

NASA

National Aeronautics and Space Administration

Office of Inspector General

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Committee on Science, Space, and Technology

KEY CHALLENGES FACING NASA'S ARTEMIS CAMPAIGN

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

Our mission is to provide independent, objective, and comprehensive oversight of NASA's programs and projects to help ensure that the Agency operates with transparency, efficiency, and accountability. As part of this mission, we provide oversight on significant challenges facing NASA and impacting the Artemis campaign.

After more than a decade of preparation and several delays, in December 2022 NASA successfully completed Artemis I—an uncrewed test flight to lunar orbit. Artemis I was a significant achievement for NASA, providing important data and lessons learned from the testing of hardware, software, processes, and teams that will help prepare NASA for future Artemis missions. Despite this achievement, our oversight has identified several interrelated challenges NASA must address to achieve its ambitious Artemis goals. Of utmost importance is the resolution of technical challenges that could threaten astronaut safety while also addressing historical challenges related to unsustainable costs and a lack of transparency into funding needs.

First, the Artemis campaign's technical challenges. The Agency's immediate challenge is preparing for Artemis II—the first crewed test flight of the Space Launch System (SLS) heavy-lift rocket and Orion Multi-Purpose Crew Vehicle (Orion) system—which will return humans to lunar orbit for the first time in more than 50 years. The Agency continues to analyze mission data from Artemis I and must address a variety of technical challenges to safely fly four astronauts to lunar orbit on their planned 10-day Artemis II mission. While considered a near-perfect flight by NASA officials, Artemis I revealed technical issues such as the unexpected erosion of protective material on the Orion heat shield. In addition, the Mobile Launcher 1 platform—the ground structure used to assemble, process, transport, and launch the SLS for Artemis I through III—sustained more damage than expected. Just last week, NASA delayed the Artemis II mission to September 2025.

Looking ahead to Artemis III—the mission that will return humans to the surface of the Moon—NASA's commercial partner SpaceX must conduct multiple flight tests and launches of its Human Landing System (HLS) Starship before using its lander variant with astronauts onboard. The HLS requires SpaceX to launch a series of Starship vehicles to establish a "fuel depot" in low Earth orbit to refuel each Starship heading to the Moon. Moreover, under its contract with NASA the company is required to send an uncrewed Starship to the lunar surface and back prior to Artemis III to demonstrate its readiness for a crewed mission. At the same time, NASA must develop additional capabilities including next-generation spacesuits. With last week's announcement, NASA also delayed Artemis III to September 2026 in part to provide additional time to develop SpaceX's HLS Starship and next-generation spacesuits.

For missions beyond Artemis III, the second mobile launcher (ML-2) is a critical part of the infrastructure needed to launch the upgraded SLS Block 1B and Block 2. In June 2022, we reported that the ML-2 project is significantly behind schedule and over budget, jeopardizing launch schedules for Artemis IV and beyond. While the ML-2's first steel components were delivered to Kennedy Space Center in May 2023, we estimate completion of the launcher will not occur until late 2026 at the earliest, 2.5 years behind the project's originally scheduled date.

The second challenge is the Artemis campaign's enormous expense. Overall, we project NASA's total Artemis campaign costs to reach \$93 billion between fiscal years 2012 and 2025. We also project the SLS/Orion system and related ground launch infrastructure will cost at least \$4.2 billion per launch for the first four Artemis missions, a figure that does not include \$42 billion in formulation and development costs spent over the past dozen years to bring these systems to the launch pad.

Development of the systems required to transport humans to the Moon and Mars safely has proven to be especially challenging due to increased costs stemming from significant technical issues, changing requirements, and overly optimistic schedules.

Given these estimated costs and the significant challenge they pose to the long-term sustainability of the Artemis campaign, it is critical that the Agency identify and implement effective ways to reduce costs. This will be especially important as Congress urges NASA to increase the SLS/Orion launch cadence at the same time NASA—and much of the federal government—may be operating under a flat annual budget. Our recent work has shown that some key cost reduction efforts may fall short of expectations.

For example, in May 2023 we reported that NASA is projecting manufacturing cost savings of 30 percent per engine for the SLS starting with production of the seventh of 24 new RS-25 engines. However, these projected savings do not capture overhead and other costs associated with restarting production of the engine, which we estimated to reach \$2.3 billion. Likewise, in October 2023 we reported on NASA's efforts to reduce the cost of lunar missions beyond Artemis IV by transitioning management of multiple contractors for production of SLS systems and hardware, as well as systems integration and launch services, to a single contractor service. We found this approach would likely not achieve its cost reduction goals due to a variety of unrealistic assumptions, such as finding customers outside of NASA to use the SLS. Additionally, NASA aims to make its Moon to Mars plan more sustainable by sharing costs with its international partners. However, we found NASA's cost-sharing strategies with its international partners are still evolving and the Agency lacks an overall architecture, or blueprint, that includes cost estimates and responsibilities for international partners beyond Artemis IV.

The final challenge we highlight today is the Artemis campaign's lack of cost and schedule transparency. In particular, NASA still lacks a comprehensive and accurate estimate that accounts for all Artemis costs. For example, we previously reported that NASA had neither established life-cycle costs nor made cost and schedule commitments for some of the programs supporting the Artemis campaign. By failing to do so, the Agency is circumventing congressional requirements for reporting and tracking such costs. We continue to believe the Agency needs to provide full visibility into its investments as it begins a multi-decade Moon to Mars initiative at a cost that could easily reach into the hundreds of billions of dollars. As the programs that support these exploration missions transition from development to production and operation, it is critical that NASA establish credible, complete, and transparent cost and schedule estimates from which they can measure success and be accountable to Congress and other stakeholders.

Over the past two years, the OIG has issued nine audit reports that examine issues critical to NASA's effort to land humans on the Moon as a prelude to a crewed Mars mission. We assessed NASA's transition of the SLS to a commercial services contract, the Artemis supply chain, communication infrastructure, SLS engine and booster contracts, partnerships with international space agencies, ground systems and launch infrastructure, cost estimating and reporting practices, management of the Agency's astronaut corps, and management of the Artemis missions. Below, we summarize these reports, findings, and recommendations.

NASA's Transition of the Space Launch System to a Commercial Services Contract ([IG-24-001](#), October 2023)

In an effort to increase the affordability of the Artemis campaign, NASA is preparing to award a sole-sourced services contract, known as the Exploration Production and Operations Contract (EPOC), to Deep Space Transport, LLC (DST)—a newly formed joint venture of The Boeing Company and Northrop

Grumman Systems Corporation—for the production, systems integration, and launch of at least 5 and up to 10 SLS flights beginning with Artemis V scheduled for 2029.

We found that despite NASA's noteworthy adjustments to the EPOC transition plan and its affordability initiatives, the price of the SLS Block 1B rockets will not be significantly reduced through a sole-source contract with DST. NASA's aspirational goal is to achieve a 50 percent cost savings over current SLS production costs using DST, which by our calculation would reduce the contract cost of a single SLS rocket from \$2.5 billion to \$1.25 billion. Our analysis shows this goal cannot be achieved and the production cost alone will remain over \$2 billion. We reach this conclusion after examining what we believe are unrealistic assumptions on NASA's part. First, the Agency expects to achieve cost savings through reduced SLS production costs under a contract with DST. However, ongoing affordability efforts by SLS contractors to reduce the workforce and improve manufacturing processes have yet to achieve cost savings on the high-cost stages and RS-25 engine contracts. Second, DST expects to drive down costs by increasing the SLS production rate and building more SLSs for non-NASA customers such as the Department of Defense and commercial entities. However, thus far other potential users have declined to use the SLS due to lower-cost alternatives. Finally, NASA's ability to negotiate less costly services with DST will be hindered by the lack of competition given EPOC is sole sourced to the existing SLS contractors.

The OIG made seven recommendations to improve the sustainability of the SLS system.

NASA's Management of the Artemis Supply Chain ([IG-24-003](#), October 2023)

Each of NASA's Artemis-related programs rely on specialized parts supplied by contractors and subcontractors from across the United States and around the world. NASA's contractors employ a network of subcontractors and suppliers to provide the hardware, raw materials, electronic parts, and other resources needed to fulfill their contracts. To support the Artemis campaign, NASA obligated approximately \$40 billion to 860 contractors from fiscal years 2012 to 2022.

We found that NASA and its prime contractors continue to experience challenges obtaining key components and necessary supplies to meet Artemis goals resulting in cost increases and schedule delays. Supply chain delays and disruptions over the past several years have resulted from a variety of factors outside the Agency's control, from the COVID-19 pandemic to inflation of wages and material costs to the Russia-Ukraine conflict. That said, several factors related to managing Artemis supply chain issues are within NASA's purview. Most importantly, this includes the Agency's lack of visibility into its critical suppliers, with many Artemis programs and projects not tracking their prime contractors' supply chain impacts. Even when issues with subcontractors and suppliers are identified, performance challenges are not shared across Artemis programs to enable effective procurement decisions. To its credit, NASA is undertaking efforts to better understand supply chain issues and manage them more proactively, but these initiatives are still in the early stages.

The OIG made seven recommendations to improve NASA's management and visibility into its supply chain.

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

NASA relies on its Deep Space Network (DSN) to provide communication links that guide and control spacecraft such as the Orion and bring back images and other data from missions such as the James

Webb Space Telescope. The DSN consists of three communications facilities in the United States, Spain, and Australia that use antennas to communicate with spacecraft located between 10,000 miles from Earth to beyond the edge of the solar system.

We found DSN antennas are 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. The Agency’s crewed Artemis missions to the Moon will require increasingly higher amounts of bandwidth and further constrict the network’s ability to meet growing mission demands. 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. NASA’s primary solution to address the DSN’s capacity issues is to construct additional antennas and make upgrades to existing infrastructure. However, these efforts are behind schedule and over budget, experiencing nearly 5 years of delays, only partial completion of two phases of construction, and an expected 68 percent cost increase.

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

NASA’s Management of the Space Launch System Booster and Engine Contracts ([IG-23-015](#), May 2023)

Key to NASA’s Artemis campaign is development of the SLS—a two-stage, heavy-lift rocket with two boosters and four RS-25 engines that will launch the Orion into space. From fiscal years 2012 through 2025, NASA’s overall Artemis investment is projected to reach \$93 billion, of which the SLS Program costs represent \$23.8 billion spent through 2022. This audit examined two SLS booster contracts with Northrop Grumman and two RS-25 engine contracts with Aerojet Rocketdyne. We found that NASA is experiencing significant scope growth on both contracts, as well as approximately \$6 billion in cost increases and over 6 years in schedule delays. As a result of the cost and schedule increases under these four contracts, we calculate NASA will spend \$13.1 billion through 2031 on boosters and engines.

We found long-standing management issues—including underestimating the scope and complexity of work, concurrent development and production activities, inadequate procurement workforce, and inappropriate use of award fees—caused the cost increases and schedule delays. Further, NASA’s poor contract management practices are impacting the SLS Program and Artemis campaign, causing us to question \$49.9 million in costs and award fees. Facing continuing cost and schedule increases, we found NASA is undertaking efforts to make the SLS more affordable. Under the RS-25 Restart and Production contract, NASA and Aerojet Rocketdyne are projecting manufacturing cost savings of 30 percent per engine starting with production of the seventh of 24 new engines. However, those savings do not capture overhead and other costs, which we currently estimate at \$2.3 billion. For SLS boosters, NASA is procuring 10 boosters on a fixed-price-incentive-fee basis starting with Artemis IV—an important step in its affordability initiatives—but any additional requirements will limit these projected cost savings.

The OIG made eight recommendations to help increase transparency, accountability, and oversight of the SLS booster and engine contracts and NASA’s affordability efforts.

NASA's Partnerships with International Space Agencies for the Artemis Campaign ([IG-23-004](#), January 2023)

NASA's partnerships with international space agencies are critical to achieving a robust and sustainable presence on the Moon as a precursor to a human mission to Mars. Key early Artemis commitments from partner agencies include the provision of a Gateway habitat, communications satellites, spacecraft service modules, external robotics, astronauts, and lunar rovers.

We found, however, future international cooperation for Artemis may be hindered by a variety of factors. This includes the Agency's lack of an overarching strategy to coordinate Artemis contributions from international space agencies and entities. While the architecture, or blueprint, for the first three Artemis missions is well established, an overall architecture beyond Artemis IV for lunar exploration that includes estimated costs to be borne and responsibilities assumed by its international partners is not yet established. As a result, partners have insufficient information to work with their governments to develop their own budgets and identify potential contributions to the Artemis effort. In addition, U.S. export control regulations can be overly complex and restrictive which may limit NASA's international collaborations on Artemis. Finally, NASA's cost sharing strategies with its international partners for Artemis are still evolving and, in contrast to International Space Station operations where international partners contribute almost 25 percent of the costs, we estimate that less than 6 percent of the human space flight mission costs will be borne by international partners for the first three Artemis missions.

The OIG made ten recommendations to increase the effectiveness and affordability of Artemis integration efforts with international partners.

NASA's Management of the Mobile Launcher 2 Contract ([IG-22-012](#), June 2022)

Key to NASA's goals of sustaining a human presence on the Moon and future exploration of Mars is the Agency's development of two mobile launchers that will serve as the ground structure to assemble, process, transport to the pad, and launch various iterations of the integrated SLS/Orion system into space. In 2019, NASA awarded a cost-plus contract to Bechtel National, Inc. to design, build, test, and commission a second mobile launcher to support larger variants of the SLS beginning with the Artemis IV mission. Valued at \$383 million, the original contract had a performance period from July 2019 through March 2023.

We found that for completion of contract requirements and delivery of an operational ML-2, Bechtel estimated it would need an additional \$577.1 million, for a total cost of \$960.1 million, and an October 2025 delivery date rather than March 2023 as initially planned. Additionally, we found ML-2's substantial cost increases and schedule delays could be attributed primarily to Bechtel's poor performance on the contract, with more than 70 percent (\$421.1 million) of the contract's cost increases and over 1.5 years of the delays experienced being related to the company's performance. These increases and delays were further compounded by NASA's management practices and decision to award the contract before the SLS's Exploration Upper Stage requirements were finalized. Further, NASA's usage of award fees did not improve Bechtel's performance.

The OIG made five recommendations to improve management of the ML-2 contract and contractor performance. In September 2023, the OIG initiated a new audit to examine the actions NASA is taking to control future cost growth and schedule delays.

NASA's Cost Estimating and Reporting Practices for Multi-Mission Programs ([IG-22-011](#), April 2022)

NASA has a long history of groundbreaking accomplishments but has struggled to establish credible cost estimates for some major acquisitions; particularly, human space flight missions, which are comprised of multiple programs with numerous deliverables—like rockets and spacecraft—stretching over many years. As a result, Congress and other stakeholders lack meaningful visibility into the complete costs of NASA's major acquisitions. Without adequate transparency, it is difficult for stakeholders to hold the Agency accountable for these large, years-long expenditures of taxpayer funds.

We found that Congress is not receiving the federally mandated cost and schedule information it needs to make fully informed funding decisions for NASA's programs—specifically, the SLS, Orion, and Exploration Ground Systems—that support Artemis. NASA only made cost and schedule commitments to Congress to demonstrate the initial capability of each system. Even though NASA has multiple Artemis missions planned, it has not adjusted the three programs' life-cycle cost estimates or commitments to account for future missions. The result is incomplete cost estimates and commitments for these programs and missions.

In August 2021, the Agency made an update to NASA Procedural Requirements 7120.5F, *NASA Space Flight Program and Project Management Requirements*, which establishes the requirements, life-cycle processes, and procedures NASA uses to formulate and implement space flight programs and projects. NASA stated that it intended to establish new policies and procedures that would provide additional transparency for major programs with multiple deliverables and unspecified end points. Instead, it codified its poor cost estimating and reporting practices in a new policy that fails to comply with Title 51 of the United States Code, *National and Commercial Space Programs*, which requires the Agency to annually provide an estimate of the life-cycle cost for major programs, with a detailed breakout of the development cost, program reserves, and an estimate of the annual costs until development is completed. The policy also weakens NASA's ability to account for some risks in programs consisting of multiple projects, potentially affecting cost and schedule if risks are unidentified in the estimates.

The OIG made seven recommendations to ensure that all major programs and activities are reported to Congress in accordance with Title 51. In July 2023, NASA informed the OIG that it would not implement four of the recommendations.

NASA's Management of Its Astronaut Corps ([IG-22-007](#), January 2022)

As NASA enters a new era of human space flight, effective management of its astronaut corps is critical to the Agency's success. With the upcoming crewed Artemis II mission, the margin of time available to identify skillset needs, recruit and hire additional astronaut candidates, develop a framework for Artemis training, and adjust current processes for sizing, aligning, training, and assigning its astronaut corps is quickly diminishing.

We found NASA's processes used to size, train, and assign the astronaut corps are primarily calibrated toward meeting the current needs of the International Space Station. However, work has begun to align NASA's astronaut corps to Artemis mission needs. As the Agency prepares for crewed Artemis missions, astronaut training needs will change. While the Astronaut Office is in the process of developing a framework for Artemis training, it has not been formally chartered. Delays in moving beyond the

current Space Station-focused approach increases the risk of delays in developing the necessary training to meet Artemis mission goals.

Additionally, as NASA moves to deep space Artemis missions, it has begun to review its policies and conduct additional studies on human health impacts from longer duration missions and missions beyond low Earth orbit. If the nature of Artemis missions medically disqualifies certain astronauts as a result of exceeding the Agency-set maximum level of radiation exposure because of the duration of the mission beyond low Earth orbit, NASA may need to adjust its astronaut corps size and assignment process.

The OIG made four recommendations to help ensure the astronaut corps is aligned to meet current and future mission needs.

NASA's Management of the Artemis Missions ([IG-22-003](#), November 2021)

We found that NASA is projected to spend \$93 billion on the Artemis campaign from fiscal years 2012 through 2025. However, as a result of NASA's decision not to classify Artemis as a formal program under the Agency's Space Flight Program and Project Management Requirements, Artemis officials were not required to develop an official Artemis-wide full life-cycle cost estimate. By failing to develop an official cost estimate that includes all relevant costs, NASA lacks transparency of the true funding requirements for a long-term Artemis effort.

Multiple factors contribute to the high cost of exploration system development programs, including the use of sole-source, cost-plus contracts; the inability to definitize key contract terms in a timely manner; and the fact that except for the Orion capsule, its subsystems, and supporting launch facilities, all components are expendable and "single use" unlike emerging commercial space flight systems.

For HLS, NASA has modified its traditional acquisition approach for large space flight programs to reduce costs, encourage innovation, and meet an aggressive schedule for its Artemis lunar landings. HLS will use less standardized milestone reviews and instead utilize other project management techniques throughout development and testing. While the HLS Program leveraged lessons learned and is modeled, in part, after the Commercial Crew Program, HLS tailored its programmatic milestone approach to better fit a services model approach versus the traditional hardware development program. Although these modified approaches have the potential benefit of decreasing costs and encouraging innovation, they also raise the possibility of technical changes later in development plus schedule and performance risks on NASA's human-rated systems.

The OIG made nine recommendations to increase transparency of costs and improve program management.

Conclusion

While Artemis I was a significant achievement for NASA, the Agency faces higher stakes as it flies astronauts on its Artemis II mission. We urge NASA leadership to continue balancing the achievement of its mission objectives and schedule with prioritizing the safety of its astronauts and to take the time needed to minimize any undue risk on this first crewed Artemis mission.

Moving forward, the Agency must continue to look for ways to reduce the enormous costs of the systems required to transport humans to the Moon and Mars safely within the funding allocated by Congress. Failure to reduce these costs will ultimately make the Artemis campaign unsustainable. At the same time, improved transparency of Artemis costs will be crucial to its success. Without NASA fully accounting for and accurately reporting the overall cost of current and future missions, it will be difficult for Congress, the Office of Management and Budget, and the American public to make informed decisions about NASA's long-term funding needs—a key to making Artemis a sustainable venture.

We look forward to helping NASA achieve its ambitious Artemis goals. To that end, we plan to continue examining key challenges in NASA's human exploration missions to the Moon and Mars.