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NASA's Management of the Artemis Missions

November 15, 2021

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RESULTS IN BRIEF

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November 15, 2021 IG-22-003 (A-20-008-01)

WHY WE PERFORMED THIS AUDIT

The Artemis program seeks to return humans to the Moon by late 2024 rather than 2028 as initially planned. Faced with a shortened timeframe, an uncertain budget, and the nascency of the required development work, NASA implemented modifications to its routine procurement and program management practices in an attempt to accelerate the mission schedule and reduce costs. The Agency's lunar strategy includes development of the Space Launch System (SLS) heavy-lift rocket, the Orion Multi-Purpose Crew Vehicle (Orion) capsule, a Human Landing System (HLS) to transport astronauts from lunar orbit to the Moon's surface, the Gateway outpost orbiting the Moon, next-generation spacesuits, and delivery of science investigations and technology demonstrations to the lunar surface by commercial landers.

Currently NASA's most ambitious and costly activity, the Artemis program faces schedule, procurement, technical, and funding risks. This includes procurement of Artemis-related technologies and space flight hardware using research and development contracts that leverage commercial capabilities but require a Federal Acquisition Regulation (FAR) deviation for acquiring services and hardware. SLS and Orion have also experienced technical challenges in later development phases as well as the effects of COVID-19 restrictions and severe weather events. Additionally, the Gateway and HLS Programs received significantly less funding in fiscal year (FY) 2021 than required to meet NASA's initial acquisition strategy.

As the second in a series of audits examining NASA's Artemis plans, this report assessed the Artemis program's schedule and projected costs as well as how the Agency's acquisition and programmatic approaches facilitate landing astronauts on the Moon. To complete this work, we reviewed documents, systems, policies, and procedures pertaining to schedule, cost, budget, operations, acquisition strategy, and program/project management requirements related to Artemis, its programs, and contactors. We also reviewed contracts, interviewed NASA and contractor officials, and conducted site visits at SpaceX headquarters in California and its Starbase facility in Texas.

WHAT WE FOUND

NASA's three initial Artemis missions, designed to culminate in a crewed lunar landing, face varying degrees of technical difficulties and delays heightened by the COVID-19 pandemic and weather events that will push launch schedules from months to years past the Agency's current goals. With Artemis I mission elements now being integrated and tested at Kennedy Space Center, we estimate NASA will be ready to launch by summer 2022 rather than November 2021 as planned. Although Artemis II is scheduled to launch in late 2023, we project that it will be delayed until at least mid-2024 due to the mission's reuse of Orion components from Artemis I. While the Advanced Exploration Systems (AES) Division—which includes HLS, Gateway, and next-generation spacesuits—is working on an integrated master schedule (IMS) for Artemis III that incorporates Exploration Systems Development (ESD) Division programs—SLS, Orion, and Exploration Ground Systems—the draft version does not include information on programs critical to Artemis that are outside of AES and ESD. Given the time needed to develop and fully test the HLS and new spacesuits, we project NASA will exceed its current timetable for landing humans on the Moon in late 2024 by several years.

In addition, NASA lacks a comprehensive and accurate cost estimate that accounts for all Artemis program costs. For FYs 2021 through 2025, the Agency uses a rough estimate for the first three missions that excludes $25 billion for key activities related to planned missions beyond Artemis III. When aggregating all relevant costs across mission directorates, NASA is projected to spend $93 billion on the Artemis effort up to FY 2025. We also project the current production and operations cost of a single SLS/Orion system at $4.1 billion per launch for Artemis I through IV, although the Agency's ongoing initiatives aimed at increasing affordability seek to reduce that cost. Multiple factors contribute to the high cost of ESD 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 the supporting launch facilities, all components are expendable and "single use" unlike emerging commercial space flight systems. Without capturing, accurately reporting, and reducing the cost of future SLS/Orion missions, the Agency will face significant challenges to sustaining its Artemis program in its current configuration.

Further, 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. While its acquisition approach relies on competition to drive down costs and ensure redundancy, the Agency selected a single provider—SpaceX—after receiving $2.5 billion less than requested for HLS development in FY 2021. To help compensate, the Agency is accelerating its Lunar Exploration Transportation Services procurement for sustainable, regularly-recurring crewed lunar transportation services, and in September 2021 awarded five HLS contracts for the continued development of sustainable HLS capabilities as a prelude to the competitive services procurement. Over the past year, NASA has worked to solidify its HLS requirements and standards, established insight and collaboration teams, and plans to establish resident offices at SpaceX. However, under NASA's tailored project management approach, HLS will use less standardized milestone reviews and instead utilize other techniques such as annual synchronization reviews throughout development and testing, but this approach runs the risk of technical changes later in development. Finally, instead of using a systems integrator or Artemis program manager, NASA is establishing various collaborative processes including new boards and a multi-directorate council to facilitate the communication and approval process. The effectiveness of this approach remains to be seen. While these modified approaches have the potential benefit of decreasing costs and encouraging innovation, they also raise the possibility of schedule and performance risks on NASA's human-rated systems.

WHAT WE RECOMMENDED

To increase accuracy, transparency, and safety of human space flight, we recommended NASA's Associate Administrator for Exploration Systems Development Mission Directorate: (1) develop a realistic, risk-informed schedule that includes sufficient margin to better align Agency expectations with the development schedule; (2) expand upon the existing draft Artemis IMS to include Artemis programs outside AES and ESD to properly align dependencies across directorates; (3) develop an Artemis-wide cost estimate and update it on an annual basis; (4) maintain an accounting of per-mission costs and establish a benchmark against which NASA can assess the outcome of initiatives to increase the affordability of ESD systems; (5) definitize outstanding Artemis-related contracts within 180 days in accordance with NASA FAR Supplement 1843.7005(a); (6) develop a realistic funding profile and schedule given the underfunding of HLS in FY 2021, selection of one HLS award, and desire to compete a sustainability contract for future lunar missions; and (7) identify measurable cost reduction targets for its ESD contractors. We also recommended NASA's Chief Engineer in coordination with the HLS Program Manager: (8) validate annual synchronization reviews meet the intent and expectations of the milestone reviews replaced by the tailored acquisition approach, and the NASA Deputy Administrator in coordination with Mission Directorate Associate Administrators: (9) codify the remaining governance structure such as the Federated Boards and Joint Directorate Program Management Council.

We provided a draft of this report to NASA management who concurred with Recommendations 1, 5, 6, 7, and 8, and described planned actions to address them. We consider the proposed actions responsive for these recommendations and will close them upon completion and verification. In addition, the Agency partially concurred with Recommendations 2 and 9 and non-concurred with Recommendations 3 and 4. These four recommendations will remain unresolved pending further discussions with NASA.

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Acronyms

ABC	Agency Baseline Commitment
AES	Advanced Exploration Systems
CLPS	Commercial Lunar Payload Services
COVID-19	Coronavirus Disease 2019
EGS	Exploration Ground Systems
ESA	European Space Agency
ESD	Exploration Systems Development
EVA	Extravehicular Activity
FAR	Federal Acquisition Regulation
FY	fiscal year
GAO	Government Accountability Office
HALO	Habitation and Logistics Outpost
HEOMD	Human Exploration and Operations Mission Directorate
HLS	Human Landing System
IMS	integrated master schedule
ISS	International Space Station
JCL	Joint Cost and Schedule Confidence Level
KDP	Key Decision Point
LETS	Lunar Exploration Transportation Services
NextSTEP	Next Space Technologies for Exploration Partnerships
NFS	NASA FAR Supplement
OIG	Office of Inspector General
PPE	Power and Propulsion Element
SE&I	Systems Engineering and Integration
SRA	Schedule Risk Analysis
SLS	Space Launch System
TRL	Technology Readiness Level
VIPER	Volatiles Investigating Polar Exploration Rover
xEMU	Exploration Extravehicular Mobility Unit
xEVA	Exploration Extravehicular Activity

INTRODUCTION

In March 2019, NASA committed to landing humans on the Moon's South Pole by 2024 instead of 2028 as initially planned.[1] Faced with a shortened timeframe, an uncertain budget, and the nascency of the required development work, NASA implemented modifications to its routine procurement and program management practices in an effort to reduce costs and accelerate the mission schedule. In addition to the Space Launch System (SLS) heavy-lift rocket, the Orion Multi-Purpose Crew Vehicle (Orion) capsule, and a Human Landing System (HLS), the Agency's lunar strategy includes development of both the Gateway outpost orbiting the Moon and next-generation spacesuits capable of sustaining astronauts on the lunar surface, as well as multiple deliveries of science investigations and technology demonstrations to the Moon by commercial landers.

This ambitious schedule is not without risk. NASA is procuring Artemis-related technologies and space flight hardware using a variety of methods, including research and development contracts that leverage commercial capabilities and state-of-the-art innovation, but require a Federal Acquisition Regulation (FAR) deviation. Additionally, and not unexpectedly, Orion and SLS have experienced technical challenges in later development phases, along with enduring the effects of Coronavirus Disease 2019 (COVID-19) restrictions for over 18 months and numerous severe weather events. For example, during testing, Orion had an internal power and data unit that lost redundancy in November 2020, and the SLS required a second hot fire test of its Core Stage in March 2021 adding months to an already delayed schedule, making the planned November 2021 Artemis I launch date not feasible.[2]

In addition to the procurement and technical risks, both the Gateway and HLS Programs received significantly less funding for fiscal year (FY) 2021 than initially required. Costs for the Artemis mission, spread among various NASA directorates and divisions, are expected to reach $93 billion by FY 2025.[3] Although the Biden Administration has indicated it will continue the Artemis program, the funding level is still being determined and the Administration's commitment to the current goal of landing astronauts on the Moon in 2024 is in flux with a revised timetable expected in late 2021.

This report is the second in a series of audits examining NASA's Artemis plans. In this review, we assessed the Artemis program's schedule and projected costs, as well as how the Agency's acquisition and programmatic approaches seek to facilitate landing astronauts on the Moon. See Appendix A for details on the audit's scope and methodology.

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[1] In a recent report on NASA's development of next-generation spacesuits, we concluded that delays in the Agency's efforts will preclude a lunar landing in late 2024. NASA Office of Inspector General (OIG), *NASA's Development of Next-Generation Spacesuits* (IG-21-025, August 10, 2021).

[2] In October 2021, the Agency announced that the Artemis I launch would be delayed until February 2022 at the earliest. NASA officials said they plan to announce an official target launch date after several key tests are completed in the coming months. In November 2021, the NASA Administrator announced additional delays with Artemis II launching no later than May 2024 and Artemis III launching no earlier than 2025.

[3] The $93 billion figure was derived from examining NASA's obligations, FY 2021 Budget Operating Plan, and budget projections for programs and projects involved in the Artemis program between FY 2012 and FY 2025.

Background

Scheduled to launch in late 2021, Artemis I is planned as the first uncrewed flight of the integrated SLS/Orion system on a trajectory that will include a series of orbits around the Moon. The second mission and first crewed flight—Artemis II—will also orbit the Moon and prepare the way for Artemis III in late 2024. In this third mission, the Orion capsule will dock in lunar orbit directly to the HLS to transport astronauts to and from the lunar surface.[4] Prior to the astronauts' arrival, NASA intends to explore the lunar landing area with robotic systems as part of its Commercial Lunar Payload Services (CLPS) initiative.[5] Subsequent Artemis missions will include a longer-term presence on the Moon that incorporates use of the Gateway in lunar orbit, ground infrastructure on the lunar surface such as a habitat, and surface transportation like a lunar rover. NASA's plan to land astronauts on the Moon relies heavily on the maturity of a number of key systems, including the SLS/Orion and next-generation spacesuits. In addition, NASA will rely on the commercial sector to launch both the Gateway and HLS into Near Rectilinear Halo Orbit.[6] Figure 1 shows the current schedule for the Artemis exploration missions and commercial launches in support of a lunar landing.

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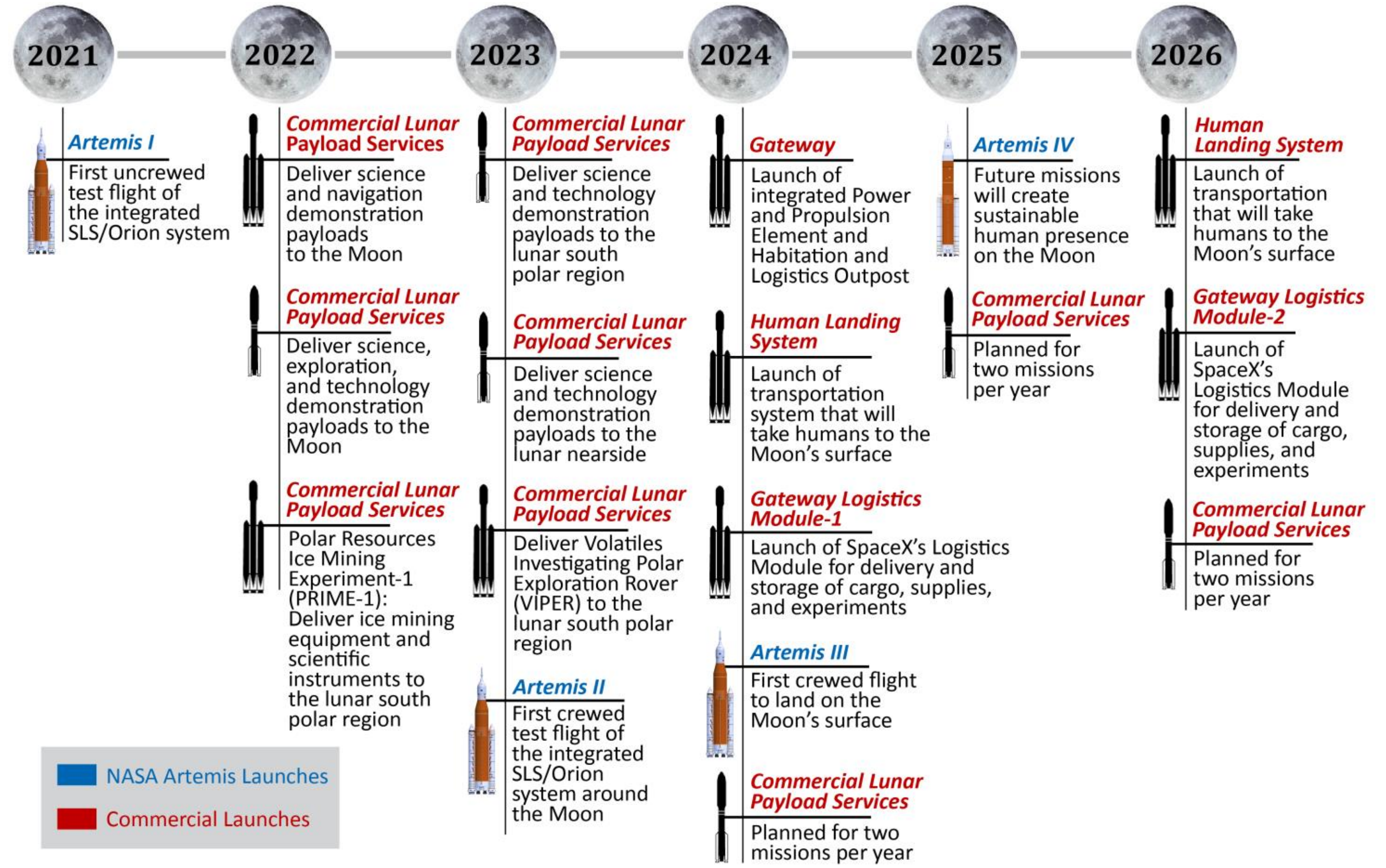
[4] NASA's goal is to have the Gateway in an orbit around the Moon to support Artemis IV. The initial elements of the orbiting lunar platform will consist of the Power and Propulsion Element, which provides electrical power and propulsion to the Gateway, and the Habitation and Logistics Outpost, which provides working and living space for the astronauts while the Orion is docked to it.

[5] Initiated in 2018, NASA's CLPS initiative is intended to allow rapid acquisition of lunar delivery services from American companies for payloads that advance science, exploration, and commercial development of the Moon.

[6] Near Rectilinear Halo Orbit is an orbit around the Moon with a 7-day cycle, which will take the Gateway, Orion, and HLS as close to the lunar surface as 1,600 kilometers (1,000 miles) and as far away as 68,260 kilometers (42,415 miles). Consequently, the lunar lander can efficiently depart the Gateway to travel to the lunar surface approximately every 7 days.

Figure 1: Calendar Year Timeline of NASA Artemis and Related Commercial Launches (as of September 2021)



Source: NASA Office of Inspector General (OIG) depiction of Agency program information.

Artemis Concept for Returning Astronauts to the Moon

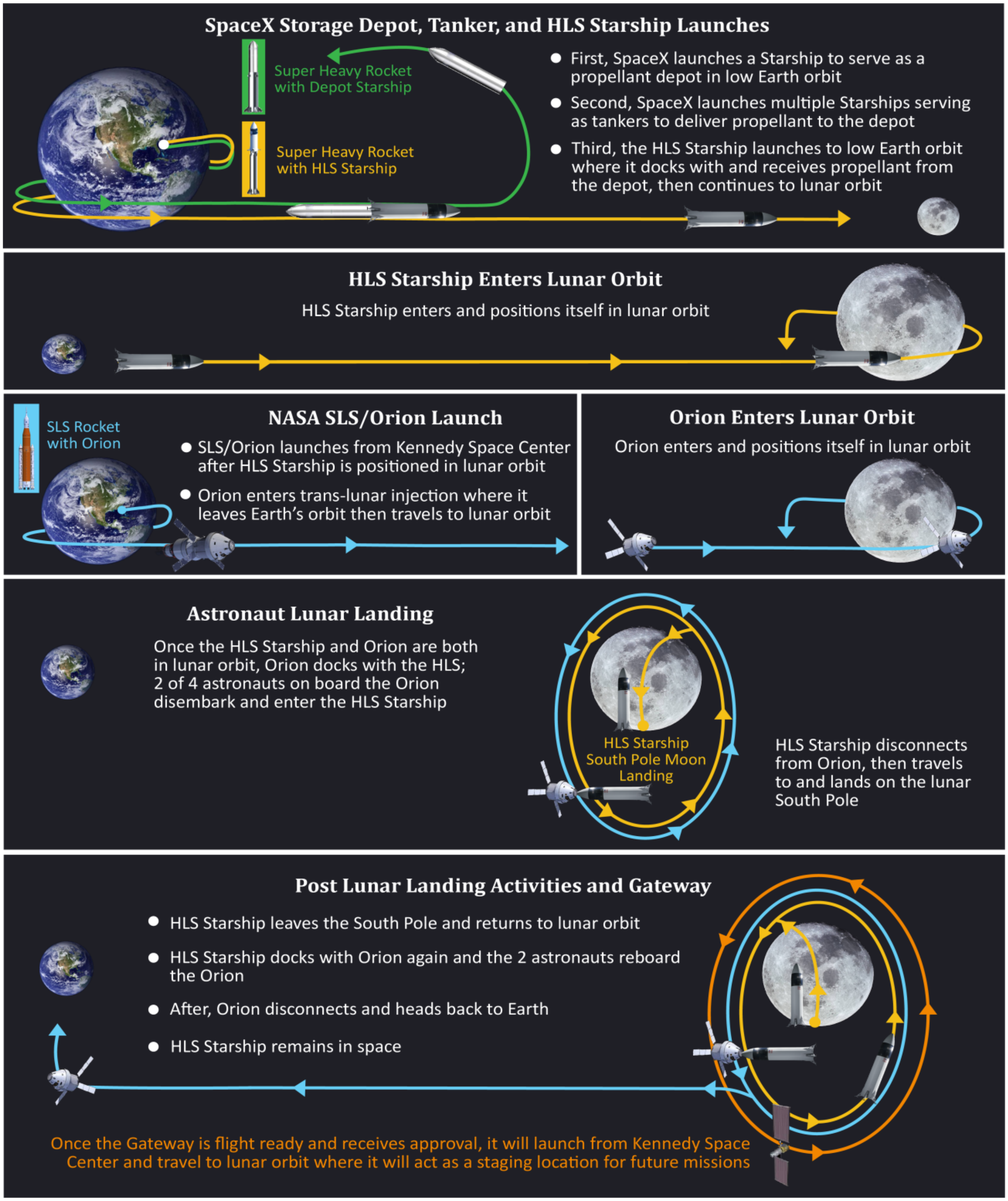
By the time Artemis III launches, NASA expects to have flown the SLS/Orion system twice with one uncrewed mission (Artemis I) and a second crewed mission (Artemis II) around the Moon with a functioning Environmental Control and Life Support System. During the Artemis II mission, Orion will remain in Earth's orbit for several days to ensure the life support system is fully operational before proceeding to the orbit around the Moon. All three missions will send the spacecraft into a trans-lunar injection that places the Orion capsule and its service module in a trajectory toward the Moon.[7] On Artemis III, the Orion spacecraft will then use the propulsion produced by its service module to travel to Near Rectilinear Halo Orbit around the Moon. NASA also plans to position the Gateway in this orbit to act as an outpost for staging Moon landings and future deep space or Mars departures.

NASA considers Artemis III a demonstration mission that will illustrate the capability to land a crewed spacecraft on the Moon. NASA has contracted with Space Exploration Technologies Corp. (SpaceX) to develop an HLS vehicle to transport two astronauts to the Moon's South Pole on this mission. Compared to the first two missions, the Artemis III mission profile is much more complicated in that it

[7] A trans-lunar injection is a propulsive maneuver used to set a spacecraft on a trajectory that will cause it to arrive at the Moon.

will require a number of launches of Tanker Starships and a fuel depot to provide propellent for the HLS and will also involve flying the SLS/Orion separately to link up the astronauts with the HLS in lunar orbit. Figure 2 presents a graphical summary of the Artemis III mission.

Figure 2: Planned Artemis III Mission Profile (as of October 2021)



Source: NASA OIG presentation of Agency data.

SpaceX will use a Super Heavy rocket booster currently in development to launch the HLS Starship from Kennedy Space Center (Kennedy) and SpaceX's launch facility in Boca Chica, Texas, into the Earth's orbit where it will dock with SpaceX's depot spacecraft for refueling.[8] From there, the Starship will use its internal propulsion to travel to Near Rectilinear Halo Orbit where it will position in lunar orbit to dock directly with the Orion capsule. NASA plans to separately launch and fly four astronauts in the Orion to dock directly with the pre-positioned HLS Starship. Two astronauts will board the HLS and descend to the Moon's surface while the other astronauts remain on the Orion to provide support and communication for the landing team. While on the surface for up to a week, the astronauts will leave the spacecraft and conduct one or more lunar excursions. Upon completion, the HLS will launch from the Moon and return to the Orion in lunar orbit before Orion heads back to Earth with the four astronauts for a landing in the Pacific Ocean. Following this demonstration of the HLS, NASA intends to return crew to the lunar surface by using a FAR-based contract, Lunar Exploration Transportation Services (LETS), in which commercial companies will develop sustainable human landing systems and provide recurring crewed lunar landing services. Follow on missions will use additional capabilities including the Gateway and lunar rovers, with longer duration stays on the lunar surface. See Appendix B for information on HLS's programmatic approach.

High-Altitude Test Flight of SpaceX Starship Prototype

Source: SpaceX.

NASA's Organizational and Programmatic Structure for Integrating Space Flight Elements

Artemis is not a formal program under NASA management standards despite spanning multiple mission directorates, divisions, and programs.[9] Unlike the Apollo or Shuttle Programs that consolidated all efforts under a single programmatic organization, NASA decided to establish a more distributed method for integrating Artemis elements and capabilities. As part of this process, the Agency first designated lead directorates or divisions to integrate the missions. Overall, the Human Exploration and Operations Mission Directorate (HEOMD) is responsible for integrating the Artemis missions.[10] For Artemis I and II, NASA's Exploration Systems Development (ESD) Division, which includes the SLS, Orion, and Exploration

[8] Although not fully planned yet for Artemis flights, future missions are expected to launch from a floating launch pad in the Gulf of Mexico, which could add additional launch facilities and potentially ease safety and regulatory concerns with launching a massive rocket near populated areas.

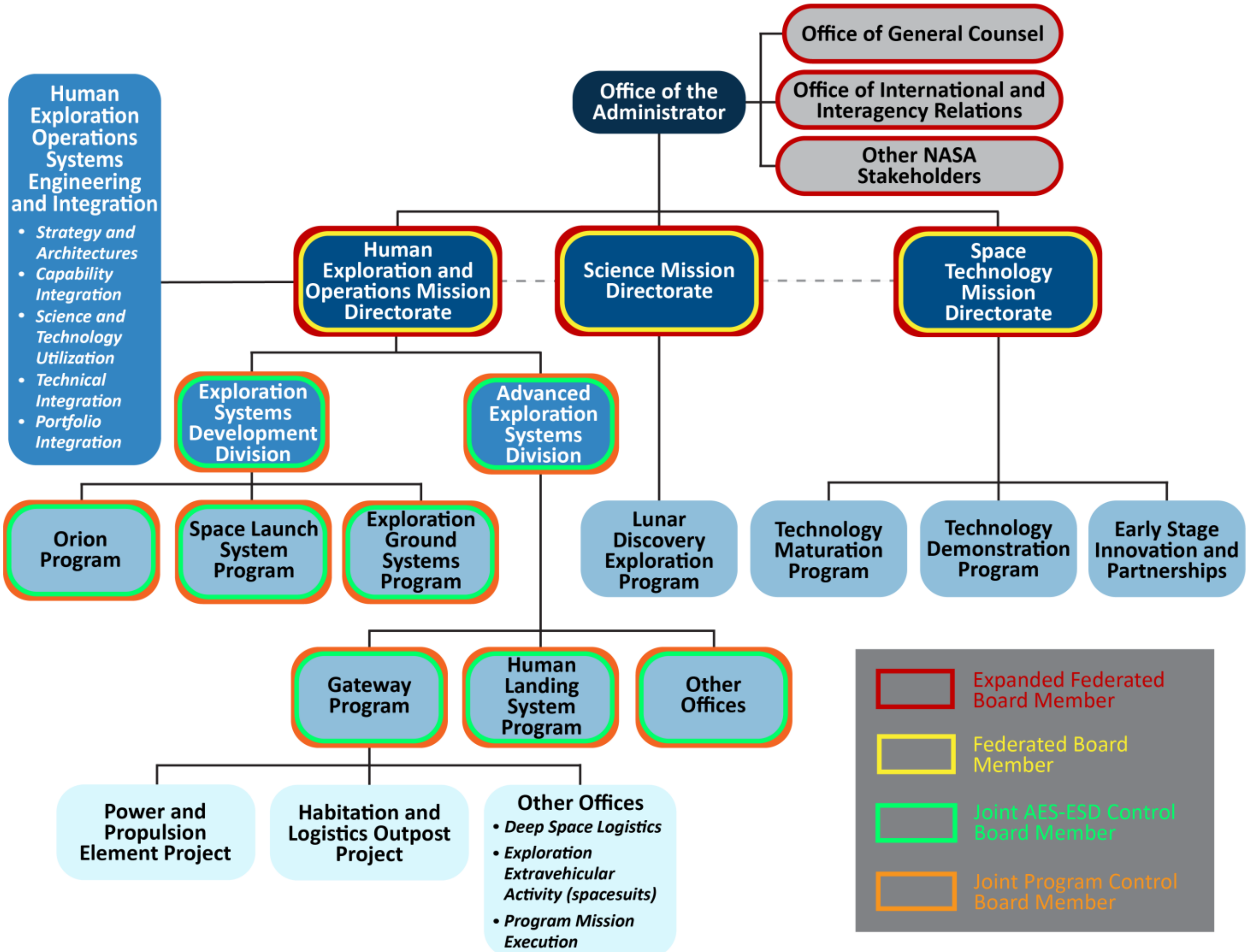
[9] NASA Procedural Requirements 7120.5E, *NASA Space Flight Program and Project Management Requirements (Updated w/Change 18)* (August 14, 2012). A program is defined as a strategic investment by a Mission Directorate or Mission Support Office that has a defined architecture and/or technical approach, requirements, funding level, and management structure that initiates and directs one or more projects. A program implements a strategic direction that NASA has identified as needed to accomplish Agency goals and objectives.

[10] On September 21, 2021, the NASA Administrator announced that the Agency would be splitting HEOMD into two separate mission directorates. The Exploration Systems Development Mission Directorate is responsible for integrating the early Artemis missions, defining and managing systems development for programs critical to NASA's Artemis program, and planning for NASA's Moon to Mars exploration approach in an integrated manner. The other space flight mission directorate—Space Operations Mission Directorate—will focus on launch and space operations, including the International Space Station, commercialization of low Earth orbit, and eventually operations around the Moon. The implementation process for this organizational change will take several months. For purposes of this report, we refer to the organization using its pre-transition terminology.

Ground Systems (EGS) Programs, is the lead authority for integration. The Advanced Exploration Systems (AES) Division is responsible for NASA's return of humans to the Moon; associated lunar programs such as Gateway, HLS, Lunar Terrain Vehicle, and next-generation spacesuits; and overall mission integration starting with Artemis III. NASA's Science and Space Technology Mission Directorates also contribute vital aspects to the Artemis missions such as technology demonstrations and robotic explorations of the Moon prior to astronaut landings. See Appendix C for a description of key Artemis systems such as the SLS and HLS and related science missions.

In order to ensure strategic alignment across the Agency, in October 2019 the NASA Administrator announced the formation of a Federated Board for Artemis missions led by the deputy associate administrators of HEOMD and the Science and Space Technology Mission Directorates (see Figure 3). The Board was charged with cross-directorate coordination and implementation of Agency strategic guidance; out-year planning integration, including future architecture definition and planning; and long-term strategic assessments to inform NASA's strategy. The Board meets weekly and focuses specifically on technical development and integration of a long-term lunar surface presence as well as the first human mission to Mars. Additionally, an "expanded" Federated Board was created that includes other NASA stakeholders, such as the Offices of General Counsel and International and Interagency Relations, and also meets weekly.

Figure 3: Artemis Program Organizational Structure and Integration (as of August 2021)



Source: NASA OIG presentation of Agency information.

In September 2020, HEOMD was reorganized to include a Systems Engineering and Integration (SE&I) function at the mission directorate level responsible for ensuring program and project requirements reflect HEOMD's overall strategy, leading the formulation of mission plans, and providing technical direction for HEOMD activities. The SE&I function can also participate in several joint control boards that bring together HEOMD programs for the purpose of issue resolution. AES has a similar capability with its SE&I function to integrate all programs and projects operating as part of the lunar landing missions starting with Artemis III. AES was designated the lead office to oversee different phases of mission operations—known as "integration spheres"—and has delegated technical work and integration to designated programs: from launch, to lunar orbit, to the lunar surface, and everything in between. AES maintains overall accountability and integration responsibility over Artemis missions beginning with Artemis III and has insight over these processes via joint control boards, integration panels, and working groups. By also involving ESD, these boards help define requirements and evaluate risks across all major Artemis programs within HEOMD.

Artemis Acquisition Strategy

For Artemis, NASA is using a variety of acquisition strategies for the design, development, and purchase of space flight systems or services, with most approaches utilizing FAR-based contracts.[11] However, the Agency used Space Act Agreements for more recent space flight developments, including cargo transportation services to the International Space Station (ISS) and the early stages of the Commercial Crew Program.[12] Upon completion of these developments, NASA did not own the space flight systems but rather purchased transportation services under a FAR contract. For the HLS demonstration contract with SpaceX, NASA is relying on a research and development section of the FAR—FAR Part 35 Broad Agency Announcements—rather than Space Act Agreements, as the contracting method for development. For the transportation services phase of HLS, NASA will use a FAR-based approach to purchase recurring transportation services. While a similar type of FAR Part 35 contracting is being used for the Gateway, the Agency will take delivery and ownership of the first Gateway elements prior to their launch on a SpaceX Falcon Heavy rocket.[13]

The FAR outlines contract vehicles to acquire goods and services, such as cost-reimbursement and fixed-price contracts. In cost-reimbursement contracts, the Agency agrees to pay all allowable costs the contractor incurs in delivering the service or product. Such contracts are often used in space flight development projects when the government does not fully know the requirements of the project, changes are likely, and estimated costs are difficult to identify. All three ESD Programs—SLS, Orion, and EGS—have used these types of contracts along with a periodic award fee based upon contractor performance, and in some cases an incentive fee for cost reductions and meeting milestones on time or ahead of schedule. For each of these programs, we previously reported on significant cost growth, schedule slips, and performance issues, and additionally for SLS and Orion the inappropriate use of award fees during periods of poor contractor performance.[14] While NASA owns both the SLS and Orion space flight systems, having a different contractor other than the one who developed the systems take over production would have been extremely costly, and as a result both incumbents—The Boeing Company (Boeing) and Lockheed Martin Corporation (Lockheed Martin)—received follow-on contracts for production of additional SLS and Orion vehicles, respectively (Appendix D provides a summary of SLS, Orion, and other ongoing contracts critical to the Artemis mission).

In fixed-price contracts, the contractor agrees to deliver a product or service at an agreed-upon price with profit built-in to the price. NASA generally uses fixed-price contracts when it can clearly define costs and risks, like in the later phases of Commercial Crew Transportation Services. For both the HLS and Gateway's Power and Propulsion Element (PPE) and Habitation and Logistics Outpost (HALO)

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[11] Although NASA is leading the Artemis program, it will still rely on international partnerships to establish a sustainable presence on the Moon. As of June 2021, 12 nations have signed the Artemis Accords, a framework that establishes a shared vision for space exploration and commercial activity.

[12] Not covered by the FAR, Space Act Agreements provide NASA with the ability to advance science and technology and stimulate industry to start new endeavors. See National Aeronautics and Space Administration Authorization Act of 2010, Pub. L. No. 111-267, 124 Stat. 2805 (2010).

[13] For acquisition of Gateway's two initial elements, NASA chose a fixed-price contract using FAR Part 35, *Research and Development Contracting* (2019) and NASA Federal Acquisition Regulation Supplement (NFS) 1835.016, *Research and Development Contracting—Broad Agency Announcements* (March 2020) relating to research and development contracting and the use of Broad Agency Announcements to leverage commercial capabilities. These announcements are used to acquire basic and applied research in addition to Announcements of Opportunity using NFS 1872, *Acquisition of Flight Investigations* (March 2020).

[14] NASA OIG, *NASA's Management of Space Launch System Program Costs and Contracts* (IG-20-012, March 10, 2020) and *NASA's Management of the Orion Multi-Purpose Crew Vehicle Program* (IG-20-018, July 16, 2020).

systems, NASA utilized firm-fixed-price Broad Agency Announcements to solicit for commercial companies to develop space capabilities for use beyond low Earth orbit.[15] NASA chose these fixed-price research and development contracts to enable public-private partnerships in which the companies take on a significant portion of development costs.[16] However, the NASA Assistant Administrator for Procurement granted a deviation to the "research only" clause in the FAR to gain the efficiencies of a commercial partnership that included cost-sharing and allowed the eventual purchase of the PPE, HALO, and the first demonstration mission for the HLS.

HLS Procurement Plans

In October 2019, NASA solicited proposals from industry to facilitate the rapid development and demonstration of an HLS to deliver a crew to the Moon by 2024. Five companies submitted proposals and NASA ultimately selected and provided initial funding to three—Blue Origin Federation, LLC (Blue Origin) for $479.7 million; Dynetics, Inc. (Dynetics) for $239.7 million; and SpaceX for $139.6 million—using firm-fixed-price research and development contracts under FAR Part 35. NASA identified several required milestone reviews, including a Certification Baseline Review and Continuation Review, which the contractors needed to include in their proposals, but otherwise the Agency gave the contractors the flexibility to include their own milestones and associated payments as part of their submissions.[17] Following this base period award, NASA intended to foster a competitive environment to drive cost savings and enhance capabilities through the subsequent award of two development contracts for the Artemis program's initial lunar landings: one to a contractor to build a spacecraft to conduct the first Moon landing in 2024 and the second to a contractor to demonstrate its lander in 2026.

HEOMD and HLS officials have repeatedly noted that having multiple contractors would encourage innovation and drive down costs through competition. However, in FY 2021 NASA received $850 million in HLS funding from Congress, substantially less than the $3.4 billion it requested. Due in part to this reduction, in April 2021 NASA awarded a single company—SpaceX—a firm-fixed-price contract for a potential total value of $2.9 billion to further develop and demonstrate its HLS by ferrying astronauts between a lunar orbit and the lunar surface on the Artemis III mission.[18]

[15] Gateway's initial elements consist of the PPE, which powers and propels the spacecraft in orbit, and the HALO, which provides a docking location for the Orion capsule and living and working spaces for crewmembers staying less than 30 days. NASA instituted the Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) for commercial companies to develop space capabilities for use beyond low Earth orbit. NextSTEP is a partnership model between NASA and the private sector that seeks commercial development of deep space exploration capabilities to support more extensive human space flight missions in and beyond cislunar space, the space near Earth that extends just beyond the Moon. There have been two NextSTEP announcements, one in 2014 and the other in 2016. The first NextSTEP sought proposals from U.S. industry for concept studies and technology development for advanced propulsion, habitation, and small satellites. NextSTEP-2 included all U.S. and non-U.S. institutions and covered areas such as prototypes for habitation systems, power and propulsion system studies, and HLS studies and demonstrations.

[16] FAR Part 35, NFS 1835.016.

[17] During the Certification Baseline Review milestone, NASA examined the progress of each contractor toward the design of their HLS and established design, construction, safety, health, and medical standards for each system. The Continuation Review allowed the companies to provide additional details to NASA on their respective designs, mission plans, hardware, and software.

[18] Blue Origin and Dynetics protested the SpaceX award to the Government Accountability Office (GAO), and both protests were denied in July 2021. Shortly thereafter, Blue Origin, in effect, appealed this decision by filing a bid protest lawsuit with the U.S. Court of Federal Claims, which caused NASA and SpaceX to halt work on SpaceX's HLS demonstration contract. In November 2021, this protest was also denied.

In awarding SpaceX the demonstration contract, NASA noted that SpaceX's HLS spacecraft still had technology that needed to be matured, measured by what is known as a Technology Readiness Level (TRL).[19] Specifically, SpaceX's design needed to mature a complex propulsion system and an unprecedented propellant transfer system within the Earth's orbit. To support a successful demonstration, SpaceX will need to test fly its HLS prototype, develop and fly its Super Heavy rocket booster for its launch vehicle, practice refueling operations in low Earth orbit, and demonstrate an uncrewed HLS mission. As of August 2021, SpaceX has flown several test flights of its upper stage Starship prototype—the basis for what will become the HLS—and currently plans to test fly its Super Heavy rocket booster in late 2021.

To meet a 2024 launch date, NASA and SpaceX will need to navigate a number of programmatic milestones to ensure the HLS is meeting Agency requirements as critical technology continues to mature (see Figure 4).[20] Specifically, NASA is planning its HLS Key Decision Point (KDP) C—the milestone that allows the program to move from early design work to final design and fabrication—for 8 months after the contract receives a NASA directed Authority to Proceed and SpaceX data becomes available to NASA. Following that, NASA's Standing Review Board will participate in contractor led reviews as well as all of NASA's KDPs. For its part, SpaceX needs to complete a series of tests demonstrating different aspects of its HLS operations, as well as serve as the lead for a Critical Design Review and Design Certification Review—reviews needed to ensure the HLS can enter into final fabrication, assembly, integration, and testing. NASA's Standing Review Board will participate in each of those contractor-led reviews.

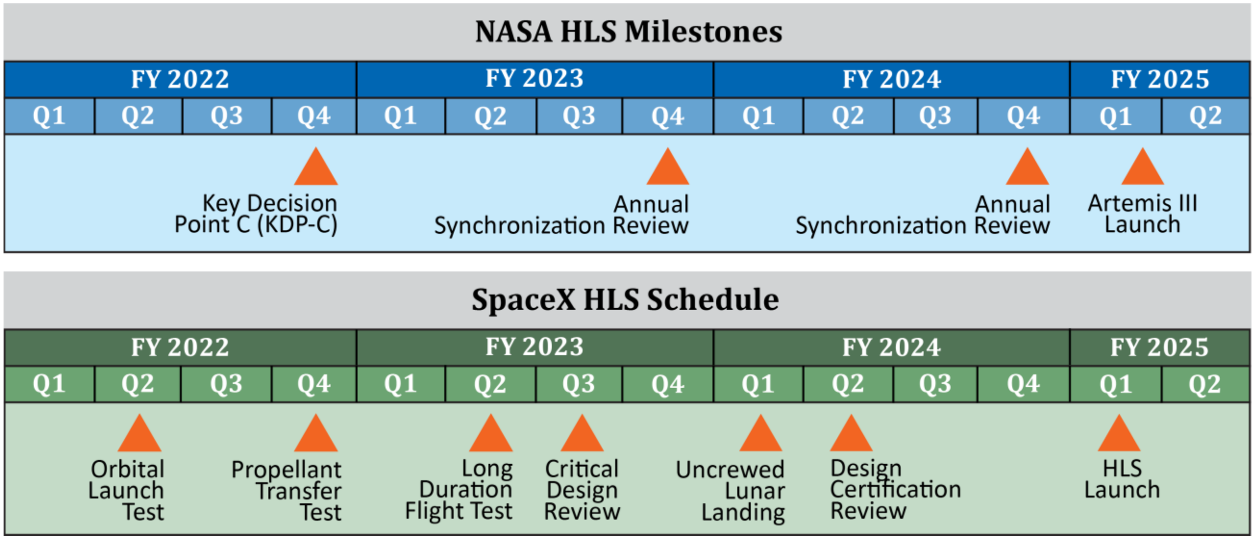
Starship Prototype Stacked on Top of the Super Heavy Rocket Booster

Source: SpaceX.

[19] NASA categorizes space technologies into TRLs 1 through 9. At TRL 1, scientific research is in the early stage compared to TRL 9 when the technology has been proven on a successful flight. NASA and GAO guidelines state that critical technologies should be at least at a TRL 6—at a model or prototype demonstration in a relevant environment—at the time a project completes its Preliminary Design Review (a checkpoint in the design life cycle before hardware manufacturing can begin). TRL levels for the Artemis-related space flight systems can be found in Appendix C.

[20] The milestone reviews include completing Key Decision Point (KDP) C in July 2022, which will move the program from Formulation to Implementation; a Critical Design Review in the third quarter of FY 2023; and annual synchronization reviews thereafter.

Figure 4: HLS Milestone Schedule (as of August 2021) and SpaceX HLS Schedule (as of December 2020)



Source: NASA OIG presentation of Agency data.

Note: SpaceX schedule information does not reflect impacts from the bid protests and stay of performance.

Since NASA had only enough funds to award a single HLS initial demonstration contract, it has accelerated its LETS acquisition and created additional opportunities for industry to receive research and development funding from NASA for lunar landers. On September 14, 2021, NASA announced firm-fixed-price awards with a total potential value of $146 million to Blue Origin, Dynetics, Lockheed Martin, Northrop Grumman, and SpaceX for research and development services that are unique to each provider's HLS designs. These awards are intended to help prepare industry to be competitive for an award under the LETS procurement.

Artemis Program Making Progress But Timetable Slipping By Months for Test Flights and Years for Lunar Landing

NASA's initial three Artemis missions—which are expected to culminate in a crewed lunar landing—face varying degrees of technical difficulties and delays that will push launch schedules from months to years past their current goals. With all necessary elements for the Artemis I mission now being integrated and tested at Kennedy, we estimate that NASA is progressing toward a launch by summer 2022 (a projected slip of about 6 months attributable to technical challenges, the COVID-19 pandemic, and multiple weather events—compared to the target date of November 2021). With Artemis II currently scheduled to launch in late 2023, NASA is facing longer schedule delays—until at least mid-2024—due to the second mission's reuse of Orion components from Artemis I. Finally, given the time needed to develop and fully test the HLS and NASA's next-generation spacesuits, the Agency will exceed its current timetable of landing humans on the Moon in late 2024 by several years.

Artemis I Progressing Toward Launch by Summer 2022

Four years after the presidential directive that initiated what would become the Artemis program, but more than 10 years into development of its SLS rocket and Orion capsule, NASA's preparations are nearly complete for its inaugural flight of its rocket/capsule combination. The Orion Crew Module was delivered to Kennedy in January 2021, and following completion of its Green Run tests the SLS Core Stage was delivered to Kennedy in late April 2021.[21] Since then, the EGS Program has been assembling the SLS/Orion configuration and testing the integrated system for the first time. Despite missing Artemis I's revised Agency Baseline Commitment (ABC) launch date of November 2021, ESD officials are confident the integration and launch will be completed in spring 2022, with a higher probability of launch—in our estimation—by summer 2022.[22]

The need for a second hot fire test of the SLS Core Stage rocket, along with the impacts of several hurricanes, delayed necessary pre-launch ground operations which were estimated to take 10 months to complete following receipt of the Core Stage at Kennedy.[23] NASA's first hot fire test on January 16, 2021, was shut down after just 1 minute—far short of the 8-minute objective—due to conservative testing parameters intended to reduce the risk of damaging the Core Stage during the test. Prior to the second attempt of the hot fire test, scheduled for February 25, 2021, engineers were forced

[21] The Green Run is a series of eight tests on the SLS's Core Stage flight hardware, culminating with a hot fire test. These tests verify the stage is ready for the first and future Artemis missions.

[22] An ABC establishes and documents an integrated set of project requirements, cost, schedule, technical content, and an agreed Joint Cost and Schedule Confidence Level that forms the basis for NASA's commitment to the Office of Management and Budget and Congress. The original 2014 SLS ABC established a goal to launch in December 2017 and a commitment to launch by November 2018. The SLS and EGS Programs were rebaselined in early 2020 to a November 2021 Artemis I ABC launch date. This assessment did not include COVID-19 impacts, as it occurred prior to the onset of the pandemic.

[23] The 10 months accounts for integration activities, technical risks, and uncertainties.

to repair a valve in the Core Stage main propulsion system, resulting in further delays. Finally, on March 18, 2021, the hot fire test was completed with the Core Stage firing its engines for over 8 minutes. Following a planned month of engine refurbishment and travel by barge from Stennis Space Center, the Core Stage arrived at Kennedy on April 27, 2021, nearly 3 months after the intended date. As a result of these delays, the COVID-19 pandemic, multiple weather events, and the 10 months required for integration and testing, Artemis I will not be ready to launch until at least late February 2022, 3 months after its ABC launch readiness date. EGS Program schedules and a June 2021 HEOMD Schedule Risk Analysis (SRA) cite a risk-informed launch readiness date of mid-April 2022.[24]

In our judgment, the Agency is on track to launch Artemis I by summer 2022. While first-time integration issues may cause additional delays, NASA currently reports no remaining major issues. Specifically, flight and ground software are at a mature state and require only minor modifications, the Core Stage passed its hot fire test, and an issue with a redundant component in one of Orion's six power and data units was waived for Artemis I.[25]

Artemis II Delayed Until at Least Mid-2024 Due to Artemis I Dependencies and Reuse of Orion Avionics

Artemis II is currently scheduled to launch in late 2023, though NASA is likely to face schedule delays due to the reuse and installation of Orion components following Artemis I and a tight delivery schedule of the Orion service module. After the Orion capsule is recovered from the Pacific Ocean at the conclusion of the Artemis I mission, ESD personnel plan to refurbish and reuse several of its non-core avionics systems in the Artemis II Orion.[26] This avionics reuse, which is driven entirely by when the Orion capsule returns from its first mission, is considered the primary critical path for Artemis II.[27] Another key Artemis II component requiring integration is the service module. Built by Airbus in Bremen, Germany, for the European Space Agency (ESA), the Artemis II Service Module was delivered to Kennedy for integration with the Orion Crew Module in October 2021, a date that had already slipped by several months due to impacts from the COVID-19 pandemic and numerous technical issues. Orion Program officials were tracking delivery of the Service Module as a top program risk for Artemis II.

In preparation for the crewed Artemis II launch, NASA will also install an Environmental Control and Life Support System on the capsule. The Agency opted not to fly Artemis I with an operational life support system citing cost savings and lack of crew on the flight. However, as we previously reported, in contradiction to the "test like you fly" qualification approach, Artemis II—with astronauts on board—will

[24] An SRA analyzes the potential impact of schedule uncertainties and risks to determine the likelihood that a program plan is achievable. The SRA can inform program management of priority schedule risks and adequacy of schedule margins.

[25] In November 2020, engineers identified an issue with a redundant component on one of Orion's power and data unit communications cards. Given the limited accessibility to this unit, NASA determined that disassembling the Crew Module Adapter to address the faulty component would put the spacecraft at higher risk of damage than not addressing the issue. NASA elected to accept the risk and proceeded into integration without replacing the component.

[26] Avionics refers to the spacecraft's electronics systems and includes its communications, navigations, display, and flight control systems.

[27] The critical path refers to the sequential path of tasks in a schedule that represents the longest overall duration from the present time through project completion. Any slippage of these tasks will increase the project's duration.

be the first flight using this system, a situation that presents an operational and safety risk.[28] The Program plans to mitigate the risk by remaining in the Earth's orbit for the mission's first 2 days to ensure a fuller assessment of the life support system's performance before continuing on to the Moon. Other modifications between the first two flights include upgrades to the Mobile Launcher 1 including an Emergency Egress System for astronauts and an Environmental Control System.[29] While not all upgrades will occur between the Artemis I and II launches, those planned are estimated to take about 5 months.

Between the reuse of avionics, installation of vital components, integration and testing, modifications and upgrades to launch facilities, and other ground operations, Artemis II preparations following completion of the Artemis I mission will take approximately 27 months. Reusing some components between the first two launches mean that Orion's readiness issues after Artemis I—if they are realized—could delay the Artemis II launch until mid-2024—several months later than NASA's current plans.[30] NASA has attempted to mitigate Artemis II's schedule risk by initiating the purchase of an additional set of avionics should the Artemis I launch schedule continue to slip, thereby decoupling the Artemis II launch schedule from Artemis I.

Time Needed for Development, Testing, and Certification of the HLS and Spacesuits Will Delay Planned Lunar Landing Schedule by Several Years

HLS Development Schedule Is Unrealistic and Not Supported by Recent Schedule Risk Analysis

We found the HLS development schedule to be unrealistic when compared to other major NASA space flight programs. Specifically, space flight programs in the last 15 years have taken on average about 8.5 years from contract award to first operational flight and the HLS Program is attempting to do so in about half that time (see Figure 5).[31]

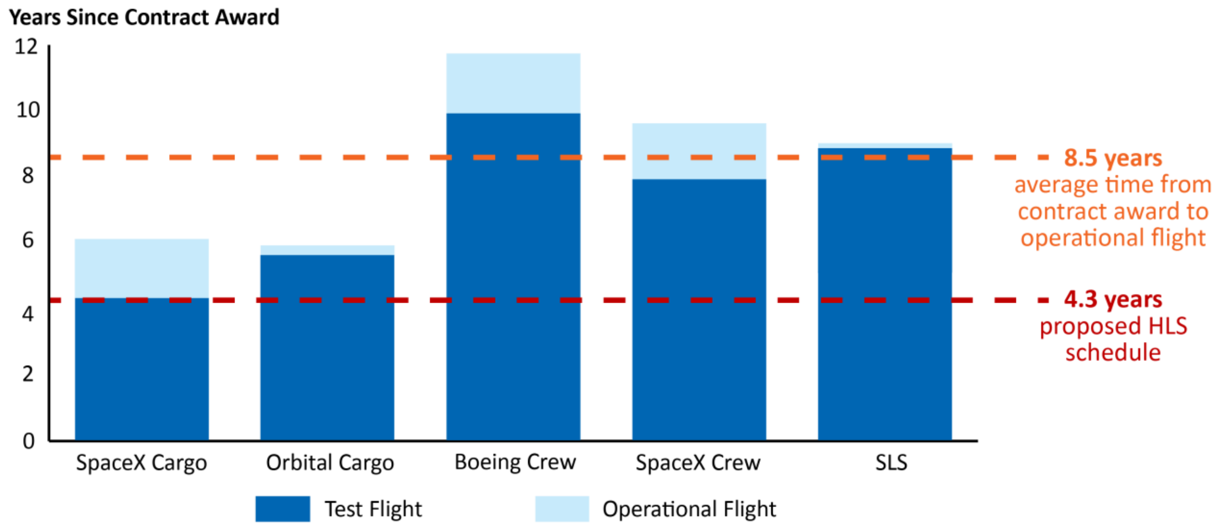
[28] The "test like you fly" approach tests the spacecraft utilizing the same hardware, software, people, and processes that will be utilized during mission operations. We discussed this risk in our 2017 report, *NASA's Plans for Human Exploration Beyond Low Earth Orbit* (IG-17-017, April 13, 2017).

[29] The mobile launcher is the ground structure that will be used to assemble, process, and launch the combined SLS/Orion spacecraft from Launch Pad 39B at Kennedy.

[30] Since there is no component reuse between Artemis II and III, ESD will only require 6 to 12 months to complete ground operations between those launches.

[31] For reference, the Apollo Lunar Lander took approximately 6 years from contract award to its launch on the Apollo 11 mission (the first landing of humans on the Moon). That said, Apollo lander development received substantially higher levels of funding controlled for inflation.

Figure 5: Time to Operational Flight for Recent NASA Space Flight Programs



Source: NASA OIG presentation of Agency data.

Further, while recent space flight programs have on average taken about 2 years between test and operational flights, SpaceX plans to launch its crewed HLS 1.2 years after its uncrewed demonstration mission. To their credit, the company's rapid "design-build-fly" testing approach and in-house production facilities are unique capabilities that may allow for faster development and production timelines than previous NASA space flight programs.[32] During our August 2021 visit to both its California and Texas facilities, we observed SpaceX's rapid production ability with 20 Starship prototypes and 100 Raptor engines built to date. This fast pace is possible due in part to the fact that SpaceX manufactures many engine parts and components in-house, which also reduces costs. The launch tower at the company's Starbase in Texas was nearing completion with fueling facilities expected to be completed by October 2021. For its next major tests, SpaceX intends to launch the Super Heavy rocket booster and HLS into the Earth's orbit by the end of 2021 with a demonstration of its in-orbit fueling operations planned for late 2022. Nonetheless, delays in its current timetable are likely given the technologies that must be developed and the tight schedule.

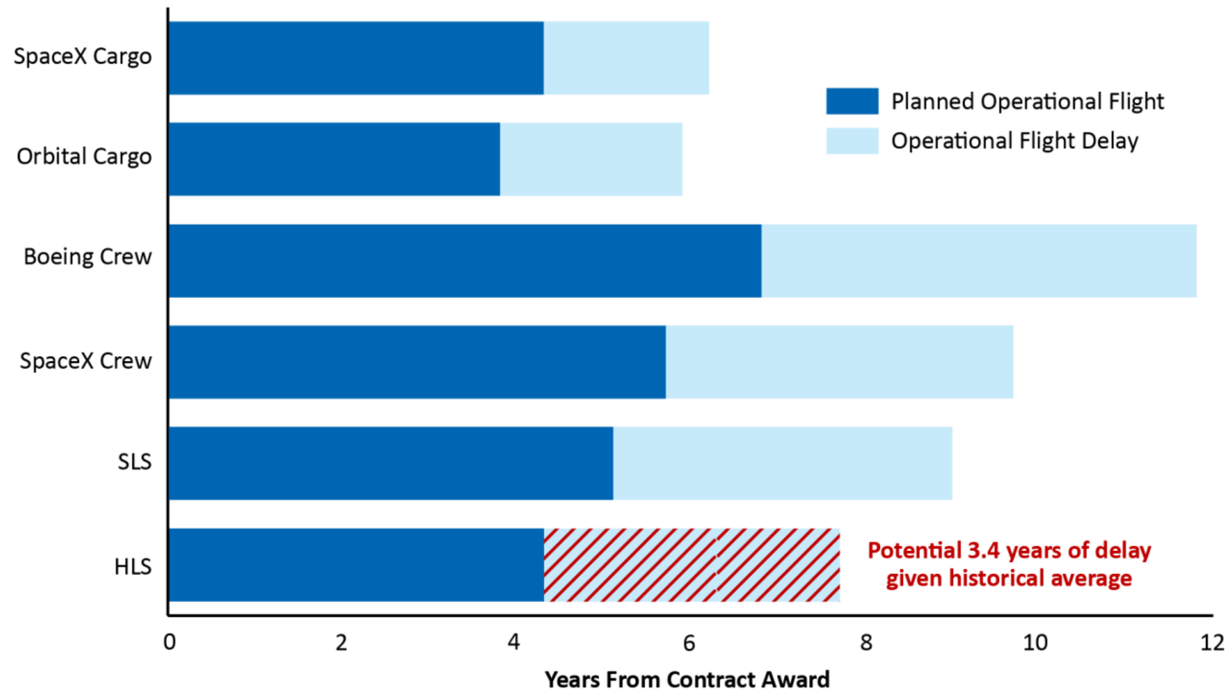
A February 2020 HEOMD-directed SRA prepared by the Aerospace Corporation found an HLS would likely not be ready until mid-2026.[33] Subsequent to that SRA, the HLS Program encountered a series of delays, including 6 weeks in awarding the development and demonstration contract in April 2021 and a nearly 4-month delay caused by the bid protests from Blue Origin and Dynetics over NASA's award to SpaceX. Combined, these events contributed to 6 months in program delays and do not factor into ongoing delays due to Blue Origin's late August 2021 lawsuit in the U.S. Court of Federal Claims. Based on the HLS base period contract award date (May 2020) and the average delay for recent major NASA space flight programs, we estimate the HLS Program could face up to 3.4 years of delays before

[32] SpaceX's philosophy involves extensively testing and flying their vehicles as early as possible—made possible by rapid in-house manufacturing capabilities that provide a steady stream of hardware—to aggressively reduce risks and acquire flight data.

[33] As a part of the Continuation Review in December 2020, SpaceX also conducted an SRA that projected a 2024 landing was possible. SpaceX officials told us this projection will need to be refined once the Blue Origin litigation is concluded and data exchanges can begin again.

operational flights begin (see Figure 6). As a contingency plan, ESD officials raised the possibility of using Artemis III to complete an additional fly-by of the Moon rather than a lunar landing mission should necessary systems not be available in time.

Figure 6: Historical Delays in Operational Space Flights



Source: NASA OIG presentation of Agency data.

Note: Operational flights for Boeing Crew and SLS are estimates based on Agency statements.

Spacesuits Encountering Continuous Delays

Prior to 2019, NASA planned to design, test, develop, and provide next-generation Exploration Extravehicular Mobility Unit (xEMU) spacesuits to the ISS by 2023 and to the Artemis III mission by 2028. However, when the timeline for Artemis III was accelerated, NASA was required to fast-track its schedule by 4 years. Since then, delivery of the spacesuits necessary for lunar expeditions have been delayed due to technical challenges, funding shortfalls, and COVID-19 impacts. AES schedules indicate that the projected delivery date for the ISS demonstration and Artemis III spacesuits is December 2024. Given the subsequent integration requirements, the suits will not be ready for flight until May 2025 at the earliest, making the suits and associated hardware unavailable for a planned 2024 lunar landing. In August 2021, we reported that given the projected delays and lack of contingency plans, the current pace of spacesuit development will preclude a 2024 crewed lunar landing.[34] We also projected that by the time two flight-ready spacesuits are completed, NASA will have spent over a billion dollars on the development and assembly of its next-generation spacesuits, along with development of associated Extravehicular Activity (EVA) tools and equipment and upgrade of aging EVA facilities and infrastructure. Going forward, NASA officials told us that they plan to reduce technical risks for a future services

[34] IG-21-025.

contract by using an online Technical Library for spacesuit components and assemblies accessible by potential contractors, and through planned on-orbit testing of spacesuit components to increase their technical maturity. While this will be helpful for companies competing for and receiving a spacesuit contract, even with these modifications in approach, we determined the new spacesuits will still not be ready by 2024.

Gateway Experiencing Technical Development and Funding Issues

Though not required to support the Artemis III lunar landing, NASA is moving forward with development of the Gateway for sustained lunar operations. However, the Gateway Program continues to work with technical and schedule risks associated with its Advanced Electric Propulsion System—a solar electric system that will be used to propel the PPE.[35] The PPE is expected to be three times more powerful and require less propellant than current satellite platforms and is responsible for transporting itself and the HALO to Near Rectilinear Halo Orbit. Illustrating the severity of the risk, hardware delivery for the Advanced Electric Propulsion System is not only considered the top risk to the Gateway Program, but to the AES Division as well.

In announcing the contract award to SpaceX to launch a co-manifested PPE and HALO on a single rocket, NASA signaled a no-earlier-than launch date of May 2024. With a 10-month travel time to Near Rectilinear Halo Orbit, the earliest the Gateway could arrive in the designated orbit is March 2025, as we projected in our 2020 report.[36] A March 2025 arrival would render the Gateway unavailable to serve as communications support for a 2024 lunar landing. In addition, program schedules indicate further Gateway launch delays until November 2024—with zero schedule margin—which would result in an initial operating capability for the Gateway of September 2025. However, a Gateway Program SRA indicated a less than 1 percent chance of meeting this replanned launch date, with a late 2025 or early 2026 date more likely.

Funding instability has forced various mission changes and delays within the Program, which ultimately impact the overall cost and schedule. Early estimates for the Gateway Program required $3.7 billion over 5 years in order to deploy a configuration of Gateway in lunar orbit by 2024. However, the FY 2021 President's Budget Request for Gateway was $2.7 billion and reflected the elimination of the U.S. Habitation Module, which would have provided additional living and working space on the Gateway; a delayed Authority to Proceed for the Gateway Logistics Services contract; a schedule slip into at least 2025 for PPE and HALO initial operating capability in Near Rectilinear Halo Orbit; and a strong reliance on international partners for full system capability.[37] Between FY 2021 appropriations and the FY 2022 President's Budget Request, though, Gateway funding projections are now back to $3.7 billion.[38]

[35] NASA OIG, *NASA's Management of the Gateway Program for Artemis Missions* (IG-21-004, November 10, 2020).

[36] IG-21-004.

[37] NASA plans to procure logistics services—for delivery of cargo, science experiments, and supplies—for the Gateway that will be provided under the Gateway Logistics Services contract.

[38] In 2020, the Gateway Program projected a funding estimate of approximately $892 million for FY 2021; however, the Program only received $699 million, or 22 percent less than estimated.

NASA Developing Artemis Mission Schedules

Though individual NASA divisions have their own integrated master schedules (IMS), the AES Division is working to create mission specific IMSs that will incorporate schedule information from both AES and ESD programs, starting with Artemis III. The IMSs will serve as a bottoms-up schedule that incorporates program inputs from both summary and detailed schedules. Programs will also identify and report on key performance milestones each quarter, with the corresponding data being leveraged for additional schedule analyses like SRAs. AES is currently identifying cross-program interdependencies with ESD programs to ensure that the schedules—starting with Artemis III—properly reflect linkages between divisions. Completion of the Artemis III IMS is reliant upon successful contract awards and Authorities to Proceed, particularly with the HLS Program and Exploration Extravehicular Activity (xEVA) Project.

While the AES-ESD schedule covers the main Artemis activities, we found the draft version is missing information from programs and projects outside of the mission critical path. As we note in Table 2 (see page 22), several NASA organizations outside of AES and ESD (e.g., Lunar Discovery Exploration Program, Space Technology Mission Directorate, Mission Support Directorate) are important to the overall Artemis mission and have the potential to affect mission success. Both the Government Accountability Office's (GAO) and NASA's scheduling best practices dictate that a comprehensive IMS should identify and sequence all program activities so interdependencies can be captured.[39] Further, HEOMD's 2020 Program Status Assessment recommended a "single, authoritative risk informed master schedule" for the Artemis program.[40] While we recognize that the Artemis program is not a formalized program according to NASA policy—and is thus not subject to specific procedural requirements related to such programs—a regularly updated, NASA-wide IMS would provide more complete and timelier schedule insight for the entire Artemis mission, rather than just programs within AES and ESD.

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[39] GAO, *Schedule Assessment Guide: Best Practices for Project Schedules* (GAO-16-89G, December 2015) and NASA/SP-2010-3403, Revision 1, *NASA Schedule Management Handbook* (January 30, 2020).

[40] Comprised of NASA personnel and outside aerospace experts, the Program Status Assessment examined planned activities to achieve a human lunar landing by 2024, reviewing early Artemis architecture, management and integration across programs, schedule risks, technical risks, technical systems engineering integration, and test program thoroughness.

NASA's Estimates Significantly Understate Costs of Artemis Program

NASA lacks a comprehensive and accurate cost estimate that accounts for all Artemis program costs. Instead, the Agency's Artemis Plan presents a rough estimate of the costs for the first three missions between FYs 2021 and 2025 that excludes $25 billion for key activities related to planned missions beyond Artemis III. When aggregating all relevant costs across mission directorates, we found that NASA is projected to spend $93 billion on the Artemis effort from FY 2012 through FY 2025.[41] Moreover, while NASA has several initiatives underway aimed at increasing affordability, we project the current production cost of a single SLS/Orion system to be $4.1 billion per launch. Looking ahead, without capturing, accurately reporting, and reducing the cost of future SLS/Orion missions, the Agency will face significant challenges to sustaining its Artemis program in its current configuration.

NASA Lacks a Credible Cost Estimate for the Artemis Missions

NASA does not have a credible estimate that consolidates all Artemis costs across mission directorates. 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, program officials were not required to develop an Artemis-wide full life-cycle cost estimate. Instead, NASA's disparate programs and projects individually submit budget estimates through their directorates and divisions to the Office of the Chief Financial Officer.[42] However, the Agency does not consolidate cost estimates into an overall Artemis projection. Currently, the only publicly available Artemis cost projections are in NASA's Lunar Exploration Program Overview—"the Artemis Plan"—released in September 2020 (see Table 1).

[41] In April 2021, NASA OIG released the *Artemis Status Update* (IG-21-018), which cites total Artemis-related costs of $86 billion from FY 2012 through FY 2025. The $93 billion estimate cited in this report updates that previous estimate by including Artemis costs from outside of HEOMD and using the FY 2021 Budget Operating Plan for FY 2021 costs (rather than FY 2021 appropriations) and the FY 2022 President's Budget Request. Additionally, our cost projections begin in FY 2012 because that is the year the SLS and Orion Programs began Artemis-related work in earnest.

[42] The Office of the Chief Financial Officer is responsible for the official listing of Agency-approved programs and projects and tracking performance against individual Agency-approved project cost and schedule commitments.

Table 1: Artemis Phase 1 Funding Requirements (Dollars in Millions)

Artemis Elements	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	Total
Orion/SLS/EGS	$2,894.7	$2,070.6	$1,487.6	$919.0	$252.0	$7,623.9
Initial Human Landing System	3,222.5	3,553.1	4,100.4	3,571.3	1,719.0	16,166.4
Lunar Suits	177.3	141.0	94.2	63.1	42.5	518.1
Surface Logistics	67.6	69.2	141.9	196.0	77.7	552.4
Exploration Technologies	251.0	292.0	268.0	223.0	158.0	1,192.0
Lunar Discovery and Exploration Program	451.5	517.3	491.3	458.3	0.0	1,918.3
Total Phase I Requirements	**$7,064.7**	**$6,643.1**	**$6,583.4**	**$5,430.7**	**$2,249.2**	**$27,971.1**

Source: NASA's Lunar Exploration Program Overview, *Appendix 5: Artemis Plan Funding Requirements* (September 2020).

Note: Amounts are rounded. Totals may not equal the sum of the rounded amounts. Lunar Discovery and Exploration Program does not have any estimated funding requirements in FY 2025 because, under a 2024 lunar landing schedule, its activities related to Artemis III will be completed by 2024.

According to the Artemis Plan, returning astronauts to the surface of the Moon by 2024 would cost nearly $28 billion between FYs 2021 and 2025.[43] However, this projection is limited to funding required for Phase 1 of NASA's two-phase lunar exploration strategy. Phase 1 is the near-term focus on achieving the initial human landing by 2024—costs directly associated with the first three Artemis missions. Phase 2 is defined as the development and deployment of sustainable systems that will allow America's human space flight program to maintain a robust lunar presence into the next decade—Artemis IV and beyond. The $28 billion excludes funding for any system not directly necessary for Artemis I, II, or III, including the SLS Block 1B—the next, more powerful iteration of the SLS heavy-lift rocket—and Mobile Launcher 2— the ground platform that will launch Block 1B to the Moon—as well as future Orion capsules and the Gateway, all of which are in various stages of development or production.[44]

Best practices for developing reliable cost estimates are grounded on the precepts that the estimate should be comprehensive, well-documented, accurate, and credible.[45] NASA officials maintained that the total Phase 1 funding requirement contained in Table 1 was not an "official cost estimate" and instead was largely compiled using program and project estimates from the FY 2021 President's Budget Request. Given the exclusion of Phase 2 costs, the Artemis Plan is certainly not comprehensive or consistent with cost estimating best practices. In addition, ESD Programs—SLS, Orion, and EGS—do not track costs by Artemis mission. We therefore question the accuracy of cost information for the Artemis Plan's funding table, which specifically includes costs for the Artemis I, II, and III missions only. While the cost estimates in NASA's Artemis Plan provides important context about the level of funding needed for near-term Artemis missions, it lacks the comprehensiveness, analytical rigor, and credibility of an Artemis program-wide cost estimate. By failing to develop an official cost estimate that includes all relevant costs, NASA is underreporting the true funding requirements for a long-term Artemis program.

[43] NASA's Lunar Exploration Program Overview, *Appendix 5: Artemis Phase 1 Funding Requirements* (September 2020).

[44] On August 26, 2021, NASA OIG announced that it would be conducting an audit of NASA's management of the Mobile Launcher 2 contract.

[45] GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs* (GAO-20-195G, March 12, 2020).

Total Artemis Costs Expected to Reach $93 Billion by 2025

To account for all Artemis costs for FYs 2021 through 2025, including Phase 2 projects like the SLS Block 1B, Mobile Launcher 2, and Gateway, we found that $25 billion should be added to the Artemis Plan's estimated costs, increasing the total costs over this 5-year period to $53 billion. Furthermore, when considering the $40 billion already spent on the Artemis mission from FYs 2012 to 2020, the total projected cost through FY 2025 becomes $93 billion.[46] The $93 billion reflects the cost of supporting Artemis throughout NASA's directorates and divisions, particularly HEOMD and the Science Mission Directorate. See Table 2 for the breakdown of full Artemis mission costs from FYs 2012 to 2025.

[46] We used NASA's official accounting system to capture program costs from FYs 2012 through 2020, segregating Artemis-related work by Work Breakdown Structure code. For FYs 2021 through 2025, we used the FY 2021 Budget Operating Plan, FY 2022 President's Budget Request, and FY 2021 President's Budget Request and accounted for additional costs such as the development of the SLS Block 1B configuration, Mobile Launcher 2, and Gateway; production of future Orion capsules; and mission support to calculate the $25 billion added to the $28 billion NASA projection for the same time period.

Table 2: Artemis Cost Breakdown and Budget Projection through FY 2025 (as of August 2021, Dollars in Millions)

Program/Project	FYs 2012-2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	Total
Exploration Systems Development	$32,878.4	$4,544.6	$4,483.7	$4,384.0	$4,219.0	$3,888.0	$54,397.7
Orion	11,398.8	1,403.7	1,406.7	1,340.0	1,239.0	1,084.0	17,872.2
Space Launch System	17,233.6	2,560.9	2,487.0	2,486.0	2,466.0	2,290.0	29,523.5
Exploration Ground Systems	4,246.0	580.0	590.0	558.0	514.0	514.0	7,002.0
Advanced Exploration Systems	1,280.5	1,627.1	1,980.0	2,077.2	2,344.5	2,659.0	11,968.3
Human Landing System	577.8	928.3	1,195.0	1,266.7	1,579.5	1,989.0	7,536.3
Gateway	702.7	698.8	785.0	810.5	765.0	670.0	4,432.0
Extravehicular Spacesuit Development[a]	174.2	N/A	N/A	N/A	N/A	N/A	$174.2
Exploration Research and Development[b]	3,327.9	345.7	416.7	552.9	700.2	967.9	6,311.3
Lunar Discovery and Exploration Program	605.1	443.5	497.3	501.3	458.3	458.3	2,963.8
Other Space Technologies[c]	1,237.5	1,211.4	1,442.0	1,658.0	1,756.0	1,854.0	9,158.9
Mission Support[d]	498.3	1,551.0	1,506.0	1,501.0	1,492.0	1,440.0	7,988.3
Total	**$40,001.9**	**$9,723.3**	**$10,325.7**	**$10,674.4**	**$10,970.0**	**$11,267.2**	**$92,962.5**

Source: Costs are based on total obligations from NASA's official accounting system (FYs 2012 through 2020), FY 2021 Budget Operating Plan, FY 2021 President's Budget Request, and FY 2022 President's Budget Request (FYs 2021 through 2025).

[a] Prior to FY 2020, extravehicular spacesuit development was funded through multiple NASA entities including the ISS Program. In FY 2020, funding was split between those entities and the Gateway Program and starting in FY 2021, funding for spacesuits was budgeted in the Gateway Program. As a result, spacesuit funding is no longer applicable in the Extravehicular Spacesuit Development line as of FY 2021 and is instead reflected in the Gateway funding line.

[b] Exploration Research and Development includes Other Advanced Exploration Systems, Advanced Cislunar and Surface Capabilities, and the Human Research Program.

[c] Other Space Technologies includes Space Technology and Space Communications and Navigation. The Space Technology Mission Directorate portfolio consists of thousands of projects, activities, grants, and contracts which support technology investments benefiting multiple stakeholders, including the Artemis program. The total Space Technology obligations (FYs 2019 through 2020) reflected in the table above, within the Other Space Technologies line item, represent a high-level estimate and may be inclusive of activities which are not solely Artemis-specific.

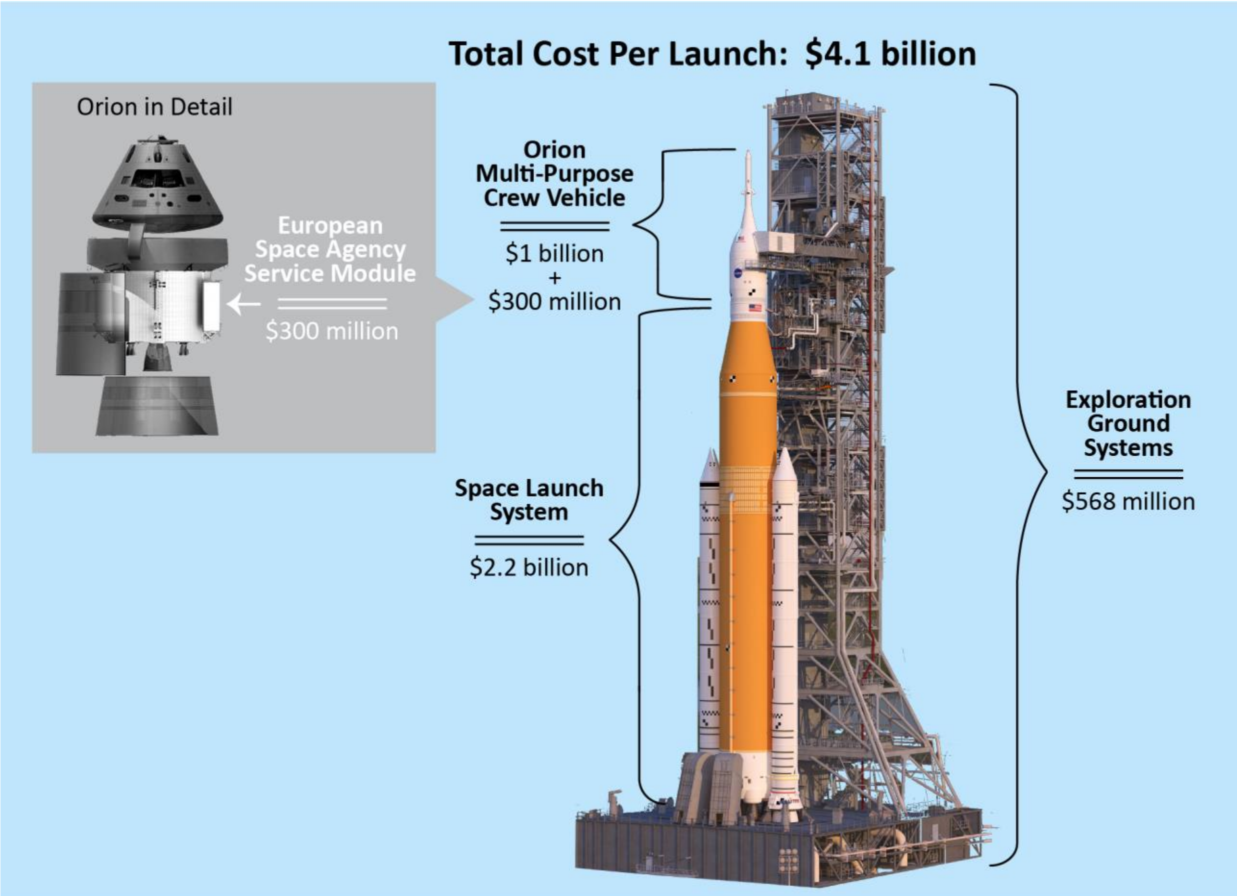
[d] Mission Support includes Safety, Security, and Mission Services and Construction and Environmental Compliance and Restoration.

SLS/Orion Production and Operating Costs Will Average Over $4 Billion Per Launch

We project the cost to fly a single SLS/Orion system through at least Artemis IV to be $4.1 billion per launch at a cadence of approximately one mission per year.[47] Building and launching one Orion capsule costs approximately $1 billion, with an additional $300 million for the Service Module supplied by the ESA through a barter agreement in exchange for ESA's responsibility for ISS common system operating costs, transportation costs to the ISS, and other ISS supporting services. In addition, we estimate the single-use SLS will cost $2.2 billion to produce, including two rocket stages, two solid rocket boosters, four RS-25 engines, and two stage adapters. Ground systems located at Kennedy where the launches will take place—the Vehicle Assembly Building, Crawler-Transporter, Mobile Launcher 1, Launch Pad, and Launch Control Center—are estimated to cost $568 million per year due to the large support structure that must be maintained. The $4.1 billion total cost represents production of the rocket and the operations needed to launch the SLS/Orion system including materials, labor, facilities, and overhead, but does not include any money spent either on prior development of the system or for next-generation technologies such as the SLS's Exploration Upper Stage, Orion's docking system, or Mobile Launcher 2. Figure 7 provides a breakout of the operating cost per launch for the SLS/Orion system.

[47] The cost per launch was calculated as follows: $1 billion for the Orion based on information provided by ESD officials and NASA OIG analysis; $300 million for the ESA's Service Module based on the value of a barter agreement between ESA and the United States in which ESA provides the service modules in exchange for offsetting its ISS responsibilities; $2.2 billion for the SLS based on program budget submissions and analysis of contracts; and $568 million for EGS costs related to the SLS/Orion launch as provided by ESD officials.

Figure 7: Estimated SLS and Orion Operating Costs Per Launch



Source: NASA OIG presentation and analysis of Agency data.

NASA has spent billions of dollars to date on the design, development, testing, and evaluation of the ESD systems needed for the Artemis missions, and expects significant cost savings once the systems reach sustaining operations. Although NASA has worked diligently to find production efficiencies and other cost-saving measures—such as HEOMD's establishment of a review team in January 2021 to examine methods to reduce the high cost of a single launch—the system will remain extremely costly due to sole sourcing the SLS and Orion follow on-production awards, continuing to use cost-plus contracts, and the high cost of ground support. Moreover, except for the Orion capsule, its subsystems, and supporting launch facilities, all components are expendable and "single use" unlike emerging commercial space flight systems such as SpaceX's HLS Starship and Dragon capsule/Falcon 9 booster.

A myriad of interrelated factors contribute to the high cost of ESD Programs, many of which we reported on in the past several years.[48] First, in the NASA Authorization Act of 2010, Congress directed NASA to incorporate preexisting Shuttle- and Constellation-era contracts and modify heritage equipment in

[48] NASA OIG, *Audit of NASA's Development of Its Mobile Launchers* (IG-20-013, March 17, 2020); *NASA's Management of the Space Launch System Stages Contract* (IG-19-001, October 10, 2018); IG-20-018; and IG-20-012.

developing the SLS and Orion.[49] As such, these large development contracts—the SLS's stages, boosters, and engines and Orion's capsule—were sole sourced, eliminating any potential cost benefits of competition. Competing follow-on awards for production several years later became a non-starter due to the high cost of a new contractor instituting its own manufacturing processes and building facilities—a cost estimated at $4.5 billion for the Core and Exploration Upper Stages. Second, NASA continues to use a cost-plus contracting structure even though it has experienced 3 years of delays and cost increases of $4.3 billion for the three ESD Programs. Although NASA officials say they intend to transition to potentially less costly fixed-price contracts, only the Orion Program has successfully negotiated a fixed-price component in its production contract—but even that structure will not commence until Artemis IX. Third, multiple contractors associated with the Artemis program have been permitted to begin work without NASA adequately defining the contract's specific terms. For example, the first stages contract took 2 years before NASA and the contractor agreed on pricing and as of August 2021 NASA is still negotiating the follow-on production contracts for the SLS boosters and stages.[50] Over time, failure to agree on such key contract terms reduces the government's ability to influence the final pricing as it invests more and more time and money into a project.

Finally, NASA has not consistently used the award fee structure to incentivize better contractor performance. Even when a contractor performed poorly, NASA provided award fees commensurate with a company whose performance was very good or excellent. Despite being 3 years behind schedule and billions over budget, Boeing averaged 86 percent in award fees for core stage production over the life of the initial SLS Stages contract, receiving a "very good" rating. In another case, after a contracting officer for the SLS booster office denied Northrop Grumman's request multiple times over a 4-year period for award fees on costly redesign work, the SLS Program ultimately conceded and recommended an "excellent" award fee rating for work previously considered unsatisfactory.[51] Additionally, in our 2020 examination of the Orion Program, we questioned $27.8 million in fees awarded to Lockheed Martin from September 2006 to April 2015.[52]

Ongoing Affordability Initiatives and Commercial Alternatives

While the SLS is required for the near-term transportation of astronauts beyond low Earth orbit, in our judgment continuing to rely on such an expensive heavy-lift space flight system will inhibit NASA's ability to reach its long-term human exploration goals in a timeframe anywhere close to its stated schedule. Transportation is only one aspect of deep space exploration with NASA requiring substantial funding for the science, technology, and infrastructure required to sustain astronauts on the lunar surface and ultimately Mars. Notably, HEOMD recognizes the need to enhance the affordability and

[49] Pub. L. No. 111-267, 124 Stat. 2805. The Constellation Program was established during the George W. Bush Administration in 2006 and canceled under the Obama Administration in 2010. Constellation was similar to Artemis in that it sought to return humans to the Moon, explore the solar system, and promote international and commercial participation in space exploration.

[50] NFS 1843.7005(a), *Definitization* (2018) provides that NASA's goal is to definitize contracts within 180 days—approximately 6 months—after issuance.

[51] An award fee rating of "excellent" means the contractor *exceeded almost all* of the significant award fee criteria and met overall management, cost management, technical performance, and several other criteria. A rating of "very good" means the contractor *exceeded many* of the expectations.

[52] IG-20-018.

sustainability of ESD systems and is exploring options to this end. First, HEOMD was successful in stabilizing the flight manifest—changes in missions and rocket configurations caused requirements changes and thus increased costs with contractors.[53] In January 2021, HEOMD's Associate Administrator informed the directorate that a senior advisor would be leading a sustainability assessment team to develop ideas on how to make ESD systems more cost effective. Further, HEOMD directed its program managers to include a roadmap for potential cost-saving actions as part of the recent FY 2023 budget development process. The suggestions included collaboration with contractors on process improvements, reductions of production cycle time, and a reduction in both the civil servant and contractor work force, among others. However, with respect to specific commitments with contractors, only the RS-25 new engine program has established cost reduction targets for its contractor—in this case 33 percent—for the Agency to measure its progress.

In June 2021, the SLS Program forecasted a 13 percent reduction or approximately $5 million a month in labor hours between the production of Core Stage 1 and Core Stage 2. NASA and Boeing are also working on a 5-year project to optimize the Stages production areas at the Michoud Assembly Facility, including rearranging the factory for better flow and integration sequencing and reducing downtime for welding tools. Boeing plans to arrange a schedule to share welding structures for optimal efficiency, as well as automating processes previously done by hand. However, achieving overall cost savings will be challenging even with components such as the RS-25 engines and their 33 percent cost reduction target given that the Space Shuttle-era engines were existing government-owned equipment with modifications that included new engine controllers. In addition, NASA's engine costs will soon increase since the SLS Block 1 upper stage has only one RL-10 engine while the Block 1B configuration requires four.[54]

As we reported in 2020, Orion is moving forward on a number of initiatives aimed at reducing production costs.[55] The Program plans to transition to a fixed-price contract structure for Artemis IX and beyond. There are also plans to reuse high-value interior components such as avionics and life support systems, light reuse of crew systems beginning on Artemis V, and/or reusing the assembled pressure vessels and all interior components once for two missions beginning with Artemis VI. Additionally, NASA hopes to leverage economies of scale and reduce costs by 21 percent by ordering Orion capsules in batches of three, the most affordable approach for production as determined by NASA officials in 2019.

In the near-term, the SLS is the only launch vehicle with the capability to lift the 27-metric ton Orion capsule to lunar orbit. However, in the next 5 to 7 years other human-rated commercial alternatives may become available. These commercial ventures will likely capitalize on multiple technological innovations, making them lighter, cheaper, and reusable. Further driving down costs is the competition between aerospace companies such as SpaceX and Blue Origin. Although Congress mandated that NASA build the SLS and Orion for its space exploration goals in 2010, the Agency may soon have more affordable commercial options to carry humans to the Moon and beyond.[56] In our judgment, the

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[53] For example, on July 23, 2021, NASA awarded a contract to SpaceX to launch the Europa Clipper science mission, rather than an SLS.

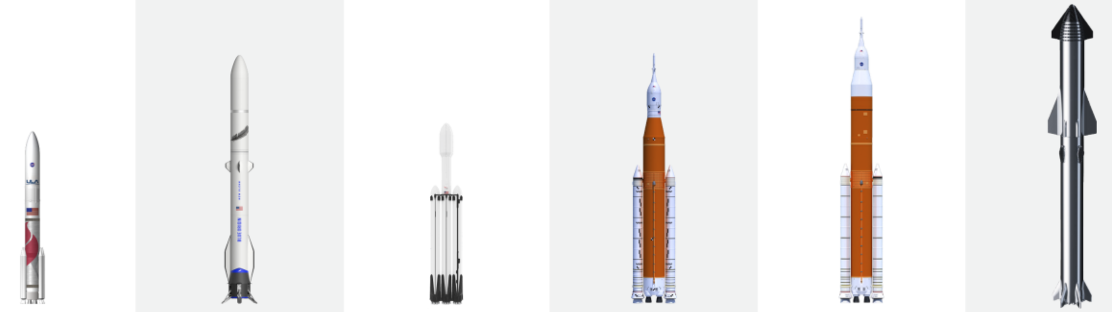
[54] NASA purchases the RL-10 engines on a contract separate from the Stages and Stages Production and Evolution Contract contracts at a cost of $10.8 million each; therefore, the cost for the Block 1B upper stages engines will rise approximately $32.4 million.

[55] IG-20-018.

[56] As an example, SpaceX is designing the Starship to fly astronauts from Earth to its destination and back on the same spacecraft. Congress's mandates are found in: Pub. L. No. 111-267, 124 Stat. 2805.

Agency should continue to monitor the commercial development of heavy-lift space flight systems and begin discussions of whether it makes financial and strategic sense to consider these options as part of the Agency's overall plan to support its ambitious space exploration goals. Figure 8 shows a comparison of commercial medium- to heavy-lift launch vehicles that may become available in the near-term.

Figure 8: Selected Near-Term Medium-to-Heavy Lift Launch Vehicle Comparisons



	Vulcan Centaur with Heavy Booster	New Glenn	Falcon Heavy	SLS Block 1	SLS Block 1B	Starship with Super Heavy Booster
Vehicle Maker	United Launch Alliance	Blue Origin	SpaceX	NASA	NASA	SpaceX
Upmass to Low Earth Orbit	27 metric tons	45 metric tons	64 metric tons	70 metric tons	105 metric tons	100+ metric tons[b]
Upmass to Trans-Lunar Injection	12 metric tons	See note[a]	16 metric tons	27 metric tons	37 metric tons	100+ metric tons[b]
Planned Features	Designed for affordability	First Stage reusable minimum of 25 times; human rated	Partially reusable; not human rated	Capsule partially reusable; human rated	Capsule partially reusable; human rated	Fully reusable; human rated
Anticipated Launch Readiness Date	2022	See note[a]	Operational	Late 2021	2026	Late 2021

Source: NASA OIG depiction of Agency program and company information.

[a] In response to a NASA OIG request, Blue Origin declined to provide information about the New Glenn rocket. Data displayed in the table is from publicly available sources and has not been confirmed with the company.
[b] Starship upmass capabilities to low Earth orbit and trans-lunar injection require multiple launches and in-space refueling.

NASA's Modified Acquisition and Management Approaches for HLS Will Reduce Costs and Encourage Innovation But Also Increase Risk

NASA modified both its HLS acquisition and management approaches to reduce costs, encourage innovation, and meet an aggressive schedule for its Artemis lunar landings. While its acquisition approach relies on competition to drive down costs and ensure redundancy, the Agency selected only one provider after receiving $2.5 billion less than requested for HLS development in FY 2021 alone. To mitigate this constraint, the Agency is accelerating the LETS procurement. In September 2021 NASA awarded five contracts to companies to continue developing HLS capabilities, which are intended to help prepare industry to be competitive for a future lunar transportation services award under the LETS procurement. NASA has also worked diligently to solidify its HLS requirements and standards; however, under the Agency's tailored project management approach for HLS the contractor retains significant latitude with less technical reviews than NASA has historically afforded and this approach runs the risk of technical changes later in development. Finally, NASA is using a series of new collaborative processes instead of a systems integrator or Artemis program manager as it has in previous multi-component projects. Although these modified approaches have potential benefits of decreasing costs and encouraging innovation, they correspondingly raise the possibility of schedule and performance risks on NASA's human-rated systems.

Only One Company Selected for HLS Demonstration Mission Due to Reduced Funding

NASA's HLS Program received significantly less funding from Congress than requested, presenting both immediate and longer-term challenges. Specifically, NASA requested $3.4 billion to fund multiple HLS demonstration awards to create a competitive environment intended to drive down costs, offer redundancy, and promote innovation. However, the Agency only received about 25 percent of its requested amount in FY 2021, ultimately allocating about $928 million for the HLS in its final FY 2021 operating plan.[57] Under its initial appropriation request, the HLS Program proposed a heavily front-loaded funding profile with awards to multiple contractors to demonstrate lunar landings of their HLS vehicles on an ambitious timetable. Under this plan, one contractor would provide its HLS for a 2024 crewed landing while another would demonstrate its HLS design on a follow-on 2026 landing. The FY 2021 appropriation led to NASA selecting a single HLS contractor—SpaceX—in April 2021 rather than two as the Program preferred.

[57] The Budget Operating Plan allocates NASA's appropriation into the program line items with limited flexibility to reallocate funding from one category to another.

In response to awarding only one initial demonstration contract, NASA decided to accelerate the LETS acquisition instead of continuing to procure single demonstration missions and also created additional lunar lander research, development, and demonstration opportunities for industry. NASA developed a Broad Agency Announcement open to all U.S. Industry for insight into sustaining requirements, standards, and risk reduction efforts unique to the provider's design. In September 2021, the HLS Program awarded contracts to five companies to develop lander design concepts, evaluate their technical capabilities, conduct critical component tests, and advance the maturity of key technologies, thereby better positioning multiple contractors for future HLS service awards.

Further, the FY 2022 President's Budget Request does not currently contain funds to support a second HLS demonstration award—a scenario NASA expected would provide redundancy while creating a competitive environment that would likely drive down costs.[58] For both NASA's Commercial Cargo and Crew Transportation Programs, redundancy proved to be essential as both programs experienced failed flights that were mitigated by having a second provider available to fly missions to the ISS.[59] Additionally, each of the three companies in the initial HLS design phase offered different approaches—including a range of in-flight refueling; crew station layouts; and ascent, descent, and transfer elements—to tackle technical and operational challenges.

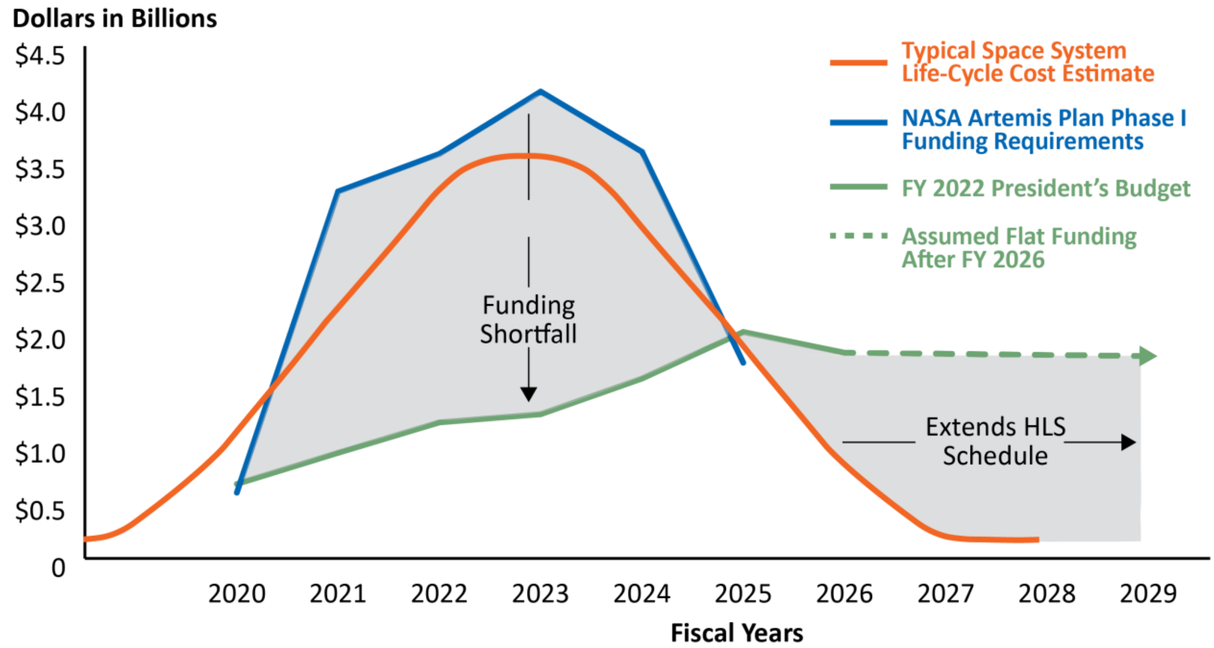
A lack of funding early in development not only delays the awarding of a contract to a second HLS provider, it also raises the possibility of schedule delays if project managers have to defer the development of critical technologies. Additionally, it is essential for the funding to be allocated appropriately over the course of a program's life cycle. Although NASA contends that it has sufficient funding for SpaceX to conduct the single demonstration mission, several milestones had to be delayed to compensate for its smaller funding profile. In accordance with best practices, a system life-cycle model resembles a bell-shaped funding curve for research, development, testing, and evaluation with more resources needed as development progresses and programmatic risks are identified and remediated (see Figure 9).[60] Space flight systems in particular must invest heavily in these activities because once a system is launched into space it cannot be retrieved for maintenance.

[58] In May 2021 the President submitted to Congress a funding request of $1.2 billion for the HLS for FY 2022. Despite not requesting additional money to support a second HLS award, the Administration maintained in its new budget request that NASA still plans to have multiple landing systems either prior to or after the planned 2024 lunar landing demonstration.

[59] Failed flights for the commercial cargo and crew missions included: Orbital Sciences Orbital-3, a 2014 cargo mission that exploded seconds after liftoff; SpaceX's CRS-7, a 2015 cargo mission that disintegrated shortly after launch; and Boeing's Orbital Flight Test, a 2019 crew vehicle test that failed to enter its correct orbit and rendezvous with the ISS. More recently, in August 2021, Boeing was unable to launch its second commercial crew flight test due to valve issues in its Starliner propulsion system, delaying again any crewed flights.

[60] GAO-20-195G.

Figure 9: HLS Funding Profiles vs. Representative System Life-Cycle Cost Estimate



Source: NASA OIG presentation of Agency data and extrapolation of guidance from GAO-20-195G.

Note: The annual President's Budget Request spans five fiscal years. For our analysis, we assumed a flat level of funding from FY 2026 onward. In addition, the orange curve represents a single system profile even though the HLS Program intends to fund the development of multiple systems.

Maintaining a late 2024 timetable to land astronauts on the Moon will mean SpaceX's HLS Starship will have less than 5 years for development and human-rated testing. As demonstrated in Figure 9, NASA's initial proposal for HLS funding (blue line) more closely resembles the shape of a typical development bell curve (orange line), but receipt of substantially less money in FY 2021 (green line) resulted in a significant flattening of that curve. This increases risks of schedule delays and long-term costs if the underfunding continues early in development. Given that NASA received significantly less funding than requested and the technical issues the Agency identified in its reviews of contractor design submissions, HLS will take longer and cost more money than expected if not adequately funded in its current development period.

Modified Fixed-Price Contract Will Reduce Cost Growth and NASA's Process to Mitigate Technical and Safety Risks Is Being Implemented

NASA has traditionally used cost-plus contracts for space flight development but modified this approach to use firm-fixed-price and FAR Part 35 contracts for HLS development to help manage costs. In the past, the Agency relied on cost-plus contracts as requirements evolved and fixed-price contracts when it could clearly define costs and risks.[61] Firm-fixed-price contracts have the benefit of consistent, upfront costs to a program, eliminating the potential for cost growth that has been typical with the Agency's cost-plus contracts.

While NASA's use of firm-fixed-price contracts for HLS will help limit the excessive cost growth experienced by the SLS and Orion Programs, the Agency's approach for HLS has its own challenges. For example, NASA's use of a modified firm-fixed-price approach for HLS will likely reduce cost, but may also exacerbate schedule, performance, and safety issues should the contractor be slow to meet certification requirements. Much like the Commercial Cargo and Crew Programs in their initial stages, NASA's acquisition strategy includes companies developing the HLS to share development costs with the Agency, a procedure that, coupled with a system of milestone payments, is designed to reduce costs.[62] Towards this end, SpaceX has contributed much more than half of the required funding to date for the HLS system and plans to continue this level of contribution.[63] In addition, contractor flexibility in meeting requirements provides the freedom to innovate; however, it also runs the risk of not meeting NASA requirements, especially when it comes to human rating the spacecraft. To its credit, NASA added specific design and construction standards to the demonstration contract with SpaceX to better ensure compliance with requirements as well as a special clause that strengthens the Agency's insight to ensure certification of flight readiness. Nonetheless, in a 2019 report on the Commercial Crew Program we noted a significant amount of verification work needed to achieve flight readiness, and thus the challenge for NASA and SpaceX will be the timely processing of HLS documents and test results to verify compliance with Agency standards.[64]

The Commercial Crew Program was ultimately successful in using a similar approach, but it took the commercial partners 10 years to reach flight readiness, largely because of difficulties meeting human rating requirements. Even if the first HLS flight occurred in 2028 as originally planned, that would still be a faster development timeline than the Commercial Crew Program, which delivered astronauts to the ISS in low Earth orbit rather than to the Moon, a distance nearly 200 times farther. However, we found NASA's process for conducting insight with commercial partners to mitigate technical and safety risks throughout development is already well developed and is being implemented.[65] Although NASA's Aerospace Safety Advisory Panel had expressed concerns in their 2020 annual report about the Agency's lack of oversight over key commercial partners in the HLS Program, recent AES interactions with the Panel have noted the HLS Program's progress in establishing its governance and integration model

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[61] Examples of NASA's previous fixed-price contracts for space flight systems include the later developmental periods of the Commercial Crew Program and the third generation of NASA's Tracking and Data Relay Satellites, which provide tracking, data, voice, and video services to the spacecraft and to NASA's space and science missions, other federal agencies, and commercial users.

[62] In the Commercial Crew Program, as the schedule slipped nearly 3 years milestone payments were also delayed, but the overall fixed-price contract costs have not increased more than 5 percent. See NASA OIG, *NASA's Management of Crew Transportation to the International Space Station* (IG-20-005, November 14, 2019). Slippage in schedule also occurred in the initial HLS design phase, but payment was not released until the milestone was achieved, thereby incurring no additional cost.

[63] SpaceX officials provided this characterization of the amount of its corporate funding—the exact number is withheld from our report to protect future competitions.

[64] IG-20-005.

[65] Oversight is the process in which NASA approves and directly manages contractor activities while insight occurs when the Agency monitors contractor activities but does not require specific approvals for most decisions. HEOMD published its *Crewed Deep Space Systems Human Rating Certification Requirements and Standards for NASA Missions* document in March 2021. In turn, the HLS Program cross-walked the program requirements with the HEOMD guidance and published its own set of required guidance for certification.

which is key in providing oversight.[66] Moreover, NASA's Chief Engineer noted the progress made in both establishing safety standards and governance. Finally, while we observed that the Commercial Crew and Cargo Programs have personnel on-site at SpaceX's facilities and the HLS Program does not, officials plan to institute resident offices at SpaceX locations once the Blue Origin litigation is concluded. NASA officials have told us personnel resident at contractor sites help ensure effective communication among all parties.

Project Management Approach for the Human Landing System Modeled After Commercial Crew Program

To meet the aggressive goal of a crewed lunar landing in 2024, the HLS Program adopted a tailored project management approach that is modeled, in part, after the Commercial Crew Program. Specifically, instead of using the Agency's standardized series of technical milestones for major acquisitions, HLS is leveraging an approach that relies on reduced reviews and data submissions to encourage innovation and reduce costs. For example, HLS held two design reviews—a Certification Baseline Review and Continuation Review—for the three companies that received a contract for the initial HLS design work. Both of these reviews took the place of the typical series of design reviews required in the Formulation phase of an acquisition, meeting the intent of standard review requirements.[67] After completing this initial design work, the Program plans to follow its standardized project management approach where an Agency Baseline Cost and Schedule commitment will be made following its next milestone—KDP-C.[68] Contractually negotiated design reviews for SpaceX, such as the Critical Design Review, will follow for the SpaceX HLS Starship.[69] Programmatically, after KDP-C, the Program will deviate again from the typical program milestones and use annual reviews (called synchronization reviews) throughout development and testing, ending with the HLS's landing on the lunar surface.

The Commercial Crew Program awarded multiple early development contracts during a 4-year period before holding the Certification Baseline Review to provide time to develop more mature designs. While HLS Program officials told us they are leveraging lessons learned from the Commercial Crew Program, HLS had only 4 months from the start of the contract before they held the Certification Baseline Review. NASA officials told us that the HLS team successfully worked with all three contractors during the initial design work, which helped determine design and construction standards and resulted in agreements on how to build the landers prior to finalization of the demonstration mission contract. Nonetheless, since all three HLS submissions had immature technologies, NASA could have benefitted from additional time to mature the designs and key technologies prior to holding both reviews, much like with the Commercial Crew Program.

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[66] The Aerospace Safety Advisory Panel evaluates NASA's safety performance and advises the Agency on ways to improve that performance.

[67] In Formulation, a typical NASA acquisition will have a Systems Readiness Review, Systems Design Review, and Preliminary Design Review. Rather than doing those reviews, the HLS Program opted for a Certification Baseline Review intended to finalize functional and performance requirements, and a Continuation Review intended to evaluate the design's readiness for a potential award for demonstration and to be equivalent to a less stringent version of a Preliminary Design Review.

[68] KDPs are the events where the decision authority determines the readiness of a program or project to continue to the next phase of the life cycle. Specifically, KDP-C allows the HLS to progress to final design and fabrication.

[69] The Critical Design Review demonstrates that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and testing.

Moving forward, NASA is taking on additional risk if the new annual synchronization reviews do not meet the intent of milestones KDP-D and -E, the Systems Integration Review, and the Operational Readiness Review that take place before spacecraft flight in order to address technical and engineering risks.[70] Milestone reviews are important opportunities for a program to assess and mitigate risks throughout development, such as ensuring that key technologies and subsystems are maturing and safety requirements are met. Without holding those reviews or ensuring the substance of those reviews are captured in the annual synchronization reviews, NASA may lack appropriate insight into HLS development.

For its part, NASA officials told us that in addition to insight teams looking into the HLS's development, they stood up "collaboration teams" during the initial design contracts to serve as a NASA resource to the contractors and assist with solving problems. Initially, the HLS Program dedicated about 50 NASA employees to work with each contractor, with plans to increase that number for the follow-on development contract.

NASA Managing Artemis Activities Using Newly Established Processes Rather Than a Systems Integrator or Program Manager

NASA has developed a multi-faceted management structure to facilitate systems integration among the multiple Artemis programs and projects. In addition, GAO's Standards for Internal Control notes that management should establish an organizational structure, assign responsibility, and delegate authority to achieve the entity's objectives.[71] Table 3 provides a description of the membership, status, and responsibilities of the recently created collaboration entities.

[70] Annual synchronization reviews are tailored reviews where the contractor provides data similar to KDPs including a review of configuration, maturity, and integrated analyses, as well as Standing Review Board Independent Assessments. KDP-D is the milestone event that allows a project to proceed to Assembly, Integration and Test, and Launch and KDP-E moves the project into Operations and Sustainment. A Systems Integration Review ensures segments, components, and subsystems are on schedule to be integrated into the system. The Operational Readiness Review ensures that all system and support (flight and ground) hardware, software, personnel, procedures, and user documentation accurately reflect the deployed state of the system.

[71] GAO's *Standards for Internal Control in the Federal Government* (GAO-14-704G, September 10, 2014) sets the standards for an effective internal control system for federal agencies and provides the overall framework for designing, implementing, and operating that system. The standards note that having a control environment that has discipline and structure helps define objectives and how control activities are structured.

Table 3: Summaries of Newly Instituted Artemis Coordination, Collaboration, and Board Processes

Collaboration Process	Membership	Status	Responsibilities
Federated Board	HEOMD, Science, and Space Technology Mission Directorates, and Program Offices	Implemented: Yes Codified: No	• Established by the prior NASA Administrator to address cross-directorate issues represented by divisions within HEOMD and the Science and Space Technology Mission Directorates • Only for discussions, not a decision board
Expanded Federated Board	HEOMD, Science, and Space Technology Mission Directorates, and Program Offices; General Counsel; Mission Support; and Office of International and Interagency Relations	Implemented: Yes Codified: No	Larger version of the Federated Board that includes other support and groups
Joint Directorate Program Management Council	As needed: HEOMD, Science, and Space Technology Mission Directorates, and Program Offices	Implemented: Yes Codified: No	Decision making authority for Artemis programs and projects across all NASA directorates
HEOMD Systems Engineering and Integration Function	Office is a delegated function of the HEOMD Associate Administrator across all HEOMD divisions	Implemented: Yes Codified: Yes	• Responsible for providing overall strategic guidance and input on system requirements • Lead overall Artemis architecture and has key role in formulation mission planning • Integrate science and technology goals from mission directorates and international partners for Artemis missions, and the strategy to prepare for future human missions to Mars
Joint AES-ESD Control Board	Co-Chairs: AES and ESD Deputy Associate Administrators and supporting staff, Artemis-related Program and Project Managers HEOMD SE&I: Ad-hoc member	Implemented: Yes Codified: Charter approved; awaiting signature	• Disposition program changes jointly affecting AES/ESD that exceed individual or multiple program cost and schedule authority, including joint AES/ESD controlled schedule and milestone changes • Review and approve joint AES/ESD mission content, priorities, and integrated scope through flight readiness certifications to ensure AES and ESD programs and personnel are ready to support the mission
AES Control Board	AES Deputy Associate Administrator and supporting staff, AES Managers, and Artemis Program Offices; Ad Hoc members from ESD, other directorates, and programs involved in Artemis crewed missions	Implemented: Yes Codified: Charter approved; awaiting signature	• Establish and manifest Artemis III and subsequent missions' launch and landing services, logistics and payload manifests, flight objectives, and priorities • Establish and manage the AES Division technical and programmatic baseline (budget, schedule, technical, mission definition, and risks) • Disposition and approval for elevation for recommended changes, exceptions, deviations, or waivers

Collaboration Process	Membership	Status	Responsibilities
Joint Program (Integration) Control Boards at various levels	AES and ESD programs and projects conducting integration activities; HEOMD SE&I: Ad-hoc attendance	Implemented: Yes Codified: Draft waiting approval	Joint Program (Integration) Control Board charters and individual programs and projects

Source: NASA OIG presentation of Agency data.

Unlike the first crewed missions to the lunar surface under the Apollo Program, NASA has no overall NASA program manager overseeing the Artemis missions or a main contractor, as in the Space Shuttle Program, serving as a lead systems integrator.[72] Instead, the Agency is giving as much flexibility as possible to the individual programs supporting Artemis while encouraging cross-program, directorate, and international partner communication through a range of collaboration processes, including those identified in Table 3. NASA has taken several steps to formalize this coordination: delegated Artemis planning for the lunar landing missions to AES, codified the integration approach, stood up and staffed the SE&I function, and developed charters for new joint control and integration boards at multiple levels. Further, NASA intends to use its existing Agency governance (Agency Program Management Council and Directorate Program Management Council), along with convening the Joint Directorate Program Management Council, for Artemis implementation and decision making. Even so, neither the Federated Boards nor the Joint Directorate Program Management Council are codified yet in Agency policy. As a result, these processes may not be smoothly executed, especially if leadership, program priorities, or key members of the workforce change. This is essential because the requirements and designs of one system affect the programs and projects across multiple directorates.

[72] Lead system integrators are prime contractors hired to manage large and complex programs within a given budget and schedule.

CONCLUSION

NASA's goal to land astronauts on the Moon's South Pole in late 2024 faces multiple significant challenges including major technical risks, an unrealistic development schedule, and lower-than-requested funding levels. As a result, the 2024 date will likely slip to 2026 at the earliest. On top of an overly optimistic development schedule, the HLS bid protests to GAO delayed the HLS Program's schedule by 6 months with an additional 3-month delay due to Blue Origin's follow-up lawsuit at the U.S. Court of Federal Claims. Moreover, delays in developing the Gateway will likely preclude the lunar outpost's availability to provide communications and supplies for both the Orion and HLS during NASA's early Moon landing missions.

Given that NASA is likely to spend $93 billion on the Artemis program through FY 2025, and in light of the $4.1 billion cost-per-launch for at least its first four Artemis missions, it is important that the Agency not only identify ways to reduce costs but also take steps consistent with best practices to make current cost estimates more reliable and transparent. The Agency has acknowledged the high costs of its lunar and Mars goals and is examining ways to make the missions sustainable by transitioning some programs to fixed-price contracts. With the emerging capabilities provided by commercial partners, the Agency may have future options that can help control costs to meet its exploration goals. While NASA has made strides in ensuring communication and integration between the Artemis programs—such as establishing a HEOMD SE&I, Federated Boards, Joint Directorate Program Management Council, and Joint Program Boards—these nascent procedures remain at risk to unfamiliarity and changes in organization, leadership, or program priorities.

Whether acquiring space flight systems for Artemis or eventually for crewed missions to Mars, NASA must determine its procurement and programmatic strategies to best support its objectives. This includes encouraging competition, using appropriate instruments—various FAR-based contracts or Space Act Agreements—and employing appropriate insight and oversight mechanisms to ensure NASA receives systems that meet its needs. Importantly, as we pointed out in our first Artemis report, understanding the state of technology development and level of maturity of requirements for each Artemis system will help inform decision makers on the best approach and produce realistic schedule and cost estimates.[73]

[73] IG-21-004.

Recommendations, Management's Response, and Our Evaluation

To increase accuracy, transparency, and safety of human space flight, we recommended NASA's Associate Administrator for Exploration Systems Development Mission Directorate:

1. Develop a realistic, risk-informed schedule that includes sufficient margin to better align Agency expectations with the development schedule.
2. Expand upon the existing draft Artemis IMS to include Artemis programs outside AES and ESD to properly align dependencies across directorates.
3. Develop an Artemis-wide cost estimate, in accordance with best practices, that is updated on an annual basis.
4. Maintain an accounting of per-mission costs to increase transparency and establish a benchmark against which NASA can assess the outcome of initiatives to increase the affordability of ESD systems.
5. Definitize outstanding Artemis-related contracts within 180 days in accordance with NASA FAR Supplement 1843.7005(a), *Definitization* (2018).
6. Develop a realistic funding profile and schedule given the underfunding of HLS in FY 2021, the selection of one HLS award, and the desire to compete a sustainability contract for future lunar missions.
7. Identify measurable cost reduction targets for its ESD contractors.

In addition, we recommended NASA's Chief Engineer in coordination with the HLS Program Manager:

8. Validate that the annual synchronization reviews meet the intent and expectations of the milestone reviews replaced by the tailored acquisition approach.

We also recommended that the NASA Deputy Administrator in coordination with Mission Directorate Associate Administrators:

9. Codify the remaining governance structure such as the Federated Boards and Joint Directorate Program Management Council.

We provided a draft of this report to NASA management who concurred with Recommendations 1, 5, 6, 7, and 8; partially concurred with Recommendations 2 and 9; and non-concurred with Recommendations 3 and 4. We consider management's comments responsive to Recommendations 1, 5, 6, 7, and 8 and therefore those recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions. However, we found the Agency's response to Recommendations 2, 3, 4, and 9 unresponsive. Consequently, those recommendations will remain unresolved pending further discussions with the Agency.

NASA partially concurred with Recommendation 2 to include Artemis activities across the various directorates as part of its IMS. During the course of our audit, NASA developed a schedule that includes both AES and ESD activities, but still lacks other important lunar activities such as the CLPS missions which intends to fly missions biannually to the Moon. While NASA tells us the Artemis missions are not dependent on these other activities, deconfliction of time, space, and resources is still needed as is integration of the essential information provided by these science investigations and technology demonstrations.

NASA also partially concurred with Recommendation 9 to codify its remaining governance structures. NASA agreed with codifying the Joint Directorate Program Management Council, a key decision-making and review authority for the Artemis missions. However, the Agency did not agree to codify the Federated Board because it is a coordination entity and does not make decisions. We learned late in this audit that NASA was in the process of reviewing the necessity of maintaining this Board. To the extent the Agency retains the Federated Board, we believe a charter is needed because such a senior-level board can wield significant influence even if it does not have official decision-making authority.

Additionally, NASA non-concurred with Recommendations 3 and 4 that address the need to track the overall cost of the Artemis program and each individual Artemis mission. For Recommendation 3, the Agency states that Artemis-wide cost tracking is not required according to its policy and as such Agency officials are following best practices in providing cost estimates and commitments for Agency-approved programs and projects. Likewise, in response to Recommendation 4—tracking costs by mission—NASA maintains it should not account for costs on a per-mission basis because doing so would reduce contractual transparency to key stakeholders. While we appreciate the importance of tracking metrics aimed at managing individual contracts within specific projects, failure to track the overall cost of the Artemis program and each individual mission reduces insight into the actual costs of the Artemis program and, in turn, makes it difficult to assess the Agency's progress in reducing costs.

Management's comments are reproduced in Appendix E. Technical comments provided by management have been incorporated as appropriate.

Major contributors to this report include Ridge Bowman, Space Operations Director; Kevin Fagedes, Project Manager; Scott Bruckner; Kelsey Dalton; Wayne Emberton; Tyler Martin; Daniel Mills; Lauren Suls; Earl Baker; and Shani Dennis.

If you have questions or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at 202-358-1543 or laurence.b.hawkins@nasa.gov.

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Paul K. Martin
Inspector General

Appendix A: Scope and Methodology

We performed this audit from December 2020 through November 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

In this report, we assessed the Artemis program's schedule and projected costs, and how the Agency's acquisition and programmatic approaches facilitate its plans to land astronauts on the Moon. Our review included interviews with officials at NASA Headquarters, Johnson Space Center, Kennedy Space Center, Marshall Space Center, and SpaceX. We conducted a site visit at SpaceX's headquarters in Hawthorne, California, and their Starbase in Boca Chica, Texas.

To assess the Artemis program's schedule and projected costs, we used a combination of document reviews, interviews, and numerous discussions with NASA officials and selected contractors. In addition, we visited SpaceX facilities in California and Texas to observe HLS development firsthand. Our schedule analysis included examining ESD manifests, integrated master schedules, schedule risk analyses, and program quarterly reviews. As for projected costs, we examined program budget submissions, presidential budget requests, appropriations, quarterly program data sheets, and operating plans. We also reviewed the 2020 Artemis Phase 1 Funding Requirements in NASA's Lunar Exploration Program Overview—Appendix 5, and the following prime contracts: SLS stages, boosters, RS-25, and upper stage; Orion; and Gateway's HALO and PPE. In addition, for actual expenditures, we used NASA's financial system, our data analytics team, and program feedback to determine and analyze NASA's obligations. For both schedule and costs, we compared current information against baseline commitments. We then followed up with program officials—both NASA and SpaceX—to confirm our analysis and the information we found. Our interviews on cost and schedule included officials from HEOMD, AES, ESD, and SpaceX, as well as multiple discussions with program and budget analysts to determine which Work Breakdown Structure codes—the accounting method used to count costs—were properly accounted for as Artemis costs.

To determine how the Agency's acquisition and programmatic approaches facilitate its plans to land astronauts on the Moon, we reviewed the September 2020 Artemis Plan, architecture briefings, and detailed Artemis project acquisition strategy documents that describe the different methods for how astronauts will travel to the lunar surface. We examined each of the three initial design contracts for the three HLS contractors (SpaceX, Blue Origin, and Dynetics), all contract modifications, and the source selection statements associated with the various contracts. Additionally, we reviewed the acquisition strategy and approved tailored programmatic approach as outlined in the HLS Acquisition Strategy Meeting and quarterly program briefings. We reviewed federal and NASA policies and procedures for types of contracts and program and project management requirements. We also reviewed documents from the HLS Continuation Review for SpaceX, which outlined the status of technical challenges, technology development, and the operational approach for SpaceX's HLS. Further, we conducted interviews with officials from HEOMD, HEOMD SE&I, ESD, Office of the Chief Engineer, the HLS Program Manager, HLS Contracting Officer, and the Launch Services Program, as well as SpaceX.

Assessment of Data Reliability

We relied upon computer-generated data as part of performing this audit. We reviewed and analyzed NASA obligation and funding data for FYs 2012 through 2021 in NASA's financial accounting system and used program budget estimates for FYs 2022 through 2025. The obligation and funding data were mainly derived from Artemis mission costs: Exploration Systems Development, Advanced Exploration Systems, Exploration Research and Development, Science, Space Technology, and Mission Support. We assessed the reliability of the financial data by (1) verifying the data with the NASA OIG's Advanced Data Analytics Program and Artemis Dashboard Tracker, (2) reviewing data provided by NASA's directorates and divisions, and (3) interviewing Agency officials knowledgeable about this data. We determined that the data was sufficiently reliable for the purposes of this report.

Review of Internal Controls

We assessed internal controls and compliance with laws and regulations necessary to satisfy the audit objectives. Specifically, we assessed the Artemis program's schedule and projected costs, and how the Agency's acquisition and programmatic approaches facilitate its plans to land astronauts on the Moon, which are identified and discussed previously in this report. However, because our review was limited to these internal control elements and underlying principles, it may not have disclosed all internal control deficiencies that may have existed at the time of this audit. Our recommendations, if implemented, will correct the identified control weaknesses.

Prior Coverage

During the last 5 years, the NASA Office of Inspector General and GAO have issued 21 reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html and https://www.gao.gov, respectively.

NASA Office of Inspector General

NASA's Development of Next-Generation Spacesuits (IG-21-025, August 10, 2021)

Artemis Status Update (IG-21-018, April 19, 2021)

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

NASA's Challenges to Safely Return Humans to the Moon by 2024 (IG-21-007, December 1, 2020)

NASA's Management of the Gateway Program for Artemis Missions (IG-21-004, November 10, 2020)

NASA's Management of Its Acquisition Workforce (IG-21-002, October 27, 2020)

NASA's Management of the Orion Multi-Purpose Crew Vehicle Program (IG-20-018, July 16, 2020)

NASA's Development of Ground and Flight Application Software for the Artemis Program (IG-20-014, March 19, 2020)

Audit of NASA's Development of Its Mobile Launchers (IG-20-013, March 17, 2020)

NASA's Management of Space Launch System Program Costs and Contracts (IG-20-012, March 10, 2020)

NASA's Management of Crew Transportation to the International Space Station (IG-20-005, November 14, 2019)

2019 Report on NASA's Top Management and Performance Challenges (November 13, 2019)

NASA's Management of the Space Launch System Stages Contract (IG-19-001, October 10, 2018)

NASA's Plans for Human Exploration Beyond Low Earth Orbit (IG-17-017, April 13, 2017)

Government Accountability Office

NASA Lunar Programs: Significant Work Remains, Underscoring Challenges to Achieving Moon Landing in 2024 (GAO-21-330, May 26, 2021)

NASA: Assessments of Major Projects (GAO-21-306, May 20, 2021)

NASA Human Space Exploration: Significant Investments in Future Capabilities Require Strengthened Management Oversight (GAO-21-105, December 15, 2020)

NASA: Assessments of Major Projects (GAO-20-405, April 29, 2020)

NASA Lunar Programs: Opportunities Exist to Strengthen Analyses and Plans for Moon Landing (GAO-20-68, December 19, 2019)

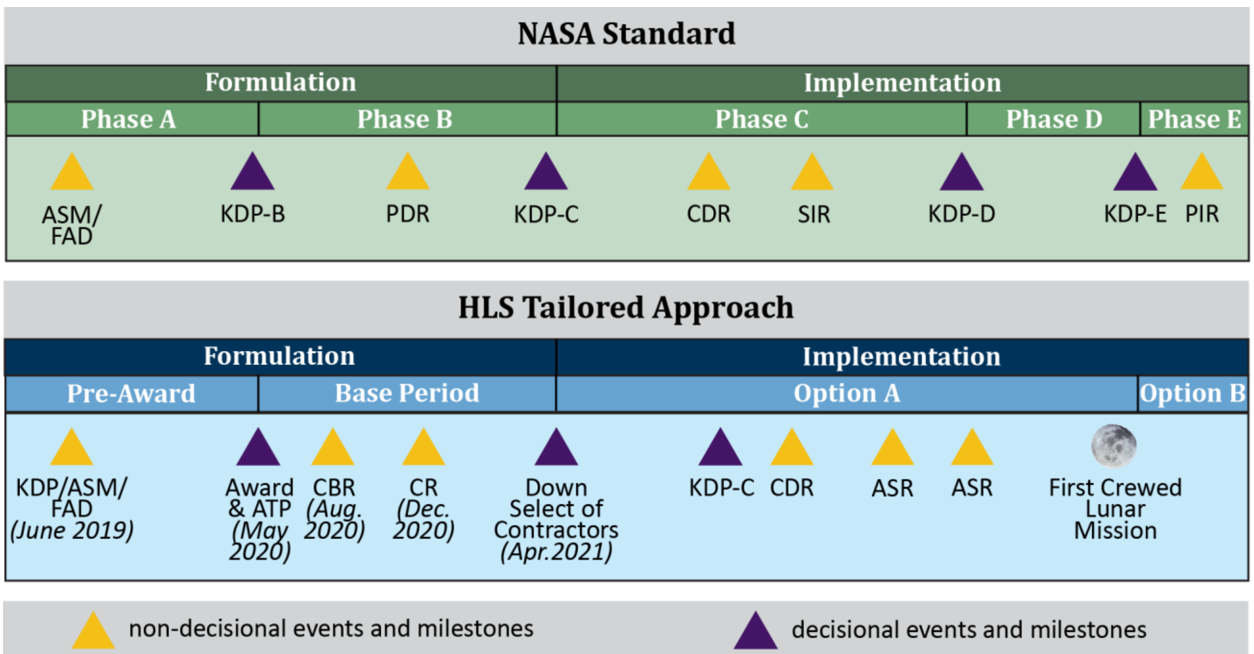
NASA Human Space Exploration: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs (GAO-19-377, June 19, 2019)

High-Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas (GAO-19-157SP, March 6, 2019)

Appendix B: HLS Program's Tailored Project Management Approach

NASA is utilizing a tailored approach for the HLS Program to streamline typical program management processes similar to the Gateway Program. NASA policy for program and project management dictates certain requirements for oversight, life-cycle reviews, and other programmatic matters, while also providing the flexibility to adjust those requirements to fit the unique needs of a program or project. NASA has tailored requirements for several other programs, including the SLS, Orion, and Commercial Crew Programs. The HLS Program will undergo extensive tailoring—modeled after the Commercial Crew Program—that it believes will result in significant cost and schedule savings without sacrificing technical and programmatic insight (see Figure 10).

Figure 10: HLS Program Tailoring Compared to NASA Standard



Source: NASA OIG presentation of Agency data.

Note: Acquisition Strategy Meeting (ASM), Formulation Authorization Document (FAD), Preliminary Design Review (PDR), Key Decision Point (KDP), Critical Design Review (CDR), Systems Integration Review (SIR), Program Integration Review (PIR), Authority to Proceed (ATP), Certification Baseline Review (CBR), Continuation Review (CR), Annual Synchronization Review (ASR).

The tailoring approach will impact Program-level design reviews and KDPs, important governing documents, and programmatic analyses like an Agency Baseline Commitment (ABC) and Joint Cost and Schedule Confidence Level (JCL).[74] NASA policy outlines various design reviews at the program level (e.g., System Definition Review, Critical Design Review, System Integration Review), which are typically followed by KDP-A, -B, -C, and -D. The HLS Program is tailoring these requirements and will instead negotiate design reviews with the contractor to facilitate efficiency and align with industry best practices. These reviews will include evaluations by independent technical and programmatic authorities. In lieu of four KDPs, the Program will hold a KDP-C about 8 months after contract award, with annual synchronization reviews thereafter. This is in addition to an Acquisition Strategy Council meeting in May 2019 that served the purpose of a KDP-A.

NASA policy also requires programs to submit guiding documents like the Formulation Authorization Document and Program Plan to authorize transition to the following life-cycle stage and establish important programmatic baselines. The HLS Program captured content similar to the Formulation Authorization Document in meeting minutes from the May 2019 Acquisition Strategy Council meeting, while a final Program Plan is not expected until KDP-C is completed.

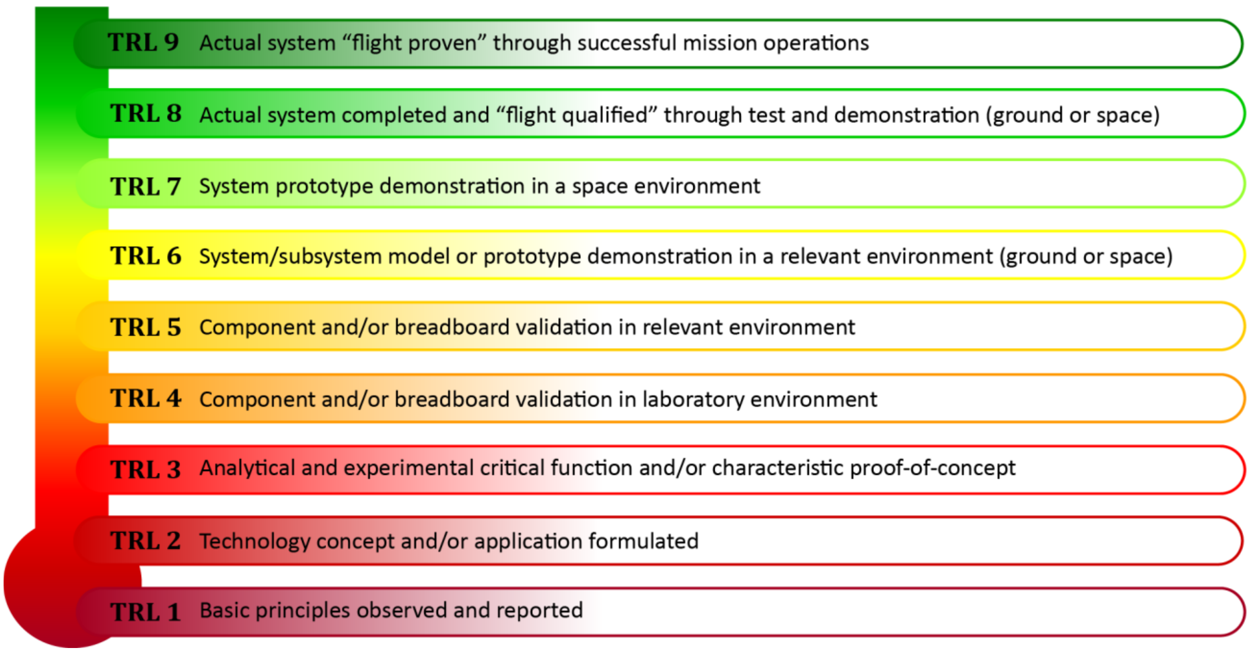
For cost and schedule analysis requirements, single-project programs like HLS are required to submit an ABC and JCL at KDP-C. The HLS Program intends to submit an ABC that captures costs up to the initial lunar landing demonstration, as opposed to the full life cycle of the Program. With regard to the JCL, the Program will create a "lean" JCL or Schedule Risk Analysis using a milestone summary schedule, which the Program believes will provide the flexibility to both inform the ABC and provide regular and timely schedule risk updates. The contractor partner will also provide the Basis of Estimates to allow for continuing NASA insight into cost and schedule. The former NASA Associate Administrator approved these tailored requirements on June 24, 2019.

[74] An ABC establishes and documents an integrated set of project requirements, cost, schedule, technical content, and an agreed to JCL that forms the basis for NASA's commitment to the Office of Management and Budget and Congress. A JCL analysis is used to inform management of the likelihood of a project's programmatic success, establish cost and schedule baselines, determine 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.

APPENDIX C: ARTEMIS SYSTEM DESCRIPTIONS

To achieve its Artemis ambitions, NASA requires multiple space flight systems to both explore the Moon prior to the astronauts' arrival and deliver the astronauts to the lunar surface. The space flight systems that will be used for Artemis I through III are explored further in this appendix including the SLS, Orion, EGS, Gateway, and HLS. In addition, we describe spacesuits, the Volatiles Investigating Polar Exploration Rover (VIPER), and an example of a landing system for science investigations—the Masten Lunar Lander. Prior costs described in the systems updates are identified as obligated funds. Each system is also at various levels of development with its progress tracked according to its Technology Readiness Level (TRL), which begins at 1 and ends at 9. Figure 11 shows how the TRL number increases based upon the level of progress or milestone achieved.

Figure 11: Technology Readiness Levels



Source: NASA OIG presentation of Agency data.

Space Launch System

NASA's SLS is a two-stage, heavy-lift rocket that will launch the Orion capsule into space.[a] To fulfill America's future needs for deep space missions, the SLS will evolve into increasingly more powerful configurations. For the first three Artemis missions, NASA will use the Block 1 configuration. By Artemis IV, NASA will be using the Block 1B configuration with eventual evolution to the Block 2 configuration by the ninth Artemis mission, each of those with increased lift capability.

In 2011 and 2012, NASA contracted with three commercial companies to develop the SLS's major elements—Boeing (for the launch system's Core Stage and Upper Stage, known as the Interim Cryogenic Propulsion Stage), Aerojet Rocketdyne (Aerojet) (for RS-25 and RL-10 engines adapted to SLS requirements), and Northrop Grumman (for solid rocket boosters to help power the SLS). SLS has experienced cost growth of 43 percent for the Artemis I mission and 3 years of schedule delays from the initial target of November 2018 to November 2021.

Space Launch System

NASA Lead	NASA Lead Center	Cost as of FY 2020[b]
Exploration Systems Development, SLS Program Office	Marshall Space Flight Center	$17.2 billion

	Launch Schedule	Total Program Costs at Time of Launch[c]
Artemis I	November 2021	$19.8 billion
Artemis II	December 2023	$24.8 billion
Artemis III	December 2024	$27.2 billion

Proposed System Timeline

TD[d] | Formulation | Implementation

- **2010** TD begins
- **2011**
- **2012** SLS Program established/ funded
- **2014**
- **2015** Critical Design Review
- **Nov. 2021** Artemis I *Orion uncrewed test flight using Block 1*
- **Dec. 2023** Artemis II *Orion crewed test flight using Block 1*
- **Dec. 2024** Artemis III *crewed lunar landing using Block 1*
- **Dec. 2025** Artemis IV *crewed lunar landing using Block 1B*

Performance Capabilities

	Configuration	Maximum Thrust	Lift Capability	Destination
Initial Capabilities	Block 1	8.8 million pounds	70 metric tons	Orbit around the Moon and return to Earth
Improved Capabilities	Block 1B	8.8 million pounds	105 metric tons	Lunar surface
Sustained Capabilities	Block 2	11.9 million pounds	130 metric tons	To Mars and beyond

Technology Readiness Levels (the Program reports no new critical technologies)									
Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Core Stage								●	
Interim Cryogenic Propulsion Stage								●	
RS-25 Engines								●	
Solid Rocket Boosters								●	

[a] NASA released the SLS Program of the requirement to launch a science mission - the Europa Clipper - on the SLS rocket and therefore early SLS missions will be dedicated to supporting Artemis and lunar operations.

[b] Cost as of FY 2020 includes costs for multiple Artemis missions and is not confined to costs solely attributable to Artemis I.

[c] Total program costs at time of launch are the Program's total estimated expenditures by the time of the anticipated launch date and include development costs for future missions beyond Artemis III. These costs are based on total obligations from NASA's official accounting system (FYs 2012 through 2020), the FY 2021 Budget Operating Plan, and the FY 2022 President's Budget Request (FYs 2022 through 2025), rounded to the fiscal year end closest to the anticipated launch date.

[d] Technology Development (TD).

Orion Multi-Purpose Crew Vehicle

Orion will serve as the exploration vehicle that will transport astronauts beyond low Earth orbit, sustain the crew during space travel, and provide safe reentry from deep space return velocities. The Orion vehicle—built by prime contractor Lockheed Martin—has four major components, including a Launch Abort System; Crew Module; Service Module, composed of the NASA Crew Module Adapter and European Service Module; and Spacecraft Adapter. Originally conceptualized in 2005 under the now defunct Constellation Program, Orion has evolved to meet the needs of NASA's Moon and Mars missions. On December 5, 2014, the Orion first flew in space on a Delta IV rocket during the Exploration Flight Test–1; however, the test article did not include a functional service module or demonstrate an abort capability. The next flight planned is Artemis I, the first launch of the combined SLS/Orion system. This 22- to 25-day uncrewed mission, which was planned for November 2021, is over 3 years later than initially scheduled. Despite the slippage, Orion is proceeding with the production of crew capsules for later Artemis missions before the first mission is completed.

Orion Multi-Purpose Crew Vehicle

NASA Lead	NASA Lead Center	Cost as of FY 2020[a]
Exploration Systems Development, Orion Program Office	Johnson Space Center	$11.4 billion

	Launch Schedule	Total Program Costs at Time of Launch[b]
Artemis I	November 2021	$12.8 billion
Artemis II	December 2023	$15.5 billion
Artemis III	December 2024	$16.8 billion

Proposed System Timeline

Technology Development — Formulation — Implementation

2006 Program funded *(as Crew Exploration Vehicle under the Constellation Program)*

2010 Continuation of Orion after Constellation Program cancellation

2012 Transitioned to Orion Program

2014 Exploration Flight Test-1 launch

2015

2019 Ascent Abort Test-2 flight test

Performance Capabilities

	Number of Crew	Mission Duration	Habitable Volume	Docking Capability	Abort Capability	Life Support	Return Entry Velocity
Initial Capabilities *(Artemis I)*	0	21 to 42 days	316 cubic feet	None	Limited	Limited	+36,000 feet per second
Sustained Capabilities *(Artemis III and beyond)*	4	21 days	316 cubic feet	Gateway or Human Landing System	Full	Full	+36,000 feet per second

Technology Readiness Levels									
Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Launch Abort System								●	
Crew Module							●		
Crew Module Heat Shield							●		
Service Module							●		
Spacecraft Adapter							●		

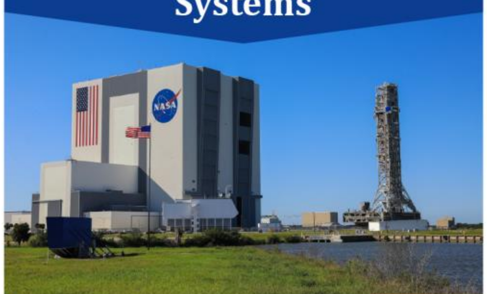
[a] Cost as of FY 2020 includes costs for multiple Artemis missions and is not confined to costs solely attributable to Artemis I. We did not include the costs for the period of 2006 through 2011 for Orion's predecessor under Constellation, the Orion Crew Exploration Vehicle. If added, the total cumulative cost as of FY 2020 would be $18 billion.

[b] Total program costs at time of launch are the Program's total estimated expenditures by the time of the anticipated launch date and include development costs for future missions beyond Artemis III. These costs are based on total obligations from NASA's official accounting system (FYs 2012 through 2020), the FY 2021 Budget Operating Plan, and the FY 2022 President's Budget Request (FYs 2022 through 2025), rounded to the fiscal year end closest to the anticipated launch date.

Exploration Ground Systems

The EGS Program is developing, modernizing, and upgrading the ground systems, software, and launch site infrastructure, and preparing the operations team to assemble, test, and launch the SLS and Orion Flight Systems and recover the Orion Crew Module. EGS is supporting the transformation of Kennedy from a historically government-only launch complex to a spaceport that can handle several different kinds of spacecraft and rockets—both government and commercial. The ground systems include the Launch Control Center, Vehicle Assembly Building, Mobile Launcher, Crawler-Transporter, and Launch Pad 39B, all of which are needed for the uncrewed Artemis I mission. In addition, a second Mobile Launcher is being built to accommodate the larger SLS Block 1B rocket.

Exploration Ground Systems



NASA Lead	NASA Lead Center	Cost as of FY 2020[a]
Exploration Systems Development, EGS Program Office	Kennedy Space Center	$4.2 billion

	Launch Schedule	Total Program Costs at Time of Launch[b]
Artemis I	November 2021	$4.8 billion
Artemis II	December 2023	$6.0 billion
Artemis III	December 2024	$6.5 billion

Proposed System Timeline

Technology Development — Formulation — Implementation

- **2010** New funding after transition to the Ground Systems Development and Operations Program *(previously the Constellation Program)*
- **2012**
- **2014** Preliminary Design Review
- **2015** Critical Design Review
- **2021** Artemis I launch

Performance Capabilities

	Launch Readiness Date	Mission	Type of Rocket/System	Launch Capacity
Initial Capabilities *(Mobile Launcher 1)*	November 2021	Artemis I, II, and III	SLS Block 1 configuration and Orion	Up to two per year
Sustained Capabilities *(Mobile Launcher 2)*	December 2025	Artemis IV and beyond	SLS Block 1B and 2 configuration and Orion	Up to two per year

Technology Readiness Levels (the Program reports no new critical technologies)

Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Vehicle Assembly Building									●
Mobile Launcher 1								●	
Crawler-Transporter									●
Launch Pad 39B								●	

[a] Cost as of FY 2020 includes costs for multiple Artemis missions and is not confined to costs solely attributable to Artemis I.

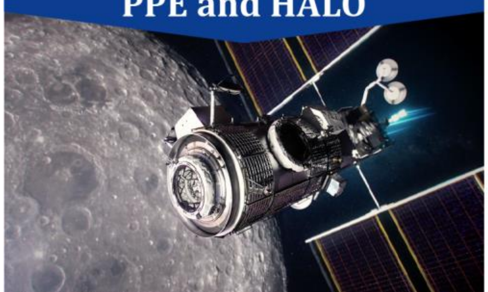
[b] Total program costs at time of launch are the Program's total estimated expenditures by the time of the anticipated launch date and include development costs for future missions beyond Artemis III. These costs are based on total obligations from NASA's official accounting system (FYs 2012 through 2020), the FY 2021 Budget Operating Plan, and the FY 2022 President's Budget Request (FYs 2022 through 2025), rounded to the fiscal year end closest to the anticipated launch date.

Gateway

The Gateway is a lunar orbiting outpost that will function as a small space station and support NASA's deep space exploration plans. The Gateway will not only act as a waystation for astronauts prior to embarking on missions to the lunar surface and beyond but will also provide opportunities for further scientific research and technology demonstration. While several elements are expected to be part of the Gateway once it is complete, the first two elements—the Power and Propulsion Element (PPE) and Habitation and Logistics Outpost (HALO)—will provide initial capabilities with the goal to support initial lunar landings.[a]

In May 2019, NASA awarded a contract to Maxar Technologies (Maxar) to develop and build the PPE, which will provide 60-kilowatt power generation, solar electrical and chemical propulsion, and communications capabilities as the foundation of the Gateway. Following that, NASA awarded a contract to Northrop Grumman in July 2019 to design the HALO, which will provide the Gateway with initial living and working space and additional life support systems. Though originally planned to be launched separately, NASA announced in February 2020 that the PPE and HALO will be integrated and launched together in a co-manifested payload through a commercial launch service provider in November 2023. In February 2021, the Agency announced that the co-manifested PPE and HALO would be launched on SpaceX's Falcon Heavy rocket no earlier than May 2024, though funding shortages have delayed the launch until November 2024.

Gateway – PPE and HALO



NASA Lead	NASA Lead Center	Cost as of FY 2020
Advanced Exploration Systems, Gateway Program Office	Johnson Space Center (Gateway, HALO), Glenn Research Center (PPE)	$703 million (Gateway) $299 million (PPE) $209 million (HALO)

	Launch Schedule	Total Program Costs at Time of Launch[b]
Co-manifested Launch of PPE and HALO	November 2024	$3.8 billion (Gateway) $683 million (PPE) $1.2 billion (HALO)

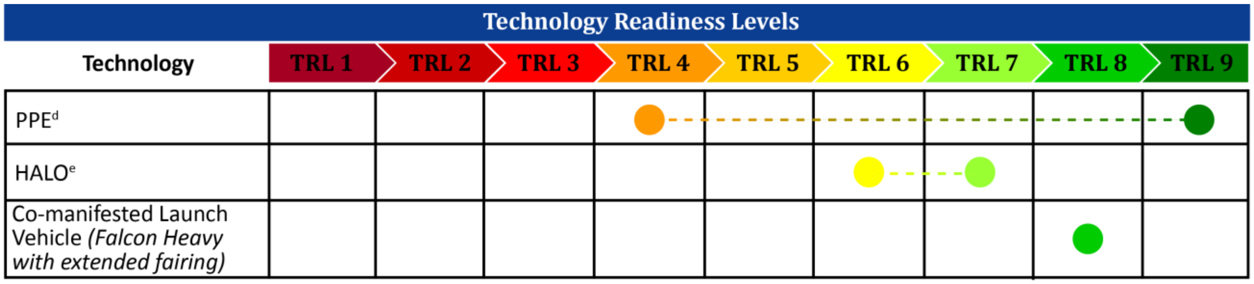
Proposed System Timeline

Technology Development | Formulation | Implementation

- **2018** PPE funded
- **Early 2019** HALO funded
- **Apr. 2019** Gateway Formulation Authorization Document approved
- **Mar. 2022** HALO Critical Design Review
- **Mid-2022** KDP-I/KDP-C (Apr.); PPE Critical Design Review (May)
- **2024** PPE delivered to HALO for integration at Kennedy Space Center (Sept.); Co-manifested launch of PPE and HALO (Nov.)
- **Sept. 2025** Gateway initial operating capability in NRHO[c]

Performance Capabilities

	Elements Involved	Crew Stay Duration
Initial Capabilities	PPE, HALO, Logistics Module	Up to 30 days
Sustained Capabilities	PPE, HALO, Logistics Module, International Habitat Module, ESPRIT Module, External Robotics, Airlock	Up to 90 days



[a] NASA has signed individual Memoranda of Understanding with the European Space Agency, Canadian Space Agency, and Japanese Aerospace Exploration Agency for each international agency to contribute towards an element of the Gateway.

[b] Cost as of FY 2020 and total program costs that reflect the Gateway are inclusive of all Gateway obligations such as Program, PPE, and HALO among others. Total program costs at time of launch are the Program's total estimate expenditures by the time of the anticipated launch date. These costs are based on total obligations from NASA's official accounting system (FYs 2018 through 2020), the FY 2021 Budget Operating Plan (or FY 2021 President's Budget Request for PPE and HALO), and the FY 2022 President's Budget Request (FYs 2022 through 2024), rounded to the fiscal year end closest to the anticipated launch date.

[c] Near Rectilinear Halo Orbit (NRHO).

[d] PPE module includes several critical technologies (e.g., Mission Processor, Roll-Out Solar Array, and Maxar/SSL 1300 Series bus) that range from TRLs 4 to 9.

[e] HALO module includes several critical technologies (e.g., Environment Control and Life Support System, element structure, flight avionics) that range from TRLs 6 to 7.

Human Landing System

NASA's HLS will be used to ferry astronauts from either the Orion or Gateway to the Moon's surface. In April 2021, NASA selected SpaceX for a contract to demonstrate its HLS Starship on a crewed lunar mission in 2024. After NASA's selection announcement, the two other HLS competitors that submitted proposals—Blue Origin and Dynetics—filed bid protests on that decision, which GAO denied on July 30, 2021, allowing NASA to continue executing its contract with SpaceX. All three competitors received initial design contracts, completing a Certification Baseline Review and Continuation Review evaluating the progress on each of those designs. Moving forward, SpaceX is planning to conduct a series of test flights in anticipation of the HLS demonstration mission, including an orbital test flight, in-space refueling test, and uncrewed landing of the HLS on the lunar surface. With SpaceX's proposal, a fuel depot will fly to low Earth orbit prior to the HLS launch where it will be filled with propellant from multiple tanker vehicles. After the HLS launches, it will then receive propellant from the depot before continuing its journey to the lunar Near Rectilinear Halo Orbit where it will receive the crew.

Human Landing System

NASA Lead	NASA Lead Center	Cost as of FY 2020
Advanced Exploration Systems, HLS Program Office	Marshall Space Flight Center	$577.8 million

	Launch Schedule	Total Program Costs at Time of Launch[a]
First HLS Demonstration	2024	$5.5 billion

Proposed System Timeline

Technology Development | Formulation | Implementation

- **2019** Program funded
- **2020** HLS initial contract; Continuation Review
- **2021** Option A selection
- **2022** KDP-C
- **2023** Uncrewed lunar landing
- **2024** First crewed demonstration mission

Performance Capabilities

	Number of Crew	Crew Staging Vehicle	Landing Sites	Surface Stay Duration
Initial Lander Demonstration Capabilities	2	Orion or Gateway	Lunar South Pole only	6.5 days
Sustained Service Capabilities	2 to 4 (mission dependent)	Orion and Gateway	Extended mission at Lunar South Pole or non-polar locations	TBD

Technology Readiness Levels[b]

Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Super Heavy Rocket Booster					●				
HLS Propulsion System						●	●		
Propellent Transfer/ Storage				●	●				
Space Communications						●	●		
Life Support System							●		

[a] Total program costs at time of launch are the Program's total estimated expenditures by the time of the anticipated launch date. These costs are based on the total obligations from NASA's official accounting system (FY 2020), the FY 2021 Budget Operating Plan, and the FY 2022 President's Budget Request (FYs 2022 through 2024), rounded to the fiscal year end closest to the anticipated launch date.

[b] TRL levels provided by SpaceX officials. Super Heavy rocket booster TRL will increase from 5 to 6 after the planned static fire test later in 2021.

Spacesuits

NASA has been developing Extravehicular Activity (EVA) technologies for space exploration missions since 2007, and originally planned to design, manufacture, and certify the Artemis III suits in-house. This included Exploration Extravehicular Mobility Unit (xEMU) spacesuits planned to be worn by astronauts for visits to the lunar surface during Artemis missions. The xEMU suits were designed to provide astronauts with critical life support and communications capabilities and protect them from the harsh lunar environment. These suits, along with Vehicle Interface and Flight Support Equipment and additional tools, comprised the three development areas of the Exploration Extravehicular Activity (xEVA) project within the Gateway Program. However, in April 2021, the Agency altered their acquisition approach for the suits, opting to instead utilize a commercial services approach to acquire EVA services for the ISS, Artemis, and other advanced programs. Similar to the commercial crew and cargo efforts, the approach will involve NASA paying for contractor-developed suits as opposed to building the suits in-house or purchasing the suits outright.

Spacesuits

NASA Lead	NASA Lead Center	Costs between FYs 2016-2020
Advanced Exploration Systems, Gateway Program Office	Johnson Space Center	$197.2 million

	Launch Schedule	Total Program Costs at Time of Launch[a]
Artemis III	December 2024	$794 million

Proposed System Timeline

Technology Development | Formulation | Implementation

2017
Program funded

2021
Gateway KDP-0 (April);
xEVA System Preliminary Design Review (October)

2022

2024
Deliver xEMU for Artemis III and International Space Station flight demonstration (December)

Performance Capabilities

	Flight Hardware	Suited Training Event *(supports NASA's training of crew on systems and development of EVA task content)*	Number of EVAs
Initial Capabilities *(ISS EVA Demonstration)*	Hardware for 4 crewmembers	60 events	TBD
Sustained Capabilities *(ISS EVA Service)*	Hardware for 10 crewmembers	80 events per mission plus 5 events per EVA	10 per year
Initial Capabilities *(Artemis EVA Demonstration)*	Hardware for 4 crewmembers	160 events	5 per mission
Sustained Capabilities *(Artemis EVA Service)*	Hardware for 4 to 8 crewmembers	160 events	5 per mission

Technology Readiness Levels[b]									
Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
xEMU Portable Life Support Subsystem					●				
xEMU Pressure Garment Subsystem					●				
Vehicle Interface to Suit Equipment Development				●					
Tools									●

[a] Total program costs at time of launch are the Program's total estimated expenditures by the time of the anticipated launch date. These costs are based on total obligations from NASA's official accounting system (FYs 2016 through 2020), the FY 2021 President's Budget Request, and the FY 2022 President's Budget Request (FYs 2022 through 2024), rounded to the fiscal year end closest to the anticipated launch date.
[b] For more information on individual spacesuit technologies, see *NASA's Development of Next-Generation Spacesuits* (IG-21-025, August 10, 2021).

Volatiles Investigating Polar Exploration Rover

NASA's VIPER will explore the extreme Moon environment in search of water ice and other potential resources. This mobile robot (or rover) is scheduled to land at the lunar South Pole region in late 2023 on an approximately 100-day mission to provide critical information on the origin and distribution of water on the Moon and will steer future approaches to harvesting in-situ resources for future human space exploration. Ames Research Center is the lead Center for VIPER, leading project management, science, systems engineering, rover flight software, and real-time rover surface operations. Johnson Space Center is responsible for the design of the rover hardware, while Ames Research Center, Kennedy, and commercial partner Honeybee Robotics provide the four VIPER instruments. NASA awarded a contract under Commercial Lunar Payload Services (CLPS) to Astrobotic Technology (Astrobotic) to deliver VIPER to the lunar surface. Subsequently, Astrobotic awarded a contract to SpaceX to provide the launch service.

Volatiles Investigating Polar Exploration Rover

NASA Lead	NASA Lead Center	Obligations as of August 2021
Planetary Science Division, VIPER Project Team	Ames Research Center	$169.7 million

	Launch Schedule	VIPER Lunar Mission Plus CLPS Delivery Costs[a]
VIPER Lunar Launch	Late 2023	$664.4 million

Proposed System Timeline

Formulation — Implementation

2019 VIPER funding begins

2020 Contract awarded to Astrobotic Technology (June); VIPER Preliminary Design Review (August)

2021 VIPER Key Decision Point C (February); VIPER Critical Design Review (October)

2023 VIPER launch (November)

Requirements To Be Met

The rover is required to survive an approximate 100 Earth-day mission (3 lunar days) to provide critical information on the origin and distribution of water on the Moon. Science results may steer future approaches to harvesting in-situ resources for future human space exploration. VIPER science mission requirements are derived from the planetary decadal study.

Technology Readiness Levels

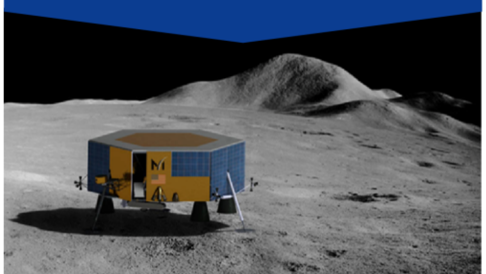
Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Near-Infrared Volatile Spectrometer System							●		
Regolith and Ice Drill for Exploring New Terrain							●		
Mass Spectrometer Observing Lunar Operations							●		
Neutron Spectrometer System							●		

[a] VIPER lunar mission plus CLPS delivery costs are based on NASA's Agency Baseline Commitment of $433.5 million for VIPER's life-cycle cost and the Exploration Science Strategy and Integration Office's delivery provider task order of $230.9 million (cumulative costs $664.4 million).

Masten Space Systems Commercial Lunar Payload Services Task Order

A key part of NASA's Artemis lunar exploration, CLPS facilitates an innovative, service-based, competitive acquisition approach that enables rapid, affordable, and frequent access to the lunar surface via a growing market of American commercial providers. By 2019, NASA had contracts with 14 companies that were eligible to bid on specific task orders for the delivery of science instruments and technology demonstrations. The NASA CLPS initiative plans for two lunar delivery task orders each year, and it selected Masten Space Systems for delivery of nine separately procured instruments, including MoonRanger—a small robotic rover that weighs less than 30 pounds—using Masten's XL-1 Lander to deliver to the Moon's South Pole in 2023. The lunar deliveries result from firm-fixed-price task orders competitively awarded under indefinite-delivery, indefinite-quantity contracts with a potential maximum value of $2.6 billion over a period of 10 years. NASA intends to continue issuing competitive task order solicitations for future payload deliveries from among the catalog of 14 CLPS vendors.

Masten Lunar Lander



NASA Lead	NASA Lead Center	Cost as of August 2021
Exploration Science Strategy and Integration Office, Commercial Lunar Payload Services	Johnson Space Center	$64.7 million

	Launch Schedule	Total Delivery Cost[a]
Masten Lunar Launch	November 2023	$79.5 million

Proposed System Timeline

- **2020** Task order funded (April)
- **2022** Thermal Models due (June)
- **2023** Landing (no later than December)

Performance Capabilities and Requirements	
Initial Requirements *(Landing Location)*	Land at lunar pole site within a landing ellipse of 100 meters in diameter that can maintain sunlight for at least 14 days after landing
Initial Requirements *(Mission Duration)*	Provide services to all NASA payloads for a 7-day minimum after landing
Initial Requirements *(Payload)*	Accommodate at least 80 kilograms of NASA payloads, power each payload at 28 volts of direct current, support payload wired communications using RS-422 communication interface, and provide both payload-specific thermal environments at least 6 months prior to planned payload delivery and a wireless router for MoonRanger
Initial Requirements *(Integration and Testing)*	Enable NASA to inspect all payloads after receipt and before integration onto lander, accommodate a NASA payload checkout during trans-lunar coast, and maintain environmental considerations after delivery and before launch
Initial Requirements *(Mission Operations)*	Enable remote and secure data access for payload teams, retain local storage caches on XL-1 lander until after valid confirmation and complete data receipt by NASA, allow for real-time payload command capability during planned communication windows, and provide real-time commanding windows to enable instrument checkout and operations

Technology Readiness Levels
(no new critical technologies reported for the Masten Lunar Lander)

[a] This does not include the Science Mission Directorate payload costs of $26 million.

APPENDIX D: ARTEMIS CONTRACTS

The commercial partners supporting Artemis are integral to the success of the mission. Below is information on major contracts by Artemis element as of August 2021. Table 4 provides a summary, including scope of work, required deliverables, performance period, contract type, contract value, and obligated amount.

Orion Multi-Purpose Crew Vehicle. The contractor responsible for building the Orion capsule is Lockheed Martin. The base contract, awarded in August 2006 under the now-defunct Constellation Program, was originally worth $3.9 billion. As of August 2021, the contract value had grown to $13.8 billion. NASA also awarded Lockheed Martin the follow-on production contract using a justification for other than full and open competition. The Orion Production and Operations Contract is currently worth $2.7 billion. Together these two contracts accounted for up to 77 percent of Orion's obligated funding for FY 2021.

Space Launch System. The value of the six major SLS element contracts is $20.4 billion. Boeing has the Stages contract and is currently negotiating the follow-on Stages Production and Evolution Contract, which was awarded sole source. Boeing is also working with United Launch Alliance on the Interim Cryogenic Upper Stage contract. Northrop Grumman is providing the SLS's Solid Rocket Boosters. Aerojet is providing the RS-25 engines under two separate contracts—one for the adaptation of Shuttle-era engines (RS-25 Adaptation) and another for production of new RS-25 engines (RS-25 Restart). In FY 2021, these six contracts accounted for $1.7 billion of obligated funding, or 70 percent of the total SLS Program obligations.[75]

Exploration Ground Systems. The contractor selected to design and build the second Mobile Launcher, which will support more powerful iterations of the SLS, is Bechtel. The cost-plus-award-fee, end-item contract is valued at $411 million. We previously reported on NASA incorporating lessons learned from the Mobile Launcher 1 development project into the contract for Mobile Launcher 2.[76] One of those lessons was utilizing a single contract to both design and build the Mobile Launcher in order to remedy communication and integration issues that occurred with the first Mobile Launcher project. As of August 2021, this contract accounted for 13 percent of EGS's obligated funding for FY 2021.

Human Landing System. The total base period contract value awarded to Blue Origin, Dynetics, and SpaceX—the three contractors originally selected to compete for the HLS demonstration—was $859 million, with 100 percent of that value obligated to date. With the selection of SpaceX to further develop and demonstrate its lunar lander, SpaceX's total HLS contract value increased significantly—from $139.6 million in the base period to $3 billion.

Gateway. Contracts for the first two major elements of the Gateway—PPE and HALO—were awarded in 2019 and have a combined value of $1.6 billion. These two elements comprise 45 percent of total funding spent in FY 2021 on all Gateway contracts. The $7 billion Gateway logistics services award includes multiple missions to and from the Gateway over a 15-year period and is available to other

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75 To learn more about the NASA OIG's audit work of the SLS Program contracts, see IG-20-012.

76 IG-20-013.

commercial providers once selected. Currently SpaceX is the only provider selected and has been guaranteed two missions. Awardees will be paid by the mission.[77]

Commercial Lunar Payload Services. CLPS contracts are indefinite-delivery, indefinite-quantity contracts with a cumulative maximum contract value of $2.6 billion through 2028. They are end-to-end delivery missions to the lunar surface. Included in Table 4 are three high-value CLPS missions: delivery of NASA's VIPER by Astrobotic, delivery of the Polar Resources Ice Mining Experiment-1 by Intuitive Machines, and a science and technology payload mission by Masten Space Systems. The total contract value of these three missions is $358 million, 14 percent of the $2.6 billion available.

Table 4: Summary of Major Artemis Contracts by System (as of August 2021)

Contractor	Contract	Deliverables	Performance Period	Contract Type[a]	Contract Value	Obligated Amount
Orion Multi-Purpose Crew Vehicle						
Lockheed Martin	Orion Development	Design, develop, test, and evaluate the Orion spacecraft; test laboratory program; software verification; and sustain engineering and operations support	9/6/06-3/31/23	Cost-plus-award-fee, cost-plus-incentive-fee, and IDIQ	$13.8B[b]	$13.6B
Lockheed Martin	Orion Production and Operations Contract	Production of 6 additional Orion capsules in support of Artemis III and future missions	6/5/19-9/30/30	Sole source; IDIQ, cost-plus-incentive-fee	$2.7B	$623.3M
Space Launch System[c]						
Boeing	Stages	Design, build, test, and evaluate 2 Core Stages, 1 Exploration Upper Stage, and test articles	11/1/12-12/31/25	Sole source; cost-plus-award-fee, cost-plus-incentive-fee, IDIQ, and firm-fixed-price	$9.2B	$7.8B
Boeing	Stages Production and Evolution	Produce 2 Core Stages and procure materials for 8 additional Core Stages and 8 Exploration Upper Stages	10/16/19-11/15/21	Sole source; under negotiation	$1.9B	$294.8M
United Launch Alliance; Boeing	Interim Cryogenic Propulsion Stage	3 Interim Cryogenic Propulsion Stages, 1 structural test article, and flight software	10/1/12-12/31/24	Sole source; firm-fixed-price, cost-plus-award-fee, and IDIQ	$954.4M	$613.3M
Northrop Grumman	Boosters[d]	Produce 35 booster segments and upgrade the boosters for future flights by replacing outdated parts	12/16/11-12/31/23	Sole source; cost-plus-award-fee, incentive-fee, fixed-fee	$4.3B	$4.0B

[77] To learn more about NASA OIG audit work of the Gateway Program contracts, see IG-21-004.

Contractor	Contract	Deliverables	Performance Period	Contract Type[a]	Contract Value	Obligated Amount
Aerojet	RS-25 Adaptation	Adaptation of 16 Space Shuttle-era RS-25 engines and development of new engine controller units used for communicating with the vehicle	12/1/11-9/30/20	Sole source; cost-plus-award-fee, cost-plus-incentive-fee, and IDIQ with fixed-fee	$572.7M[e]	$572.7M
Aerojet	RS-25 Restart	Restart production and certification of 24 new RS-25 engines	11/1/15-9/30/29	Sole source; cost-plus-award-fee and cost-plus-incentive-fee	$3.5B	$1.7B
Exploration Ground Systems						
Bechtel	Mobile Launcher 2	Design and construction of Mobile Launcher 2 with delivery by March 2023	7/1/19-6/14/23	Cost-plus-award-fee, end item; provisions to convert to firm-fixed-price once design is 90% complete	$411.1M	$407.3M
Human Landing System						
Blue Origin	A Landing System	Design and development of human landing system	5/13/20-8/23/21	Firm-fixed-price, milestone payments, and IDIQ	$479.7M	$479.7M
Dynetics	B Landing System	Design and development of human landing system	5/13/20-8/23/21	Firm-fixed-price, milestone payments, and IDIQ	$239.7M	$239.7M
SpaceX	C Landing System	Design, develop, test, evaluate, and demonstrate a human landing system	5/13/20-2/28/25	Firm-fixed-price, milestone payments, and IDIQ	$3.0B	$439.6M
Gateway						
Maxar	Power and Propulsion Element	Design, develop, test, manufacture, and demonstrate the power and propulsion element	5/23/19-12/31/27	Firm-fixed-price with IDIQ portion	$346.0M	$315.0M
Northrop Grumman	Habitation and Logistics Outpost	Design, develop, test, and manufacture the habitation module	7/31/19-6/17/26	Sole source; firm-fixed-price then cost-plus-incentive-fee through Preliminary Design Review; then firm-fixed-price	$1.3B	$377.7M
SpaceX	Logistics Services	Delivery of cargo to and from Gateway to support crewed missions	3/25/20-3/25/35	Firm-fixed-price and IDIQ	$7.0B	$56.4M

Contractor	Contract	Deliverables	Performance Period	Contract Type[a]	Contract Value	Obligated Amount
Commercial Lunar Payload Services						
Astrobotic	Commercial Lunar Payload Services—VIPER	Delivery of VIPER to the lunar surface	6/11/20-4/30/24	Firm-fixed-price and IDIQ	$230.8M	$83.8M
Intuitive Machines	Commercial Lunar Payload Services—PRIME-1	Delivery of PRIME-1 to the lunar surface by December 2022	10/16/20-1/31/23	Firm-fixed-price and IDIQ	$47.0M	$25.9M
Masten Space Systems	Commercial Lunar Payload Services	Deliver and operate 9 payloads of science and technology instruments to the lunar surface in 2022[f]	4/8/20-1/29/23	Firm-fixed-price and IDIQ	$79.9M	$64.7M
				Total[g]	**$50.1B**	**$31.8B**

Source: NASA OIG presentation of Agency information.

Note: Indefinite-delivery, indefinite-quantity (IDIQ); billion (B); and million (M). This table is not a comprehensive list of all Artemis-related contracts.

[a] Using a cost-plus approach, NASA approves all designs, manages all development and schedules, and owns the vehicle once delivered by the contractor. While the process gives NASA maximum control over the contractor's design and final product, the majority of cost, schedule, and outcome risks are borne by the federal government. An IDIQ contract refers to NASA's ability to issue an undefined number of task orders for services up to a specified amount of money. A firm-fixed-price contract provides a set price that does not change even if the contractor's costs increase during the performance period.

[b] The contract value for the Orion Development contract includes approximately $6.4 billion awarded under the Constellation Program which was canceled in 2010.

[c] The contract value represents SLS deliverables and excludes money spent on the Constellation Program.

[d] NASA originally awarded this contract to Alliant Technosystems, which merged in 2015 with Orbital Sciences Corporation to become Orbital ATK. In 2018, Orbital ATK was purchased by Northrop Grumman.

[e] This does not include approximately $277 million of funds spent in FY 2012 on the J-2X Engine in support of the SLS Program.

[f] The science and technology instruments for this CLPS mission are L-CIRiS, LETS, Heimdall, MoonRanger, Neutron Spectrometer System, MSolo, NIRVSS, LRA, and SAMPLR.

[g] Amounts are rounded. Total figures may not equal the sum of the rounded amounts

Appendix E: Management's Comments

National Aeronautics and
Space Administration

Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001

November 9, 2021

Reply to Attn of: Exploration Systems Development Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Exploration Systems Development Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of Artemis Missions" (A-20-008-01)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Management of Artemis Missions" (A-20-008-01), dated October 14, 2021.

NASA recognizes that the integration of Artemis, the focus on the Moon to prepare for Mars, is of critical importance. The Agency proactively identified that a restructure of the Human Exploration and Operations Mission Directorate (HEOMD) organization was necessary to ensure effective management of these strategic efforts. To that end, a new Directorate has been formed, the Exploration Systems Development Mission Directorate (ESDMD), led by Jim Free, to land the first woman and the first person of color on the surface of the Moon, and provide leadership nationally and internationally as we take these steps forward into deep space. Under this new focused structure, the Agency will be positioned to address the integration and management challenges, to include schedule, cost, and performance, represented by the OIG's findings and recommendations. NASA looks forward to providing updates on our progress in implementing the recommendations as we continue to move forward with the initial Artemis missions as the next step in human space exploration.

In the draft report, the OIG makes seven recommendations addressed to the Associate Administrator (AA) for ESDMD, one recommendation to the NASA Chief Engineer, and one recommendation to the NASA Deputy Administrator intended to increase accuracy, transparency, and safety of human spaceflight:

Specifically, the OIG recommends the following to the NASA AA for ESDMD:

Recommendation 1: Develop a realistic, risk-informed schedule that includes sufficient margin to better align Agency expectations with the development schedule.

Management's Response: NASA concurs with this recommendation. NASA is developing an integrated master schedule (IMS) for the Artemis missions that will include development and production schedule details from each program included in the mission that will be sourced from contractor schedules and data. Schedule Risk Assessments (SRAs) will be performed against the mission schedules to identify margin and risk-informed dates for Artemis missions. The results of the schedule assessments and program updates will be periodically codified in official planning updates to the Artemis mission dates and program baselines. The evidence of the implementation of this recommendation will be shown with the initial baselined Artemis mission planning dates as well as the Artemis mission IMS, including contractor-informed schedules from the programs and projects.

Estimated Completion Date: September 2022

Recommendation 2: Expand upon the existing draft Artemis IMS to include Artemis programs outside AES and ESD to properly align dependencies across directorates.

Management's Response: NASA partially concurs with this recommendation. NASA does concur that ESDMD/Advanced Exploration Systems (AES) will work with and include programs, projects, and other efforts across Mission Directorates in the Artemis mission IMS that have interdependencies with or constraints to defined Artemis mission content. NASA non-concurs with including all Artemis-related efforts that do not have an interdependency with a defined mission in an effort to preserve a logically linked and critical-path-driven master schedule that allows for analysis and clear distinction of content related to Artemis mission integration.

Estimated Completion Date: September 2022

Recommendation 3: Develop an Artemis-wide cost estimate, in accordance with best practices, that is updated on an annual basis.

Management's Response: Non-concur. NASA is already following best practices and Agency policy in providing cost estimates and commitments for Agency-approved programs and projects. These cost estimates and commitments have a defined set of content over a specific period which is a best practice and meets the standards required for cost estimating. This policy also aligns with estimates and commitments at a similar level to which funding is provided from Congress, which increases transparency. NASA does provide annually the President's Budget Request that includes the budget requirements for Artemis content with a five-year forward projection. Agency-approved programs and projects also establish cost estimates at their defined life cycles marked by Agency Key Decision Points (KDPs) and provide baseline commitments to their development costs and operations costs with already established reporting requirements. As Artemis is the campaign of the Agency's efforts towards lunar exploration, and not an Agency-defined program with a specific set of content or period of time, a cost estimate for Artemis would not be in accordance with best practices or provide additional transparency into specific development, production, and operation costs for programs and projects.

Estimated Completion Date: N/A

Recommendation 4: Maintain an accounting of per-mission costs to increase transparency and establish a benchmark against which NASA can assess the outcome of initiatives to increase the affordability of ESD systems.

Management's Response: Non-concur. NASA remains committed to transparency in its cost reporting practices that accommodate the unique nature of space exploration development projects and mission planning. Consistent with previous responses, NASA continues to maintain that it does not account, track, or report costs on a per-mission basis, precisely because doing so would reduce contractual transparency to key stakeholders.

NASA contracts are typically structured to align with the successful development and production of hardware that meets a specified series of requirements. Multi-mission programs are required to make decisions in the short term that may have longstanding implications for future missions, as ongoing development is required to enable necessary future capabilities. By benchmarking each contract against the development of a specific capability(ies), NASA programs are able to practically and efficiently track success metrics (e.g., Earned Value Management, award fee bases, etc.) regardless of changes to the mission manifest, requirements, launch availabilities, etc. Breaking out costs to align by mission may lead to inefficiencies in the tracking of these pivotal metrics and may disincentivize the flexibility needed for contractors to continue innovating through changes in budgeting and appropriations. As such, NASA categorically maintains that current accounting and reporting practices provide stakeholders the most transparency into forward mission planning and looks forward to continued engagement with the OIG to ensure these existing practices are carefully executed and reviewed.

Estimated Completion Date: N/A

Recommendation 5: Definitize outstanding Artemis-related contracts within 180 days in accordance with NASA FAR Supplement 1843.7005(a), *Definitization* (2018).

Management's Response: NASA concurs with the intent of this recommendation. The Center procurement offices are actively negotiating with the contractors to definitize the undefinitized contract actions (UCAs) and Letter Contracts. In order to reduce future reliance on UCAs and Letter Contracts, ESDMD's Strategic Integration Management Division (SIMD) and Exploration Systems Development (ESD) Division are undertaking analysis of past procurement action lead times to form recommendations for when to initiate pre-award activities ahead of schedule requirements. ESDMD plans to apply any lessons learned from ESD's analysis across the Mission Directorate.

Contract Procurement Statuses are reported as part of Directorate Program Management Council (DPMC) briefs on a quarterly basis. At the DPMC, prolonged definitization schedules will require explanation and resolution plans to be briefed to the Council. NASA's Office of Procurement (OP) also monitors the number and age of open UCAs and Letter Contracts in the Agency as part of the Baseline Performance Review. All UCAs over $100K must be approved by the Head of Contracting Authority. OP and

ESDMD have established a monthly tag up to discuss contract actions, including UCAs. NASA can only concur with the intent as NASA FAR Supplement 1843.7005(a) states: "The NASA goal is to definitize UCAs within 180 days from date of issuance." NASA does concur with working to meet the goal to definitize UCAs within 180 days from date of issuance and is actively ensuring processes are in place to meet that goal as described.

Estimated Completion Date: April 2022

Recommendation 6: Develop a realistic funding profile and schedule given the underfunding of HLS in FY 2021, the selection of one HLS award, and the desire to compete a sustainability contract for future lunar missions.

Management's Response: NASA concurs with this recommendation. The Human Landing System (HLS) has made significant progress to advance the Program and the goal of landing on the Moon in response to the provided funding in FY 2021. This progress has included an adjustment to the funding profile as demonstrated in the FY 2022 President's Budget Request, the selection of an awardee for the HLS for the initial lunar lander, awards for risk reduction and industry advancement of sustainable human lunar landers, and an acceleration of the procurement planning for lunar landing services. The HLS Program is proceeding to the Agency-level Key Decision Point-C (KDP-C) in 2022, which will include probabilistic cost and schedule risk assessments. From this KDP-C, an Agency Baseline Commitment to the cost and schedule of the initial lunar lander will be made as reflected in the HLS Program Plan. Evidence of NASA's implementation of this recommendation will be shown with the HLS KDP-C and Lunar Exploration Transportation Services (LETS) Request for Proposal (RFP) release.

Estimated Completion Date: August 2022

Recommendation 7: Identify measurable cost reduction targets for its ESD contractors.

Management's Response: NASA concurs with this recommendation. The Exploration Ground Systems (EGS), Space Launch System (SLS), and Orion programs are in the process of implementing a series of affordability initiatives that align with the ongoing transition from development to operations. These initiatives will take a multi-pronged approach at restructuring contracts (e.g., shifting contract vehicles, award fee policies, etc.), redefining NASA's insight/oversight model, and transitioning workforce as the programs transition from development to production and operations. The programs, in conjunction with their Centers and a Headquarters (HQ) Affordability Team, have focused on several key themes:

- Implementing alternative acquisition approaches. Examples: The Agency has released a Request for Information on possible new contracting structures (Exploration Production and Operations Contract) and is increasingly transitioning to Firm-fixed Price (FFP) structures (e.g., the SLS Interim Cryogenic Propulsion Stage hardware, Upper Stage Engines, and follow-on SLS Booster contract are FFP; Orion is currently transitioning its Cost Plus Incentive Fee contract to FFP; EGS is exploring opportunities for contract consolidation).

- Instituting process improvements. Examples: NASA is creating a new insight/oversight governance model through the restructuring of program boards and organizational structures; ESD Safety & Mission Assurance is pursuing risk-based assessments to assign an appropriate level of oversight to Government Mandatory Inspection Point (GMIP) requirements.
- Reducing production time cycles and facility footprints. Example: EGS has established facility reduction/divestment targets with Kennedy Space Center and is drafting facility cost-sharing plans, to be implemented in FY 2022.
- Reviewing requirements and specifications for streamlining, implementing lessons learned, and measuring technical performance against costs. Examples: For the SLS Boosters team, learning curve improvements reduced non-conformances by 76 percent; similarly, the SLS Core Stage team achieved a 52 percent reduction in discrepancies per 1,000 labor hours.
- Planning for sustainable workforce transition and utilization as requirements change and the programs transition from development to operations. Examples: Reductions have already occurred on several SLS teams (13 percent reduction in labor hours forecast from Core Stage 1 to Core Stage 2; on the RS-25 engines team, 45 percent reduction in touch labor cost, 59 percent reduction in support labor cost, and 28 percent reduction in nozzle and powerhead costs); EGS and Orion are tracking attrition and retirement rates expected upon completion of Artemis I and II missions; HQ workforce transition lead is performing ongoing analysis and planning in conjunction with the AES and Systems Engineering & Integration Divisions.

Initial work towards these initiatives has already begun. Each program has identified an affordability lead to work with relevant stakeholders. Additionally, structured board processes to evaluate/implement cost reduction initiatives have been established. In the near term, the individuals will work to establish metrics and schedule goals for the approaches mentioned above.

Estimated Completion Date: December 2022

NASA's Chief Engineer, in coordination with the HLS Program Manager:

Recommendation 8: Validate that the annual synchronization reviews meet the intent and expectations of the milestone reviews replaced by the tailored acquisition approach.

Management's Response: NASA concurs with this recommendation. The HLS tailoring approach was reviewed and endorsed by the Office-of-the-Chief-Engineer-chaired Program and Project Management Board (June 19, 2019) as a recommendation to the Agency Program Management Council (APMC), then presented to and approved by the APMC (June 24, 2019). Further details associated with all HLS Reviews, including KDP-C and the Annual reviews, will be defined in the Review plans and Terms of Reference. These products are developed by the HLS Program and reviewed by all Agency Technical Authorities. Technical Authorities' and, specifically, the HLS Program Chief Engineer's, involvement will ensure the tailored HLS approach meets the intent, expectations, and needs of milestone reviews for the HLS Program. NASA will demonstrate the implementation of this recommendation with the life cycle review portion of the Program Plan, which will be updated and approved at KDP-C.

Estimated Completion Date: August 2022

The NASA Deputy Administrator, in coordination with Mission Directorate Associate Administrators:

Recommendation 9: Codify the remaining governance structure such as the Federated Boards and Joint Directorate Program Management Council (DPMC).

Management's Response: NASA partially concurs with this recommendation. NASA concurs with the recommendation to codify the Joint DPMCs. NASA recognizes the value of multi-Directorate DPMCs and has recently conducted a joint DPMC with HEOMD (ESDMD/Space Operations Mission Directorate), Space Technology Mission Directorate, and the Science Mission Directorate for requirements definition, and will work to document the roles and responsibilities of future Joint DPMCs.

NASA non-concurs with the recommendation to codify the structure of the Federated Boards. The Federated Board was established to be a strategic coordination forum and not a decisional governance body and is currently operating in that manner. Agency governance structure follows Agency policy documentation which establishes decisional meetings in the form of Control Boards and Councils of which the Federated Board is not a part. Additionally, the Federated Board is being reevaluated in the context of the new leadership personnel that have joined the Agency and the reorganization of HEOMD into two new Mission Directorates.

Estimated Completion Date: February 2022

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have not identified information that should not be publicly released.

Once again, thank you for the opportunity to review and comment on the subject draft report. If you have any questions or require additional information regarding this response, please contact Kelly O'Rourke on (202) 358-1635.

Free, James M. (HQ-AA000) Digitally signed by Free, James M. (HQ-AA000) Date: 2021.11.09 08:53:38 -05'00'	RALPH ROE Digitally signed by RALPH ROE Date: 2021.11.09 15:53:30 -05'00'
James Free	Ralph Roe, Jr.

Appendix F: Report Distribution

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(Assignment No. A-20-008-01)