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Committee on Science, Space, and Technology

ADVANCING SCIENTIFIC DISCOVERY: ASSESSING THE STATUS OF NASA'S SCIENCE MISSION DIRECTORATE PORTFOLIO

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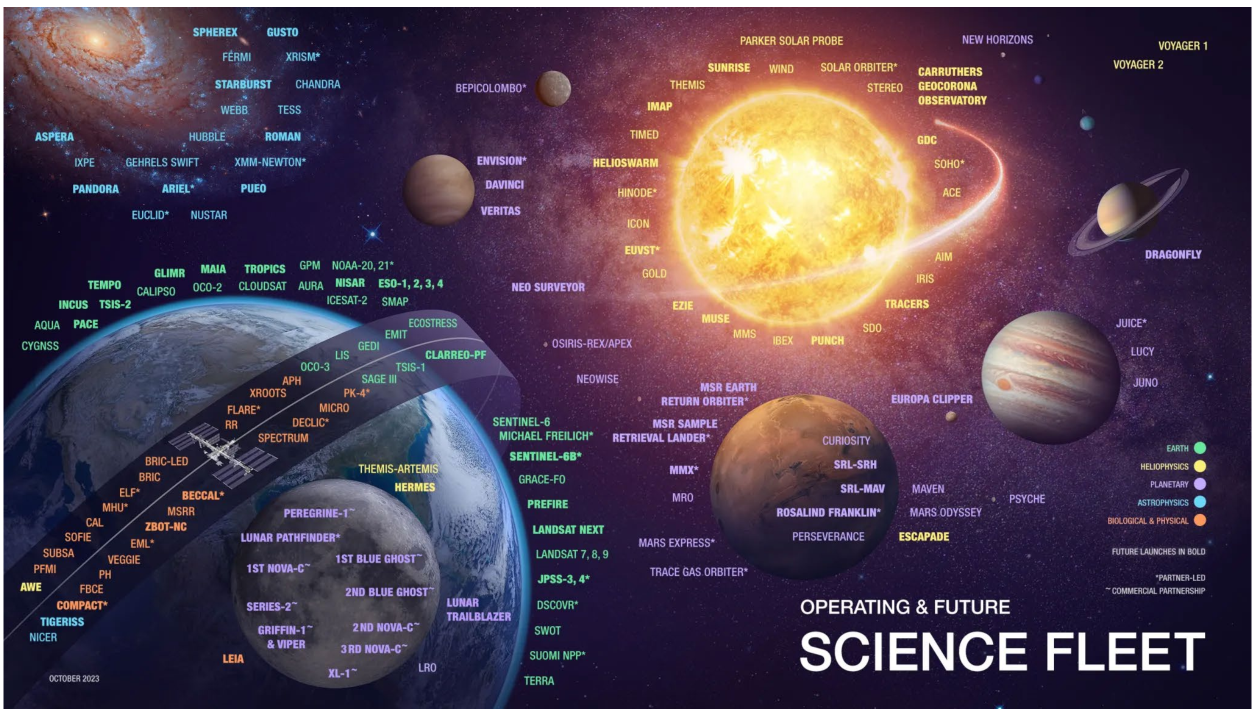
Chairman Babin, Ranking Member Sorensen, and Members of the Subcommittee:

The Office of Inspector General (OIG) is committed to providing independent, objective, and comprehensive oversight of NASA programs and projects. We welcome this opportunity to discuss the Agency's Science Mission Directorate and some of the longstanding challenges it faces.

With direction provided by Congress, Administration priorities, and recommendations of the larger science community, NASA's Science Mission Directorate portfolio consists of approximately 150 individual missions. The portfolio enables scientists to make first-of-their-kind discoveries and contributes tangible benefits to society through technology enhancements and breakthroughs that provide a better understanding of Earth and its environment.

As shown in Figure 1, these missions operate throughout the solar system and beyond. For example, launched in 1977, Voyager 1 and Voyager 2 are NASA's longest continuing missions and are now more than 15 billion and 12 billion miles, respectively, from Earth.

Figure 1: NASA's Operating and Future Science Fleet (as of October 2023)



Source: NASA.

My testimony today is informed largely by the work our office has conducted over the past 5 years (see the Appendix for summaries of relevant reports) and focuses on key challenges NASA faces in managing its science portfolio, including developing accurate and timely cost and schedule estimates, a culture of over optimism, funding instability, and workforce issues.

NASA's Large Science Projects Frequently Take Longer Than Expected and Cost More Than Estimated

NASA's accomplishments in technology development, Earth and space exploration, and scientific discovery continue to demonstrate the Agency's achievements. In fact, NASA's Science Mission Directorate has had many significant accomplishments this past year. For instance, the Mars 2020 Ingenuity helicopter—the first aircraft in history to fly under its own power on another planet—surpassed 2 years of operations and completed 72 flights after only expecting to fly 5 times. And the Parker Solar Probe completed its 18th close approach to the Sun, matching its own distance record of just 4.51 million miles from the solar surface, which it had achieved on its previous close approach just a few months prior.

Despite these successes, we must note that some of NASA's most impressive missions now in operation—Hubble Space Telescope, the Mars Science Laboratory's Curiosity rover, and the James Webb Space Telescope (JWST)—experienced significant cost increases and schedule slippages from what was originally planned. These cost increases and schedule delays have often created cascading effects across the remainder of the portfolio. For example,

- In fiscal year (FY) 2012 NASA moved $156 million from other Science Mission Directorate projects and accounts to cover JWST cost increases.[1] In addition,
    - What was then named the Wide-Field Infrared Survey Telescope—now Nancy Grace Roman Space Telescope—and several other missions were delayed to make funding available for JWST, and
    - NASA ended an agreement with the European Space Agency on two Mars missions and reevaluated its entire Mars exploration strategy due to limited funding availability.
- In June 2022, the Psyche mission—launched in October 2023 and now on its way to a metal-rich asteroid orbiting the Sun between Mars and Jupiter—was delayed a year, which resulted in about $132 million increase to its development costs.

Notably, Psyche's problems have now led the Agency to delay the Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy (VERITAS) mission for at least 3 years. Moreover, the Janus spacecraft was consequently put in long-term storage while it awaits future funding and a new launch opportunity.[2]

We recognize that each project is unique, as are the circumstances that lead to cost increases and schedule delays. However, through our work we have noted that NASA's culture of optimism often results in overly optimistic assumptions about cost, schedule, and the level of effort required to develop new technologies for missions.[3] NASA has demonstrated time and again its ability to overcome

[1] JWST was initially baselined in 2009 with a life-cycle cost of about $5 billion and a launch date in 2014. JWST launched in December 2021 with a life-cycle cost of about $10 billion.

[2] Janus was a mission designed to send two small spacecraft to near-Earth asteroids and planned as a rideshare on the Psyche mission. The updated Psyche launch was not favorable to achieving the Janus science requirements.

[3] We first reported on this effect in *NASA's Challenges to Meeting Cost, Schedule, and Performance Goals* (IG-12-021, September 27, 2012).

technological and scientific obstacles to accomplish objectives. However, many of the Agency's planned missions are ambitious endeavors that need to be grounded in more realistic cost and schedule commitments. Both the Psyche and Mars Sample Return Independent Review Boards have made this same observation in their recent assessments of these projects.[4]

We have identified funding instability, or inconsistency in funds, as another impediment to NASA's project management success.[5] Unstable funding, whether in terms of the total amount of funds dedicated to a project or the timing of when those funds are disbursed to the project, can result in inefficient management practices that contribute to poor cost, schedule, and performance outcomes.

For example, inadequate funding in the early phases of a project's life cycle decreases management's ability to identify and address key risks at project inception. In the absence of sufficient funding, project managers may have to defer the development of critical technologies to a time when integration of those technologies may be more difficult or when the costs of material and labor may be greater. In some cases, shifting tasks to later project phases may require managers to sustain a workforce longer than originally planned or add shifts to make up for lost time, both of which can lead to increased costs.

Lastly, there is the funding instability that results from lengthy appropriation continuing resolutions that lock the Agency's funding at the previous fiscal year's level. For example, in November 2023, NASA slowed work on the Mars Sample Return mission because of funding uncertainty. NASA's Jet Propulsion Laboratory (JPL) cited the absence of a new appropriation as a primary cause, necessitating a workforce reduction.

NASA's Cost and Schedule Commitments

NASA's success in managing its major projects begins with proper stewardship of taxpayer funds and the Agency's adherence to cost and schedule commitments it makes to Congress and other stakeholders. NASA does this via an Agency Baseline Commitment (ABC) that establishes and documents an integrated set of project requirements, cost, schedule, and technical content. In turn, the ABC is based on a Joint Cost and Schedule Confidence Level (JCL) to support NASA's commitment to the Office of Management and Budget and Congress.[6]

Our recent work has found instances where the Agency failed to establish ABCs that consider the entirety of the program and project risks. For example, in April 2022 we reported that NASA chose not to conduct a JCL that would encompass the entirety of the mission risks for the Commercial Lunar Payload Services (CLPS) initiative's Volatiles Investigating Polar Exploration Rover (VIPER) mission.[7]

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[4] NASA, Psyche Independent Review Board Report (November 4, 2022); Mars Sample Return (MSR) Independent Review Board-2 Final Report (September 1, 2023).

[5] IG-12-021.

[6] The JCL is an analysis of the probability that cost will be equal to or less than the targeted cost and schedule will be equal to or less than the targeted schedule date. To read more about NASA's JCL process, see our *Audit of NASA's Joint Cost and Schedule Confidence Level Process* (IG-15-024, September 29, 2015).

[7] NASA OIG, *NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission* (IG-22-010, April 6, 2022). VIPER, the most expensive mission in the CLPS portfolio, is a mobile robot intended to land at the South Pole of the Moon in late 2024. We also reported the same lack of transparency and adherence to JCL and ABC principles in the Agency's Artemis campaign as documented in *NASA's Cost Estimating and Reporting Practices for Multi-Mission Programs* (IG-22-011, April 7, 2022) and *NASA's Management of the Mobile Launcher 2 Contract* (IG-22-012, June 9, 2022).

Specifically, NASA excluded the VIPER delivery system—under development by a company that had never demonstrated this capability—from the JCL analysis and the ABC.

In other words, NASA essentially ignored this risk when estimating the mission timeline. Subsequently, the Agency announced the mission would launch in 2024 instead of 2023, VIPER development costs would increase by $64 million, and $67.8 million would be added to the cost of the CLPS task order for the contractor, Astrobotic Technologies Inc (Astrobotic), to conduct additional ground tests to reduce risk.

Though the mission is now planned to launch in November 2024, we expect additional cost increases and schedule delays because NASA may require expanded risk mitigation measures in light of Astrobotic's experiences on its first CLPS mission and its Peregrine lander earlier this year.[8]

To its credit, NASA has taken some action to address and attempt to mitigate these challenges. In early 2022, NASA established the Chief Program Management Officer (CPMO) in the Office of the Administrator to strengthen NASA's enterprise-wide oversight, management, and implementation of program management policies and best practices across Headquarters and Centers.

Early Project Estimates Are Routinely Immature and Unreliable

We believe part of the challenge NASA faces can be traced in part to the expectations established in the National Academies of Sciences, Engineering, and Medicine's decadal surveys that guide the Science Mission Directorate in its development of the portfolio. As Congress directed in the NASA Authorization Act of 2008, the NASA

> *Administrator shall enter into agreements on a periodic basis with the National Academies for independent assessments, also known as decadal surveys, to take stock of the status and opportunities for Earth and space science discipline fields and Aeronautics research and to recommend priorities for research and programmatic areas over the next decade.*

Updated approximately every 10 years, the decadal surveys of the Science Mission Directorate's Astrophysics, Biological and Physical Sciences, Earth Science, Heliophysics, and Planetary Science portfolios identifies what the Academies believe are the most pressing science questions based on input from the wider science community. The law also requires that the surveys provide life-cycle cost estimates for the recommended missions. The challenge for the Academies, and subsequently for NASA, is coming up with missions that are executable within cost and schedule estimates.

This has proven extremely challenging. Many of NASA's missions include first-time efforts and developments, and the cost, time, and effort required to mature these from initial concept to operationally functional may not be well understood and difficult to estimate until the project is further matured in formulation.

For example, the 2023 Planetary Science Decadal laid out a cost and schedule for Mars Sample Return mission that is proving untenable.[9] Specifically, the 2023 Decadal Survey stated that "the highest

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8 Astrobotic's Peregrine spacecraft was launched on January 8, 2024, but soon encountered what appeared to be a propellant leak in the lander's propulsion system and was destroyed when it reentered Earth's atmosphere after flying past the Moon's orbit.

9 National Academies of Sciences, Engineering, and Medicine, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032* (2022).

scientific priority of NASA's robotic exploration efforts this decade should be completion of Mars Sample Return," noting that the mission "is of fundamental strategic importance to NASA, U.S. leadership in planetary science, and international cooperation and should be completed as rapidly as possible." The survey also stated that costs needed to be contained to not undermine the balance of the planetary portfolio. For instance, if costs increased by 20 percent or more above $5.3 billion or annual budget requests exceeded approximately 35 percent of the total Planetary Science Division budget, then NASA should work with the Administration and Congress to secure additional funding.

In our recent report on the Mars Sample Return Program, we noted several issues with the $5.3 billion cost estimate.

- It was developed from 2020 to late 2021 and includes an assumption of inflation at 2 percent—far below actual inflation rates in the range of 5 to almost 9 percent from mid-2021 to early 2023.
- The Decadal Survey's estimate also includes a sample receiving facility, which is not included in the Mars Sample Return Program's scope or cost estimates.
- It assumes a European Space Agency-provided Sample Fetch Rover (not included in the Decadal Survey cost), which was descoped in the summer of 2022 and replaced by NASA-developed Sample Recovery Helicopters.
- The $5.3 billion funding level is not a life-cycle cost estimate as it includes only those costs incurred during the 2023 to 2032 Decadal Survey period and not costs incurred outside this period.

In 2020, the Science Mission Directorate concluded a study of its largest missions to examine how NASA makes critical decisions that either impede or support mission and programmatic success.[10] One of the goals was to help inform leaders to improve decision-making, management, and review processes, with an emphasis on establishing and keeping more achievable commitments. The report made the following observation:

> *Early [cost and schedule] estimates often show a high degree of precision but have poor accuracy. This creates a false sense of confidence in early numbers and timelines, leading stakeholders to latch onto these inaccurate preliminary estimates, which can unrealistically constrain the project in later phases*.

Additional Challenges Affecting Key Priorities of the Science Mission Directorate

In addition to the issues discussed above, NASA also faces challenges with Deep Space Network upgrades, radioisotope power systems development, and workforce capacity. If not adequately addressed, these challenges will affect NASA's ability to successfully execute a range of science missions and priorities.

Deep Space Network (DSN). NASA relies on its DSN to provide communication links that guide and control spacecraft and bring back images and other data from missions. The DSN uses antennas to

[10] NASA Science Mission Directorate, *Large Mission Study Report* (October 2020).

communicate with spacecraft located from between 10,000 miles from Earth to the edge of the solar system and beyond.

As we reported in July 2023, DSN antennas are currently operating at capacity and are oversubscribed—meaning more time is requested by missions than the network's current capacity can provide—with demand exceeding supply at times by as much as 40 percent.[11]

The Agency's Mars Perseverance Rover, James Webb Space Telescope, and upcoming Nancy Grace Roman Space Telescope and Artemis missions will require increasingly higher amounts of bandwidth that will far exceed the network's ability to meet growing mission demands. Furthermore, as crewed Artemis missions come online and receive priority over uncrewed science missions, DSN time may not be available. As a result, some science missions may not receive the full amount of capacity required for timely navigation and data transfer. In our report, mission managers for the Mars 2020 Perseverance Rover stated that their mission was impacted by DSN oversubscription at least seven times in a 21-month period. These mission managers also said that missed opportunities to send commands delayed the Rover's progress.

Like many other large NASA projects in development, DSN antenna upgrades are over cost by $287 million (68 percent) and 5 years behind schedule. But even with needed upgrades, it is possible that NASA may not be able to receive all the future missions' data that could advance our understanding of the universe and our place in it.

Radioisotope power systems (RPS). As NASA plans for more ambitious exploration of the solar system and beyond, it will need RPS to power longer and more distant missions. However, NASA has not produced a new RPS technology, which uses heat from the natural decay of plutonium-238 (Pu-238) to generate electric power, since establishing the RPS Program in 2010, despite an average investment of $40 million per year.[12]

NASA's inability to bring new nuclear power technologies to fruition has negatively impacted its objectives of enabling space-based science outcomes. Exacerbating this challenge is the strained relationship and lack of communication with the Department of Energy (DOE)—the federal agency responsible for plutonium production and its use in nuclear power systems. Restrictions on the level of detail DOE can share with the RPS Program due to national security concerns regarding Pu-238 production affect ongoing mission planning and new mission proposals. Consequently, we are concerned that NASA will not have the power systems needed to support its future, ambitious science mission goals.

Workforce capacity. Our work has shown that NASA faces multiple workforce challenges, including increasing the representation of women and minorities in its civilian and leadership ranks; developing a pipeline of women and minorities in Science, Technology, Engineering, and Mathematics fields; focusing on the fact that a significant percentage of the NASA workforce is retirement eligible; and addressing a shortfall of employees with the right skills in specific technical occupations. As early as 2018 we have highlighted workforce capacity and availability issues at NASA's JPL, managed by Caltech, and made recommendations for NASA to address them.[13] In each case, management's response was limited to

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[11] NASA OIG, *Audit of NASA's Deep Space Network* (IG-23-016, July 12, 2023).

[12] NASA OIG, *NASA's Management of Its Radioisotope Power Systems Program* (IG-23-010, March 20, 2023).

[13] NASA OIG, *NASA's Surface Water and Ocean Topography Mission* (IG-18-011, January 17, 2018); *Management of NASA's Europa Mission* (IG-19-019, May 29, 2019); and *NASA's Planetary Science Portfolio* (IG-20-023, September 16, 2020).

individual projects but did not address broader workforce capacity issues impacting JPL's ability to complete work in a timely manner. However, the Psyche mission missed its planned launch because of workforce issues as noted by an Independent Review Board.

We are similarly concerned that other Centers face the same workforce challenge. For example, Goddard Space Flight Center faces a heavy workload with large projects such as the On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1) mission; Roman Space Telescope; and the Capture, Containment, and Return System for the Mars Sample Return mission. All of these missions are competing for a limited technical workforce as each prepares for launch in the next 3 to 5 years—though some of these pressures may be abated by recent NASA decisions to pause work or cancel missions (e.g., OSAM-1). However, any decision that could result in workforce reductions, similar to those at JPL in February 2024, potentially has the unintended secondary effect of making it more difficult to hire personnel with the skills needed for future missions.

Conclusion

While we acknowledge the wide-ranging accomplishments and enormity of tasks the Science Mission Directorate has in managing its portfolio, NASA leadership should continue to establish sustainable budgets and realistic timelines that consider the Agency's overall mission goals and priorities. Given that the Agency is currently anticipated to operate with less than $8 billion annually for the Science Mission Directorate; absent complete, credible, and transparent cost and schedule commitments, it will be difficult for NASA, Congress, and external stakeholders to make informed decisions about the prioritization of these efforts and the Agency's long-term funding needs.

As discussed in our recent report on f the Mars Sample Return Program, characteristics intrinsic to big and complex missions are difficult to quantify in estimates but can drive project costs upwards. These characteristics include less than a full understanding of the mission's complexity and optimal design at inception, over-optimism, and assumptions regarding the project team and contractors' ability to meet requirements.

To this end, we encourage NASA to redouble its efforts to ensure that its science projects are grounded in accurate estimates, while also addressing those additional challenges that can affect the operational performance of these missions.

We look forward to helping NASA achieve its ambitious science exploration goals and plan to continue examining key challenges facing the Agency's Science Mission Directorate and related programs and projects.

APPENDIX

Over the past 5 years, the OIG has issued 15 audit reports that evaluate specific projects within the portfolio, such as Europa Clipper and Mars Sample Return, and Agency-level issues that can affect portfolio operations and goals, such as risks posted by orbital debris and the Agency's technology transfer process. We have also assessed smaller programs within the portfolio, such as the Earth System Science Pathfinder Program and both the Heliophysics Division and Planetary Science Division portfolios. The following is a summary of those reports.

Audit of the Mars Sample Return Program (IG-24-008, February 28, 2024)

The Mars Sample Return (MSR) Program, a partnership between NASA and the European Space Agency (ESA), is part of a four-phase MSR Campaign to collect, retrieve, return, and examine samples from the surface of Mars. It is one of the most technically complex, operationally demanding, and ambitious robotic science missions ever undertaken by NASA. With components currently scheduled to launch in 2027 and 2028, the MSR Program is approaching its next Key Decision Point (KDP) review (KDP-C) at which time NASA will evaluate Program plans, establish cost and schedule baseline commitments, and determine whether it should proceed from formulation to development.

We found that the MSR Program is facing significant obstacles completing its Formulation Phase—specifically, establishing a stable design with realistic cost and schedule estimates—in a timely and effective manner. The MSR Program recently acknowledged it likely cannot meet the life-cycle cost estimate and launch dates established at KDP-B. A delayed Preliminary Design Review for one of the Program's components, due to technical issues and the restructuring of the project's architecture, will add approximately $200 million to the budget and result in one year of lost schedule. Additionally, the trajectory of the MSR Program's life-cycle cost estimate, which has grown from $2.5 to $3 billion in July 2020, to $6.2 billion at KDP-B in September 2022, to an unofficial estimate of $7.4 billion as of June 2023 raises questions about the affordability of the Program. Finally, MSR Program formulation is impacted by coordination challenges between NASA and ESA.

The OIG made four recommendations related to program plans to be presented at the KDP-C review and to improve the Agency's pre-formulation guidance.

NASA's Earth System Science Pathfinder Program (IG-23-018, September 5, 2023)

NASA's Earth System Science Pathfinder (ESSP) Program was established to stimulate new scientific understanding of the global Earth system to meet the challenges of climate change and other environmental events such as forest fires and floods by funding small, rapid-development missions. In 2009, NASA introduced the ESSP Earth Venture Class to create low-cost missions focused on developing innovative research and higher risk technologies that ultimately can help communities respond to the changing environment. With an annual budget of $236 million, ESSP currently supports 22 active projects. Through the development of orbital and suborbital remote-sensing instruments, these projects produce data to address key Earth science research questions concerning the atmosphere, oceans, land surface, polar ice regions, and solid Earth.

We identified major weaknesses with project management, mission design and operations, and instrument development in several selected projects within the ESSP Program. NASA did not adequately vet principal investigators (PIs) during the solicitation phase to ensure they have appropriate project management and contracting experience as well as sufficient time dedicated to adequately manage their projects. We also found that NASA provided PIs inconsistent and unclear expectations on project reporting requirements during the solicitation process. While the ESSP Program has controlled cost growth and met milestones for 18 of its 22 active projects, as of May 2023 the remaining four of seven unlaunched projects faced cost and schedule challenges primarily related to subcontractor disruptions, access to space costs, and limited experience of PIs managing projects. Finally, we found Earth Venture Class projects are making progress incorporating more societal applications, but the comprehensive incorporation of societal applications remains secondary and underrealized and their requirements are loosely required, poorly understood by proposers, and nominally considered during the selection process.

The OIG made eight recommendations to improve NASA's management of its ESSP Program.

Audit of NASA's Deep Space Network (IG-23-016, July 12, 2023)

NASA relies on its Deep Space Network (DSN) to provide communication links that guide and control spacecraft and relay images and other data from its missions. The DSN consists of three communications facilities located near Goldstone, California; Madrid, Spain; and Canberra, Australia. The complexes use antennas to communicate with spacecraft located from between 10,000 miles from Earth to the edge of the solar system and beyond. In 2010, NASA initiated the Deep Space Network Aperture Enhancement Project (DAEP) to provide upgrades and capacity expansion to ensure continued operation and meet new mission needs.

We found that NASA's DSN is currently oversubscribed and will continue to be overburdened by the demands created by an increasing number of deep space missions. Limitations on the DSN's capacity have already impacted Agency missions' ability to fully meet objectives and achieve full return on investment. In the past 5 years, NASA missions received between 8,500 and 15,000 fewer DSN tracking hours than requested. Internal capacity and loading studies project that demand for DSN support will increase dramatically in the coming decade with excess demand for hours on the DSN reaching about 50 percent by the 2030s. NASA's primary solution to address the DSN's capacity issues is to construct additional antennas and make upgrades to existing infrastructure. Additionally, NASA continues to face challenges in completing DAEP on cost and schedule while working under international agreements and contracts. As NASA pivots toward extended human exploration of the Moon, the Agency may need to give DSN capacity to priority missions in critical phases, such as launches, while other missions make do with limited or no data during those periods.

The OIG made four recommendations to ensure NASA's progress towards upgrading the DSN's ability to support current and future mission requirements.

NASA's Management of Its Radioisotope Power Systems Program (IG-23-010, March 20, 2023)

NASA has used various nuclear power systems for its spacecraft for more than 60 years and continues to develop the technology—generally using plutonium-238 (Pu-238)-based radioisotope power systems (RPS)—to expand solar system exploration capabilities where conventional solar or chemical powered space flight is impractical or impossible. These types of power systems can enhance mission capability by reducing spacecraft size and mass and providing constant power output irrespective of the distance from the Sun. To manage its investments and research in this area, NASA established the RPS Program to ensure the availability of nuclear power systems for space-based scientific mission exploration with the goal of making RPS a low-risk, cost-effective option for the Agency's exploration needs.

We found that NASA has not produced a viable new RPS technology since the Program began in 2010 despite an average investment of $40 million per year. We also found that NASA lacks a clear resource allocation strategy to ensure completion of its new technology development projects. In addition, the Program's optimistic assumptions about the maturity of nuclear power technologies and its lack of formal assessments of technology readiness, coupled with associated technology maturation risks, contributed to the termination of two technology development projects and portend cost and schedule challenges for current and future RPS developments. The RPS Program's inability to bring new nuclear power technologies to fruition has negatively impacted its core objective of enabling space-based science outcomes because upcoming missions are less likely to propose projects incorporating unproven RPS technologies. Lastly, the RPS Program faces communication challenges with both DOE and internal stakeholders that negatively impact NASA's use of nuclear power system technologies for mission proposals.

The OIG made nine recommendations to ensure the RPS Program effectively and efficiently meets its goals.

NASA's Management of Its Johns Hopkins University Applied Physical Laboratory Portfolio (IG-22-017, September 29, 2022)

The Johns Hopkins University Applied Physics Laboratory (APL) is headquartered in Laurel, Maryland, with six field offices located around the country and has provided important scientific instruments and contributed to space science, spacecraft design and fabrication, and mission operations since its founding in 1942. As of February 2022, NASA activities constituted 19 percent of APL's total work, including the Double Asteroid Redirection Test (DART) mission, testing technologies to defend the Earth against hazardous asteroids, and Dragonfly, which will sample and examine sites around Saturn's moon, Titan. NASA manages two indefinite-delivery, indefinite-quantity (IDIQ) Agency-wide contracts with APL for robotic space missions and supporting research—ARDES I (2006) and ARDES II (2020)—with a combined potential value not to exceed $3.8 billion.

We found that the Laboratory is appropriately managing its NASA portfolio. Although several projects experienced cost increases or schedule delays, APL was not the primary factor for any cost or schedule performance issues experienced on those projects. For other projects with cost increases or schedule delays, APL's performance was considered a factor but not the primary cause. However, we found that NASA's decision to move two existing tasks from the ARDES I to ARDES II contract was unnecessary and costly. Specifically, task orders on ARDES I were ended, and the remaining in-scope work was awarded to the ARDES II contract. As a result, rather than the 4.1 percent fixed-fee rate charged for projects under the ARDES I contract, NASA paid the ARDES II rate of 6.5 percent, resulting in cost increases of at least $3.88 million in ARDES II contract fees for the same scope of work originally covered by the ARDES I contract.

The OIG made one recommendation to ensure NASA does not pay more than required on IDIQ contracts and task orders and one recommendation related to contract modification processes.

NASA's Management of the Earth Science Disasters Program (IG-22-013, June 14, 2022)

NASA's Earth Science Disasters Program (ESDP) is focused on using space- and ground-based observations to provide disaster-related data and information products to domestic and international partners and stakeholders. These products promote global disaster resilience—that is, the ability of nations and communities to prevent, withstand, adapt to, and recover from the harmful impacts of adverse events on people, places, and the natural environment. NASA's Earth Science Division's (ESD) Applied Sciences Program (ASP) initially provided disaster response support on an ad-hoc basis, but in 2016 ESDP was formalized as a program under ASP. NASA is required by the Robert T. Stafford Disaster Relief and Emergency Assistance Act to assist the federal government in responding to disasters, and from 2018 through 2021 ESDP assisted with 204 disasters.

We found that ESDP effectively collects and distributes relevant imagery, data products, and damage assessments to domestic and international partners and stakeholders to predict, prepare for, respond to, and recover from disasters. However, the Program struggles to do so efficiently because ESD and ASP leadership has not created a strategic plan or requirements document to outline the Program's mission, goals, and objectives. Lack of clear and consistent communication from leadership about ESDP's priorities has also created a disconnect regarding Program expectations, goals, and objectives. Guidance for providing disaster support is also incomplete and inconsistently used by ESDP staff. In addition, we found that ESDP's $6.5 million budget has remained relatively flat for the past 5 years, with a staff consisting of 5 full-time employees and 18 part-time disaster coordinators. As a result, we found ESDP's budget and personnel resources inadequately allocated to scale support, ensure continuity, and maintain sustainable disaster response support.

The OIG made seven recommendations to improve NASA's management of the ESDP.

NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission (IG-22-010, April 6, 2022)

The Volatiles Investigating Polar Exploration Rover (VIPER) will survey the Moon's South Pole and its concentration of water ice as a precursor to returning humans to the Moon. The VIPER mission, which includes the rover, four science instruments, launch and delivery of the rover to the Moon by a commercial vendor, and lunar surface operations, will help determine whether it is practical to use the Moon's water ice to "live off the land," thereby reducing the need for multiple missions to ferry oxygen, food, fuel, and other supplies needed to sustain long-term human exploration on the Moon and potentially missions to Mars.

We found that the VIPER mission carries higher costs, criticality, and schedule risks compared to other current CLPS task orders. Further, NASA's ABC for the VIPER mission includes costs only for development of the rover, science instruments, lunar operations, and applicable cost reserves, and not those associated with a contract to launch and deliver VIPER to the Moon, valued at $226.5 million when the baseline was completed. Additionally, leading project management tools were not implemented. As a result, NASA and other stakeholders may not have full visibility into the risks and their potential costs to the mission and may not be accurately monitoring mission cost and schedule performance to make timely risk-informed decisions.

The OIG made four recommendations related to enhancing information sharing and policy updates to improve decision-making and implement development best practices for major projects.

NASA's Management of Universities Space Research Association's Cooperative Agreements (IG-21-022, July 14, 2021)

Among the multitude of organizations to whom NASA awards cooperative agreements (as well as grants and contracts) is Universities Space Research Association (USRA)—an independent, nonprofit research corporation established in 1969 to conduct collaborative research in astronomy, astrophysics, lunar science, planetary science, heliophysics, Earth science, and computer science and technology. USRA outsources much of this research to hundreds of universities and nonprofit organizations across the country through subcontracts or grants. Examples of USRA's most significant research for NASA are operation of the Stratospheric Observatory for Infrared Astronomy (SOFIA) program, the Keck Remote Observation Center (operation of Mauna Kea telescopes in Hawaii), and the Goddard Earth Sciences Technology and Research partnership. In addition, NASA has cooperative agreements with USRA to recruit, identify, and place interns across the Agency.

We found that while USRA plays an important role in many NASA science missions, the Agency does not have adequate management or financial oversight of USRA's cooperative agreements. For instance, we found that total funded extensions and augmentations increased the overall value of USRA's 21 agreements from $200.8 million to $475.6 million with a lack of information available to support these increases and award decisions. In addition, the financial reports NASA receives from USRA do not contain sufficient information to determine whether funds are being spent appropriately. We identified approximately $6.8 million in transactions on 17 cooperative agreements that met our keyword search criteria for potential unallowable costs. We also identified that for FYs 2015 through 2020, USRA overcharged the government a total of $246,060 for its President/Chief Executive Officer's compensation package.

The OIG made 12 recommendations to increase management and financial oversight accountability for cooperative agreements.

COVID-19 Impacts on NASA's Major Programs and Projects (IG-21-016, March 31, 2021)

The COVID-19 pandemic created a health and economic crisis and affected all facets of the federal government. In March 2020, in accordance with Centers for Disease Control and Prevention guidance regarding COVID-19, the President directed federal agencies to modify their operations, including closing facilities and requiring mandatory telework of nonessential federal and contractor workforces. In NASA's case, while maintaining vital operations such as the International Space Station and efforts to launch the first commercial flight of astronauts into space, the Agency altered—essentially overnight—how it conducts business to protect its employees and contractors. By mid-April, 90 percent of the Agency's workforce was working from home; all nonessential travel was canceled; 12 of the Agency's 18 major facilities were closed while the remaining 6 transitioned to in-person support for "mission critical" operations only. To accomplish this dramatic shift in operations, NASA had to make difficult decisions about which missions to prioritize and which to pause or delay. Additionally, NASA received $60 million under the Coronavirus Aid, Relief, and Economic Security (CARES) Act and the Agency directed the funds across seven broad categories to fund potential mission delays and contractor costs, enhanced information technology infrastructure, facility cleaning, and personal protective equipment.

We provided a snapshot review of the impact the COVID-19 pandemic had on major NASA programs and projects (those with life-cycle costs of at least $250 million) as estimated at the end of FY 2020, including cost, schedule, performance, and technical challenges. Based on the information provided by project officials, as of October 2020 COVID-19 impacted 56 NASA programs and projects in FY 2020, 30 of which fit the criteria as a major program or project. The estimated cost impact of the COVID-19 pandemic on these 30 major programs and projects was over $1.6 billion. In addition to cost impact, launch dates for several NASA missions were delayed between 1 and 10 months.

The OIG did not make any formal recommendations but encouraged the Agency to continue collecting accurate and comprehensive information to fully quantify the pandemic's impact and to provide oversight and guidance to ensure reporting of COVID-19 impacts was comparable and consistent across all Directorates.

NASA's Efforts to Mitigate the Risks Posed by Orbital Debris (IG-21-011, January 27, 2021)

Orbital debris is defined as human-made objects in space that no longer serve a useful purpose, such as decommissioned satellites and parts of spacecraft. Millions of pieces of orbital debris exist in low Earth orbit (LEO). Of those pieces, at least 26,000 are the size of a softball or larger that could destroy a satellite on impact; over 500,000 are the size of a marble big enough to cause damage to spacecraft or satellites; and over 100 million are the size of a grain of salt that could puncture a spacesuit. The growing volume of orbital debris threatens the loss of important space-based applications used in daily life, such as weather forecasting, telecommunications, and global positioning systems that are dependent on a stable space environment. At NASA, the Orbital Debris Program Office (ODPO) has taken the national and international lead in conducting measurements of the debris environment and in developing the technical consensus for adopting mitigation measures.

We found that NASA models of the orbital debris environment lack sufficient data. For objects larger than 3 millimeters, ODPO's data is limited by the decreasing amount of time available on the three radars it uses to detect and statistically estimate debris due to funding, inoperable equipment, and competing priorities from multiple users. In addition, NASA does not have the ability to track debris smaller than 10 centimeters in the range of LEO where the International Space Station resides and plans to rely on the Department of Defense's Space Fence, a ground-based radar system that has not yet reached full operational capability, to track such debris. Finally, we found that Orbital Debris Assessment Reports and End of Mission Plans were not consistently submitted to the Office of Safety and Mission Assurance in a timely manner, and the process used to route the reports for approval was laborious.

The OIG made seven recommendations to better protect spacecraft and maintain the space environment.

NASA's Planetary Science Portfolio (IG-20-023, September 16, 2020)

NASA's Planetary Science Division (PSD) manages a series of high-profile programs such as Lunar Discovery and Exploration, Mars Exploration, Outer Planets and Ocean Worlds, Planetary Defense, and Near-Earth Object Observations. Within those programs, the planetary science portfolio consists of 32 space flight missions in various stages of operation—including orbiters, landers, rovers, and probes—that seek to advance our understanding of the solar system by exploring the Earth's Moon, other planets and their moons, asteroids and comets, and the icy bodies beyond Pluto. We assessed the Agency's management of its planetary science portfolio.

We found that PSD has taken positive steps in response to recommendations and goals outlined by the National Academies of Sciences, Engineering, and Medicine. However, as NASA's planetary science missions become more complex, the life-cycle costs of PSD missions are increasing due to project management challenges and mission complexity. While PSD and NASA Centers are focused on meeting current mission needs, they are at risk of neglecting investments—including technical capabilities, workforce, the Deep Space Network, and technology development—that would help ensure long-term maintenance of NASA's unique planetary science infrastructure. Additionally, in examining discrete planetary science missions, the Lunar Discovery and Exploration Program is accepting higher risk than necessary in the CLPS project, which provides contracts to U.S. commercial entities to develop landers to deliver NASA science instruments and other payloads to the Moon's surface. Finally, Near-Earth Object Observations Program resources were insufficient to meet the program's congressional mandate of cataloging near-Earth objects.

We made 11 recommendations to improve NASA's management of its planetary science portfolio.

NASA's Management of the Stratospheric Observatory for Infrared Astronomy Program (IG-20-022, September 14, 2020)

The Stratospheric Observatory for Infrared Astronomy (SOFIA) was an airborne observatory with a 106-inch telescope mounted onboard a Boeing 747SP that makes observations from between 38,000 and 45,000 feet, putting it above 99 percent of water vapor that interferes with ground-based infrared observations. SOFIA reached full operational capability in 2014 after a problematic 23-year development history and at a cost of $1.1 billion—more than 300 percent over original estimates.

We found that while SOFIA is responsible for several first-of-its-kind discoveries, a 13-year development delay reduced the Program's ability to produce impactful science in a cost-effective manner, and SOFIA did not fully utilize its unique capabilities to serve as an instrument test bed or to fly anytime, anywhere. In addition, SOFIA experienced operational and technical challenges related to flight operations, observation completion, data processing, contractor award fees, and instrument development. Further, the lack of clear and achievable performance expectations and science output goals reduced productivity and threatened the Program's future viability. Since issuance of our report SOFIA ceased operations and concluded its final science flight on September 29, 2022.

We made 9 recommendations to improve the SOFIA Program's productivity.

Management of NASA's Europa Mission (IG-19-019, May 29, 2019)

Scientists believe that Europa, one of Jupiter's 79 known moons, may have a large liquid ocean, suitable for sustaining life, below its icy surface. In 2011, the National Research Council determined that an orbiter mission to Europa should be NASA's second priority flagship planetary science mission. In response, Congress directed the Agency to plan two separate missions to Europa: (1) a flyby orbiter known as Clipper and (2) a Lander intended to place scientific instruments on the moon's surface. Congress also directed NASA to use the Space Launch System as the launch vehicle for both missions with launch dates of no later than 2023 for the Clipper and 2025 for the Lander.

We found that the Clipper was at risk of not meeting its 2023 launch date due to challenges in developing the Clipper's science instruments, addressing technical workforce gaps, choosing a launch vehicle, and overcoming funding risks that could delay the Clipper or impact other projects in the Agency's planetary science portfolio. Specifically, NASA's aggressive development schedule, a stringent conflict of interest process during instrument selection, and an insufficient evaluation of cost and schedule estimates has increased project integration challenges and led the Agency to accept instrument cost proposals subsequently found to be far too optimistic. Since issuance of our report, NASA missed the 2023 launch date and now has a target launch date of October 2024.

We also found workforce and schedule risks render a 2025 launch date for the Lander unfeasible; requiring the Agency to pursue the Lander at the same time as the Clipper is inconsistent with the National Research Council's (NRC) process of strategically selecting and prioritizing flagship missions and would preclude NASA from producing optimal science. Additionally, the Lander would require substantial and ongoing funding for at least the next 10 years and could adversely affect the Agency's planetary science portfolio.

We made 10 recommendations for the Europa mission to achieve its technical objectives, meet milestones, and control costs.

NASA's Heliophysics Portfolio (IG-19-018, May 7, 2019)

NASA's space missions and much of the U.S. power grid, communications systems, and navigation infrastructure operate in an environment highly susceptible to the Sun. NASA's Heliophysics Division (HPD) and its portfolio of spacecraft, programs, and missions provide observations of solar and geophysical events—also known as "space weather" events—to advance our understanding of the Sun and its interaction with Earth's atmosphere. We assessed the Agency's management of its heliophysics portfolio.

We found that HPD has developed a comprehensive strategy to successfully manage NASA's heliophysics science capabilities and maintain its portfolio of missions. That said, we noted that the Division's 2014 roadmap had not been updated to account for changes in HPD's portfolio and subsequent-year budgets. In addition, although NASA has generally controlled costs for all of its operational HPD missions, the Division's three missions in implementation had missed planned launch dates and collectively incurred almost $41 million in cost growth. NASA also had not completed 19 of its assigned National Space Weather Action Plan tasks, 1 recommendation from the NRC's 2003 Heliophysics Decadal Survey, and 6 recommendations from NRC's 2013 Heliophysics Decadal Survey. Finally, while NASA had established a successful working relationship with the National Oceanic and Atmospheric Administration, the Agency could more effectively collaborate with the Department of Defense and the commercial space industry on heliophysics-related issues.

We made four recommendations to improve NASA's management of its heliophysics portfolio.

NASA's Technology Transfer Process (IG-19-016, April 15, 2019)

Throughout its existence, NASA has shared its inventions and scientific breakthroughs with the public, academia, and private industry. This transfer of technology—consistent with the legislation that created NASA—can happen in a variety of ways including through the publishing of information and, more formally, through partnerships or licensing of intellectual property.

We found that NASA has made concerted efforts in recent years to improve overall awareness of its Technology Transfer Program through increased communication and outreach, resulting in a considerable increase in the number of New Technology Reports submitted, patent applications filed, and licenses negotiated—effectively increasing the Agency's overall commercialization efforts. However, Goddard Space Flight Center (Goddard) was experiencing poor technology transfer performance outcomes when compared to the other three Centers we reviewed, to include a lower percentage of licenses as well as delays in processing of New Technology Reports and patent applications. Further, we noted that Goddard's technology transfer process was hindered by a lack of adequate controls and poor collaboration between its Technology Transfer Office and the Office of Patent Counsel.

The OIG made four recommendations to improve the effectiveness of the Technology Transfer Program.