NASA OFFICE OF INSPECTOR GENERAL

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

November 15, 2016

TO: Charles F. Bolden, Jr.
Administrator

SUBJECT: *2016 Report on NASA's Top Management and Performance Challenges*

Dear Administrator Bolden,

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 2016 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.

In addition to addressing these ongoing issues, the year ahead also includes the challenge of preparing for a leadership transition following the presidential election. As history has shown, changes in administrations can lead to great uncertainty about Agency programs, which can be particularly challenging for an agency like NASA that must plan its projects and missions years in advance. Abrupt changes in direction such as the 2009 cancellation of the previous Administration's human spaceflight program resulted in significant challenges for management while decision makers crafted compromise exploration plans.

Consequently, the challenge for NASA during the forthcoming transition will be to move forward on its ongoing projects and missions while retaining the flexibility to adapt to changes in direction from new leadership.

Looking to 2017, we identified the following as the top management and performance challenges facing NASA:

- Positioning NASA for Deep Space Exploration
- Managing the International Space Station and the Commercial Cargo and Crew Programs
- Managing NASA's Science Portfolio
- Overhauling NASA's Information Technology Governance
- Securing NASA's Information Technology Systems and Data
- Addressing NASA's Aging Infrastructure and Facilities
- Ensuring the Integrity of the Contracting and Grants Processes
- Ensuring the Continued Efficacy of the Space Communications Networks

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

cc: Dava Newman
Deputy Administrator

Robert Lightfoot
Associate Administrator

Lesa Roe
Deputy Associate Administrator

Michael French
Chief of Staff

Enclosure – 1

NASA's Top Management and Performance Challenges, November 2016

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:

- Positioning NASA for Deep Space Exploration
- Managing the International Space Station and the Commercial Cargo and Crew Programs
- Managing NASA's Science Portfolio
- Overhauling NASA's Information Technology Governance
- Securing NASA's Information Technology Systems and Data
- Addressing NASA's Aging Infrastructure and Facilities
- Ensuring the Integrity of NASA's Contracting and Grants Processes
- Ensuring the Continued Efficacy of the Space Communications Networks

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; its susceptibility to fraud, waste, and abuse; and the Agency's progress in addressing it. The challenges described in this report track, in most major respects, those we identified in our November 2015 report, and like last year, are not listed in priority order.

Positioning NASA for Deep Space Exploration

NASA's long-term objective for its human exploration program is a crewed mission to Mars. To meet this challenging goal, the Agency must develop more sophisticated rockets, capsules, and related hardware, as well as strategies to mitigate the risks posed by radiation and other space-induced hazards that could prevent astronauts from performing their missions or affect their mental and physical health. Successful development of the Space Launch System (SLS), the Orion Multi-Purpose Crew Vehicle (Orion), and launch infrastructure under development by the Agency's Ground Systems Development and Operations (GSDO) Program are among the projects critical to achieving NASA's human exploration goals beyond low Earth orbit.

Space Launch System

The NASA Authorization Act of 2010 directed the Agency to develop a Space Launch System as a follow-on to the Space Shuttle and prepare infrastructure at Kennedy Space Center (Kennedy) to enable processing and launch of the system as a key component in expanding human presence beyond low Earth orbit.[1] To fulfill this direction, NASA established the SLS, Orion, and GSDO programs. The Agency plans to develop three progressively more powerful SLS launch vehicles and the Orion capsule to transport humans and

[1] The National Aeronautics and Space Administration Authorization Act of 2010, Pub. L. No. 111-267, 124 Stat. 2805.

cargo into space and has committed to a launch readiness date for the first test flight of the SLS-Orion combination no later than November 2018, with the first crewed flight expected no later than 2023. NASA is using the Space Shuttle's main engine to power the SLS and 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 and use an interim cryogenic propulsion stage to propel Orion around the Moon on Exploration Mission-1 (EM-1) in 2018. Later versions of the SLS will be designed to lift 130-metric tons and incorporate an upper stage to travel to deep space.

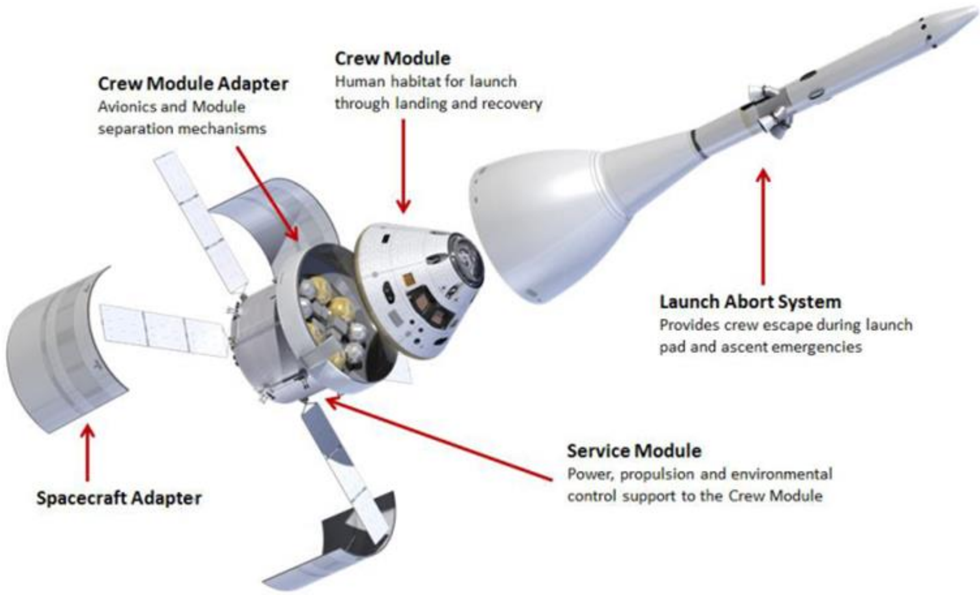
In July 2016, the Government Accountability Office (GAO) reported that the SLS Program has made solid progress in resolving several technical issues and maturing the design of the launch system. However, the Program's management of risks such as late delivery of core stage components and development of flight software coupled with the upcoming integration and test phase has put pressure on the Program's cost and schedule reserves and therefore threatened the November 2018 launch readiness goal.[2] Further, unforeseen technical challenges are likely to arise once the Program reaches final integration and integration with its companion programs – challenges that are likely to place further pressure on the SLS Program's cost and schedule reserves.

Orion

Orion will be mounted atop the SLS and serve as the crew vehicle for up to four astronauts. Orion 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 (see Figure 1). NASA began developing Orion in 2006 as part of the Agency's Constellation Program and had spent about $3.7 billion on the effort when the Constellation Program was cancelled in 2010. Since then, NASA has spent about $1 billion annually, or about 6 percent of its overall budget, on the Orion Program. According to current estimates, the Agency will have devoted approximately $17 billion to the Program by the time Orion makes its first crewed flight in April 2023.

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

Figure 1: Orion Components



Source: NASA.

As of late 2016, NASA had completed one mission and planned three additional missions for Orion:

- *Exploration Flight Test-1*, an uncrewed mission in December 2014 on a Delta IV rocket.
- *EM-1*, a 22- to 25-day uncrewed lunar orbit mission scheduled for September 2018 that will be the first launch of the combined SLS-Orion system.
- *Ascent Abort Test 2*, scheduled for December 2019 when NASA plans to launch a mock-up of Orion to test its launch abort and other systems
- *Exploration Mission-2 (EM-2),* the first crewed flight for the combined system to lunar orbit with a promised launch no later than April 2023. However, the Orion Program has been working toward an August 2021 launch date for EM-2 in an effort to reduce costs.

In an September 2016 audit, we reported the Orion Program met several key development milestones on the path to EM-2 but much work remains, including evaluating options related to the delayed delivery of the service module being developed by the European Space Agency (the European Service Module); continuing mitigation for seven critical risks while operating with a less-than-optimal budget profile for a developmental project; addressing a potential shortfall of $382 million in reserves managed by prime contractor Lockheed Martin Corporation; and successfully launching and recovering EM-1 after its test flight.[3] At the same time, Program officials are working toward an optimistic internal launch date of August 2021 for EM-2 – a date 20 months earlier than the Agency's external commitment date of April 2023. We noted our concern that such an approach, particularly given the Program's flat budget profile, has led the Program to defer addressing several technical tasks to later in the development cycle, which in turn could delay the Program's schedule, increase costs, and negatively affect safety.

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

Over its life, the Orion Program has experienced funding instability both in terms of overall budget amounts and the erratic timing of receipt of its annual appropriation. The most effective budget profile for complex space system development programs provides steady funding in the early stages and increased funding during the middle stages of development. In contrast, the Orion Program's budget profile through at least 2018 has been nearly flat. Program officials acknowledged this funding trajectory increased the risk that costly design changes may be needed in later stages of development. In addition, they noted that receiving funding between 4 and 8 months after the start of fiscal years (FY) 2012 through 2016 affected their ability to perform work as planned.

We also found Lockheed Martin is expending funds at a higher rate than both the Orion Program and the company expected and that, if continued, would deplete its management reserve account almost a year before the planned launch of EM-1. Although Program officials acknowledged the current depletion rate is high, they believe it unlikely the company will continue to draw at that rate and noted that, if the reserve is depleted before the EM-2 launch, Lockheed could cover the costs or NASA could draw on other Agency funds. In our judgment, Orion Program managers would be better informed by formally addressing Lockheed's use of the management reserve as a Program cost risk.

To improve the likelihood Orion is safely operated and developed on cost and schedule, we made four recommendations to NASA in our audit, including reevaluating the internal launch readiness dates for EM-1 and EM-2. NASA concurred with all four recommendations.

Ground Systems Development and Operations Program

NASA's GSDO Program is modifying infrastructure at Kennedy formerly used for the Space Shuttle to prepare for launch of the SLS and 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, and Launch Pad 39B. In 2015, we reported GSDO had made steady progress on the major equipment and facilities modernization initiatives needed to launch SLS and Orion, but significant technical and programmatic challenges originating primarily from interdependencies between the GSDO, SLS, and Orion programs remained before NASA could meet a November 2018 launch date.[4] Similarly, GAO reported in July 2016 that although the Program is making progress in modifying selected facilities and equipment to support SLS and Orion, it is encountering technical challenges that require time and money, which in turn has reduced cost and schedule reserves that threaten the November 2018 launch readiness goal.[5]

As a follow-up to our 2015 report on the GSDO Program, we examined in depth NASA's management of the Program's software development effort known as the Spaceport Command and Control System (SCCS). SCSS 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 launch. To develop the SCCS, NASA is writing a large amount of computer code to "glue" together multiple existing software products or, in some cases, the parts of those products the Agency deems most effective for its purposes. In the past, NASA has experienced difficulties with similar large, complex software development efforts. For example,

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4 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).

5 GAO-16-612.

between 1995 and 2002 the Agency spent more than $500 million on two separate attempts to update command and control software at Kennedy, both of which failed to meet their objectives and were substantially scaled back or cancelled prior to completion.

In a March 2016 audit, we reported the SCCS development effort had significantly exceeded its initial cost and schedule estimates.[6] 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. In addition, several planned capabilities had been deferred because of cost and timing pressures, including the ability to automatically detect the root cause of specific equipment and system failures, without which it will be more difficult for controllers and engineers to quickly diagnose and resolve issues. Although NASA officials believe the SCCS will operate safely without these capabilities, they acknowledge the reduced capability could affect the ability to react to unexpected issues during launch operations and potentially impact the launch schedule for the combined SLS-Orion system.

The root of these issues largely stem from NASA's implementation of a June 2006 decision to integrate multiple products or, in some cases, parts of products rather than developing software in-house or buying an off-the-shelf product. Writing computer code to "glue" together nine disparate products turned out to be more complex and expensive than anticipated. As of January 2016, Agency personnel had developed 2.5 million lines of "glue-ware" with almost two more years of development activity planned. In comparison, NASA re-engineered the Hubble Space Telescope command and control system by integrating 30 products with approximately 500,000 lines of "glue-ware" code.
We noted that NASA's 2006 decision may no longer be the most prudent course of action given significant advances in commercial command and control software over the past 10 years. For example, the two companies under contract with NASA to deliver supplies to the International Space Station (ISS or Station) – Orbital Sciences Corporation (Orbital) and Space Exploration Technologies Corporation (SpaceX) – both use commercial command and control software products. Therefore, we recommended NASA commission an independent assessment to evaluate the status of the SCCS software development effort and determine the steps needed to reduce the risk of further cost, schedule, and performance issues, including consideration of acquiring commercial command and control software to replace some or all of the system currently under development. NASA agreed to take this step once software for EM-1 is successfully delivered, which is currently expected in early 2017.

Management of Health and Human Performance Risks

Apart from the tremendous engineering challenges in launching and returning astronauts safely to Earth, humans living in space experience a range of physiological changes that can affect their ability to perform necessary mission functions and, in the long term, lead to cancers, damaged vision, reduced bone strength, and other harm to their health and wellbeing. Although NASA has developed mitigation strategies to reduce the impact of most of the risks associated with travel in low Earth orbit, the Agency's plans to send humans deeper into space for extended periods of time will expose astronauts to new and increased physical and psychological hazards.

In October 2005, NASA established the Human Research Program to focus Agency research investment on investigating and mitigating the highest risks to astronaut health and performance. The Program conducts basic, applied, and operational research with the goal of increasing understanding of and

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

developing countermeasures for 23 of the 30 human health and performance risks and the 2 "concerns" NASA has identified.[7] In 2014, the Program completed a detailed schedule known as the Path to Risk Reduction outlining a strategy for how it plans to develop countermeasures for the 23 risks. In February 2015, the Program reported that the majority of risks for ISS missions up to a year in duration could be mitigated to an acceptable level; however, more than half of the risks for a 3-year planetary mission, such as a trip to Mars, remain unmitigated.

In an October 2015 audit, we examined NASA's efforts to manage the health and human performance risks posed by space exploration.[8] Although the Agency continues to improve its process for identifying and managing health and human performance risks associated with space flight, we believe that given the current state of knowledge NASA's risk mitigation schedule is optimistic and the Agency will not develop countermeasures for many deep space risks until the 2030s at the earliest. Moreover, the Agency may be unable to develop countermeasures that will lower the risk to deep space travelers to a level commensurate with Agency standards for low Earth orbit missions. Accordingly, the astronauts chosen to make at least the initial forays into deep space may have to accept a higher level of risk than those on missions to the ISS. We also found that NASA cannot accurately report the true costs of developing countermeasures for the identified risks.

Furthermore, NASA's management of crew health risks could benefit from increased efforts to integrate expertise from all relevant disciplines. While many life science specialists attempt to utilize the range of available expertise both inside and outside the Agency, NASA lacks a clear path for maximizing expertise and data at both the organizational and Agency level. For example, NASA has no formalized requirements for integrating human health and research among life sciences subject matter experts, nor does the Agency maintain a centralized point of coordination to identify key integration points for human health. Moreover, integrating the experiences of NASA's engineering and safety efforts would benefit the outside life sciences community. The lack of a coordinated, integrated, and strategic approach may result in more time consuming and costly efforts to develop countermeasures to the numerous human health and performance risks associated with deep space missions.

According to NASA's Space Flight Human System Standards, the human system should be viewed as an integral part of overall vehicle design. In other words, the standards of the human system should be centrally incorporated into vehicle design, mission architecture, countermeasures, and research. Several senior Agency officials we met with noted that although NASA has traditionally and successfully operated with a vehicle-centered design focus, a shift to a more human-centered design is necessary for missions to Mars and other distant exploration goals. While Agency officials agreed that a shift in the Agency's focus is required, they offered little insight into how NASA would effectively utilize human-centered design in mission planning and vehicle design.

In order to ensure NASA management has the best possible information available to make decisions related to human health and performance risks to Agency missions, we made six recommendations, including that the Path to Risk Reduction accurately reflect the status of research and realistic timeframes for countermeasure development. As of September 2016, NASA had implemented all six recommendations.

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7 "Concerns" are issues the Agency has not yet accepted as risks.

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

Managing the International Space Station and the Commercial Cargo and Crew Programs

In November 2015, NASA formally extended the life of the ISS through 2024, ensuring this unique facility, which has operated in low Earth orbit for more than 15 years, remains available to support research into the development of new exploration technologies and ways to mitigate the dangers posed by deep space travel.[9] A critical component of sustaining the ISS is ensuring safe and reliable transportation of cargo and crew to and from the Station.

International Space Station

The result of an international effort to build and operate a permanently crewed space station, the ISS is a groundbreaking technological achievement and a key part of NASA's plans to send humans to Mars. Specifically, the Agency utilizes the ISS as a research platform to develop countermeasures to mitigate a variety of risks associated with human travel and long-term habitation in space. The Station also serves as a laboratory for NASA and other Government agencies and private entities to conduct scientific research in areas such as medicine, robotics, manufacturing, and propulsion.

With its plan to continue Station operations into the next decade, NASA must ensure a spacecraft originally designed and tested for a 15-year life span will continue to operate safely and as economically as possible. Moreover, as it works toward sending astronauts deeper into space for extended periods of time, NASA must continue to be strategic in utilizing the Station's limited research capabilities. The United States has invested more than $84 billion in the ISS over the last 23 years.[10] 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 to increase to $3.8 billion by 2021. As we reported in 2014, we believe this estimate is based on overly optimistic assumptions and that actual costs are likely to be higher.[11]

A significant amount of research aboard the ISS is related to understanding and mitigating the health and performance risks associated with human space travel. According to our October 2015 report, as of June 2015 NASA's Human Research Program was managing 25 such risks, including inadequate food and nutrition and radiation exposure.[12] The Station is a platform for research geared toward mitigating many of these risks, including validating effective countermeasures against bone loss and testing new technologies to overcome the challenges associated with preventing, diagnosing, and treating medical conditions during long-duration, exploration missions. However, even after extending Station operations until 2024, NASA will be unable to mitigate several known risks. Accordingly, the Agency needs to prioritize its research to address the most important risks in the time available.

Since late 2011, the Center for the Advancement of Science in Space (CASIS) has managed non-NASA research aboard the ISS under a cooperative agreement with the Agency. Pursuant to this agreement, NASA provides CASIS $15 million annually and expects the organization to raise additional funds from

[9] 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 is expected to be fully complete by June 2018.

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

[11] NASA OIG, "Extending the Operational Life of the International Space Station until 2024" (IG-14-031, September 18, 2014).

[12] IG-16-003.

private entities as part of its efforts to encourage companies to self-fund research on the Station. In an April 2015 assessment of the group's activities, the GAO reported CASIS needs to establish better metrics for measuring program performance, including measurable targets.[13] In early 2016, the NASA Advisory Council recommended the Agency conduct an internal evaluation of its "top priority research directly related to the journey to Mars" and determine whether resources such as crew time and transportation of research materials associated with non-NASA research on the Station could be reallocated to advance that journey. We plan to initiate a follow-up review in FY 2017 examining ISS utilization that will include an assessment of CASIS and its efforts to spur private research on the Station.

While the amount of research being conducted on the ISS has increased over the past 6 years, several factors continue to limit full utilization. Most pointedly, 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.[14] Moreover, the failures of two commercial resupply missions – a SpaceX mission in June 2015 and an Orbital mission in October 2014 – have led to compressed launch schedules in FYs 2016 and 2017, with 11 cargo resupply missions in addition to 7 Russian cargo missions and 1 Japanese cargo mission scheduled to arrive at the Station. In mid-2014, NASA astronauts were spending as much as 44 hours per week on research-related activities. While NASA officials stated that the number of research hours will not fall below the 35-hour per week minimum, the total time devoted to research may decrease from 2014 levels due to the time astronauts will spend receiving, unpacking, and repacking cargo vehicles.

Commercial Transportation to the ISS

For many years, NASA used the Space Shuttle to ferry astronauts and materials to the ISS. With the Shuttle's retirement in 2011, NASA has invested in a different model for transporting cargo and crew to the ISS by working with U.S. corporations to develop privately owned and operated 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.

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.[15] 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

[13] GAO, "International Space Station: Measurable Performance Targets and Documentation Needed to Better Assess Management of National Laboratory" (GAO-15-397, April 27, 2015).

[14] 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.

[15] NASA also 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 to the ISS in July 2014.

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 and disposal of waste (downmass) to Earth.[16]

NASA subsequently extended SpaceX's contract into 2018 and issued task orders for 8 additional flights for a total of 20 missions. Similarly, Orbital's contract has been extended into 2018 with 3 additional flights for a total of 11 missions.[17] As of July 2016, Orbital had received $2.2 billion and SpaceX $1.9 billion from NASA under the CRS-1 contract.

Both companies have experienced launch failures. 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 all 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 2016, had completed two successful missions since using an Atlas V launch vehicle and its Cygnus capsule. Orbital is planning to use its redesigned Antares rocket for its next mission anticipated in October 2016.

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 a total loss of all cargo aboard. Like Orbital, SpaceX suspended resupply missions until completion of an investigation and acceptance by NASA of a Return to Flight Plan.[18]

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.[19] Although this was not a NASA mission, because of its contracts with SpaceX to deliver cargo and eventually crew to the ISS, NASA needs to understand the cause of the mishap and ensure the company takes appropriate steps to prevent similar incidents in the future. Accordingly, NASA is both participating in the company's investigation and conducting its own independent review of the failure. As of September 2016, neither SpaceX nor NASA had announced the results of their reviews or the date when SpaceX plans to resume commercial and NASA launches.

While SpaceX completes the processes necessary to return to flight, supplies and experiments will be ferried to the ISS by Orbital and Japan's H-2 Transfer Vehicle. In August 2016, the Japanese space agency announced the H-2 launch scheduled for October 1, 2016, would be delayed because of an air leak in the spacecraft. Moreover, until SpaceX resumes flights, NASA will lack the capacity to return experiments and other items to Earth, as the company is the only provider with downmass capability.

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[16] 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.

[17] As a result of these additional missions, contract values increased to more than $2 billion for each company.

[18] In addition to the Orbital and SpaceX failures, a Russian Progress cargo mission failed to reach the ISS in April 2015.

[19] 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.

In September 2015, we examined the effects of the Orbital failure on resupply of the ISS, finding Orbital's Return to Flight Plan contained technical and operational risks. 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.[20]

In June 2016, we issued a similar examination of the SpaceX cargo failure. 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 earlier SpaceX missions, a Japanese cargo flight, and six Russian flights, thereby reducing the total upmass shortfall from 3.48 to 2.63 metric tons.[21]

The most significant item lost during the SPX-7 mishap was the first of two Docking Adapters necessary to support upcoming commercial crew missions. Although NASA had planned to have two adapters installed on the Station before the first commercial crew demonstration mission scheduled for May 2017, it is now likely there will be only one installed in time for these missions. 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 are scheduled to begin in late 2018.

We also found NASA effectively managed its commercial resupply contract with SpaceX to reduce cost and financial risk by taking advantage of multiple mission pricing discounts and negotiating equitable adjustments of significant value to the Agency. However, NASA did not fully utilize the unpressurized cargo space available in the Dragon 1 capsule trunk for the first seven cargo missions, averaging 423 kg for SPX-3 through SPX-7 when the trunk is capable of carrying more. The ISS Program noted that unpressurized payloads depend on manifest priority, payload availability, and mission risk, and acknowledged it struggled to fully utilize this space on early missions. As of June 2016, Agency cargo manifests show full trunks on all future SpaceX cargo resupply missions.

Our report also examined the Agency's risk management approach for commercial cargo launches, which deviates from existing procedures for evaluating launch risks. In practice, NASA has treated all commercial resupply missions as the lowest level risk classification irrespective of the cargo's value and relies primarily on its commercial partners to evaluate and mitigate launch risks. As a result, risk mitigation procedures are not consistently employed and the subjective launch ratings the Agency uses provide insufficient information to NASA management concerning actual launch risks. Finally, we noted NASA does not have an 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.

In January 2016, NASA awarded the second round of CRS (CRS-2) contracts to Orbital, SpaceX, and the Sierra Nevada Corporation (Sierra Nevada). The maximum combined potential value of the CRS-2 contracts is $14 billion with a period of performance from 2016 through 2024.[22] NASA is expected to order a minimum of six missions from each provider at fixed prices with specified cargo amounts and

[20] 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).

[21] NASA OIG, "NASA's Response to SpaceX's June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station" (IG-16-013, June 28, 2016).

[22] The first CRS-2 missions are expected in 2019.

performance dates based on the Station's needs. SpaceX and Orbital will continue to fly capsule designs similar to those used under their CRS-1 contracts while Sierra Nevada will use its Dream Chaser, a winged vehicle that resembles a mini Space Shuttle and, like the Shuttle, launches aboard a rocket but glides back to Earth to land on a runway.

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 ranging from $21 million to $82 million per roundtrip. Prior to the end of the Shuttle Program, NASA began working with several U.S. companies to develop the capability to provide safe, reliable, and cost-effective crew transportation to and from the ISS and low Earth orbit. The goal of the Commercial Crew Program is to foster an industry that would meet the Agency's transportation needs as well as those of other Government and nongovernmental entities.

As of May 2016, NASA had spent approximately $3.4 billion on the Commercial Crew Program. The final phase of the effort began in September 2014 when NASA awarded SpaceX and The Boeing Company (Boeing) firm-fixed-price contracts to complete development of their crew transportation systems and, assuming they meet the Agency's safety and performance requirements, receive certification to begin flying astronauts to the ISS on a regular basis.

While NASA imposed the same design requirements on both contractors, Boeing and SpaceX were permitted to establish additional milestones and target completion dates to meet both those requirements and the needs of their individual programs. As such, the contractors have different approaches to developing and launching crewed missions. Boeing plans to use a United Launch Alliance Atlas V launch vehicle to carry its CST-100 Starliner capsule to the ISS. The Atlas V has a long history of successful uncrewed launches – 64 between August 2002 and July 2016, including Orbital cargo missions to the ISS in December 2015 and March 2016. Boeing plans to launch from Cape Canaveral Air Force Station's Space Launch Complex 41 and is assembling and processing the Starliner at the Kennedy Space Center's Commercial Crew and Cargo Processing Facility, which NASA used for 20 years to process the Space Shuttle between flights.

Boeing's Launch Site at Cape Canaveral Air Force Station

Source: NASA.

SpaceX plans to launch its Crew Dragon capsule on the Falcon 9, a rocket of its own design and manufacture. Although a relative newcomer to the rocket industry, SpaceX made 27 successful launches between June 2010 and July 2016, including 8 cargo resupply trips to the ISS, with only 1 failure.[23] SpaceX is modifying a former Space Shuttle launch pad at Kennedy to accommodate launches of its Falcon 9/Crew Dragon combination. Although both companies are designing their capsules to carry up to seven crew members (or the equivalent combination of crew and cargo), the vehicles will use different landing approaches, with Boeing planning to land on a dry surface and SpaceX, at least initially, planning a water-based landing.

SpaceX Launch Site at the Kennedy Space Center

Source: SpaceX.

We first reported on the status of and challenges facing the Commercial Crew Program in November 2013.[24] At that time, we noted the Program had received only 38 percent of its requested funding for FYs 2011 through 2013, and as a result NASA had delayed the first crewed mission to the ISS from 2015 to at least 2017. We also reported that although Boeing and SpaceX were making steady progress in the initial stages of development, the Program faced several obstacles, including an unstable funding stream, aligning cost estimates with Program schedule, providing timely requirement and certification guidance to Boeing and SpaceX, and coordinating with other Federal agencies that have a stake in manned space flight. We concluded that failure to address these challenges in a timely manner could significantly delay the availability of commercial crew transportation services and extend U.S. reliance on the Russians.

In a follow-up audit issued in September 2016, we reported 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.[25] While past funding shortfalls have contributed to the delay, technical challenges with the contractors' spacecraft designs are now driving schedule slippages. For Boeing, these include issues relating 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 that could further delay vehicle certification. While NASA has a goal of

[23] As noted previously, SpaceX suffered a second failure in September 2016 as it was preparing a mission for a commercial client.

[24] NASA OIG, "NASA's Management of the Commercial Crew Program" (IG-14-001, November 13, 2013).

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

completing its review within 8 weeks of receiving a hazard report, the contractors told us this process can take as long as 6 months. We also found that NASA does not monitor the overall timeliness of its safety review process.

Given delays in the Commercial Crew Program, NASA has extended its contract with the Russian Space Agency for astronaut transportation through 2018 at a cost of $490 million, or $82 million each, for six seats. 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.

Managing NASA's Science Portfolio

With a relatively constant annual budget averaging approximately $5 billion since FY 2009, NASA's Science Mission Directorate (SMD) oversees more than 100 projects and programs in various phases of development and operation. The selection and balance of NASA's science missions is heavily influenced by stakeholders external to the Agency. The science community – as represented by the National Research Council (NRC) – establishes mission priorities based on a broad consensus within various science research disciplines.[26] Additional stakeholders include the President, Congress, and other Federal and international agencies.

For the most part, NASA develops its SMD portfolio based on priorities set forth in the NRC's decadal surveys on the subject matter areas covered by the SMD's four divisions: Astrophysics, Earth Science, Heliophysics, and Planetary Science. Each survey lists the NRC's recommendations by priority order (e.g., the 2007 Earth Science Decadal Survey grouped missions by Tier 1 through Tier 3, with Tier 1 being the highest priority).

Although NASA is addressing the NRC's top priorities in each of the science disciplines, past surveys generally underestimated the cost of recommended missions and overestimated the amount of money NASA would have to dedicate to them. For example, in the 2007 Earth Science Decadal Survey the NRC recommended four Tier 1 missions for launch by 2013.[27] However, NASA has launched only one of these missions – the Soil Moisture Active-Passive mission in January 2015. Of the remaining three, the next planned launch is the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) in late 2017. Similarly, although the 2010 Astrophysics Decadal Survey recommended launch of the Wide Field Infrared Survey Telescope launch by 2020, NASA's FY 2017 budget request supports a launch schedule no earlier than 2025.[28]

In addition to Decadal Surveys, NASA also receives input on science priorities from Congress. For example, the 2016 Consolidated Appropriations Act directed NASA to spend $175 million in FY 2016 to develop a mission to Europa, a moon of Jupiter, when the Agency had requested only $30 million for the mission that year.[29] Further, although NASA study teams had determined that a "fly-by" mission of Europa could accomplish 80-90 percent of the science that an orbiter mission would achieve for about

[26] 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.

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

[28] NRC, "New Worlds, New Horizons in Astronomy and Astrophysics," 2010.

[29] Public L. No. 114-113, Consolidated Appropriations Act of 2016, December 18, 2015.

50 percent of the cost, the Act directed NASA to fund an orbiter and lander. In addition, the Act directed both the exact launch vehicle and timetable – specifically, the SLS rocket (currently under development) and a launch date no later than 2022.

NASA works collaboratively with foreign space agencies on many of its science projects and in 2016 was managing more than 750 international agreements with 125 different countries, approximately half related to science. For example, the Global Precipitation Measurement (GPM) mission is an international network of satellites designed to measure precipitation in the Earth's atmosphere. While the primary GPM spacecraft launched in February 2014 to provide a reference standard for precipitation measurements from space was developed by NASA and the Japanese space agency, the space agencies of several other countries, including France and India, launched research satellites as part of the mission.

In a May 2016 audit, we reported NASA faces significant challenges when using international partnerships and discussed the potential impacts when partners do not meet expectations.[30] First, the process of developing agreements with foreign space agencies requires approval from the Department of State, which often takes many months if not years to obtain. Second, U.S. export control regulations can hinder dialogue between NASA and its partners, causing frustration with project planning and implementation and reducing the competitiveness of the U.S. space industry. Third, the lack of strong, centralized international space coordination groups and restrictions on the number of NASA employees who are permitted to attend international conferences make dialog between NASA and its partners more difficult. Finally, both the U.S. political process and geopolitical realities complicate NASA's efforts to expand international partnerships, particularly with the Russian and Chinese space agencies.

Similar to problems encountered with its space exploration programs, NASA has struggled to accurately estimate the amount of time and money required to complete its science projects. The resulting cost and schedule overruns have, in turn, led to challenges in the project development process, diverted funding from other projects, and reduced the number and scope of projects the Agency can undertake. The most prominent recent example of this phenomena is the James Webb Space Telescope (JWST), the largest project in SMD's portfolio. In 2011, NASA increased JWST's life-cycle budget from $4.96 billion to $8.84 billion and delayed its launch 4 years to October 2018. The following year, the Agency moved $156 million from other SMD projects and its Cross Agency Support account to help cover the cost increases. In the following section, we discuss JWST and two other projects with histories of cost growth and schedule slippage.

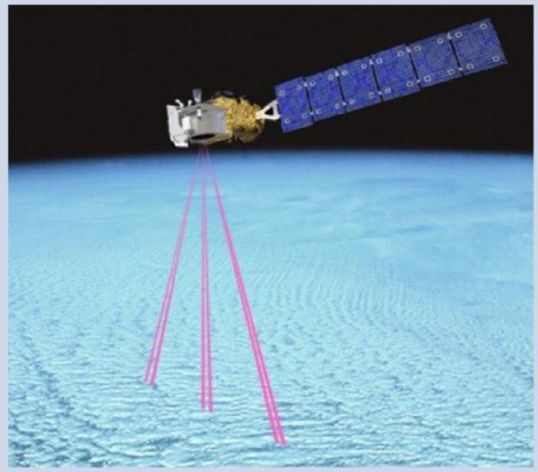
Ice, Cloud, and land Elevation Satellite-2

ICESat-2 is a satellite mission designed to provide the data necessary to determine ice sheet mass balance and track changes in such features as 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. The NRC recommended the mission in its 2007 Earth Science Decadal Survey, with a suggested launch in 2013.

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

In December 2012, NASA baselined ICESat-2with a life-cycle cost of $860 million and a launch date of May 2017.[31] However, managers underestimated the technical complexity of building the satellite's sole instrument – the Advanced Topographic Laser Altimeter System – and therefore significantly understated the cost of and schedule for the mission. In May 2014, NASA revised the baseline to reflect a $1.1 billion life-cycle cost and a planned launch date in June 2018. The funds for this 37 percent increase in costs have been drawn from other projects in the Earth Science Division portfolio. Since rebaselining, NASA has made significant progress and is now anticipating a launch in late 2017.

Artist's Rendering of ICESat-2



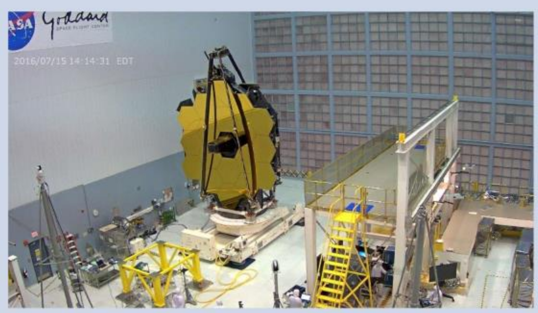
Source: NASA.

James Webb Space Telescope

The scientific successor to the Hubble 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 own solar system. The 2001 Astrophysics Decadal Survey identified JWST as its top priority for that decade.[32] However, 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, soon it became clear that neither that 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 the past year, including the installation of all 18 segments of the primary mirror at Goddard Space Flight Center, and remains within its revised baseline cost and schedule. However, manufacturing challenges related to the sunshield have delayed some integration and testing. In addition, major hardware deliveries expected this year are likely to strain the project's reserves.

Assembly of JWST



Source: NASA.

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

32 NRC, "Astronomy and Astrophysics in the New Millennium," 2001. Referred to at the time as the Next Generation Space Telescope.

Stratospheric Observatory for Infrared Astronomy

Over the past 7 years, we have twice reported on the developmental challenges facing NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) Program.[33] SOFIA is an airborne observatory designed to study the universe in the infrared region of the electromagnetic spectrum. Built within the frame of a Boeing 747SP, SOFIA contains an internally mounted 2.7-meter (approximately 9-foot) telescope – developed and provided by the German Aerospace Center – operators expose to the night sky while in flight through a uniquely designed door cavity located at the rear of the plane.[34] SOFIA is particularly well suited for investigating the origin of massive stars and the environment that leads to the formation of planets.

SOFIA in Flight

Source: NASA.

As early as 1998 – about 2 years into development – the SOFIA Program began to experience schedule delays and cost overruns. The 2001 Astrophysics Decadal expected SOFIA to be operational in 2002; however, by 2006 SOFIA had been in development for 10 years, was about 5 years behind schedule, and the prime contract value had increased by $217 million to approximately $528 million. NASA's FY 2007 budget request withheld funding from the Program pending an independent review. The review resulted in a major reorganization of the Program that required NASA to rebalance the astrophysics portfolio to accommodate SOFIA's nearly $3 billion life-cycle cost.

Less than 10 years after first proposing to cancel the Program and within months of reaching full operational capability, NASA proposed to greatly reduce funding for SOFIA in its FY 2015 budget request, intending to divert its $80 million annual operating budget to support other science missions. Within a year, however, Congress restored funding for SOFIA, again necessitating a replan of the Agency's science portfolio.

Joint Cost and Schedule Confidence Level Estimates

As discussed in last year's management challenges report, NASA has developed tools to help improve the fidelity of its cost and schedule estimates.[35] To this end, since 2006, NASA has incorporated progressively more sophisticated estimating techniques into Agency policy, culminating in 2009 with formal adoption of a Joint Cost and Schedule Confidence Level (JCL) requirement.

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[33] NASA OIG, "Final Memorandum on Audit of the Stratospheric Observatory for Infrared Astronomy (SOFIA) Program Management Effectiveness" (IG-09-013, March 27, 2009) and "SOFIA: NASA's Stratospheric Observatory for Infrared Astronomy" (IG-14-022, July 9, 2014).

[34] The Boeing 747SP is a modified version of the Boeing 747 jet airliner with a shortened fuselage making it lighter, thus permitting longer range and increased speed relative to other 747 configurations.

[35] NASA OIG, "2015 Report on NASA's Top Management and Performance Challenges" (November 5, 2015).

A JCL analysis generates a representation of the likelihood a project will achieve its objectives within budget and on time. The process uses software tools and models that combine cost, schedule, risk, and uncertainty to evaluate how expected threats and unexpected events affect a project's cost and schedule. To generate this data, project managers develop comprehensive project plans, inputs, and priorities that integrate costs, schedules, risks, and uncertainties.

We examined NASA's JCL process in a September 2015 report.[36] Based on our review of the 22 projects for which NASA had completed a JCL analysis since 2009 (combined price tag of more than $49 billion), we reported that JCL policy appeared to be having a positive impact on NASA's historical challenges with cost and schedule fidelity. That said, we noted the process is still relatively new and evolving and has inherent limitations in that, like any estimating practice, it does not fully address some of the root causes of NASA's project management challenges such as funding instability and underestimation of technical complexity, or the issue of predicting "unknown/unknowns."[37] For example, after the issuance of our September 2015 report, NASA announced it was delaying launch of the Interior Exploration using Seismic Investigations Geodesy and Heat Transport (InSight) when a leak in the primary instrument could not be repaired in time for the planned March 2016 launch.[38] The instrument, provided by France's Centre National d'Études Spatiales, is designed to measure ground movements as small as the diameter of an atom. NASA is now planning for a May 2018 launch date.

Overhauling NASA's Information Technology Governance

In 2016, NASA spent approximately $1.4 billion or 7.3 percent of its $19.3 billion budget on information technology (IT). 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. Indeed, 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.

IT governance is a process for designing, procuring, and protecting IT resources. Because IT is intrinsic and pervasive throughout NASA, the Agency's IT governance structure directly affects its ability to attain its strategic goals. For this reason, effective IT governance must balance compliance, cost, risk, security, and mission success to meet the needs of internal and external stakeholders. However, for more than 2 decades NASA has struggled to implement an effective IT governance approach that appropriately aligns authority and responsibility commensurate with the Agency's overall mission.

In June 2013, 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.[39] We found the decentralized nature of NASA's operations and its longstanding culture of autonomy hindered the Agency's 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,

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

[37] "Unknown/unknowns" are future situations that are impossible to predict.

[38] The mission is designed to investigate Mars' interior to increase understanding of how rocky planets formed and evolved.

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

and could not enforce security measures across NASA's computer networks. Moreover, the IT governance structure in place at the time was overly complex and did not function effectively. As a result, Agency managers tended to rely on informal relationships rather than formalized business processes when making IT-related decisions. While other Federal agencies were moving toward a centralized IT structure under which a senior manager has ultimate decision authority over IT budgets and resources, NASA continued to operate 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 Agency CIO. As a result, NASA's IT governance model weakened accountability and did not ensure that IT assets across the Agency were cost effective and secure.

To overcome the barriers that resulted in inefficient and ineffective management of the Agency's IT assets, we made a series of recommendations to overhaul NASA's IT governance structure by centralizing IT functions and establishing the Agency CIO as the top management official responsible for the Agency's entire IT portfolio. This would include empowering the CIO to approve all IT procurements over a monetary threshold that captures the majority of IT expenditures and making the CIO a direct report to the NASA Administrator. We also recommended the Administrator reevaluate the relevancy, composition, and purpose of NASA's primary IT governance boards in light of the changes made to the governance structure and require the use of reconstituted governance boards for all major IT decisions and investments. Finally, we recommended the NASA Administrator reevaluate the resources of the OCIO to ensure the Office has the appropriate number of personnel with the appropriate skills.

After issuance of our report, NASA established a Business Services Assessment to evaluate the health of and assess opportunities to achieve efficiencies and improve alignment for IT services. The group conducted assessments in six areas and, in May 2015, reported its findings to the Agency's Mission Support Council, which tasked the NASA CIO with developing a plan to respond to the recommendations.

By February 2016, we had closed the recommendations from our 2013 report based on actions NASA has taken as a result of the Business Services Assessment process. However, in March 2016 we opened a follow-up review to evaluate NASA's IT governance in light of the changes the Agency has made. As part of this review, we will examine aspects of NASA's implementation of the Federal Information Technology Acquisition Reform Act (FITARA), which aims to strengthen the role of Federal agency CIOs in overseeing IT investments, acquisitions, and programs. NASA was one of three organizations that received a failing score on its first FITARA score card, a government-wide effort to assess compliance with and performance in four key areas: (1) data center consolidation, (2) IT portfolio review savings, (3) incremental development, and (4) risk assessment transparency.

Securing NASA's Information Technology Systems and Data

NASA manages approximately 1,200 publicly accessible web applications, or about half of all publicly accessible, nonmilitary Federal Government websites.[40] Coupled with the Agency's statutory mission to share scientific information, the large number of networks and websites present unique IT security challenges. For FYs 2014 and 2015, NASA reported 3,044 computer security incidents related to malicious

[40] In 2014, we examined NASA's efforts to identify and 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 large target for hackers.

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. Moreover, NASA's vast connectivity with educational institutions, research facilities, and other outside organizations offers cybercriminals a larger target than most other Government agencies.

NASA must ensure that its IT systems and associated components are regularly safeguarded, assessed, and monitored to protect against inevitable attack. To assist in this effort, NASA completed a series of initiatives over the past 2 years, 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 the completion of these initiatives improves NASA's security posture, as we have reported in our last five annual evaluations, pursuant to the Federal Information Security Management Act NASA has yet to develop an Agency-wide risk management process specific to information security. Risk management is a comprehensive process that requires an organization to describe the environment in which risk-based decisions are made to access, respond to, and monitor risk over time, and ongoing monitoring is a critical part of an agency's risk management program.

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.[41] Specifically, NASA lacks an Agency-wide risk management framework for information security and an information security architecture. In our judgment, this condition exists because the OCIO has not developed an information security program plan to effectively manage its resources. In addition, the Office experienced a period of transition with different leaders acting in the Senior Agency Information Security Officer role, which caused uncertainty surrounding information security responsibilities at the Agency level. As a result, we believe NASA's information security program could be improved to more effectively protect critical Agency information and related systems.

In November 2015, we initiated a follow-up audit of NASA's use of cloud computing services, a subject we had reported on in 2013.[42] 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. However, effectively managing the delivery of cloud-computing services requires agencies to develop contracts that address business and security risks and provide a mechanism to monitor agency and cloud provider responsibilities. Because of the wide availability and ease of purchasing services from public cloud providers, a lack of organizational control

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

42 NASA OIG "NASA's Progress in Adopting Cloud-Computing Technologies" (IG-13-021, July 2013). We reported the Agency's IT governance and risk management practices impeded NASA from fully realizing the benefits of cloud computing and potentially placed at risk its information stored in the cloud.

over the acquisition of these services can create problems. For example, if cloud-computing services are acquired without proper approvals and oversight, vulnerable systems and sensitive information may be placed in the cloud environment, legal and privacy requirements may go unmet, and costs may quickly rise to unacceptable levels.

In our current audit, we are reviewing whether NASA has implemented Agency-wide plans, procedures, and controls to meet Federal and Agency IT security requirements to protect the confidentiality, integrity, and availability of NASA data maintained by cloud service providers. Moreover, in another ongoing audit we are examining the security of NASA's industrial control systems, which are involved in the operation of launch facilities, wind tunnels, rocket testing facilities, and other critical and supporting infrastructure assets identified by NASA. Specifically, we are reviewing whether NASA has implemented effective physical and logical security controls necessary to protect these systems against physical and cybersecurity threats.

In addition to our audit work, we expend substantial resources investigating IT security issues. OIG investigators have conducted more than 90 investigations of breaches of NASA IT networks over the past 5 years and helped to secure convictions of hackers operating from such wide-ranging locations as Australia, England, Italy, Nigeria, Portugal, Romania, and Turkey. For example, one investigation led to the identification, arrest, and extradition of a Nigerian national for charges related to aggravated identity and credit card theft. After extradition to New York from South Africa, the subject pled guilty to one count of conspiracy to defraud the Federal government and was sentenced to 42 months in prison, deported, and prohibited from reentering the United States. In another case, an Estonian national was sentenced in April 2016 to 7 years and 3 months imprisonment and ordered to forfeit $2.5 million for his role in a cybercriminal scheme that infected dozens of NASA computers and millions of computer systems worldwide.

Addressing NASA's Aging Infrastructure and Facilities

NASA controls approximately 5,000 buildings and structures with an estimated replacement value of about $34 billion, making the Agency one of the largest Federal Government property holders. However, more than 80 percent of the Agency's facilities are 40 or more years old and beyond their design life. While the Agency strives to keep these facilities operational, and when not operational, in sufficient condition so they do not pose a safety hazard, NASA has not been able to fully fund required maintenance for its facilities for many years. In 2016, NASA estimated its deferred maintenance costs at $2.4 billion.

We have dedicated substantial resources over the last 6 years exploring NASA's infrastructure challenges.[43] In doing so, we examined issues ranging from NASA's plans for specific test facilities such

[43] NASA OIG, "Audit of NASA's Requirements for Plum Brook Station" (IG-15-014, April 23, 2015); "Review of NASA's Pressure Vessels and Pressurized Systems Program" (IG-15-019, June 30, 2015); "NASA's Independent Verification and Validation Program" (IG-14-024, July 16, 2014); "Audit of NASA's Environmental Restoration Efforts" (IG-14-021, July 2, 2014); "NASA's Management of Energy Savings Contracts" (IG-13-014, April 8, 2013); "Review of NASA's Explosives Safety Program" (IG-13-013, March 27, 2013); "NASA's Environmental Remediation Efforts at the Santa Susana Field Laboratory" (IG-13-007, February 14, 2013); "NASA's Efforts to Reduce Unneeded Infrastructure and Facilities" (IG-13-008, February 12, 2013); "NASA's Plans to Modify the Ares I Mobile Launcher in Support of the Space Launch System" (IG-12-022, September 25, 2012); "NASA's Infrastructure and Facilities: An Assessment of the Agency's Real Property Leasing Practices" (IG-12-020, August 9, 2012); "NASA's Infrastructure and Facilities: An Assessment of the Agency's Real Property Master Planning" (IG-12-008, December 19, 2011); "NASA Infrastructure and Facilities: Assessment of Data Used to Manage Real Property Assets" (IG-11-024, August 4, 2011); "NASA's Hangar One Re-Siding Project" (IG-11-020, June 22, 2011); and "Audit of NASA's Facilities Maintenance" (IG-11-015, March 2, 2011).

as Plum Brook Station in Ohio, to management of its Pressure Vessels and Pressurized Systems Program and its Explosive Safety Program, to its environmental remediation efforts.[44]

In a February 2013 audit, we assessed NASA's efforts to reduce unneeded infrastructure and facilities and identified 33 facilities – wind tunnels, test stands, thermal vacuum chambers, airfields, and launch infrastructure – at NASA Centers across the country the Agency was not utilizing or for which NASA officials could not identify a future mission use and that cost the Agency more than $43 million to maintain in FY 2011 alone.[45] We recommended NASA complete a facilities review process begun the year before and ensure such a process was established in policy. We also recommended NASA develop a mechanism for communicating its decisions regarding disposition of facilities to outside stakeholders and implement changes to a NASA database integral to facility management.

In 2012, NASA embarked on an effort to strategically address the technical capabilities required to support current and future Agency goals. Referred to as the Technical Capabilities Assessment Team (TCAT) and championed by the NASA Associate Administrator, this effort sought to provide NASA leadership with detailed information to make informed decisions to ensure the Agency has the right mix of people and assets to carry out its multi-faceted mission. Personnel from NASA's Centers and Mission Directorates, as well as the senior managers responsible for executing the decisions, participated in the nearly 3-year process.

As an outgrowth of the TCAT process, in 2015 NASA established 32 Capability Leadership teams composed of senior technical leaders from the engineering, science, aircraft, and mission operations disciplines. These teams are responsible for continuously assessing their disciplines from an Agency-wide perspective to meet long-term needs, optimize deployment of capabilities across Centers, and transition capabilities no longer needed.

As of August 2016, TCAT and the Capability Leadership teams had assessed 32 technical capabilities, including mission operations, propulsion, and aircraft operations, and issued 36 formal decisions. As a result, the Agency divested 17 aircraft and 21 vacuum chambers, deactivated 1 propulsion test stand, eliminated internal microgravity flight operations, updated several internal memorandums of agreement, and consolidated research and development activities in areas such as propulsion and materials development. While the Agency has exhibited positive momentum in using these processes to evaluate and make decisions regarding its infrastructure and capabilities, we are reviewing the TCAT and Capability Leadership teams' work to assess whether the process will result in meaningful, long-term actions. We expect to issue our report in 2017.

Given the disparity between the Agency's infrastructure and its mission-related needs, as well as the likelihood of ongoing funding concerns, it is imperative NASA move forward aggressively with its infrastructure assessment and reduction efforts. To achieve this goal, the Agency will need to move away from its longstanding "keep it in case you need it" mindset and overcome historical incentives for the Centers to build up and maintain unneeded capabilities. In addition, NASA officials need to manage the concerns of political leaders about the impacts eliminating or consolidating facilities will have on Centers' missions, their workforces, and the local communities.

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[44] Pressure vessels and systems include storage tanks, cylinders, and piping that deliver compressed gas or liquid under significant pressure.

[45] IG-13-008.

Ensuring the Integrity of the Contracting and Grants Processes

Approximately 77 percent of NASA's $18 billion FY 2015 budget was spent on contracts to procure goods and services, and the Agency awarded an additional $905 million in grants and cooperative agreements. Accordingly, NASA managers face the ongoing challenge of ensuring the Agency receives fair value for its money and that recipients spend NASA funds appropriately to accomplish stated goals. We seek 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.

During the past year, the OIG continued to uncover fraud and misconduct related to NASA contracts. For example, working with the National Science Foundation (NSF) OIG and the Defense Criminal Investigative Service (DCIS), we investigated a research professor who made false statements to Government officials to obtain 22 grants and contracts from NASA and other agencies valued at $6.4 million. Specifically, in his award proposals he failed to disclose all of his and his corporation's current and pending grants and contracts, thereby overstating the time he and the corporation could devote to the new projects for which he was applying. He also falsely certified that he was primarily employed by his corporation, when in reality he was employed full-time as a research professor at the University of California San Diego. The investigation further revealed the professor received more than $1.9 million in salary from 2005 to 2013 from his corporation, due in part to the fraudulently obtained grants and contracts. Ultimately, the professor pleaded guilty to wire fraud and was sentenced to 3 years of probation, paid a $175,000 fine, forfeited $180,000, and was debarred from Government contracting for three years.

In another example, an investigation by the NASA OIG, the NSF OIG, the DCIS, and the Internal Revenue Service's Criminal Investigations Division led to convictions of several subcontractors for conspiracy to pay kickbacks to a procurement official employed by a contractor that supplies satellites and satellite parts to NASA and other Government agencies. The subcontractors received prison sentences of up to 3 years and forfeited more than $700,000 in ill-gotten gains.

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. Accordingly, NASA must ensure that it maintains proper controls to mitigate the risk and proactively identify fraud.

In 2015, we launched a data analytics initiative to assist to help OIG staff identify contract, grant, and procurement fraud. We are using a variety of statistical and mathematical techniques to gather, analyze, and interpret Agency and open-source data to identify fraud indicators and help target OIG audit and investigations resources.

We also continue to focus audit resources on NASA's multibillion dollar contracting and procurement activities. In FY 2015, NASA spent $5.8 billion on service contracts pursuant to which contractors supplied time, effort, and expertise to perform specified tasks. For example, Kennedy has a $1.9 billion Engineering Services Contract with Vencore Solutions, Inc., to provide the Center with services ranging from laboratory and shop maintenance to space flight engineering.[46] This cost-reimbursement contract includes award-fee provisions, a baseline, and indefinite-delivery, indefinite-quantity (IDIQ) components. The baseline covers administrative and managerial services, while the IDIQ allows NASA to issue task orders when the need for a particular service arises.

In a May 2016 audit, we found the size and scope of Kennedy's agreement with Vencore has made managing the contract particularly challenging.[47] The cost and tasks included in its baseline and task order components are not clearly defined, managers overseeing the contract may lack appropriate expertise, and cost allocations are not clear. In addition, several tasks Vencore is performing on a cost-reimbursable basis appear more suitable for a fixed-price arrangement. Moreover, NASA has limited its ability to evaluate Vencore's performance by including generic milestones and deliverables in some task orders, as well as employing evaluation standards that do not align with the Federal Acquisition Regulation or the contract's award-fee plan. As a result, NASA's evaluations of Vencore's performance do not consistently support the award-fee scores assigned or the resulting payments, and we questioned more than $450,000 in award-fee payments NASA made to Vencore between FYs 2011 and 2014. Our findings relating to award fees mirrored similar concerns we raised in previous reports.[48]

NASA also faces the ongoing challenge of ensuring grant and cooperative agreement funds are administered appropriately and that recipients are accomplishing stated goals. NASA 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. We conducted several audits during the past year that examined NASA's management of grants and cooperative agreements, including a review of a $3.36 million National Space Grant College and Fellowship Program grant to the University of Texas at Austin to increase interest in science, technology, engineering, and mathematics.[49] We found the University had a strong system of accounting and internal controls to adequately account for expenditures and that the Consortium satisfied the overall performance goals and objectives of the grant.[50] However, we identified deficiencies in the Consortium's management of award funds and NASA's oversight of the grant's cost matching. Specifically, the Consortium inappropriately awarded $2,528 in scholarships to students who were not U.S. citizens and failed to adequately track required cost matching. Similarly, NASA did not adequately verify the Consortium's cost matching efforts.

Over the past 5 years, we have conducted 25 grant fraud investigations resulting in 5 convictions, $638,783 in recoveries, $2,921,583 in civil settlements, 2 suspensions, and 3 debarments. For example, a joint investigation by the NASA OIG, the NSF OIG, and the U.S. Secret Service revealed the owner of a small business spent nearly $800,000 in Federal grant funds on personal expenses, including mortgage payments, private school tuition for his children, vacations, shopping, and wire transfers to family and

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[46] 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.

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

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

[49] NASA OIG, "Audit of NASA Space Grant Awarded to the University of Texas at Austin" (IG-16-013, February 18, 2016).

[50] The Texas Space Grant Consortium (Consortium) was founded in 1989 and currently has 57 member institutions, including universities, industry, nonprofit organizations, and government agencies. The University of Texas at Austin (University) is the Consortium's lead institution.

friends overseas. The business owner was convicted of 7 counts of wire fraud and 2 counts of submitting false claims and sentenced to 4 months in prison and 1 year of supervised release.

Given the large amount of money at stake, we intend to continue to monitor NASA's administration of its contracts, grants, and cooperative agreement awards.

Ensuring the Continued Efficacy of the Space Communications Network

NASA's satellites and other spacecraft must communicate with Earth to receive commands from human controllers and return scientific data for study. To meet this need, NASA initiated the Space Communications and Navigation (SCaN) Program in 2006 with the goal of creating an integrated Agency-wide space communications and navigation architecture.

The SCaN Program operates three distinct communication networks and manages NASA's use of the electromagnetic spectrum. SCaN's communication networks are (1) the Near Earth Network, which covers low Earth orbit and portions of geosynchronous and lunar orbit; (2) the Space Network, which controls the Tracking and Data Relay Satellites through a network of geographically diverse ground systems and covers communications with satellites in geostationary orbit, including the ISS and the Hubble Space Telescope; and (3) the Deep Space Network, which covers communications beyond low Earth orbit, including planetary exploration missions to Mars and beyond. The spectrum encompasses various types of electromagnetic radiation from radio waves to gamma rays and is an essential but limited communications resource that makes possible virtually every mission NASA undertakes. The SCaN Program manages the frequency bands allocated to NASA and ensures Agency activities comply with national and international laws. Without SCaN services, NASA could not receive data from its satellites and robotic missions or control the missions from Earth, relegating space hardware worth tens of billions of dollars to little more than orbiting debris.

In 2014, we began a series of audits examining each aspect of the SCaN Program. As of October 2016, we had issued three reports and opened a fourth audit examining NASA's management of its electromagnetic spectrum allocation. We plan to follow our spectrum review with a "capping report" on the overall SCaN Program.

Space Network

Our first SCaN audit, issued in April 2014, examined the Space Network.[51] At the time, NASA was upgrading the Space Network through the Space Network Ground Segment Sustainment (SGSS) Project with the goal of implementing a modern ground system that would enable delivery of high quality services while significantly reducing operations and maintenance costs. We found key components of the Network were not meeting planned cost, schedule, and performance goals, and that the delays and cost growth increased the risk the Network would be unable to continue to provide adequate communication services to NASA missions and its customers. At the time of our audit, NASA's baseline commitment for the SGSS Project was $862 million and the scheduled completion date June 2017. We found the Project could cost $329 million more than this amount and the schedule for completion could

[51] IG-14-018.

slip more than 18 months. Consistent with our finding, in June 2015 NASA's Agency Program Management Council approved a new Agency baseline commitment of $1.2 billion and a Project completion date of September 2019.

Deep Space Network

Our second audit in the SCaN series, issued in March 2015, focused on NASA's Deep Space Network.[52] Established in 1963 to provide communications for NASA robotic missions operating outside of Earth orbit, the Network also supports missions by foreign partners. During FY 2016, the Deep Space Network supported more than 30 missions, including insertion of the Juno spacecraft into orbit around Jupiter.[53] Because of its importance, NASA has designated the Network as NASA Critical Infrastructure.[54]

We found that although the Deep Space Network was meeting its current operational commitments, budget reductions had challenged the Network's ability to maintain these performance levels and threatened its future reliability. Specifically, in FY 2009 the Network implemented a plan to achieve $226.9 million in savings over 10 years and use most of those savings to build new antennas and transmitters. However, in FY 2013 the SCaN Program reduced the Network's budget by $101.3 million, causing management to delay upgrades, shutter antennas, and cancel or re-plan tasks. In FY 2016, SCaN officials again reduced the budget for the Network, which will further delay maintenance and upgrade tasks. We noted that if budget reductions continue, the Network faced an increased risk that it will be unable to meet future operational commitments or complete the upgrade project on schedule.

We also found significant deviation from Federal and Agency policies and procedures for ensuring the security of the Deep Space Network's IT and physical infrastructure. For example, the Network's system security categorization process did not consider all Network mission functions, vulnerability identification, and mitigation practices and the IT security configuration baseline application did not comply with Federal and Agency policy. Further, required physical security controls were missing or inconsistently implemented at the three complexes, procedures to assign security level designations did not comply with NASA policy, required facility security assessments had not been completed, and security waivers or other risk acceptance documentation were not consistently in place. Since issuance of our audit, NASA has completed a facility security assessment and is taking action to bring the three complexes into compliance.

Near Earth Network

Our third audit, issued in March 2016, focused on NASA's management of the Near Earth Network.[55] The Near Earth Network provides tracking, telemetry, and command services to approximately 40 Agency science missions operating in low Earth orbit, including the Soil Moisture Active Passive mission

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[52] IG-15-013.

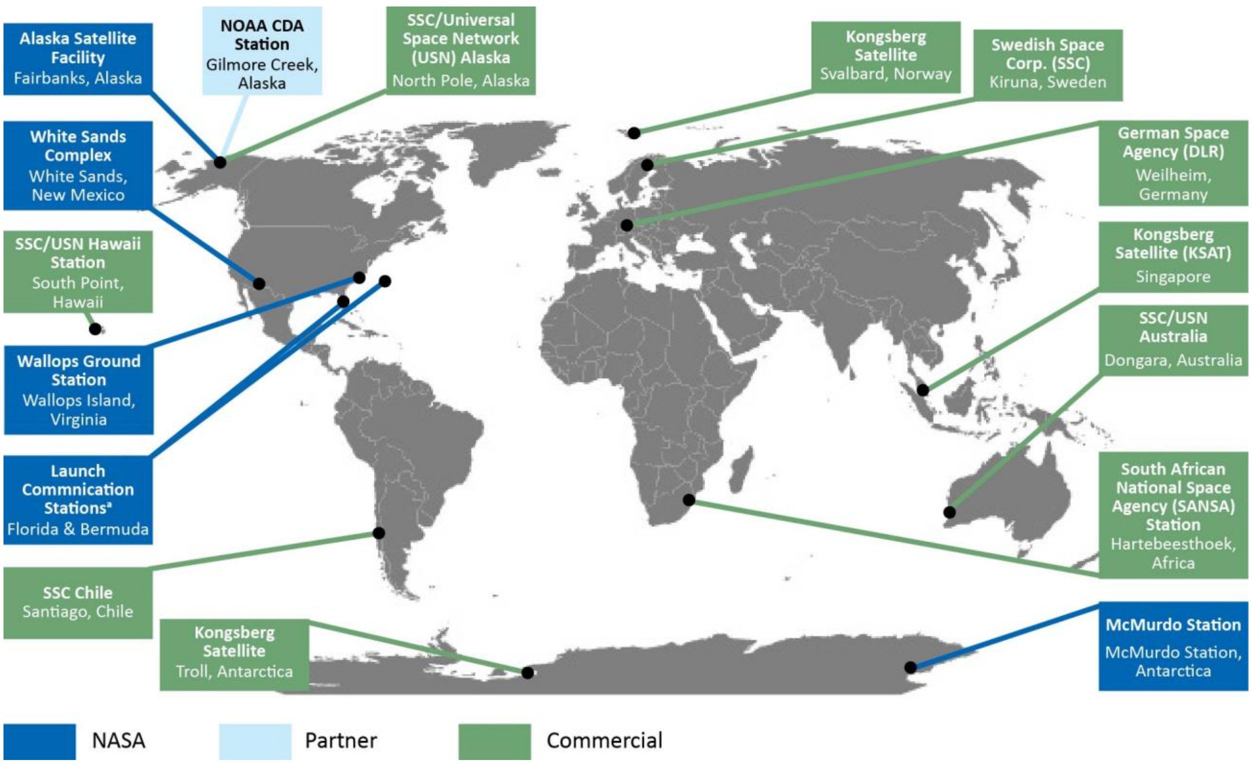
[53] Juno was launched in August 2011 with the principal goal of understanding the origin and evolution of Jupiter.

[54] NASA Critical Infrastructure are operations, functions, physical assets, or information technology resources essential to the success of the Agency's mission. NASA considers the Deep Space Network Critical Infrastructure because of its high public visibility, importance to the accomplishment of NASA missions, high-dollar value, and the difficulty of replacing the Network in a reasonable amount of time.

[55] NASA OIG, "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, 2013); and "Space Communications and Navigation: NASA's Management of the Space Network" (IG-14-018, April 29, 2014).

launched in January 2015 and the Aura mission, which is still operating more than 10 years after its 2004 launch.[56] The Network also provides launch and contingency support for the National Oceanic and Atmospheric Administration satellites that provide weather forecasting for the United States and will be used to support the SLS and Orion in the initial stage of their journey to deep space. To provide these services, the Network uses NASA-owned antennas and transmitters located in Alaska, New Mexico, Virginia, and Antarctica, as well as equipment in other parts of the world owned by other U.S. or foreign government agencies or commercial entities (see Figure 2).

Figure 2: Locations from which NASA Obtains Communication Services



Source: NASA OIG.

Note: "NOAA CDA" refers to National Oceanic and Atmospheric Administration Command and Data Acquisition, which the Network uses for emergency contingency backup.

[a] Planned stations.

The Network's customers include NASA's Science, Human Exploration and Operations, and Space Technology Mission Directorates, as well as other Government agencies, foreign civilian space agencies, and commercial entities. Most of the missions the Network supported in 2016 were investigating various aspects of the Earth's atmosphere, hydrology, geography, geology, and ecology.

[56] The Soil Moisture Active Passive mission was designed to help scientists understand the links between Earth's water, energy, and carbon cycles and to enhance the ability to monitor and predict natural hazards like floods and droughts. Aura studies the chemistry of the Earth's atmosphere by taking measurements that enable scientist to research ozone trends and air quality changes and their linkage to climate change.

Using non-U.S. Government entities to transmit Agency data presents significant security challenges. Moreover, the NASA-owned Near Earth Network assets are aging and located in extreme environments, making maintenance difficult. Constrained budgets have also led the Agency to defer some maintenance activities, which, on at least one occasion, has contributed to the unexpected failure of Network equipment.

We found NASA deviated from elements of Federal and Agency cyber and physical security risk management policies, thereby increasing the Near Earth Network's susceptibility to compromise. Specifically, the Agency assigned a security categorization rating of "moderate" to the Network's IT systems and did not include the Network in its Critical Infrastructure Protection Program. We believe this categorization was based on flawed justifications and the Network's exclusion from the Protection Program resulted from a lack of coordination between Network stakeholders. Given the importance of the Network to the success of NASA Earth science missions, the launch and contingency support it provides for Federal partners, and its importance in supporting future human space flight, we recommended a higher categorization level and inclusion in the Protection Program.

We also found IT security controls like software that identifies malicious code are not in place or functioning as intended. Moreover, due to insufficient coordination between various NASA entities, physical security controls have not been implemented on Agency-owned and supporting contractor facilities in accordance with Agency or Federal standards.

Finally, Near Earth Network components are at risk of unexpected failure due to their age and lack of proactive maintenance. Although the Network was performing preventative maintenance on NASA-owned assets, it had not been proactively inspecting and replacing cables and mechanical systems that were reaching their failure point and had already caused one unexpected breakdown.