NASA OFFICE OF INSPECTOR GENERAL

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

November 15, 2018

TO: James F. Bridenstine
Administrator

SUBJECT: *2018 Report on NASA's Top Management and Performance Challenges*

Dear Administrator Bridenstine,

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 2018 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; whether the underlying causes are systemic in nature; its susceptibility to fraud, waste, and abuse; and the Agency's progress in addressing the challenge. Not surprisingly, given the importance and scope of the issues, this year's list includes many of the same challenges discussed in previous reports.

Looking to 2019, we organized the top management and performance challenges facing NASA under the following topics:

- Space Flight Operations in Low Earth Orbit
- Deep Space Exploration
- NASA's Science Portfolio
- Information Technology Governance and Security
- Infrastructure and Facilities
- Contracting and Grants

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

Sincerely,

Paul K. Martin
Inspector General

Enclosure

NASA's Top Management and Performance Challenges—November 2018

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:

- Space Flight Operations in Low Earth Orbit
- Deep Space Exploration
- NASA's Science Portfolio
- Information Technology Governance and Security
- Infrastructure and Facilities
- Contracting and Grants

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

The challenges described in this report correspond to those we identified in last year's report apart from separating out NASA's low Earth orbit space flight activities as a standalone challenge rather than including it (as we did in 2017) as part of "Deep Space Exploration." Finally, as in previous years the challenges are not listed in priority order.

Space Flight Operations in Low Earth Orbit

For the past 20 years, the International Space Station (ISS or Station) has served as NASA's primary platform for conducting space flight operations and research in low Earth orbit. From 1998 through 2011, NASA primarily relied on its Space Shuttle fleet to ferry astronauts and materials to the Station. With the Shuttle's retirement in 2011, NASA initially relied on European and Japanese vehicles to ferry cargo and the Russian Soyuz spacecraft to transport crew while partnering with U.S. corporations to develop privately owned and operated cargo and crew transportation systems.[1] Unlike the Shuttle, NASA does not own these systems but instead purchases flights from these companies to carry NASA supplies and crew to the ISS. The ISS Program is currently authorized by Congress and scheduled to continue operations until October 1, 2024.

[1] When needed, NASA has used Japanese and Russian spacecraft to deliver cargo to the ISS. Until 2014, the European Space Agency also transported cargo. For crew transport, NASA has relied solely on the Russian Federal Space Agency (known as Roscosmos).

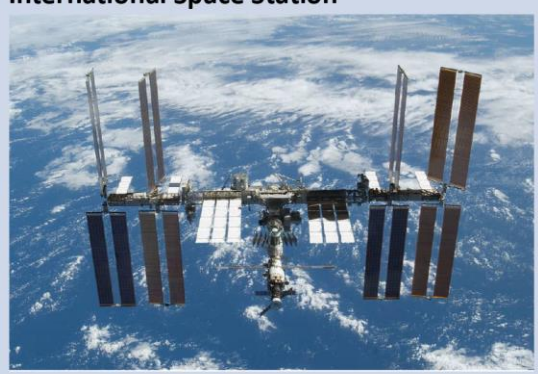
NASA's current plan beyond 2024 is to begin leveraging private industry to help lower the government's costs for maintaining access to low Earth orbit. This would include potentially transitioning responsibility for operating the Station—in whole or in part—to a commercial entity and allow NASA to become one of many public and private users. NASA expects this transition could offset some of the Agency's $3 to $4 billion annual investment in ISS operations, provide more cost-effective Station operations through increased private sector investment, and spur greater commercial development of low Earth orbit.

International Space Station

A significant amount of research aboard the ISS is related to: (1) understanding and mitigating the health and performance risks associated with human space travel (such as protecting against bone loss and eyesight degeneration) to overcome challenges that may develop during long-duration exploration missions and (2) testing new technologies necessary for cislunar and deep space exploration.

In July 2018, we reported that research for at least 6 of 20 human health risks that require the ISS for testing and 4 of 40 technology gaps will not be completed by the end of fiscal year (FY) 2024 when funding for the Station's operation is scheduled to end.[2] In addition, research into 2 human health risks and 17 technology gaps is not scheduled to be completed until around 2024, which increases the risk that even minor schedule slippage could push completion past when the funding runs out at the end of that fiscal year. As a result, NASA may be forced to choose among a variety of options, including extending operation of the ISS past 2024, relying on alternate testing methods (i.e., non-space-based), or accepting higher levels of risk for future missions.

International Space Station



Source: NASA.

NASA's contract with Roscosmos for seats on the Soyuz to transport U.S. astronauts to the ISS ensures access to the Station continues through early 2020. Consequently, delays in NASA's efforts to develop and certify commercial crew vehicles could leave the United States without a means to transport its astronauts to the Station. Moreover, while the amount of research conducted on the ISS has increased over the past 8 years, several factors continue to limit the Station's full utilization. In particular, many of the investigations require hands-on participation by crew members in some capacity, especially those related to human health research. However, because the amount of time available for crew to conduct these investigations is limited, they are not able to utilize the ISS to its full research capacity. In addition, a limited number of external payload sites and limited capability to store research samples on the Station affects utilization rates. Moreover, launch failures of two commercial resupply missions—one from Orbital ATK in October 2014 and one from Space Exploration Technologies Corporation (SpaceX) in June 2015—led to compressed launch schedules in FYs 2016 and 2017 and affected researchers' ability to obtain samples

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[2] NASA OIG, *NASA's Management and Utilization of the International Space Station* (IG-18-021, July 30, 2018).

and data from the ISS. Lastly, NASA must also share its research capacity on the ISS with the Center for the Advancement of Science in Space (CASIS) and honor its agreements with international partners, commitments that reduce the amount of research resources available to NASA.[3]

The United States has invested more than $90 billion in the ISS over the last 25 years, and the Station continues to account for about half of NASA's annual human space flight budget.[4] In FY 2017, NASA's cost to operate the Station—including on-orbit vehicle operations, research, crew transportation, and cargo resupply missions—was almost $3 billion, which the Agency projects will increase to approximately $3.5 billion in the 2020s. Balancing continued ISS research to mitigate human exploration risks with the need to develop and test key systems required for reaching Mars will challenge the Agency's resources well into the next decade.

Our audit work found that NASA's plan to transition the ISS to private operation under the timetable currently envisioned presents significant challenges in stimulating private sector interest for such a costly and complex enterprise. Likewise, any extension of the ISS past 2024 would require continued funding of $3 to $4 billion annually to operate and maintain the Station—a significant portion of funding which could otherwise be redirected to develop systems needed for NASA's cislunar, lunar, or deep space ambitions. In addition, extending the Station's life beyond 2024 challenges the Agency to manage the risks associated with continued operation of its aging systems and infrastructure. Moreover, any extension will require the support of NASA's international partners whose continued participation hinges on issues ranging from geopolitics to differing space exploration goals. Lastly, at a future date NASA will need to decommission and deorbit the ISS, either in response to an emergency or at the end of its useful life. However, the Agency has not finalized its plans and currently does not have the capability to ensure the ISS will safely reenter the Earth's atmosphere and land in a targeted location in the South Pacific Ocean.

Commercial Transportation to the International Space Station

Since the last flight of the Space Shuttle in 2011, NASA has relied on commercial contractors to deliver cargo and the Russian Soyuz to transport crew to the ISS while the Agency works with two companies to develop crew transportation capabilities. Both cargo and crew contractors have faced delays and setbacks. Two failed missions lost critical ISS cargo and impacted resupply schedules, while crew vehicle development and certification delays have pushed back the first demonstration flights from 2016 to no earlier than 2019, which as discussed previously could result in a gap in NASA access to the Station. Together, commercial cargo and crew transportation account for about 50 percent of total ISS annual spending.[5] Under the existing contracts for commercial resupply services, NASA plans to award more than $20 billion for commercial cargo and crew transportation services to the ISS through 2024. As of the end of 2017, NASA awarded $17.8 billion towards this total—$9.3 billion for cargo and $8.5 billion for crew activities.[6]

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3 CASIS is the organization chosen by NASA to manage non-NASA research activities on the U.S. portion of the ISS, known as the National Laboratory.

4 This figure includes $30.7 billion for 37 supporting Space Shuttle flights.

5 ISS Program funding does not include commercial crew development activities, which are funded separately through the Commercial Crew Program.

6 A NASA award includes past and future expenditures that have already been committed through a contract task order or Space Act Agreement milestone. This does not include minimum mission guarantee costs that are not yet on task orders.

Cargo Resupply

NASA's first Commercial Resupply Services (CRS-1) contracts for cargo missions—valued at $1.9 billion and $1.6 billion for Orbital ATK and SpaceX, respectively—are nearing completion.[7] Through January 2020, the companies are scheduled to complete 31 missions to deliver supplies and equipment to the Station (upmass) and, depending on the requirements of the mission, either return equipment and research experiments to Earth or dispose of waste (downmass).[8]

For CRS-1, NASA selected two companies to ensure redundancy if one was unable to perform due to technical or other reasons. This strategy proved effective when both companies experienced mission failures and schedule delays—issues that NASA managers said were expected given the complexities involved in developing new launch vehicles and spacecraft. Orbital ATK encountered the first CRS-1 failure when its third mission failed seconds after liftoff on October 28, 2014.[9] Eight months later, SpaceX's seventh CRS-1 mission failed during launch on June 28, 2015.[10] The failure of a second SpaceX Falcon 9 launch vehicle in September 2016 during a static fire test for a non-NASA customer also impacted the CRS-1 schedule.[11]

Despite these setbacks, NASA officials generally view the CRS-1 contracts as successful, with roughly 45,000 kilograms (kg) of cargo delivered to the ISS from October 2012 through December 2017 and another 33,000 kg in upmass capability planned for delivery through the final CRS-1 mission in 2020. Through December 2017, NASA spent $5.12 billion on CRS-1 activities and is projected to spend an additional $810 million through completion of the contract's final cargo resupply mission in 2020.

In January 2016, NASA awarded follow-on cargo resupply contracts known as CRS-2 to Orbital ATK, SpaceX, and the Sierra Nevada Corporation (Sierra Nevada). Each company is guaranteed at least six cargo missions under the CRS-2 contract. As of December 2017, NASA had awarded $2.6 billion on these contracts with a combined, not-to-exceed value of $14 billion. NASA officials explained they selected three rather than two companies during the second round of the cargo resupply contracts to increase cargo capabilities and ensure more redundancy in the event of a contractor failure or schedule delay.

We examined the CRS contracts in an April 2018 audit report with a special emphasis on the CRS-2 contracts.[12] We found that during the CRS-2 solicitation and award process, NASA followed federal procurement rules and applied lessons learned from the CRS-1 contract to provide the ISS Program with better cargo capabilities, more transport flexibility, additional insurance coverage for NASA payloads, and clearer government insight into subcontractor activities. Further, we noted that NASA could

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[7] Between 2006 and 2008, NASA entered into a series of funded Space Act Agreements with Orbital ATK, SpaceX, and other private companies to stimulate development of space flight systems capable of transporting cargo to the ISS. CRS-1 contracts were awarded in 2008 while development was still underway.

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

[9] For more information about the Orbital ATK failure, see 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).

[10] For more information about the SpaceX failure, see NASA OIG, *NASA's Response to SpaceX's June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station* (IG-16-025, June 28, 2016).

[11] The failure destroyed AMOS-6, a private communications satellite owned by Spacecom.

[12] NASA OIG, *Audit of Commercial Resupply Services to the International Space Station* (IG-18-016, April 26, 2018).

potentially obtain additional savings under the CRS-2 contracts by competing future cargo resupply missions among the three companies after each meets their guaranteed minimum of six missions. Despite a requirement to compete task orders among all three contractors, NASA approved sole-source awards for all 31 CRS-1 missions and the 8 CRS-2 missions awarded as of December 2017.[13] With the addition of a third contractor, we believe NASA has more flexibility to compete task orders among the three companies or potential new entrants through the CRS-2 contract's On-Ramp clause, which allows the Agency to recompete contracts for any missions beyond the guaranteed six. In addition, we believe NASA could realize substantial savings if Sierra Nevada uses a less expensive launch vehicle than the Atlas V currently planned for the company's first two missions.

Our audit found that initial 2016 projections showed the CRS-2 contract was approximately $400 million more expensive than the CRS-1 contract while delivering roughly 6,000 kg less upmass capability. The higher costs for CRS-2 were the result of increased prices from SpaceX, the selection of three contractors rather than two, and $700 million in integration costs awarded through 2017. Of those integration costs, we questioned as premature $4.4 million paid to Sierra Nevada to begin certifying its second Dream Chaser spacecraft configuration. We believe ISS Program officials should have delayed these payments until after the successful demonstration of the first Dream Chaser configuration. In light of the CRS-2 contract's overall higher costs, the ISS Program evaluated whether to change the flight cadence for CRS-2 flights to potentially save $300 million by taking advantage of pricing discounts without decreasing the number of missions. By August 2018, the ISS Program had updated its flight cadence reflecting a reduction in cost by $205 million with additional savings anticipated.

We also reported that all three contractors face technical and schedule risks as they prepare for their CRS-2 missions. Development and launch of the Dream Chaser spacecraft poses the greatest risk to NASA due to its lack of flight history and Sierra Nevada's plan to not conduct a demonstration flight. Additionally, Sierra Nevada intends to build only one Dream Chaser, which raises concerns about potential schedule delays should an anomaly or failure occur. For SpaceX, certification of the company's unproven cargo version of its Dragon 2 spacecraft carries risk while the company works to resolve ongoing concerns related to software traceability and systems engineering processes. Finally, while Orbital ATK's planned use of a slightly modified Cygnus spacecraft reduces risk, the company plans to rely on the relatively new Antares 230 rocket configuration that could be affected by congressional bans on use of Russian engines.

Crew Transportation

Since the Space Shuttle Program ended in 2011, the United States has lacked a domestic capability to transport crew to the ISS, instead relying on Roscosmos to ferry astronauts at prices of up to $82 million per astronaut. The goal of NASA's Commercial Crew Program is to provide safe, reliable, and cost-effective crew transportation to and from the ISS and low Earth orbit. Through 2017, NASA spent about $3.9 billion on commercial crew activities.[14]

[13] Sole-source awards are contracts awarded without competitive bidding.

[14] These numbers do not reflect amounts NASA paid to Russia for crew transportation aboard the Soyuz.

Boeing's Launch Site at Cape Canaveral Air Force Station

Source: NASA.

NASA's efforts to facilitate the development of a commercial crew transportation capability began in earnest in February 2010. However, it was not until September 2014 that NASA awarded The Boeing Company (Boeing) and SpaceX 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 fly astronauts to the ISS.[15]

In September 2016, we reported that the Commercial Crew Program faced multiple challenges that would delay the first routine flight carrying NASA astronauts to the ISS until late 2018—more than 3 years after NASA's original 2015 goal.[16] In our 2016 audit, we found that while past funding shortfalls contributed to the delay, technical challenges with the contractors' spacecraft designs were driving schedule slippages. For Boeing, these included issues related to the effects of vibrations from intense sound waves generated during launch and challenges regarding vehicle mass. For SpaceX, delays resulted from a change in capsule design to enable a water-based rather than ground-based landing and related concerns that the capsule would take on excessive water.

SpaceX Launch Site at Kennedy Space Center

Source: SpaceX.

Both companies must satisfy NASA's review process to meet Agency requirements for ensuring vehicles are safe for astronauts, known as "human rated." 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. Our 2016 audit found significant delays in NASA's evaluation and approval of these hazard reports and related requests for variances from NASA requirements that increase the risk that costly redesign work may be required late in development, further delaying vehicle certification.

Given the delays in the Commercial Crew Program, NASA extended its contract with Roscosmos for astronaut transportation and entered into a new agreement with Boeing to purchase flights to the ISS on the Soyuz to ensure access to the Station continues through early 2020.[17] However, a recent Government Accountability Office (GAO) report cited an April 2018 analysis from the Commercial Crew Program indicating the average certification date was more likely to occur in December 2019 for Boeing

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[15] A firm-fixed-price contract provides a price that is not subject to adjustment on the basis of the contractor's costs in performing the contract. This contract type places maximum risk on the contractor for whether the contract generates a profit or loss.

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

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

and January 2020 for SpaceX.[18] Since NASA does not currently plan to purchase transportation on the Soyuz past 2020, the Agency could face a gap in its access to the ISS if commercial crew providers are not certified to transport astronauts by that time. To avoid such a gap, NASA may have to exercise contingency plans, such as refining the remaining Soyuz launch schedule, extending crew time on the Station, or using crewed flight tests as operational flights to transport U.S. astronauts.

Deep Space Exploration

NASA's long-term goal for its human exploration program is a crewed mission to Mars in the late 2030s or early 2040s. In December 2017, the President directed NASA to change its mid-term objectives from uncrewed and crewed asteroid exploration missions to a crewed return to the Moon that involves international and commercial partners.[19] To meet these goals, the Agency must develop more sophisticated rockets, capsules, and related hardware; manage the ISS to maximize its use as a platform for research and development of new technologies; place a spaceport called the Gateway in lunar orbit; and mitigate human health risks of extended deep space travel—all within the constraints of a relatively static budget profile.

In the near term, successful development of the Space Launch System (SLS), the Orion Multi-Purpose Crew Vehicle (Orion), and launch infrastructure under development by the Agency's Exploration Ground Systems Program (EGS) are critical to achieving NASA's human exploration goals beyond low Earth orbit.[20] However, the first unmanned flight of the integrated SLS, Orion, and EGS systems on Exploration Mission-1 (EM-1)—initially planned for 2017 and currently expected to launch by June 2020—and the first crewed flight, Exploration Mission-2 (EM-2)—planned for no earlier than mid-2022—face significant challenges to meet their current launch dates. NASA plans flybys of the Moon before returning to Earth for both EM-1 and EM-2.

To support in-space testing, a return to the Moon, and deep space exploration, the Agency is building a lunar-orbiting outpost called the Gateway, consisting of core functionalities that include power and propulsion, communications, habitation, robotics, an airlock, and logistics resupply capabilities. As a key element of NASA's planned mission to Mars, this space-based staging platform will assist in preparing astronauts and the space flight systems needed for deep space exploration. In September 2018, NASA solicited proposals from the private sector to develop the Gateway's power and propulsion element, which is expected to launch on a commercial rocket in 2022. The Gateway will provide capabilities for lunar exploration throughout the buildup period as additional elements are launched, with Gateway completion planned in 2026.

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[18] GAO, *NASA Commercial Crew Program: Plan Needed to Ensure Uninterrupted Access to the International Space Station* (GAO-18-476, July 11, 2018).

[19] U.S. Space Policy Directive-1, published December 11, 2017, states that, "The Administrator of NASA shall lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."

[20] Previous top management and performance challenges reports and NASA OIG audits refer to EGS as the Ground Systems Development and Operations Program or GSDO. NASA changed its name in January 2018, and therefore, EGS will be used throughout this report in all references.

While the Agency's exploration plans, known as the National Space Exploration Campaign, currently include a series of robotic surface landings followed by human missions to the Moon, their number and duration remains undecided.[21] NASA's plans for Mars missions will also be impacted—in terms of cost and schedule—by diverting funds previously intended for deep space transport to lunar lander support, delaying a potential Mars crewed mission.

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

Space Launch System

The SLS is a two-stage, heavy-lift rocket that will transport cargo and crew into space for missions beyond low Earth orbit. NASA is using RS-25 engines originally built for the Space Shuttle Program to power the SLS Core Stage and is designing the vehicle with an evolvable architecture that can accommodate longer and more ambitious missions. The initial version (Block 1) will be capable of lifting 70 metric tons to low Earth orbit and use a modified Delta IV rocket upper stage to propel the Orion capsule on a trajectory around the Moon during EM-1. Later versions of the SLS will add a more powerful upper stage (Block 1B) and advanced rocket boosters (Block 2) with a capability to lift 130 metric tons to low Earth orbit and 37 metric tons to Mars.

We reported in April 2017 that the SLS Program faced several technical challenges leading up to the EM-1 launch that negatively affected its schedule margin.[22] As a result of these challenges, NASA subsequently announced a schedule delay for the EM-1 mission from November 2018 to no earlier than December 2019 with 6 months of schedule risk to June 2020 given that significant testing of the SLS system and its subsystems has yet to be completed. Although the SLS Program factored in a schedule margin of 11 months to allow time to address any unexpected technical issues or other factors, welding problems with SLS Core Stage tanks and delays in completing the engine section and stage controller have consumed this schedule margin. Even with this additional delay, testing and delivery of the Core Stage remains a significant challenge on the critical path with no schedule margin remaining to manage

[21] NASA, *National Space Exploration Campaign Report* (September 2018).

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

problems that may arise during the integration and test phase before an integrated SLS/Orion launch.[23] Completion of the Core Stage is a critical schedule issue in meeting the planned EM-1 launch date, which in turn may affect the SLS's subsequent missions—EM-2 and potentially the Europa Clipper—both planned for launch in 2022.[24]

In October 2018, we reported cost increases and schedule delays for the SLS Core Stage development can be traced largely to management, technical, and infrastructure issues driven by Boeing's poor performance. Additionally, we projected these delays could increase contract costs to at least $8.9 billion through 2021—double the amount initially planned to deliver two Core Stages. We also found poor contract management practices by NASA contributed to the SLS Program's cost and schedule overruns and questioned nearly $64 million in award fees already provided to Boeing. The SLS Program has taken positive steps to address management and procurement issues related to the Boeing Stages contract, including making key leadership changes; requesting reviews of Boeing's management, financial, and estimating systems; adding routine, in-depth performance reviews; and changing the procurement process to improve internal controls.

The rising cost of the SLS Program presents challenges for NASA moving forward. Currently, the Program will exceed its $9.7 billion budget commitment by 15 percent in 2019. The Agency plans to spend roughly $2 billion a year on SLS development and is already using its monetary reserves to address technical challenges for EM-1. According to guidance developed at Marshall Space Flight Center (Marshall), the standard monetary reserve for a program such as the SLS during development should be between 10 and 30 percent.[25] The SLS Program did not carry any program reserves in FY 2015 and only $25 million in FY 2016—approximately 1 percent of its development budget. Starting in FY 2018, the Program increased reserves to roughly 5 percent and the 2018 reserve of $123 million was used in part to cover increased costs for the two SLS Core Stages. However, this level of monetary reserves will not be sufficient if, as expected, additional technical issues arise during SLS development and testing phases. For example, if the EM-1 launch is delayed to June 2020, NASA will need to add $1.2 billion to the SLS stages contract based on Boeing's current expenditure rate.

In May 2018, NASA decided to use the initial Block 1 configuration for crewed EM-2 in mid-2022 instead of using Block 1B with its more powerful upper stage known as the Exploration Upper Stage. In addition, EM-2 will use the same mobile launcher used on the first SLS mission, EM-1, instead of waiting for major modifications to accommodate the larger Block 1B. Moreover, NASA received an additional $350 million from Congress in 2018 to build a second mobile launcher for Block 1B in order to accommodate the more powerful rocket's increased size. However, these changes will require that NASA human-rate two separate upper stages for Block 1 and Block 1B in order to fly crewed missions. In addition, it is unclear if the $350 million appropriated is sufficient to complete the second mobile launcher in time to meet the adjusted 2024 launch date for the SLS's Block 1B version.

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[23] Critical path is the sequence of tasks that determines the longest duration of time needed to complete a project. It is important to identify the critical path and resources needed to complete the critical tasks along the path if a project is to be completed on time and within its allocated resources.

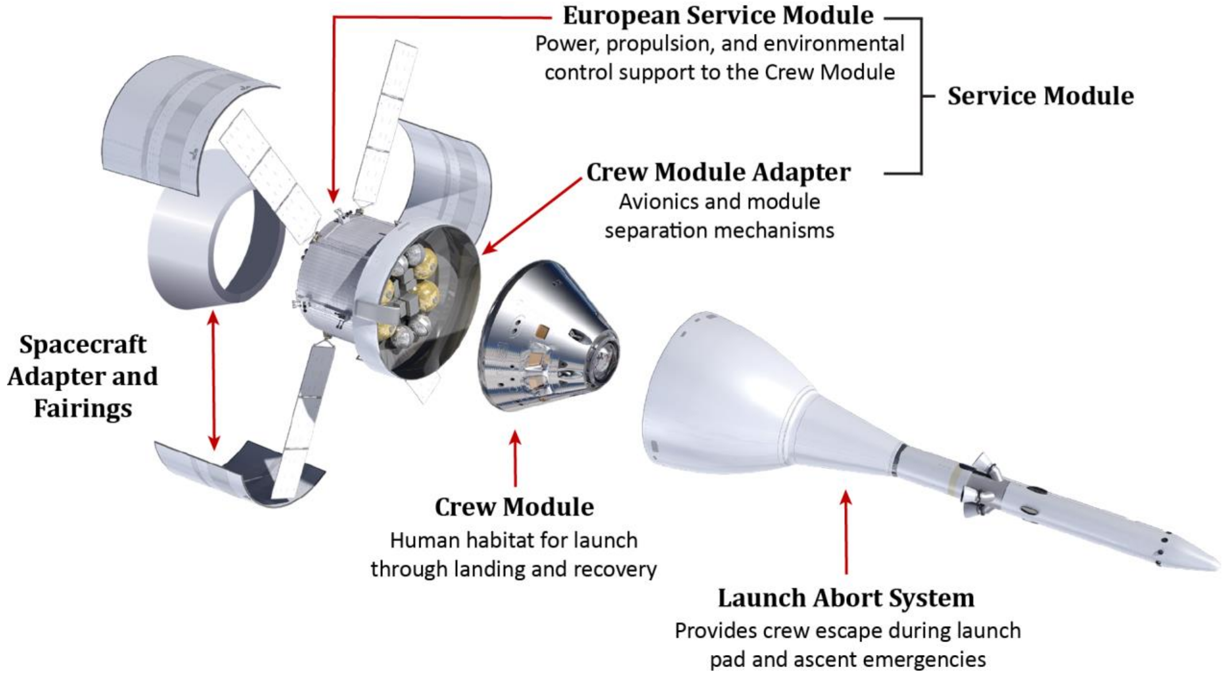
[24] The Europa Clipper is a NASA science mission that plans to send a spacecraft to Europa, one of Jupiter's moons, to determine whether the icy moon could harbor conditions suitable for life. In May 2018, we initiated an audit to assess NASA's management of the Europa Clipper mission.

[25] Marshall Procedural Requirements 7120.1, *MSFC Engineering and Program/Project Management Requirements* (October 20, 2016).

Orion Multi-Purpose Crew Vehicle

The Orion capsule—which will be mounted atop the SLS and serve as the crew vehicle for up to four astronauts—has four major components: a crew module; a service module; a spacecraft adapter that connects the vehicle to the rocket; and a launch abort system (see Figure 1).

Figure 1: Orion Components



Source: NASA (artist's rendering).

NASA began developing Orion in 2006 as part of the Agency's former deep space exploration effort known as the Constellation Program and had spent about $5.7 billion on the effort by the time the Program was canceled in 2010. Since then, NASA has spent more than $1 billion annually, or about 6 percent of the Agency's overall budget, on the Orion Program. In September 2016, we estimated the Agency will have invested approximately $17 billion for all Orion activities, including Constellation Program funding, by the time the spacecraft makes its first crewed flight on EM-2.[26]

The most significant immediate challenge NASA faces with the Orion Program continues to be delivery of the European Service Module, which contains the primary power and propulsion elements for the vehicle needed for EM-1. In September 2016, we reported that the service module had undergone design changes and, as a result, would be delivered to NASA at least 5 but possibly up to 10 months later than originally planned.[27] The module is now scheduled to be delivered in November 2018. Because the new Orion service module differs from the module flown during the first Orion test flight in December 2014, assembly, integration, and processing of the new module may delay transfer of the Orion to the EGS Program for integration with the SLS. Consequently, delivery, test, and integration of the service module is another critical schedule issue to meet the current EM-1 launch date.

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

[27] IG-16-029.

Looking ahead, one of the key challenges NASA faces is ensuring the Orion capsule's Environmental Control and Life Support System functions properly. NASA is testing portions of this critical life support system on both the ISS and in laboratories on Earth, and will fly substantial parts of the system (thermal control pumps, heat exchangers, radiators, gas containment and delivery systems, and cabin pressurization controls) on EM-1. However, the first flight test of the complete Environmental Control and Life Support System will be during EM-2 with a crew aboard. The Aerospace Safety Advisory Panel, a committee that advises NASA and Congress on safety issues, expressed concern in its 2015 and 2016 annual reports about the system's lack of flight testing before EM-2. The Panel suggested the mission remain in low Earth orbit until NASA is confident that the life support systems are performing properly.[28] In its 2016 annual report, the Panel notes that NASA had selected a mission profile in which the crew spends its first 24 hours in an elliptical high Earth orbit to check the Environmental Control and Life Support System and other systems for possible malfunction.

The Orion Program currently has 9 percent in monetary reserves leading up to EM-2. Orion strategy places reserves at the end of the Design, Development, Test, and Evaluation phase to create funded schedule margin. When additional reserves are required above what is held in a particular year, the Program content is addressed to move non-critical path items and identify the needed reserve. This enables the Program to balance development risks and allows efficient utilization of funding. However, the impact of the delay in EM-1's launch date to June 2020 on Orion's overall funding profile remains under assessment.

Exploration Ground Systems Program

NASA's EGS Program is constructing and modifying infrastructure at Kennedy Space Center formerly used by the Space Shuttle and Constellation programs to launch the combined SLS/Orion. These tasks include refurbishing the crawler transporter that will transport the SLS to the launch pad, modifying the current mobile launcher, building a second mobile launcher for Block 1B, retrofitting the Vehicle Assembly Building, and updating Launch Pad 39B. In 2015 and 2017, we reported that modifications to the Vehicle Assembly Building and mobile launcher needed to support SLS have left EGS with only 1 month of schedule margin to address any additional issues that arise.[29] Similarly, GAO reported in July 2016 that although the Program is making progress in modifying facilities and equipment to support SLS and Orion, it is encountering technical challenges that require additional time and money, which in turn has reduced cost and schedule reserves, threatening the EM-1 launch readiness date.[30] Although the subsequently announced delay in EM-1's launch date may have mitigated some of these concerns, development of software needed to launch SLS and Orion remains a key concern.

In March 2016, we reported that the software used by the EGS Program, known as the Spaceport Command and Control System (SCCS), had significantly exceeded its initial cost and schedule estimates.[31] Subsequently, GAO reported in May 2018 that EGS's software efforts continue to face

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[28] Aerospace Safety Advisory Panel, *Annual Report for 2015* (January 13, 2016) and *Annual Report for 2016* (January 11, 2017).

[29] IG-17-017 and 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).

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

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

technical challenges.[32] SCCS is a software system that will control pumps, motors, valves, power supplies, and other ground equipment; record and retrieve data from systems before and during launch; and monitor the health and status of spacecraft as they prepare for and during launch. Our report noted that compared to FY 2012 projections, development costs had increased approximately 77 percent to $207.4 million and the release of a fully operational version had slipped by 14 months from July 2016 to September 2017 for an EM-1 launch in November 2018. Given the new launch date of no earlier than December 2019, and with the expectation the date may slip further to at least June 2020, EGS has extended the SCCS completion date to July 2019 in order to align with the new launch window.

Furthermore, EGS will not be able to complete all necessary software validation and verification efforts until SLS and Orion complete development, testing, and delivery of their software. Development of EGS software is the third most critical task, schedule-wise, to meeting the current EM-1 launch date of June 2020.

NASA's Science Portfolio

NASA's Science Mission Directorate focuses on answering questions related to the origins and destiny of the universe, the Sun and its effects on Earth and the rest of the solar system, the Earth's climate, the history of the solar system, and the potential for life elsewhere. With a budget that has increased more than 20 percent over the past 5 years—from $5.1 billion in FY 2014 to $6.2 billion in FY 2018—the Directorate manages more than 100 space flight projects in various stages of development and operations, as well as research, applications, technology development, and airborne- and ground-based observation activities. Successfully managing NASA's science portfolio is dependent in large part on addressing challenges related to project management, challenges that are exacerbated by internal and external influences that we highlighted in a September 2012 report.[33]

Internal Influences on the Science Portfolio

Historically, NASA has faced challenges in successfully managing its science portfolio and completing projects as planned. When milestones and deliverables are not completed on time or within budget, especially for its largest, most expensive projects, the ripple effects can be felt throughout NASA's entire science portfolio. Since our last top management and performance challenges report, NASA's science missions have celebrated several significant milestones and accomplishments. For example, December 2017 was the 22nd launch anniversary of the Solar and Heliospheric Observatory (SOHO), the Agency's oldest heliophysics mission in operation. SOHO provided the first ever images of structures and flows below the Sun's surface and dramatically improved space weather forecasting capabilities. In August 2018, the Spitzer Space Telescope—one of NASA's four Great Observatories—had its 15th birthday in space, observing some of the most distant galaxies in the universe and compiling a detailed map of the Milky Way.[34] The telescope has also been instrumental in several significant discoveries, including the seven rocky planets in the TRAPPIST-1 system 39 light-years away from Earth. In addition, after

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[32] GAO, *NASA: Assessments of Major Projects* (GAO 18-280SP, May 1, 2018).

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

[34] NASA's four Great Observatories are the (1) Hubble Space Telescope, launched from Space Shuttle Discovery in April 1990 and still operating; (2) Compton Gamma Ray Observatory, launched from Space Shuttle Atlantis in April 1991 and deorbited in June 2000; (3) Chandra X-ray Observatory, launched from Space Shuttle Columbia in July 1999 and still operating; and (4) Spitzer Space Telescope, launched in August 2003 on a Delta 7920H rocket and still operating.

nearly 2 years of space travel, the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer spacecraft sent back its first image of Bennu, its target asteroid. Further, multiple long-orbiting NASA Earth-observing satellites, including Terra and Aqua, have helped researchers study and emergency-response crews deal with numerous wildfires in the United States and across the globe.

In the last year, the Agency launched three science missions that we highlighted in our 2017 report as vital to NASA effectively managing its science portfolio:

- In May 2018, after a 26-month delay that increased mission costs by $154 million, the Interior Exploration using Seismic Investigations Geodesy and Heat Transport (InSight) launched from Vandenberg Air Force Base in California and is scheduled to land on Mars in November 2018.[35] The lander is designed to investigate the crust, deep interior, and tectonic activity of Mars to better understand how rocky planets like Earth and Mars formed. Using a German-built penetrating "mole," InSight will pound a probe 16 feet into the Martian crust to take thermal measurements while a French-built seismometer will attempt to sense and measure "Marsquakes."
- In August 2018, the $1.6 billion Parker Solar Probe lifted off on a Delta IV Heavy rocket from Cape Canaveral Air Force Station in Florida on its mission to orbit the Sun closer than any other spacecraft while investigating its corona and outer atmosphere. The mission will sample plasma and the coronal magnetic field to investigate coronal heating and the origin and evolution of solar wind. The mission will also provide a better understanding of the radiation environment in which future space explorers will live.
- In September 2018, after several delays that resulted in its life-cycle costs increasing from $860 million to more than $1 billion that required funds to be drawn from other projects in the Earth Science Division portfolio, the Ice, Cloud, and land Elevation Satellite-2 satellite launched from Vandenberg Air Force Base on a Delta II rocket.[36] The mission is designed to collect data on the Earth's ice sheets and track changes in glaciers and sea ice, which will allow scientists to see where ice is flowing, melting, or growing, and to investigate the global impacts of these changes.

Since 2013, our top management and performance challenges reports have documented the criticality of successful completion of the James Webb Space Telescope (JWST) relative to NASA's overall science portfolio in light of the longstanding challenges with the program.[37] The 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. However, this program has a storied and troubled development history. 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 NASA review team found the 2013 launch date unachievable. Consequently, in 2009 NASA rebaselined JWST with a

[35] In November 2015, a leak was discovered in the seismometer instrument that caused NASA to delay its original March 2016 launch and increased project life-cycle costs to $829 million.

[36] Project managers underestimated the technical complexity of building the satellite's sole instrument, the Advanced Topographic Laser Altimeter System (ATLAS). In May 2014, NASA revised the baseline originally established in December 2012 to reflect a $1.06 billion life-cycle cost and a planned launch date in June 2018. In July 2016, one of the two flight lasers manufactured for the ATLAS instrument failed during thermal vacuum testing and caused NASA to delay the launch another 3 months.

[37] NASA OIG, *NASA's Top Management and Performance Challenges November 2013* (December 2, 2013).

life-cycle cost estimate of $4.9 billion and a June 2014 launch date. Again, it soon became clear that neither the new cost estimate nor the 2014 launch date were attainable. Subsequently, NASA restructured the JWST program and in September 2011 established a revised baseline life-cycle cost estimate of $8.84 billion and an October 2018 launch date. In late September 2017, the Agency delayed the JWST launch to no earlier than March 30, 2019, and soon thereafter commissioned an Independent Review Board to evaluate the program. In June 2018, NASA announced that the launch of JWST would be delayed until March 2021—2 ½ years later than its previous baseline launch date.

The Review Board found many of the same management challenges we identified in our September 2012 report on project management challenges and also cited human errors and excessive optimism in the integration and test plan that greatly affected the program's cost and schedule.[38] In spite of these challenges that resulted in the need for $1 billion to pay for additional work and a launch delay to March 2021, the Board concluded that "JWST should continue based on its extraordinary scientific potential and critical role in maintaining U.S. leadership in astronomy and astrophysics."

Although NASA has funding to continue JWST's development and testing in FY 2019, the Agency will need to identify $837 million in additional funding for development and operations in FY 2020 and beyond. Reallocating funds to cover these costs are likely to come from other projects in the Agency's science portfolio and result in delays in the launch or development of those projects.

External Influences on the Science Portfolio

While the success of NASA's science missions and projects are largely driven by internal factors within the Agency, the selection, balance, and operations of those missions are heavily influenced by external stakeholders, including the President, Congress, the science community, and, to a lesser extent, other federal and international agencies. The President and Congress provide direction through the authorization and appropriation processes, which have a strong influence on the composition of the Agency's science portfolio. The science community—as represented by the National Research Council (NRC)—establishes mission priorities based on a broad consensus within various science research disciplines.[39] These priorities are set forth in the NRC's decadal surveys on the subject matter areas encompassed by the Science Mission Directorate's four divisions: Astrophysics, Earth Science, Heliophysics, and Planetary Science. Each survey lists the NRC's recommendations by priority (e.g., the 2011 Planetary Science Decadal Survey prioritized proposed NASA large missions in the following order: a Mars sample return first, followed by a Jupiter Europa orbiter, and finally a Uranus orbiter and probe mission).[40] Managing differing priorities from numerous stakeholders amidst funding uncertainties can result in cost increases and schedule delays with a cascading effect on NASA's entire science portfolio.[41]

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[38] IG-12-021.

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

[40] NRC, *Vision and Voyages for Planetary Science in the Decade 2013-2022* (2011).

[41] IG-12-021.

On a macro scale, specific priorities identified by the President and Congress coupled with the outcome and timing of the annual appropriation process tend to create challenges for NASA in managing a science portfolio composed of projects that take many years to develop and launch.[42] For example, towards the end of FY 2017 Congress unexpectedly directed NASA to spend $15 million more than planned on the Wide Field Infrared Survey Telescope (WFIRST), $12 million more on science education, and $1.4 million more on the Stratospheric Observatory for Infrared Astronomy (SOFIA), which required the Astrophysics Division to find equivalent savings from its other projects.[43] This included delaying the scheduled launch date of the Imaging X-ray Polarimetry Explorer mission by 6 months from late 2020 to April 2021. NASA also reduced program funding for flying astrophysics experiments on balloons. A few months later, NASA's FY 2019 budget request proposed canceling the WFIRST mission even though Congress had previously supported the project, which is listed as the NRC's highest priority large space initiative in the 2010 Decadal Survey of astronomy and astrophysics.[44]

Another challenge to efficient management of NASA's science portfolio is conflicting and fluid stakeholder priorities. While Congress directs NASA to follow the priorities set out in the decadal surveys, congressional appropriations bills sometimes mandate specific spending, operational, and schedule requirements that do not align well with decadal survey goals and can challenge NASA's ability to manage its portfolio. For example, NASA's FY 2015 appropriations stated, "$100,000,000 shall be for pre-formulation and/or formulation activities for a mission that meets the science goals outlined for the Jupiter Europa mission in the most recent planetary science decadal survey," which provided the Agency significant discretion on how to meet the mission goals set out in the decadal survey.[45] However, in FY 2018 Congress stipulated that the $595 million appropriated that year to meet the science goals for the Europa mission were to be used to launch an orbiter on an SLS no later than 2022 and a Europa lander on an SLS no later than 2024.[46] In its mid-term assessment, the NRC stated that a Europa lander mission had not been prioritized or discussed in detail in the 2013-2022 Decadal Survey and recommended it as a prospective flagship mission in the next Planetary Science Decadal Survey.[47]

Flagship missions, in addition to drawing funding from other Agency priorities, have other effects on the science portfolio that might not be readily apparent. At a June 2018 hearing before the House of Representatives Subcommittee on Space, witnesses testified to the shortage of a technically skilled workforce and its impact on development of NASA's science missions.[48] Most of NASA's large interplanetary projects are developed at the Jet Propulsion Laboratory (JPL) in California and the

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[42] In last year's top management and performance challenges report, we highlighted an example where the President's FY 2018 budget request recommended termination of several Earth Science missions. Congress subsequently provided funding to continue those missions. In the President's FY 2019 budget request, those same missions (except for one NASA canceled in January 2018 due to cost overruns) are again proposed for termination.

[43] WFIRST is planned to be the next large-scale orbiting telescope. It is designed to explore the nature of dark energy, complete the exoplanet census, and directly detect exoplanets. SOFIA is an airborne astronomical observatory—specifically, a Boeing 747 with a built-in telescope—that provides the international research community access to infrared data unattainable from either ground-based or space telescopes.

[44] NRC, *New Worlds, New Horizons in Astronomy and Astrophysics* (2010).

[45] Consolidated and Further Continuing Appropriations Act, 2015, Pub. L. No. 113-235 (2014).

[46] Consolidated Appropriations Act, 2018, Pub. L. No. 115-141 (2018).

[47] NRC, *Visions into Voyages for Planetary Sciences in the Decade 2013-2022: A Midterm Review* (2018).

[48] NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges. Before the House of Representatives Subcommittee on Space, Committee on Science, Space, and Technology, 115th Congress (2018).

projects currently in development—Mars 2020, Surface Water and Ocean Topography (SWOT), and Europa Clipper—are sharing personnel in an effort to meet technical requirements and schedule timelines.[49] If Congress continues to mandate a Europa lander be launched by 2024, the additional mission costs and personnel resources required to achieve this goal would significantly impact the Agency's overall Science Mission Directorate portfolio.

Finally, in a July 2014 report we recommended NASA establish a timeline to evaluate SOFIA within the Senior Review or a similar process during its primary operational phase because its initial, planned operations phase is inordinately long in comparison to most science missions—20 years compared to 5 years.[50] However, soon after NASA proposed a timeline for the Senior Review, Congress directed NASA not to include SOFIA in the 2016 Astrophysics Senior Review and has included this restriction with each subsequent SOFIA appropriation. These types of restrictions limit NASA's ability to utilize a peer review process designed to help objectively assess and manage each of the projects in its science portfolio.

Information Technology Governance and Security

Information technology (IT) plays an integral role in every facet of Agency operations, and hundreds of thousands of individuals—from NASA personnel to members of academia to the public—rely on NASA IT systems every day. In 2017, NASA spent approximately $1.7 billion (8.2 percent) of its $20.8 billion in appropriations on IT investments and operations. The Agency's portfolio of IT assets includes over 500 information systems used to control spacecraft, collect and process scientific data, and enable NASA personnel to collaborate with colleagues around the world. For more than 10 years, we have identified securing NASA's IT systems and data as a top management challenge. Although the Agency has made progress in this area, we remain concerned about the state of the Agency's IT governance, its acquisition of IT systems, cybersecurity vulnerabilities, and IT security incident detection and handling capabilities.

Information Technology Governance

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

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[49] Scheduled to launch in 2020, the Mars 2020 rover plans to investigate a region of Mars where the ancient environment may have been favorable for microbial life, probing Martian rocks for evidence of past life. Scheduled to launch in 2021 and jointly developed and managed by NASA, the French Space Agency, and the Canadian Space Agency, the SWOT satellite is designed to make the first-ever global survey of Earth's surface water in order to improve ocean circulation models, weather and climate predictions, and aid in freshwater management around the world. We have issued reports on Mars 2020—*NASA's Mars 2020 Project* (IG-17-009, January 30, 2017)—and SWOT—*NASA's Surface Water and Ocean Topography Mission* (IG-18-011, January 17, 2018)—and are currently assessing the Agency's management of the Europa mission.

[50] NASA OIG, *SOFIA: NASA's Stratospheric Observatory for Infrared Astronomy* (IG-14-022, July 9, 2014). The Senior Review is a peer review process that evaluates the continued value of projects that have completed or are nearing completion of their initial planned operating phase.

We have examined the issue of NASA's IT governance for the past 15 years.[51] In 2005, we reported that the Agency Chief Information Officer (CIO) and IT security officials had very limited oversight and influence over IT purchases and IT security decisions at NASA Centers. In 2013, we reported the Agency CIO continued to have limited visibility and control and found the decentralized nature of NASA's operations and its longstanding culture of autonomy hindered its ability to implement effective IT governance.

Given the criticality of these issues, we reexamined the Agency's governance reform efforts in an October 2017 follow-on audit and found a continued lack of progress in improving the Agency's IT governance, casting doubt on the Office of the Chief Information Officer's (OCIO) ability to effectively oversee the billions NASA spends on IT.[52] Specifically, the CIO continues to have limited visibility into IT investments across NASA and the process the Agency developed to correct those shortcomings is flawed. Moreover, the OCIO continues its decade-long struggle to establish an effective enterprise architecture (the map of IT assets, business processes, and governance principles that drive ongoing investment and management decisions). While the OCIO has made changes to its three senior advisory boards over the past few years, these boards have yet to make strategic decisions that substantively impact how IT at NASA is managed. Consequently, slow implementation of the OCIO's revised IT governance structure left many Agency IT officials operating under the previous inefficient and ineffective framework. Further, lingering confusion regarding IT security roles coupled with poor IT inventory practices negatively impact NASA's security posture. Finally, the OCIO continues to have limited influence over IT management within the Mission Directorates and at Centers due to the autonomous nature of NASA's operations and its lack of credibility on IT issues in the eyes of many of its customers.

GAO also continues to examine the Agency's longstanding IT governance issues. Most recently, in May 2018 GAO identified weaknesses in NASA's IT management practices for strategic planning, workforce planning, and governance.[53] Moving forward, continued senior leadership attention is needed to ensure NASA improves its IT governance system to provide secure, efficient, and cost-effective IT systems for Agency personnel, contractors, and the public.

Securing Information Technology Systems and Data

NASA maintains a significant online presence with approximately 3,200 publicly accessible web applications that allow NASA to share information on its aeronautics, science, and space programs with the public and worldwide research community. The Agency's vast connectivity with educational institutions, research facilities, and other outside organizations offers cybercriminals a larger target than most other government agencies and presents unique IT security challenges.

NASA must ensure that its IT systems and associated components are safeguarded, assessed, and monitored to protect against inevitable attacks. Like most federal agencies, NASA is subject to computer security incidents related to malicious software on or unauthorized access to Agency computers. These incidents include individuals testing their skills to break into NASA systems, well-organized criminal enterprises hacking for profit, and intrusions that may be sponsored by foreign intelligence services

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[51] NASA OIG, *NASA's Information Technology Governance* (IG-13-015, June 5, 2013) and *Review of Organizational Structure and Management of Information Technology and Information Technology Security Services at NASA* (IG-05-013, March 30, 2005).

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

[53] GAO, *NASA Information Technology: Urgent Action Needed to Address Significant Management and Cybersecurity Weaknesses* (GAO-18-337, May 22, 2018).

seeking to further their countries' objectives. For example, a bad actor gained access to several JPL network applications and systems in an attack that started in April 2017 when several security controls failed, including misconfigurations of user roles and ineffective vulnerability scans. This attack, which was not identified until a year later, is believed to have been initiated when a misconfigured foreign partner's user account was exploited to gain entry to the JPL network. The incident is currently under investigation.

While NASA is continually taking actions to improve its security posture, the Agency has yet to develop an Agency-wide risk management process specific to information security.[54] Further complicating this situation is the high turnover of key personnel in the Agency's OCIO—specifically, the CIO and Senior Agency Information Security Officer roles—resulting in a lack of leadership continuity and effective program planning.

We have conducted a substantial body of audit work over the past decade examining the security and acquisition of NASA IT systems, including incident detection and response by NASA's Security Operations Center (SOC), IT supply chain risk management, cloud computing, and security of industrial control systems.

Managing IT security incidents at NASA is a highly decentralized activity involving the Agency's Headquarters and nine Centers. In November 2008, NASA created the SOC at Ames Research Center to identify and respond to Agency-wide security threats to Agency networks and IT systems. Since its inception a decade ago, the SOC has fallen short of its original intent to serve as NASA's cybersecurity nerve center. An effective Agency-wide SOC should have insight over and access to all equipment and data connected to NASA's systems to mount an effective defense and mitigate cyberattacks. However, in a May 2018 audit report we found that the effectiveness of NASA's SOC has been limited by a lack of clarity in its oversight authority; undefined relationships between different functional areas within the OCIO, Centers, and Mission Directorates; and its current contract structure.[55] In sum, we found the SOC lacks the key structural building blocks necessary to effectively meet its IT security responsibilities.

During FY 2018, we also examined the effectiveness of NASA's supply chain risk management efforts, which includes identifying, assessing, and neutralizing risks associated with IT and communications products or services.[56] As the globalization of vendors and suppliers of IT and communications products and services continues to expand, so do the risks associated with counterfeit or sabotage products entering federal supply chains. While NASA's supply chain risk management efforts have improved since we last examined them in 2013, weaknesses in the Agency's IT risk management and governance practices continue to impede NASA's progress in establishing secure IT and communications product and service supply chains.[57] Moreover, with NASA's increasing use of commercially-supplied IT and communications products and services, it is imperative the Agency strengthen its supply chain risk management and assessment practices to safeguard its data, systems, and networks.

The cloud computing marketplace has grown exponentially over the past 5 years, as has the complexity of cloud services and the threats and risks associated with storing government data in the cloud. NASA uses cloud computing to enable on-demand network access to a shared pool of configurable computing

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

[55] NASA OIG, *Audit of NASA's Security Operations Center* (IG-18-020, May 23, 2018).

[56] NASA OIG, *Audit of NASA's Information Technology Supply Chain Risk Management Efforts* (IG-18-019, May 24, 2018).

[57] NASA OIG, *NASA's Progress In Adopting Cloud-Computing Technologies* (IG-13-021, July 29, 2013).

resources such as computer servers, storage, and software applications, in its scientific, mission, and support programs. In a 2016 report, we noted weaknesses in the Agency's risk management and governance practices that impeded its progress toward fully realizing the benefits of cloud computing.[58] These weaknesses, coupled with the fact that much of the Agency's cloud computing activity occurs outside of approved cloud computing services, puts Agency information stored in the cloud environment at risk.[59] With NASA's increasing use of the cloud, it is imperative the Agency strengthen its risk management and governance practices to safeguard its data.

In addition to traditional IT systems, the security of NASA's operational technology (physical processes controlled remotely with sophisticated and interconnected IT equipment) is imperative. Many of these systems are part of the Agency's critical infrastructure used to test rocket propulsion systems, control and communicate with spacecraft, and operate ground support facilities, or are associated with electrical power, heating and cooling systems, and other supporting infrastructure. As this infrastructure becomes more interconnected and complex, NASA faces an increased risk of cyber threats that could compromise missions and underlying Agency IT systems and networks. In a February 2017 report, we found that despite its significant presence across the Agency and its criticality to the success of the Agency's mission, NASA had not adequately defined operational technology, developed a centralized inventory of operational technology systems, or established a standard protocol to protect systems that contain operational technology components.[60] Further, NASA lacked an integrated approach to managing risk associated with its critical infrastructure that incorporates physical and cybersecurity considerations in all phases of risk assessment and remediation. Increased collaboration among NASA Mission Directorates, OCIO, Office of Protective Services, and Office of Strategic Infrastructure is crucial to accurately identifying critical assets and improving the security of NASA's operational technology environment.

In addition to our audit work, we continue to aggressively review and investigate issues surrounding breaches of NASA's IT systems. The OIG also works with NASA's Office of Counterintelligence to monitor and investigate attempts by unauthorized individuals to access sensitive export-restricted Agency software. We successfully investigated a former NASA contract employee who deleted decades' worth of scientific data derived from one-of-a-kind experiments on the ISS in retaliation for being dismissed by the Agency. The individual fled overseas, but our investigative efforts led to his arrest and conviction. The deleted scientific data was eventually restored at great expense to NASA, underscoring the significant damage a trusted insider with elevated IT access can cause.

Infrastructure and Facilities

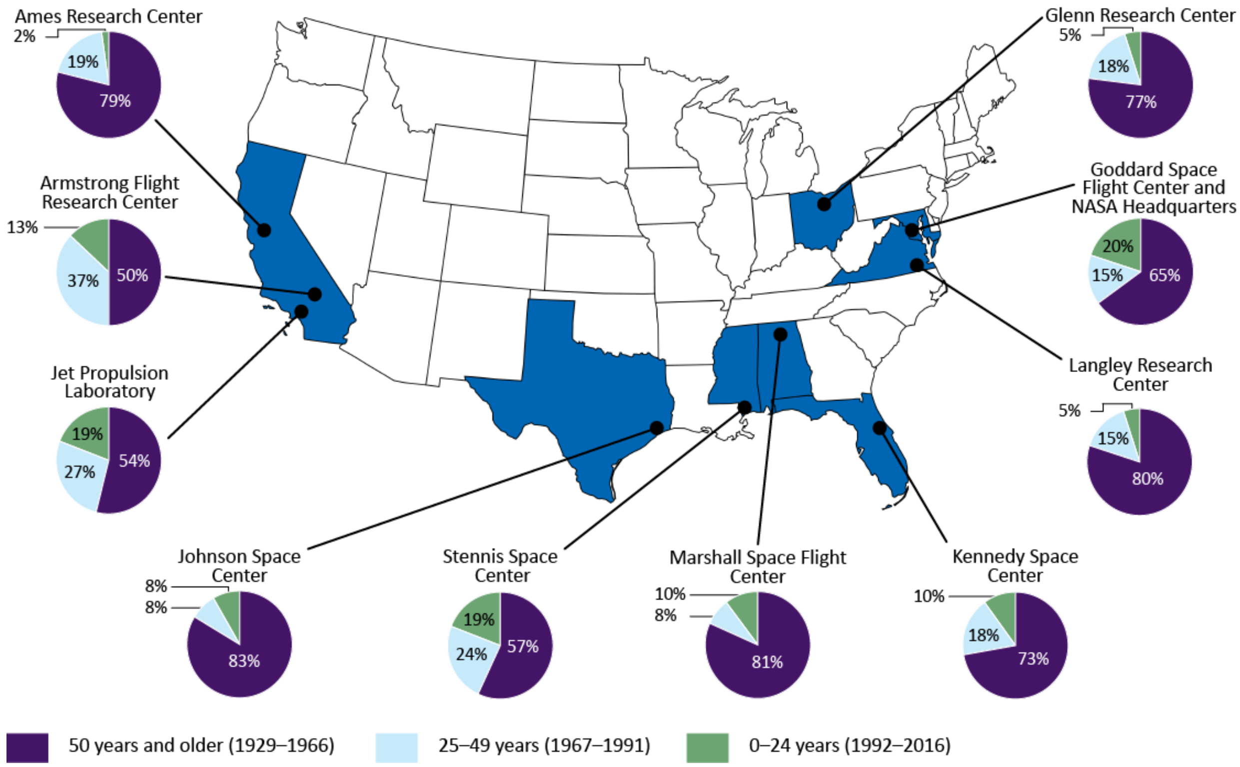
NASA controls approximately 5,000 buildings and structures with an estimated replacement value of at least $34 billion, making the Agency one of the largest property holders in the federal government. However, more than 80 percent of the Agency's facilities are 40 or more years old and are beyond their design life (see Figure 2).

[58] NASA OIG, *Security of NASA's Cloud Computing Services* (IG-17-010, February 7, 2017).

[59] The Federal Risk and Authorization Management Program (FedRAMP) includes a security assessment framework that guides the completion of system security plans based on security requirements issued by the National Institute of Standards and Technology.

[60] NASA OIG, *Audit of Industrial Control System Security within NASA's Critical and Supporting Infrastructure* (IG-17-011, February 8, 2017).

Figure 2: NASA's Facilities (as of March 2017)



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

While NASA strives to keep these facilities operational—and when not operational in sufficient condition so they do not pose a safety hazard—the Agency has not been able to fully fund required maintenance for its facilities for many years, with NASA estimating its deferred maintenance costs at $2.6 billion in 2018. The Agency faces ongoing operational challenges in this area as it juggles a long history of decentralized governance, intense political interest in its Centers and their real property assets, and competition for budget resources.

Over the last 8 years, we have dedicated substantial resources—issuing 17 audit reports—examining different facets of NASA's infrastructure challenges, including the Agency's efforts to "rightsize" its workforce, facilities, and other supporting assets; the construction of new test stands at Marshall; NASA's plans for underused test facilities at Plum Brook Station in Ohio; management of historic properties; management of its Pressure Vessels and Pressurized Systems and Explosive Safety Programs; the Agency's environmental remediation efforts; and its efforts to reduce unneeded infrastructure and facilities. Common themes throughout all of these reviews are slow implementation of corrective actions, inconsistent implementation of Agency policies, and a need for stronger life-cycle cost considerations in facility construction decisions.

NASA established the Technical Capabilities Assessment Team (TCAT) in June 2012 to assess the Agency's technical capabilities (including infrastructure and personnel resources) and make recommendations for investing in, consolidating, or eliminating capabilities based on mission requirements.[61] In our March 2017 report on that effort, we found that after more than 4 years the Agency had yet to make key decisions about its capabilities or decide whether to consolidate or dispose of assets.[62] Rather, most decisions have been iterative steps on the path to making determinations about technical capabilities, leaving us concerned that the Agency's efforts have been slow to produce meaningful results. Moreover, NASA's assessments of its capabilities did not consistently include information needed to make informed decisions, including mission needs or facility usage data, analyses to determine gaps or overlaps, recommendations to achieve cost savings, or firm timeframes for completing actions. Although these assessments are ongoing, NASA commissioned the Aerospace Corporation to independently evaluate the status of its effort. Its review identified varying degrees of engagement across the Agency and as a result, NASA officials are assessing the model's concept of operations and future direction. Regardless of the outcome of their assessment, the Agency must be willing to make difficult decisions to invest, divest, or consolidate unneeded infrastructure; effectively communicate those decisions to stakeholders; and withstand the inevitable pressures from federal, state, and local officials to retain capabilities and structures "just in case."

Test Stand 4693 at Marshall Space Flight Center

Source: NASA.

In May 2017, we reported on NASA's construction of two test stands at Marshall and found that inadequate planning ultimately increased project costs.[63] NASA built the test stands to test the liquid hydrogen and liquid oxygen tanks from the Core Stage of the SLS rocket. To meet schedule commitments, test stand design and construction began before the tank design was finalized, and as a result, NASA had to pay the contractor a premium of $7.6 million for the additional labor needed to work around-the-clock to meet the original ambitious schedule. Subsequently, when the project's requirements matured, NASA needed an additional $20.3 million to make modifications to the original test stand designs. Because NASA failed to establish adequate funding reserves to cover these increased costs, project officials had to secure $35.5 million in additional funding over the planned budget. Finally, NASA did not adequately consider alternative locations before selecting Marshall as the site for the new test stands and therefore cannot be sure it made the most cost-effective decision.

Contracting and Grants

In FY 2017, NASA spent approximately $17.5 billion or 73 percent of its $24 billion of available resources, which includes reimbursable authority, on contracts to procure goods and services.[64] The Agency

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

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

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

64 NASA has various authorities allowing the provision of goods, services, or underutilized facilities to enable other government and non-government partners to access NASA's technical capabilities and unique resources in return for reimbursement. In FY 2017, $2.3 billion of NASA's total spending authority came from funds collected through reimbursable agreements.

awarded an additional $1 billion in grants and cooperative agreements. Accordingly, NASA managers face the ongoing challenge of ensuring the Agency receives fair value for its money and that recipients spend NASA funds appropriately to accomplish agreed-upon goals. The OIG seeks to assist NASA in these efforts by examining Agency-wide procurement and grant-making processes; auditing individual contracts, grants, and cooperative agreements; and investigating potential misuse of Agency contract and grant funds. Additionally, we monitor the impact of contracts and grants awarded to assist NASA in accomplishing its aeronautics, exploration, and science missions as well as to provide support in areas like information technology.

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

During the past year, the OIG continued to uncover fraud and misconduct related to NASA contracts and grants. For example, a university agreed to pay $1.7 million in a civil settlement to resolve allegations it failed to properly track time and effort reporting under multiple federal grants based on a NASA OIG investigation. This investigation also revealed that several of the university's faculty members misappropriated federal funds for personal gain. In another NASA OIG investigation, the president of a Houston, Texas, software company was charged with one count of major fraud, six counts of false statements, and one count of false claims for inflating costs and double-billing against several NASA contracts, resulting in damages in excess of $2.6 million.

Contracting

Over the years, our audit work has identified multiple issues with NASA's contracting process, including its use of service contracts. In a May 2016 audit, we noted that vague statements of work can lead to duplication across contracts and found that in some instances task orders issued on a cost-reimbursable basis appeared more suitable to a fixed-price arrangement.[65] Similarly, NASA's management of acquisitions continues to remain on GAO's high-risk list. In addition, GAO found agencies that spend the most on service contracts may not be fully utilizing independent government cost estimates—the government's best estimate of a contract's potential costs.[66] GAO stated that while there are benefits to using contractors to provide services to help address surge capacity needs, it cautioned about the risks of over-reliance on contractors and the need for increased management attention on certain types of services such as professional and management support services.[67] In light of these challenges, in

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

[66] GAO, *Service Contracts: Agencies Should Take Steps to More Effectively Use Independent Government Cost Estimates* (GAO-17-398, May 17, 2017).

[67] GAO, *Contracting Data Analysis: Assessment of Government-wide Trends* (GAO-17-244SP, March 9, 2017).

February 2018 we initiated an audit to examine NASA's process for acquiring and managing service contracts. More recently, in August 2018 we initiated an audit of a specific service contract—the Agency's Strategic Assessment Contract—to assess whether NASA is appropriately managing the contract to accomplish its intended objectives relative to cost, schedule, and scope.

Grants

NASA also awards approximately $1 billion in grants and cooperative agreements annually to facilitate research by educational institutions or other nonprofit organizations as well as fund scholarships, fellowships, and stipends to students and teachers. The Agency faces the ongoing challenge of ensuring grant and cooperative agreement funds are administered appropriately and that recipients are accomplishing agreed-upon goals. We continue to conduct audits and investigations to assist NASA in meeting this oversight challenge.

As part of our broader examination of NASA's collaborations with universities and other nongovernmental entities, in April 2018 we reported on the Agency's management of the Goddard Institute for Space Studies (GISS).[68] The Institute plays an important role in developing long-range predictions related to Earth's atmosphere and climate through its development of global climate models and prolific publication of scientific research. However, in our review we found flaws in GISS's review process for releasing scientific information and publications. Further, we are concerned with the sufficiency of NASA's financial oversight of GISS (in FY 2016, NASA provided 96 percent of GISS's $19.1 million annual funding). Specifically, we found $1.63 million in questionable costs for GISS's agreements and contracts and loose accountability related to the purchase and tracking of computer equipment obtained using a government purchase card. Finally, although the Institute has significant ad hoc collaborations with public and private institutions, GISS could enhance its climate modeling and research activities by coordinating with agencies that conduct similar work, potentially avoiding duplicative costs.[69]

In February 2018, we examined NASA's management of its $484 million cooperative agreement with the nonprofit National Space Biomedical Research Institute (NSBRI) and how the Institute's work contributed to the Agency's biomedical research.[70] We found that NSBRI delivered research products that helped NASA make progress toward the goal of mitigating human health and performance risks associated with space travel. However, while most NSBRI charges complied with applicable laws and the award's terms, the Agency improperly permitted NSBRI to use $7.8 million of research funds to renovate and pay rent for laboratory space in a private building during the final 7 years of its 20-year agreement. In successor agreements, NASA needs to exercise stronger oversight to ensure efficient operations and prevent unnecessary duplication of research and administrative costs.

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[68] NASA OIG, *NASA's Management of GISS: The Goddard Institute for Space Studies* (IG-18-015, April 5, 2018). GISS, located in New York City, is a laboratory in Goddard's Earth Science Division established in May 1961 to conduct basic research in space sciences.

[69] GAO, *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies* (GAO-06-15, October 21, 2005).

[70] NASA OIG, *Audit of the National Space Biomedical Research Institute* (IG-18-012, February 1, 2018).

Finally, in a January 2018 audit we examined the 13-year, $196 million cooperative agreement awarded to the Center for the Advancement of Science in Space (CASIS) to manage non-NASA research activities on the U.S. portion of the ISS known as the National Laboratory.[71] Given the importance and expense of research in low Earth orbit, we reviewed CASIS's performance and assessed the quality of NASA's oversight of the organization. More than halfway through the 13-year cooperative agreement, we found that CASIS has not yet met expectations with regard to achieving the goals and objectives of the agreement—maximum utilization of the National Laboratory, a balanced project portfolio, and a robust market for small business commercial providers. Further, we found NASA needs to increase its oversight of CASIS by evaluating its performance semiannually and ensuring plans include metrics and targets for all performance categories.

[71] NASA OIG, *NASA's Management of the Center for the Advancement of Science in Space* (IG-18-010, January 11, 2018). In August 2011, NASA awarded a 10-year, $136 million cooperative agreement to CASIS to manage the National Laboratory. In July 2017, NASA extended the CASIS cooperative agreement to September 2024, increasing its total cost to $196 million.

Appendix A: Management's Comments

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

November 8, 2018

TO: Inspector General

FROM: Administrator

SUBJECT: Agency Response to Office of Inspector General Report, "NASA's 2018 Top Management and Performance Challenges"

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) report entitled, "NASA's 2018 Top Management and Performance Challenges."

NASA firmly believes that the oversight provided by the OIG affords Agency leadership and management with significant contributions in terms of insight and perspective with regard to NASA's broad portfolio of programs, projects, and mission support activities. The audits and investigations conducted by the OIG during this past year have served to strengthen the Agency's efforts to ensure responsible stewardship of scarce taxpayer resources in the execution of NASA's diverse and ambitious mission.

We concur with the OIG's assessment that the six areas outlined in the report comprise significant challenges to the Agency both in the short term and from a longer-term perspective. These areas, by their very nature, are complex and pose inherent challenges to the Agency.

The following highlights some of NASA's efforts and initiatives intended to reduce the overall risk to mission posed by the challenges you have identified as a means of demonstrating NASA's commitment in addressing its most significant management and performance challenges:

1. Space Flight Operations in Low Earth Orbit

International Space Station:

The International Space Station (ISS) International Partnership and the ISS National Lab continue to mature the safe operations and utilization of this unique on-orbit research platform. Research and utilization for the wide variety of fields, including human health and performance, long duration life support demonstrations, life and physical sciences, Earth and space science, astrophysics, and multiple technology development fields, continue to expand in the number of experiments and the number of investigators. From

ISS Increment 41/42 (first half of FY15) to Increment 55/56 (second half of FY18), the amount of crew time has increased by approximately 79 percent. In addition, the number of investigations increased by approximately 27 percent from FY16 to FY17 (Increment 49 through Increment 56).

This is possible by the combined ongoing efforts of the ISS Program, the National Lab operator Center for the Advancement of Science in Space (CASIS), and the commercial cargo suppliers to utilize and operate the ISS to its utmost capability. The ISS Program is now operating based on the many years of experience learned in pre-flight integration activities, on-orbit crew planning and execution, logistics planning and management and other aspects of ISS management and operations; all of which is providing dividends in returning benefits to humanity, enabling the development of a commercial market and enabling deep space long duration exploration. Research clients are able to get experiments to orbit in as little as four months. Seeing different resources are required for different types of research, NASA continues to evaluate the needs of the research community and add resources to alleviate limitations whenever possible.

Research, technology development, and commercial development efforts onboard the ISS by NASA, other government agencies, and by the private sector through the National Lab continues to see benefits applied here on Earth as reflected in the third version of the ISS Benefits to Humanity Document, available by the end of 2018.

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

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

Commercial Transportation to the ISS – Cargo Resupply:

Over the past year, SpaceX and Orbital ATK, now owned by Northrop Grumman, have remained very responsive to NASA's needs to resupply the ISS. Both commercial service providers have flown their expected cargo missions to the ISS over the past year. NASA is also working with the newest of the cargo resupply providers, Sierra Nevada Corporation (SNC), to safely incorporate their logistical capabilities into the ISS logistics flow. NASA continues to work with all suppliers to assess the risk to ISS operations and cargo launches within NASA's procedures documented in NPD 8610.7, "Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions" and NPD 8610.23, "Launch Vehicle Technical Oversight Policy."

Commercial Transportation to the ISS – Commercial Crew:

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

2. Deep Space Exploration

NASA's National Space Exploration Campaign Report, delivered to Congress in September 2018, describes NASA's approach to meeting the objectives of Space Policy Directive-1 (SPD-1). SPD-1 directs NASA "to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond LEO, the U.S. will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations." The National Space Exploration Campaign builds on the 18 continuous years of U.S. and international partners living and working together on the ISS. It outlines the objectives, critical decisions, and milestones for the near- and mid-term missions that will implement SPD-1, including building the Lunar Gateway as a first step in the sustainable exploration and development of the Moon. With this framework established, NASA is developing program plans, schedules, and budgets to achieve these objectives.

The Space Launch System (SLS), Orion crew spacecraft, and Exploration Ground Systems (EGS) form the critical transportation backbone for NASA's Exploration campaign. Exploration Mission-1 (EM-1) in 2020 will be the first integrated test flight of these systems in cislunar space. While the majority of the work is on track, as has been previously noted, NASA is seeing specific areas of targeted challenges consistent with a first-time design, development, test, and build of a human spacecraft system for deep space, including challenges associated with developing the world's largest friction stir weld facility and advanced welding methods, understanding and fixing unexpected contamination issues for propellant tubing, and adapting long-standing operational work management processes to incorporate the flexibility needed to accommodate the uncertainties of a first-time build. The assembly complexity of the Core Stage engine section, which is similar to the aft compartment of a Space Shuttle Orbiter with an extra engine and thrust vector control, was not completely appreciated. NASA has implemented actions and is taking further steps to improve management and performance in the SLS, Orion, and EGS programs, and the OIG's recommendations are consistent with the work NASA already has underway. Improvements NASA has made include:

- Revising the schedule management approach to improve visibility and correlation to lower-level tasks and to better account for risk in schedule projections. Activities are being added that help prepare the response to problems that will occur in preparation of the hardware for flight.

- Revising the governance approach to expedite decision-making processes while maintaining improved NASA oversight and integration in the resolution process.
- Revising technical plans to simplify work instructions, reduce errors and non-conformances, and improve flow and traceability.

- Working with contractors and international partners to offer improved technical and affordable solutions to challenges and to better align priorities and schedules, including judiciously increasing workforces to optimize the right skill sets in the right areas to address critical path issues.

NASA believes that it is essential to take the time to effectively resolve first-time build challenges now, which leads to near-term schedule and cost challenges, but yields significant benefits for out-year flight element manufacturing. NASA's goal for returning humans to cislunar space on EM-2 remains on track, and NASA is looking at ways to accelerate that schedule into mid-2022.

Progress made to date is highlighted below:

Space Launch System:

The Space Launch System (SLS) is the most powerful, most capable launch system in the history of space flight. NASA is designing and implementing a manufacturing capability to efficiently produce, test, and qualify space flight hardware for long-term use, to human rating standards, on a scale never achieved before, and this work represents a national investment in a long-term commitment to deep space exploration. Throughout the SLS development and production efforts, NASA's primary goal has been to implement processes and procedures that will support long-term production needs in a safe manner.

This year, NASA's Super Guppy aircraft delivered the EM-1 Orion stage adapter, the second of five major elements of the first SLS flight vehicle, to Kennedy Space Center (KSC). At Michoud Assembly Facility (MAF), the five major structural pieces of the SLS core stage are completing final outfitting and assembly. Construction of the forward skirt and intertank are complete, and the liquid oxygen and hydrogen tanks are nearing completion. The structural test article for the hydrogen tank will ship to the Marshall Space Flight Center (MSFC) by the end of the year for testing that will simulate the forces of flight. Structural qualification testing of the engine section was completed some time ago, and intertank structural qualification is under way. Teams have also been applying the thermal insulation to flight hardware for protection from extreme temperatures it will face during launch. Process improvements to the application process are reducing the time needed for this work.

The SLS team is putting the finishing touches on the 30-foot-tall launch vehicle stage adapter that will connect the core stage to the interim cryogenic propulsion stage, which was delivered to KSC last year. All four EM-1 RS-25 core stage engines are complete and ready for shipping to MAF for integration with the EM-1 core stage. The SLS booster team in Utah has finished eight of the ten EM-1 solid rocket motor segments and will complete the last two segments before the end of the year. EM-2 flight hardware fabrication and assembly is also well under way on the SLS core stage, boosters, and core stage engines. The liquid engines team is green-run hot-fire testing engine controllers to be used as far out as the fourth flight of SLS, as well as testing new hardware made with advanced manufacturing technologies that will reduce engine costs by better than 33 percent.

Orion:

The Orion team has completed the majority of the work to assemble the EM-1 crew module. Thousands of components like Orion's windows, avionics, wire harnessing, and parachutes that make up more than 30 subsystems have been integrated and tested through evaluations like thermal cycle testing, proof tests on propulsion lines, and functional tests to ensure systems work as planned. The team recently installed the heatshield that will protect the EM-1 crew module upon reentry from the lunar vicinity through Earth's atmosphere. The Orion European Service Module, which provides propulsion, power, water, and oxygen was shipped from Bremen, Germany, on November 5, 2018, and arrived at Kennedy Space Center (KSC) on November 6, 2018, to begin the next phase of integration and test.

Testing on a structural test article in Denver for sound and vibration evaluations has confirmed Orion can withstand the extreme acoustic and vibration environments of the launch and separation event in space. At sea, NASA and the Department of Defense have honed the procedures and skills they will use to recover Orion upon splashdown in the Pacific Ocean. Flight controllers also conducted tests to ensure that Orion can communicate with mission control through NASA's satellite network. Welding of the Orion EM-2 crew module pressure vessel was completed at MAF and the assembly has been shipped to KSC for outfitting.

The Agency tested Orion's parachute system for the final time in mid-September, bringing NASA another step closer to verifying the spacecraft is ready to bring crews home in any scenario. Work is progressing at several NASA Centers in preparation for a test of Orion's launch abort system in the spring of 2019 that will verify the crew can be carried to safety in an emergency during launch.

Exploration Ground Systems:

EM-1 will be the first integrated test flight of Orion, SLS, and the supporting ground systems. Launching from KSC in Cape Canaveral, Florida, in 2020, EM-1 will prepare the way for future missions with astronauts.

During 2018, major critical launch infrastructure neared completion in preparation for launch. EGS completed construction on the main flame deflector at the launch pad and launch control teams conducted realistic launch simulations. Over the summer, software teams completed critical updates to use for command and control from the firing room to support the first mission.

In August, EGS installed the final umbilical on the mobile launcher. In September, for the first time since the mobile launcher has been modified for the SLS, the massive tower rolled out atop the Crawler-Transporter 2 to Launch Pad 39B for a fit check that verified all physical connections between the launcher and pad systems before rolling into the Vehicle Assembly Building for further analysis and detailed adjustments.

3. NASA's Science Portfolio

The Science Mission Directorate (SMD) develops and implements an extensive portfolio of scientific programs and projects that are inherently complex and present unique challenges. We appreciate the OIG's recognition of the inherent challenges involved with managing a portfolio with incongruous guidance from our stakeholders.

External Influences:

In developing its diverse science portfolio, NASA receives guidance, sometimes conflicting, from a variety of stakeholders including the President, Congress, the National Research Council, and others. SMD strives to develop a balanced portfolio to achieve three overall, interdisciplinary objectives: 1) Safeguarding and improving life on Earth; 2) Searching for life elsewhere; and 3) Expanding our knowledge through research from here at home into the deep universe.

As noted by the National Academies of Sciences, Engineering, and Medicine, NASA's planetary science program continues on track. The Agency has met or exceeded many of the goals set by the Academies in the 2013-2022 decadal survey[1]. The Mars Exploration Program continues to be a key component of our Planetary Science Division. NASA will continue to look for additional opportunities, after Mars 2020, to capitalize on the experience base gained through recent Mars missions.

In Astrophysics, the near future will be dominated by several missions in partnership with other space agencies. Currently in development, with especially broad scientific utility, is the James Webb Space Telescope. Also in work are detectors for the European Space Agency's (ESA) Euclid mission and hardware for the Japanese

[1] Review of Progress Toward Implementing the Decadal Survey Vision and Voyages for Planetary Sciences http://sites.nationalacademies.org/ssb/currentprojects/ssb_177619

Aerospace Exploration Agency's (JAXA) X-Ray Imaging and Spectroscopy, previously named XARM (XRISM), to provide breakthroughs in the study of structure formation of the universe, outflows from galaxy nuclei, and dark matter.

Internal Influences:

Recently completed and launched on time and under budget, NASA's Parker Solar Probe is on its way to orbit the Sun closer than any other spacecraft while investigating its corona and outer atmosphere. SMD's internal processes provided some of the guidance necessary to launch this mission on time and under budget. The mission will sample plasma and the coronal magnetic field to investigate coronal heating and the origin and evolution of solar wind. The mission will also provide a better understanding of the radiation environment in which future space explorers will live.

Similarly, the Global Ecosystem Dynamics Investigation instrument heads toward an earlier launch to the ISS than previously expected. A first-of-its-kind laser instrument designed to map the world's forests in 3-D will help fill in critical gaps in scientists' understanding of how much carbon is stored in the world's forests, the potential for ecosystems to absorb rising concentrations of carbon dioxide in Earth's atmosphere, and the impact of forest changes on biodiversity.

As we look toward the future, SMD has begun exploring ways to not only conduct lunar science but to also use the area around and the surface of the Moon as a science platform to look back at the Earth, observe the Sun, or view the vast universe. These and other new missions, combined with those in operations, enable SMD to develop a balanced portfolio, implementing the cutting-edge missions necessary to advance science and produce the incredible discoveries for which NASA is known.

4. Information Technology Governance and Security

NASA's information technology (IT) provides the foundation necessary to accomplish NASA's missions. NASA remains firmly committed to managing IT as a strategic resource to enable mission success, ensure effective communications and collaboration, and safeguard both the IT environment and the resources that support these operations. NASA's focus on IT as a strategic resource began in 2014, establishing a basis for the work that continues today.

Several critical elements inform the deliberate process by which NASA continues improving the IT infrastructure and environment. These elements include: 1) assessing what we have by ensuring that all NASA IT can be identified, monitored, protected, and, if necessary, removed from the environment; 2) executing the Agency's IT governance to be a robust, engaged, and deliberative collaboration between the Chief Information Officer (CIO) and every NASA stakeholder, complying with the Federal Information Technology Acquisition Act (FITARA) and all other laws, directives, and requirements; and; 3) reducing duplications and inefficiencies, resulting in appropriate enterprise solutions.

NASA's Business Services Assessment (BSA) for IT, initiated in 2015, provided the foundation for the Office of the Chief Information Officer (OCIO) to establish quality enterprise IT, collaborate with federated IT, and obtain insight and visibility into diversified IT. The NASA IT Strategic Plan published in December 2017, articulated the plan to manage NASA IT as a strategic resource for the next four years. Utilizing these established foundations, FY 2018 focused on defining and assessing the full IT life cycle, including investment management, meeting FITARA legislation, and achieving management of cyber risk, with assistance from the Department of Homeland Security (DHS).

Information Technology Governance:

In FY 2018, NASA built upon the existing IT governance framework to include expanding NASA's IT portfolio, as reported to OMB as part of the FY 2020 budget formulation process. The Information Technology Council (ITC), NASA's senior IT decision-making body and chaired by the CIO, set NASA's IT direction, made resource decisions to obtain the most effective and efficient IT capabilities, and established opportunities to achieve greater understanding and granularity on all NASA IT spend.

OCIO participation in mission governance, boards, councils, and working groups improved as well. The OCIO, missions and Centers (including the Agency and Mission Directorate Program Management Councils), are actively working to ensure and improve consideration of IT, including cybersecurity, in mission program and project life cycles. The NASA CIO is an engaged and key member of Agency Councils, including the newly established NASA Acquisition Strategy Council, to ensure oversight of IT spend in acquisitions.

Securing Information Technology Systems and Data:

The Agency's cybersecurity posture continues to improve and address NASA's unique IT security challenges. FY 2018 improvements included: 1) gaining further insight into cybersecurity risk mitigation in NASA's mission environment; 2) establishing an Office of Cybersecurity Services (OCSS) for consolidated and effective cybersecurity service delivery; 3) gaining insight of critical, high, medium, and low criticality Operational Technology (OT) systems; and 4) establishing the NASA Cybersecurity Integration Team (CIT) to identify and mitigate top Agency IT risks across all of NASA's enterprise, including the NASA Missions and High Value Assets (HVAs). NASA re-designed the IT Supply Chain Risk Management service to better identify, assess, and neutralize risks associated with IT and communications products or services. The deployment of the DHS Continuous Diagnostics and Mitigation (CDM) Phase I Program to the corporate network offers another example of a major FY 2018 accomplishment. This deployment improved the Agency's cybersecurity posture, hardware and software asset management, vulnerability management, and configuration management. Additionally, NASA completed CDM Phase II deployment, which further strengthened the Agency's Identity, Credential, and Access Management (ICAM) capabilities.

NASA continues to improve cybersecurity monitoring and detection capabilities within the NASA Security Operations Center (SOC). NASA's SOC, which is responsible for NASA cyber incident response, reports all cyber incidents to the United States Computer Emergency Readiness Team (US-CERT), pursuant to the Federal Incident Notification Guidelines. As a result of organizational and technological improvements, NASA experienced a significant decrease in the number of cyber incidents, as noted in the table below. In FY 2017 and 2018, NASA reported the following number of incidents to the DHS US-CERT Incident Reporting System by incident category:

Category	Name	Description	Number of FY17 Incidents	Number of FY18 Incidents
CAT 1	Unauthorized Access	In this category, an individual gains logical or physical access without permission to a Federal agency network, system, application, data, or other resource.	**745**	**214**
CAT 2	Denial of Service (DoS)	An attack that successfully prevents or impairs the normal authorized functionality of networks, systems, or applications by exhausting resources. This activity includes being the victim or participating in the DoS.	**21**	**7**
CAT 3	Malicious Code	Successful installation of malicious software (e.g., virus, worm, Trojan horse, or other code-based malicious entity) that infects an operating system or application.	**344**	**76**
CAT 4	Improper Use	A person violates acceptable computing use policies.	**173**	**8**
		Total	***1,283***	***305***

There is continued work to realizing fully integrated IT governance, particularly IT Authority and Investment Management for NASA's full IT portfolio, as well as maintaining the successful management of cyber risk. This work is dependent on the Agency's continued support, partnership, and collaboration with internal and external partners. With the development and implementation of the Agency initiative known as the Mission Support Future Architecture Program (MAP), we look forward to sustained IT transformation and the expected benefits. Through robust partnerships, collaborations, and governance, NASA welcomes the opportunities available in the shared responsibility for the full life cycle of IT, including who purchases, deploys, has insight and oversight, and protects the NASA IT environment.

5. Infrastructure and Facilities

NASA continues to recognize the imbalance between the infrastructure that it maintains and the funding available to properly sustain it. To respond to and manage that imbalance, NASA has implemented a strategy to reduce its infrastructure over time, eliminate facilities that it no longer needs, consolidate capabilities when it makes sense, and make focused investments in critical capabilities. NASA continues to invest annually in new construction that is more energy efficient and which consolidates personnel and activities into a smaller footprint, thereby reducing operational costs. These investments evaluate life-cycle costs in accordance with NASA Procedural Requirements (NPR) 8820, "Facility Project Requirements (FPR)," to identify the most efficient solution set.

NASA's demolition and disposal program has demolished over 2.62 million square feet since 2013. Over that time period, NASA has also eliminated $71.4 million in deferred maintenance and 566 structures. In the last eight years, NASA has disposed of four sites (Palmdale Orbiter Processing Site, Camp Parks, White Sands Space Harbor, and Glenn Research Center North Campus). NASA continues to work to dispose of the Santa Susana Field Lab and Crows Landing sites. Toward that effort, NASA has demolished more than 61 structures at Santa Susana and 27 structures at Crows Landing. During 2018, NASA engaged the U.S. Army Corps of Engineers' demolition expertise, to manage demolition contracts for NASA including a 530,000 square foot office building at Michoud Assembly Facility (MAF) which will be demolished over the next year.

NASA manages its demolition program through a five-year plan. Centers select facilities that they would like to demolish over that timeframe and a team of Demolition Managers prioritize the proposed projects based on the fiscal year's anticipated funding cost estimates, return on investment, time awaiting demolition, footprint reduction, operations and maintenance costs, etc. Included in the five-year plan are assets that were identified through the Space Environments Testing Divestment decision in 2015. In addition, Demolition Managers implement the annual demolition program in the most cost effective manner by leveraging funded project cost savings towards additional demolitions in any given year. NASA's 2017 disposal plan indicates that NASA expects to reduce its infrastructure by four percent over the next five years. The Agency's Demolition Program is a key component of NASA's Strategic Rightsizing Goal established in 2017 of a 25 percent infrastructure reduction over 20 years. This planning goal is now being incorporated in Center Master Plans as a requirement before approval of the Center's Future Development Concept. The Agency's reduction goal is aimed at driving NASA's infrastructure to a size that is in line with estimated funds available to sustain it.

NASA's Technical Capabilities Assessment Team (TCAT) studies resulted in NASA establishing a new more centralized model for managing its technical capabilities. The NASA Technical Capability Leadership model provides cross-Agency reviews of

Since the implementation of the new management model and the establishment of capability management offices such as the Space Environments Testing Management Office (SETMO), NASA has made the following progress consolidating space environmental testing capabilities: ten assets demolished; four assets excessed; and an additional six assets added to the demolition program.

NASA has diligently responded to each of the 17 OIG reports related to infrastructure challenges published over the last seven years. NASA continually evaluates the effectiveness of its policies, issuing amendments as necessary and updating policy to reflect changing regulations and environments. NASA has completed actions on all, but two OIG recommendations from reports published prior to 2017 and is nearing publication of new policy for managing technical capabilities to close the remaining two recommendations.

6. Contracting and Grants

NASA's Office of Procurement appreciates the investigative and audit work conducted by the OIG and acknowledges the importance of this effort, particularly where fraud is uncovered and process improvements can be made. NASA continues to make strides intended to improve the contracting processes throughout the Agency. NASA continues to strengthen procurement policy implementing the NASA FAR Supplement (NFS) quality review process. This quality review process is a systematic approach for continually reviewing and updating relevant NFS parts and eliminating outdated and unnecessary policy. We continue to strengthen acquisition planning to ensure that the right contract vehicle is utilized for the requirement; issuing strategic sourcing policy and associated Web site to assist in optimizing the use of existing contract vehicles; and reducing the number of new acquisitions.

NASA is continuing its efforts regarding strengthening the overall administration and management of its grants program. The grants management function, now organized under the Office of the Chief Financial Officer (OCFO), will continue actions to enhance the NASA grants monitoring function. The OCFO is in the process of formulating grants monitoring training modules which will be presented to the NASA grants community. Likewise, the OCFO is in the initial stages of incorporating data analytics into NASA's grants monitoring model. Our continued updates to the NASA Grant and Cooperative Agreement Manual (GCAM), along with updates to our financial assistance instruments, ensures compliance with the requirements of 2 CFR 200, Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards.

Finally, in those instances where fraud is suspected or uncovered with respect to contracts and grants, NASA remains dedicated to ensuring and monitoring the coordination of criminal, civil, contractual, and administrative (suspension and debarment) fraud remedies through the Agency's Office of the General Counsel, Acquisition Integrity Program (NASA AIP). NASA's AIP is a comprehensive coordination of fraud remedies programs, which handles such matters in coordination with the Department of Justice; pertinent law enforcement agencies, including the NASA Office of Inspector General; other Federal agencies; and other NASA stakeholders including the Office of Procurement.

If you have any questions regarding NASA's response to the 2018 Top Management and Performance Challenges, please contact Paul Roberts, Audit Liaison Program Manager, on (202) 358-2260.

James F. Bridenstine

cc:
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