and Ground Systems Development and Operations (GSDO) development and production content is on track for Exploration Mission (EM-1), and work is underway to prepare for the first flight of crew on EM-2 and subsequent exploration missions. While progress on these programs has been substantial, NASA and its partners have faced challenges relative to the critical path for the EM-1 test flight and as a result is rescheduling program planning of EM-1 to reflect completion of work required to prepare for flight. NASA has made significant progress in addressing first-time development issues, such as resolving the Vertical Assembly Center (VAC) weld strength issues and all VAC assembly welding for EM-1 has been completed. Michoud Assembly Facility operations have resumed following the tornado that damaged the facility. All EM-1 booster separation motors are cast and finalized, and the engine controller qualification testing has been completed. The EM-1 Crew Module (CM) and Crew Module Adapter (CMA) production at the Operations and Checkout Center is making good progress; both the CM and the CMA have completed initial power on. European Service Module coordination on assembly, integration, and testing is improving, and NASA has increased involvement in resolving vendor technical and schedule performance issues. The Interim Cryogenic Propulsion Stage has been delivered to GSDO. At the Kennedy Space Center, Vehicle Assembly Building (VAB) platform installation is complete. Pad 39B development is progressing well, and five sets of umbilicals/attach points have been installed on the Mobile Launcher as of September. Finally, NASA is making progress on issues associated with spacecraft command and control software. SLS, Orion, and GSDO are on track to serve as the foundation of U.S. human spaceflight exploration and, along with emerging capabilities in cislunar space, will ensure continued U.S. space leadership for decades to come.

International Space Station (ISS):

This past year has seen the ISS International Partnership and the ISS National Lab mature the safe operations and utilization of this unique on-orbit research platform. Research and utilization for the wide variety of fields including human health and performance, long-duration life support demonstrations, life and physical sciences, Earth and space science, astrophysics, and multiple technology development fields continue to expand in the number of experiments and the number of investigators. From Increment 41/42 (first half of FY 2015) to the recently completed ISS Increment pair 51/52 (second half of FY 2017), the number of investigations have increased by ~40 percent and the amount of crew time has also increased by ~34 percent. This has been made possible by the ongoing efforts of the ISS Program, the National Lab operator CASIS, and the commercial cargo suppliers to utilize and operate the ISS to its utmost capability. The ISS Program is now operating based on the many years of experience learned in pre-flight integration activities, on-orbit crew planning and execution, logistics planning and management, and other aspects of ISS management and operations; all of which is providing dividends in returning benefits to humanity, enabling the development of a commercial market, and enabling deep space long-duration exploration.

Research, technology development, and commercial development efforts onboard the ISS by NASA, other government agencies, and by the private sector through the National Lab continues to see benefits applied to us here on Earth as documented in the ISS Benefits to Humanity Document that is posted on NASA's ISS Web page. NASA has prioritized the human research testing on ISS in order to develop techniques to keep crews healthy on extended microgravity missions.

Through the NASA budget process, the ISS Program has projected the resources necessary to continue with its mission based on actual contract and on-orbit performance data for many aspects of the ISS Program, including transportation, maintenance, and operations. The ISS integration process for utilization continues to become more efficient based on private industry inputs and interactions with the National Lab providers.

Overall the ISS Program is starting to realize its full potential in accomplishing NASA's and the Nation's goals in exploration, commercial development, and extending human presence beyond LEO.

Commercial Cargo/Commercial Transportation to the ISS:

Over the past year, Orbital ATK and SpaceX have continued to become more responsive to NASA's needs to resupply the ISS. Both commercial service providers have flown their expected cargo missions to the ISS over the past year. Both companies have improved their processes and timeliness of service as a result of anomalies that occurred in 2014 and 2015. NASA continues to work with both suppliers to access the risk to ISS operations and cargo launches within NASA's procedures documented in NPD 8610.7, "Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions," and NPD 8610.23, "Launch Vehicle Technical Oversight Policy."

Commercial Crew:

Both commercial crew providers, Boeing and SpaceX, are making steady progress in returning domestic crew launches to the U.S. Both providers are working through development technical challenges that are not uncommon in the human spaceflight and launch industries Nationwide. NASA maintains close coordination with both entities to understand their progress as well as to assess their readiness for flight from a safety perspective. NASA has also been working with Roscosmos and other domestic industry partners to ensure that the U.S. has uninterrupted access to the ISS for U.S. and partner astronauts.

2. Science Mission Directorate Portfolio

The Science Mission Directorate (SMD) develops and implements an extensive portfolio of scientific programs and projects that are inherently complex and present unique challenges. In developing its diverse science portfolio, NASA receives guidance, sometimes conflicting, from a variety of stakeholders including the President, Congress, the National Research Council, and others. SMD strives to develop a balanced portfolio to achieve three overall, interdisciplinary objectives: 1) Safeguarding and improving life on Earth, 2) Searching for life elsewhere, and 3) Expanding our knowledge through research from here at home into the deep universe. We appreciate the OIG's recognition of the inherent challenges involved with managing a portfolio with contradiction guidance from our stakeholders.

The Mars Exploration Program continues to be a key component of our Planetary Science Division. NASA will continue to look for additional opportunities, after Mars 2020, to capitalize on the experience base gained through recent Mars missions.

Upcoming missions, such as ICESat-2 and InSight, continue to progress toward launch. While ICESat-2 encountered challenges during thermal vacuum testing, resulting in a three month slip to the launch date, funding reserves are sufficient to cover the additional work. InSight's seismometer and penetrating mole were recently delivered and installed in the spacecraft and no longer pose any schedule risk. Recent testing has indicated that potential degradation of the parachutes are within the performance margin and will be used as is. Currently, the project has sufficient schedule and cost reserves for the launch in May of 2018.

We continue to make significant progress in the development, integration, and testing of the James Webb Space Telescope (JWST) observatory. This year, the highly complex cryovacuum test of the JWST optical telescope and instrument system (OTIS) was completed on October 22, 2016. Additionally, the integration of the sunshield components with the spacecraft bus is complete (forming the spacecraft element), leaving one major integration step - the integration of OTIS to the spacecraft element. As noted by OIG, due to future schedule considerations in the integration and test of the remainder of the JWST system, in particular testing of the spacecraft element, NASA worked with the European Space Agency (ESA) to shift the launch window of JWST to no earlier than March 30, 2019. NASA continues to work closely with the industry team leading the sunshield and spacecraft work to ensure successful development of JWST.

The Parker Solar Probe will travel closer to the Sun than any spacecraft and will dive into the corona to provide the closest-ever observations, revolutionizing our understanding of the Sun. All instruments, with the exception of one, have been delivered to the spacecraft, which recently was approved to begin environmental testing. The final instrument, the Solar Probe Cup, has been delivered to the Applied Physics Lab for testing and acceptance. The Project currently holds adequate schedule and cost reserves to achieve an August 2018 launch.

These and other new missions, combined with those in operations, allow NASA to use the vantage point of space to achieve--with the science community and our partners--a deep scientific understanding of our home planet, the Sun, and its effects on the solar system, other planets and solar system bodies, our galactic neighborhood, and the universe beyond.

3. Information Technology, Security, and Governance

The information technology (IT) necessary to accomplish NASA's missions is complex and tightly integrated within a variety of mission products and capabilities. This complexity guides the approach and pace at which the Office of the Chief Information Officer (OCIO) progresses toward the goal of managing NASA IT as a strategic resource. The Chief Information Officer (CIO) must utilize a combination of partnerships, collaborations, and governance to implement IT management that enables mission success and allows effective and secure management of mission and corporate IT operations. We appreciate the OIG's recognition of the Agency's efforts to meet the challenges facing NASA's IT governance and the security of IT systems and data.

In FY 2017, the OCIO continued to advance the effectiveness of IT governance that aligned the NASA CIO's authority and responsibility with the Agency's overall mission governance. Improvements included refining the accuracy and expansion of the CIO's visibility into NASA's IT portfolio, utilizing the Information Technology Council (ITC) as both a decision body and collaboration source with the stakeholder members, and implementing Center Functional Reviews.

In FY 2018, the Agency's planned efforts to improve IT governance include, but are not limited to:

1) Refining the Annual Capital Investment Review (ACIR) process to improve the completeness of the IT portfolio, culminating in the FY 2020 Planning, Programming, Budgeting, and Execution (PPBE) IT portfolio ITC presentation, and subsequent submission to the Office of Management and Budget.
2) Realigning IT management roles and responsibilities to establish the clear authorities of the Agency CIO for management and oversight of the NASA IT portfolio as required by Federal Information Technology Acquisition Reform Act (FITARA) and other policies and regulations.
3) Revising the program-level board charters that support senior-level IT governance.

The OCIO continues its efforts to improve the Agency's cybersecurity posture and address NASA's unique IT security challenges. FY 2017 improvements included expanding network penetration testing, deploying active intrusion detection systems, increasing anti-phishing education efforts, and implementing anti-exploitation software. The deployment of the Department of Homeland Security's Continuous Diagnostics and Mitigation (CDM) Phase 1 program to the corporate network offers another example of a major FY 2017 accomplishment, improving the Agency's cybersecurity posture, hardware and software asset management, vulnerability management, and configuration management.

In FY 2018, the OCIO will implement critical security initiatives to address Agency cybersecurity gaps as they pertain to the Agency's information security program. These initiatives include, but are not limited to:

1) Executing an Agency-wide Cybersecurity strategy, approved in FY 2017, aligned with the Agency IT Strategic Plan, to address NASA's cybersecurity priorities.
2) Deploying CDM Phase 1 tools on the mission networks.
3) Establishing a Cybersecurity Integration Team (CIT), to operationalize NASA's response to the Presidential Executive Order on Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure, including but not limited to, the evaluation and improvement of NASA's cybersecurity risk management policies, processes, and reporting, under the auspices of the ITC.

4. Aging Infrastructure

NASA recognizes the imbalance between the infrastructure that it maintains and the funding available to properly sustain the infrastructure. To respond to and manage that imbalance, NASA has implemented a strategy to reduce its infrastructure over time, eliminate facilities that it no longer needs, consolidate capabilities when it makes sense, and make focused investments in critical capabilities.

NASA's demolition and disposal program has reduced NASA's total square footage by 449,200 square feet in the last three years. During the last three years, NASA has eliminated $66.7 million in deferred maintenance through demolition. In the last seven years, NASA has disposed of four sites (Palmdale Orbiter Processing Site, Camp Parks, White Sands Space Harbor, and Glenn Research Center North Campus). NASA continues to work to dispose of the Santa Susana Field Lab and Crows Landing sites. Toward that effort, NASA has demolished more than 30 structures at Santa Susana and 27 structures at Crows Landing.

NASA has shifted from managing demolition through annual plans to managing against a five-year reduction plan. As NASA has implemented managing to five-year reduction plans, NASA has become more aggressive in its downsizing. In 2015, NASA's five-year disposal plan indicated that NASA would reduce infrastructure by 1.5 percent over a five-year period. NASA's 2017 disposal plan indicates that NASA expects to reduce its infrastructure by 4 percent over the next 5 years. This year, NASA established 25 percent infrastructure reduction as the Agency's planning goal over 20 years. This planning goal will be incorporated into future master plans. The reduction goal will increase the emphasis on infrastructure reduction and drive the infrastructure sustainment requirements to a size that is in line with estimated funds availability.

Although 80 percent of NASA's infrastructure is 40 or more years old, NASA's investments in replacing old buildings with new efficient buildings, renewing or refurbishing serviceable buildings, and demolishing old, un-needed buildings has helped to stem the tide. The trend of obsolescence (percentage of facilities more than 40 years old) was increasing through 2010, but over the past few years has not increased. In the 2017 facilities assessment, NASA's overall facilities condition improved from 3.7 to 3.8, on a 5-point scale. The assessment team concluded that investments in the areas of

"Repair by Replacement" and demolition are providing the intended results of improving facility condition and reducing deferred maintenance.

To reduce the risk from unexpected infrastructure failures, NASA is focusing on unscheduled maintenance and implementing strategies to reduce unscheduled maintenance. NASA continues to invest in remote sensing and assessment technologies to improve reliability of facilities systems while improving the efficiency of maintaining facilities systems. NASA is investing in remote monitoring by including the technology in new construction and by installing the technology during retro-commissioning of existing buildings, when practical. The emphasis on improving planned and programmed maintenance has resulted in reductions in NASA's unscheduled maintenance ratio (Unscheduled Maintenance Expenditures/Total Maintenance Expenditures). In 2017, seven of ten Centers reduced their unscheduled maintenance from 2016 levels, reducing the risk of unexpected failures at critical times. Overall, the Agency has reduced unscheduled maintenance from 31.5 percent in 2015 to 30.3 percent in 2017.

To improve management of pressure systems, NASA has revised its standard for pressure systems, evaluated management of relief devices, set minimum requirements for pressure systems managers, conducted corrosion assessments of pressurized systems, and implemented purchase controls. NASA is implementing a database management system at one Center and has adjusted resources for managing pressurized systems at another Center. NASA also continues to monitor the areas of concern raised by the OIG in a 2013 explosives safety program audit to ensure the continued effective management of the program.

NASA's Technical Capabilities Assessment Team (TCAT) studies resulted in NASA establishing a new more centralized model for managing its technical capabilities. The NASA Technical Capability Leadership model provides cross-Agency reviews of capabilities, allowing NASA to identify redundancies or capabilities that are obsolete. Since the implementation of the new management model and the establishment of capability management offices such as the Space Environments Testing Management Office (SETMO), NASA has made the following progress consolidating space environmental testing capabilities: ten assets demolished, four assets excessed, and an additional six assets added to the demolition program. In 2017, NASA completed a significant technical capability consolidation effort with the demolition of the Atmospheric Re-entry Materials and Structures Evaluation Facility (ARMSEF) at Johnson Space Center (JSC). The demolition of the JSC ARMSEF was the final phase of a five-year effort to consolidate all atmospheric re-entry materials testing at Ames Research Center. Consolidation of atmospheric re-entry materials testing eliminated $1.5 million in deferred maintenance at JSC and consolidated this critical technical expertise at one site.

NASA has diligently responded to each of the fifteen OIG reports related to infrastructure challenges published over the last seven years. NASA has completed actions on all, but two OIG recommendations from reports published prior to 2017. NASA is currently developing new policy for managing technical capabilities to close the remaining two recommendations.

5. Contracting and Grants Process

NASA appreciates the investigative and audit work cited by the OIG and acknowledges the importance of this effort, particularly where fraud is uncovered and process improvements can be made.

NASA continues to strengthen and improve contracting and grants processes throughout the Agency. NASA continues to strengthen its award fee process through training and the issuance of an updated NASA Award Fee Guide. We believe NASA's approach to award fee is sound and compliant with the Federal Acquisition Regulation and related statute. We continue to strengthen the management of grants through our issuance of revisions to the NASA Grant and Cooperative Agreement Manual as well as updates to our financial assistance forms, which ensured compliance with the requirements of 2 CFR 200, Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards.

If you have any questions regarding NASA's response to the 2017 Top Management and Performance Challenges, please contact Paul Roberts, Audit Liaison Program Manager, on (202) 358-2260.

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