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NASA's Management of the Orion Multi-Purpose Crew Vehicle Program

July 16, 2020

Report No. IG-20-018

Office of Inspector General

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RESULTS IN BRIEF

NASA's Management of the Orion Multi-Purpose Crew Vehicle Program

July 16, 2020 IG-20-018 (A-19-012-00)

WHY WE PERFORMED THIS AUDIT

Since 2006, NASA has been developing the Orion Multi-Purpose Crew Vehicle (Orion) to transport astronauts beyond low Earth orbit. With the announcement of the Artemis Program in May 2019, NASA set the ambitious goal of using Orion to return humans to the Moon by 2024. As of July 2020 Orion has flown three test flights but none with astronauts on board. The Orion Program is one-third of NASA's Exploration System Development Division, which is also overseeing development of a heavy-lift rocket known as the Space Launch System (SLS) and a ground and launch support program known as Exploration Ground Systems. The Orion vehicle is being built by prime contractor Lockheed Martin Corporation (Lockheed). In addition, a portion of the vehicle is being provided by the European Space Agency (ESA).

Artemis I—the first launch of the combined SLS-Orion system—is a planned 22- to 25-day uncrewed mission anticipated for November 2021, over 3 years later than initially scheduled. Artemis II will be the first crewed flight of the combined system and NASA has committed to a launch readiness date of no later than April 2023, but slippage in the Artemis I launch date likely will result in a delay of the Artemis II launch to August 2023. According to our estimates, by the time Artemis II launches the Agency will have spent $19 billion in development costs on Orion ($6.3 billion of which was spent on development of the crew vehicle under the predecessor Constellation Program). NASA plans to spend an additional $3 billion in production costs on the Orion Program by the time Artemis II launches, $2.2 billion of which will fall under a new contract with Lockheed for future Artemis missions signed in September 2019. Artemis III, which is included in this new production contract, will support the return of humans to the Moon in 2024. The total projected Life Cycle Cost for the Orion spacecraft through FY 2030 is $29.5 billion.

Given Orion's importance to NASA's human exploration plans, we examined the Agency's management of the program. Specifically, we assessed (1) the extent to which NASA is tracking and appropriately reporting overall cost goals; (2) whether NASA has met cost, schedule, and performance goals in readying Orion for Artemis I and Artemis II; (3) NASA's success in managing its development contract with Lockheed to control program costs; and (4) the program's efforts to increase affordability and efficiency. To conduct this audit, we observed on-going testing and assembly efforts at various locations; reviewed program information on cost and budget, management decisions, and contracts; and interviewed NASA and Lockheed personnel.

WHAT WE FOUND

We found that NASA's exclusion of more than $17 billion in Orion-related costs has hindered the overall transparency of the vehicle's complete costs. Both federal law and NASA policy call for a Life Cycle Cost estimate for all major science and space programs costing more than $250 million, and for the Agency Baseline Commitment (ABC) to be based on all formulation and development costs. The Orion Program received approval from the NASA Associate Administrator to deviate from those requirements, resulting in exclusion of $17.5 billion in Orion-related costs from fiscal year (FY) 2006 to FY 2030 due to the Agency's tailored approach to program management and cost reporting. Although these exclusions have been approved, the tailoring of these cost reporting requirements significantly limits visibility into the total amount spent on development and production efforts.

We also found that Orion has continued to experience cost increases and schedule delays. Since the cost and schedule baseline was set in 2015, the program has experienced over $900 million in cost growth through 2019, a figure expected

to rise to at least $1.4 billion through 2023. At the same time, the program's schedule for Artemis I has slipped more than 3 years, while the schedule for Artemis II has slipped 2 years. Additional delays are likely as both Orion and SLS complete development efforts for Artemis I in the next 16 months and prepare for Artemis II. Meanwhile, Orion is proceeding with production of crew capsules for future Artemis missions before completing key development activities, increasing the risk of additional cost growth and schedule delays as issues are discovered late in the development effort, potentially requiring costly rework.

Further, NASA's award fee practices have hindered the program's control of contract costs. Given the Orion Program's significant cost increases and schedule delays, we found that NASA has been overly generous with award fees provided to Lockheed. From contract inception in 2006 through January 2020, Lockheed received $740.9 million in award fees. We attribute these overly generous award fees to the subjective nature of award fee evaluations coupled with nebulous and dated criteria used by the program. The result, for both the Orion Program and frequently other NASA programs, is that adjectival ratings such as "Excellent" given to the contractor often do not accurately reflect performance shortfalls. At a minimum, we question $27.8 million in fees awarded to Lockheed from September 2006 to April 2015. In addition, we found the continued use of the "Award Fee for End-Item Contracts" clause can serve as a disincentive to contractor performance because of the second opportunity to collect unearned fees once the end-item (in this case, the Orion capsule) is delivered.

Finally, NASA has undertaken a series of development, production, and infrastructure initiatives aimed at reducing or controlling costs. These actions include modifications to the contract, award fee restrictions, new software development and cost data tracking initiatives, the use of incentive-fee and firm-fixed-price contracts, batch ordering, spacecraft component reuse, updated facilities, and reduction and consolidation of offices as development ends and production begins. While we view these initiatives as positive steps, most are in the early stages and the extent to which these initiatives will appreciably decrease Orion's costs is unclear.

WHAT WE RECOMMENDED

To increase the sustainability, accountability, and transparency of the Orion Program as it pursues the goal of landing astronauts on the moon by 2024, we recommended the Associate Administrator for Human Exploration and Operations Mission Directorate and the Deputy Associate Administrator for Exploration Systems Development, in conjunction with the Johnson Center Director, Johnson Office of Procurement, and Orion Program, (1) ensure total development and production contract costs currently not reported as part of the ABC baseline are included in quarterly financial status reporting to the Office of the Chief Financial Officer, OMB, and Congress, and (2) to the extent practicable, adjust the production schedules for Artemis IV and V to better align with the successful demonstration of Artemis II to reduce schedule delays associated with potential rework. To improve NASA's management of award fees, we recommended the Assistant Administrator for Procurement (3) ensure procurement officials minimize the availability of award fees when contract modifications and value increases are the result of shortcomings in contractor performance, and require documentation of the rationale for any award fees granted.

We provided a draft of this report to NASA management who concurred with each of our recommendations. We consider management's comments responsive for two of the three recommendations; as such, those recommendations will be closed upon completion and verification of the proposed corrective actions. In its response to Recommendation 1, management stated Orion will include ABC, production and operations, and post-Artemis II costs in regular OCFO reporting starting with the first quarter of fiscal year 2021. However, we find this action only partially responsive because management further stated that it will only include in its financial reporting costs pertaining to the current Orion Program of Record, which excludes Constellation Program costs incurred under the same development contract. We acknowledge that it may not be practicable to include the $6.3 billion in sunk costs associated with Orion development under the Constellation Program when evaluating the program's tracking of ABC costs against the Congressional notification thresholds. However, in our judgment a complete picture of Orion's Life Cycle Costs should include all costs related to the program regardless of funding source or management control over its planned lifespan. Therefore, this recommendation is unresolved pending further discussions with the Agency.

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Acronyms

ABC	Agency Baseline Commitment
DDT&E	Design, Development, Test, and Evaluation
ESA	European Space Agency
ESD	Exploration Systems Development
FAR	Federal Acquisition Regulation
FDO	Fee Determination Official
FY	fiscal year
GAO	Government Accountability Office
ISS	International Space Station
KDP	Key Decision Point
NFS	NASA FAR Supplement
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
OMB	Office of Management and Budget
OPOC	Orion Production and Operations Contract
ORCA	Orion Risk and Cost Assessment
OTB	Over Target Baseline
PEB	Program Evaluation Board
SLS	Space Launch System

INTRODUCTION

Since 2006, NASA has been developing the Orion Multi-Purpose Crew Vehicle (Orion) to transport astronauts beyond low Earth orbit. With the announcement of the Artemis Program in May 2019, NASA set the ambitious goal of using Orion to return humans to the Moon by 2024. While the program has flown three uncrewed test flights to date, as of July 2020 Orion has yet to fly with astronauts on board.

The Orion Program is one-third of NASA's Exploration System Development Division, which is also overseeing development of a heavy-lift rocket known as the Space Launch System (SLS) and a ground and launch support program known as Exploration Ground Systems.[1] The Orion vehicle—built by prime contractor Lockheed Martin Corporation (Lockheed)—has four major components: a Launch Abort System; a Crew Module; a Service Module composed of the NASA Crew Module Adapter and a European Service Module; and a Spacecraft Adapter. Orion is being assembled and tested at NASA's Kennedy Space Center (Kennedy) in Florida, Michoud Assembly Facility (Michoud) in Louisiana, and Plum Brook Station (Plum Brook) in Ohio. The Orion program office is located at Johnson Space Center (Johnson) in Texas.[2]

Artemis I—the first launch of the combined SLS-Orion system—is a planned 22- to 25-day uncrewed mission anticipated for November 2021, over 3 years later than initially scheduled.[3] Artemis II will be the first crewed flight of the combined system. The Agency has committed to a launch readiness date of no later than April 2023 for this mission but slippage in the Artemis I launch date will likely result in a delay of the Artemis II launch to August 2023.[4] According to our estimates, by the time Artemis II launches, the Agency will have spent $19 billion in development costs on Orion ($6.3 billion of which was spent under the predecessor Constellation Program). NASA plans to spend another $3 billion in production costs on the Orion Program by the time Artemis II launches, $2.2 billion of which will fall under a production contract with Lockheed for future Artemis missions signed in September 2019.[5] Artemis III, which is included in this new production contract, will support the return of humans to the Moon in 2024.[6]

Given Orion's importance to NASA's human exploration plans, we examined the Agency's management of the program. Specifically, we assessed (1) the extent to which NASA is tracking and appropriately reporting overall cost goals; (2) whether NASA has met cost, schedule, and performance goals in readying Orion for Artemis I and Artemis II; (3) NASA's success in managing its development contract

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[1] See Appendix A for details of the Program's organization.

[2] The European Service Module is being assembled in Bremen, Germany, and integrated with the Crew Module at Kennedy.

[3] Anticipated launch dates for Artemis I and II, as discussed throughout this report, are under review and as of May 2020 have not been formally approved by the NASA Administrator. In addition, these dates do not include the impacts of any work delays attributable to COVID-19.

[4] The planning date for Artemis II has slipped from November 2021 (a 2016 estimate) to August 2023 (as of May 2020).

[5] As of June 2020, Program financial data was only available through January 31, 2020. In addition, the financial data used in this report does not include any impacts of COVID-19.

[6] Artemis I and II are considered development flights. The September 2019 Orion Production and Operations contract is for production of spacecraft for Artemis III through VIII with the ability to order up to six additional missions (Artemis IX through XIV) under to-be-negotiated firm-fixed price orders.

with Lockheed to control program costs; and (4) the program's efforts to increase affordability and efficiency. See Appendix B for details on the audit's scope and methodology.

Background

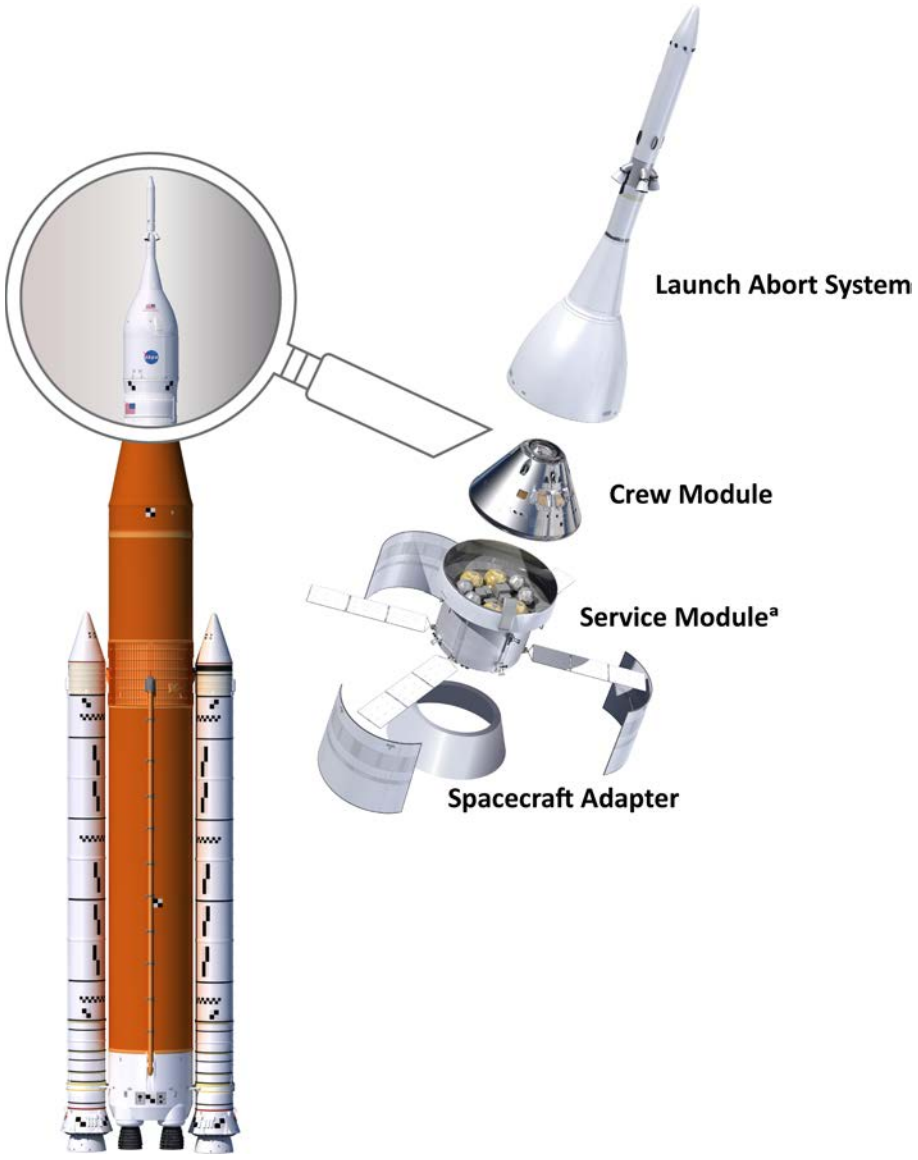
For decades, NASA has been working toward the goal of landing humans on Mars. The Artemis Program intends to set the stage for achieving this by returning humans to the Moon in 2024 and creating a sustainable presence there by 2028, with the ultimate goal of human exploration of Mars in the 2030s. Orion will serve as NASA's exploration vehicle for these missions, carrying crew beyond low Earth orbit, sustaining and supporting up to four astronauts during in-space operations, and providing safe re-entry, descent, and landings on Earth. Orion is composed of the Launch Abort System; Crew Module; Service Module; and Spacecraft Adapter. The European Space Agency is supplying its portion of the Service Module for the Artemis I and Artemis II missions.[7] The Launch Abort System sits atop the crew capsule and includes a fairing that covers the Crew Module during launch. The Launch Abort System can ignite a rocket to propel the Crew Module away from the SLS rocket beginning in the five minutes prior to launch through approximately three minutes after launch. A heat shield on the underside of the Crew Module will protect the crew during re-entry to Earth.[8] The European Service Module will provide the Crew Module system power via solar panels, carry life support supplies, and provide in-space propulsion.[9] The Spacecraft Adapter connects the vehicle to the launch system (see Figure 1).

[7] The European Space Agency is building the European Service Module for the first two Artemis missions as part of a barter agreement in order to satisfy its share of operating costs for the International Space Station (ISS).

[8] A Crew Module reentering Earth's atmosphere from a lunar mission is estimated to reach velocities of approximately 11 kilometers per second. In comparison, low Earth orbit reentries from the ISS occur at roughly 7 to 8 kilometers per second.

[9] The European Service Module's solar array spans 19 meters (about 62 feet) and provides enough electricity to power two households.

Figure 1: Orion Components (with SLS launch vehicle)



Source: SLS and Orion Programs.

[a] The Service Module is comprised of the European Service Module and the NASA Crew Module Adapter.

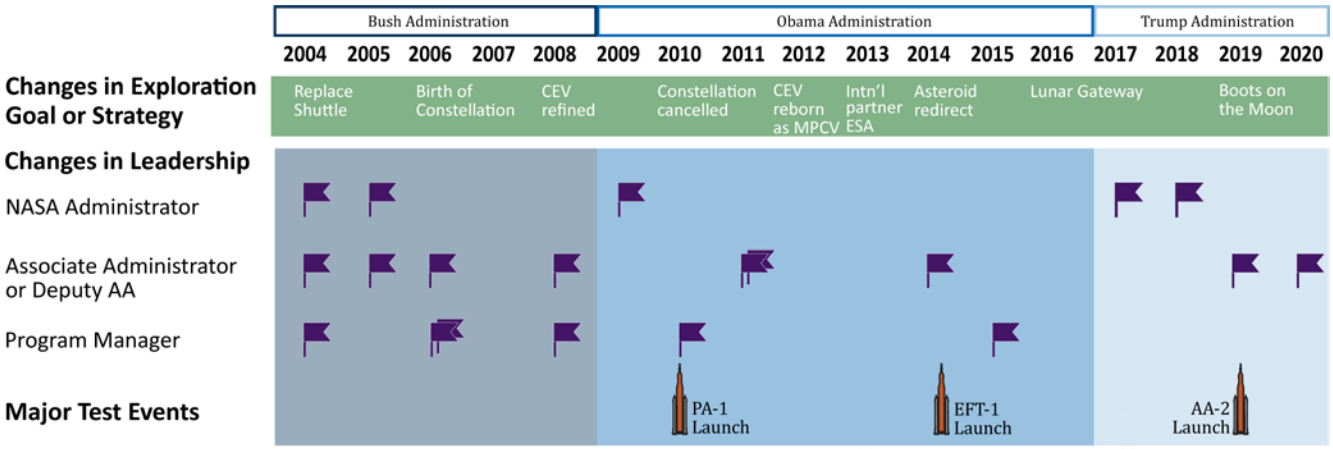
Orion Program Overview and Mission Update

NASA Authorization Acts and Congressional Direction

Since Orion's inception almost 15 years ago, NASA has transitioned through significant changes in the Agency's exploration goals and priorities that have resulted in fluctuating requirements and destinations for the spacecraft. The changing requirements associated with these programmatic directives—from

docking with the International Space Station (ISS) to rendezvousing with an asteroid, and most recently to return to the surface of the Moon by 2024—have created significant challenges for the program. Figure 2 summarizes changes in exploration goals, strategies, and leadership since 2004.

Figure 2: Orion Leadership and Programmatic Changes from 2004 to Present



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

Notes: CEV – Crew Exploration Vehicle; MPCV – Multi-Purpose Crew Vehicle; Deputy AA – Deputy Associate Administrator; PA-1 – Pad Abort Test-1; EFT-1 – Exploration Flight Test-1; AA-2 – Ascent Abort Test-2.

Pad Abort 1 (PA-1) launched May 6, 2010, at White Sands Missile Range, New Mexico. PA-1 was the first fully integrated flight test of the Launch Abort System being developed for the Orion crew exploration vehicle under the Constellation Program.

Development of the Orion spacecraft has spanned four major programs since 2004. Orion began as the Crew Exploration Vehicle in 2006 under the Constellation Program, transitioned to the Multi-Purpose Crew Vehicle in 2012, became part of the Asteroid Redirect Mission in 2014, and most recently was adopted for the Artemis Program in 2019.

- *Crew Exploration Vehicle.* The Orion Multi-Purpose Crew Vehicle (Orion) is an outgrowth of NASA's defunct Constellation Program. The Constellation Program was established in response to the NASA Authorization Act of 2005, which directed NASA to "develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce, and U.S. preeminence in space." [10] Conceptualized in 2005, the Orion Crew Exploration Vehicle was intended to provide astronaut transportation beyond low Earth orbit after the Space Shuttle's retirement and include capabilities such as rendezvous and docking with the ISS. The Agency spent about $6.3 billion on the Orion Crew Exploration Vehicle before the Constellation Program was cancelled in February 2010. At the time of its cancellation, the

[10] The Constellation Program called for the development of a crew exploration vehicle, crew launch vehicle, and heavy-lift launch vehicle to facilitate a return to the Moon as a stepping-stone to future exploration of Mars and other destinations. NASA Authorization Act of 2005, Pub. L. No. 109-155, (December 30, 2005).

Orion Crew Exploration Vehicle had completed Formulation through Preliminary Design Review but had yet to officially commence final design and fabrication.[11]

- *Multi-Purpose Crew Vehicle***.** When Constellation was cancelled, Congress passed the NASA Authorization Act of 2010 requiring the Agency to use, to the extent practicable, its existing contracts, investments, workforce, and capabilities to enable NASA to perform missions beyond low Earth orbit.[12] To this end, the Agency leveraged the existing resources of the Crew Exploration Vehicle—including the original development contract with Lockheed—to begin developing the Orion Multi-Purpose Crew Vehicle. The Act also set the goal of achieving full operational capability for the vehicle by December 2016.[13]

  After cancellation of Constellation, NASA adjusted its development strategy for Orion from an approach that focused on designing the crew vehicle for a specific mission to an approach focused on developing a set of general capabilities. The intent was to make the Orion spacecraft multi-purpose and destination-agnostic in order to manage the impact of requirement and directive changes (see Figure 2) that had historically contributed to cost and schedule increases.

- *Asteroid Redirect Mission*. From 2014 to 2017, the Orion mission consisted of goals relating to the Asteroid Redirect Mission in which a robotic vehicle would visit a near-Earth asteroid with the goal of returning a small asteroid or part of a large asteroid to lunar orbit. Astronauts aboard the Orion spacecraft would then rendezvous with the captured asteroid mass in lunar orbit and collect samples for return to Earth. White House Space Policy Directive 1, issued in December 2017, ended development of the Asteroid Redirect Mission and refocused NASA efforts on Moon landings.[14]

Currently, Orion's mission is to ferry astronauts to and from a lunar lander or Gateway spacecraft in lunar orbit in support of the Artemis missions' objective to return humans to the surface of the Moon.[15] For the Artemis III mission in 2024, Orion may dock directly with a lunar lander in lunar orbit. For subsequent missions, Orion will dock with the Gateway and astronauts will then board a lunar lander in order to access the lunar surface.

[11] The purpose of the Preliminary Design Review is to evaluate the completeness and consistency of a program's preliminary design in meeting all requirements with appropriate margins, acceptable risk, and within cost and schedule constraints, and to determine the program's readiness to proceed with the program's detailed design phase. See Appendix C for further detail on NASA's Program Life Cycle.

[12] Public Law 111-267. "National Aeronautics and Space Administration Authorization Act of 2010." October 11, 2010.

[13] The NASA Authorization Act of 2010 outlined the minimum capability requirements of the multi-purpose crew vehicle. These minimum capability requirements include: 1) to serve as the primary crew vehicle for missions beyond low Earth orbit; 2) conduct regular in-space operations, such as rendezvous, docking, and extra-vehicular activities; 3) to provide alternate means of delivery of crew and cargo to the ISS, in the event other vehicles are unable to perform that function; and 4) the capacity for efficient and timely evolution, including the incorporation of new technologies.

[14] White House Space Policy Directive 1 was a change in national space policy that provides for a U.S.-led, integrated program with private sector partners for a human return to the Moon, followed by missions to Mars and beyond.

[15] The Lunar Gateway is conceived as a small spaceship, about the size of a studio apartment, in orbit around the Moon that will provide access to the lunar surface with living quarters for astronauts designed for 30- to 90-day stays, a lab for science and research, and docking ports for visiting spacecraft. Under current NASA plans, the Gateway will be assembled in space between 2023 and 2026 to provide a platform to study the lunar environment, gain deep space operational experience, and stage missions to the Moon and Mars.

In addition to programmatic changes, we have previously reported on funding instability as a major factor inhibiting successful and timely outcomes in NASA projects.[16] The Orion Program is no exception. Orion Program officials stated that they routinely struggle to execute projects in the face of unstable funding, both in terms of the total amount of funds dedicated to the program and the timing of when those funds are distributed. This funding instability—coupled with technical challenges and contractor shortcomings—has in turn contributed to management inefficiencies and poor cost and schedule outcomes.

Completed and Planned Missions

NASA planned four significant test events for the Orion Program between 2012 and 2023—Exploration Flight Test-1 (EFT-1), Ascent Abort-2 (AA-2), and the Artemis I and II missions—which will be followed by Artemis III, the planned Moon landing, in 2024.

Source: NASA

- EFT-1 was completed in December 2014.[17] The Agency launched this uncrewed mission from Cape Canaveral Air Force Station in Florida on a United Launch Alliance Delta IV rocket and completed a successful 4.5-hour two-orbit trip around Earth.
- AA-2 was completed in July 2019. NASA successfully launched a mock-up of the Orion to test the Launch Abort System, avionics, and communications systems. Originally scheduled for December 2019, NASA decided to accelerate this test by 6 months in order to take advantage of continued delays to Artemis I and provide engineers with critical abort test data to validate computer models of the spacecraft's Launch Abort System.
- Artemis I is an uncrewed test flight of the combined Orion/SLS system, anticipated for November 2021, that will fly 38,000 miles beyond the Moon to demonstrate the integrated spacecraft system before a crewed flight. The mission will also test Orion's heatshield at a high-speed re-entry. Because the test flight is uncrewed, systems-level tests for the Artemis I test flight do not include the environmental control and life

[16] Funding instability includes situations in which a project receives a different amount than planned or funds are disbursed on a schedule different from expected. Such instability can require deferring critical tasks or de-scoping or discontinuing lower priority tasks to keep project costs within a revised budget profile—actions that ultimately lead to cost increases and schedule delays. Conversely, a large influx of unplanned funding can also create challenges. See NASA OIG, "2019 Report on NASA's Top Management and Performance Challenges" (MC-2019, November 13, 2019). NASA OIG, "NASA's Challenges to Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012). NASA OIG, "NASA's Management of the Orion Multi-Purpose Crew Vehicle Program" (IG-16-029, September 6, 2016). See Appendix D for additional information on Orion funding challenges as compared to the Apollo missions.

[17] The United Launch Alliance flew EFT-1 on the Delta rocket using its own command and control software.

support system, waste management system, fire detection/suppression system, and a fully operational Launch Abort System.

- Artemis II—currently planned for August 2023—is a crewed test flight with equipment and supplies to support a four-person crew for up to 21 days. This includes oxygen and nitrogen gas (predominantly stored in the European Service Module) and sub-systems to manage their mixture for the cabin atmosphere in the Crew Module.[18] The Artemis II vehicle design also adds computer displays and controls for the crew to be able to monitor and operate the vehicle. The Artemis II Crew Module will have a galley for food preparation, a toilet, and storage area for food supplies and other equipment.

The second crewed flight of the Artemis Program is scheduled to take place approximately 14 months after Artemis II. The objective of Artemis III will be to support the first crewed lunar landing since Apollo 17 in 1972. As noted earlier, Orion's role in Artemis III will be to transport astronauts from Earth to a lunar lander or possibly the Gateway, orbiting the Moon and back.[19] The subsequent Artemis IV through Artemis IX flights are planned as lunar crew and cargo missions. Table 1 shows Orion's notional mission plan beginning with the Artemis I uncrewed test flight through lunar crew and cargo missions through 2029. Details for additional missions beyond Artemis IX have yet to be determined.

Table 1: Orion Mission Plan as of May 2020

Mission	Primary objective	Anticipated date
Artemis I	Uncrewed test flight	November 2021
Artemis II	Crewed test flight	August 2023
Artemis III	Crewed Lunar landing	October 2024
Artemis IV through IX	Lunar crew and cargo missions	2025 through 2029 (notional)[a]
Artemis X and beyond	TBD	TBD[a]

Source: NASA OIG presentation of program information.

Note: Launch readiness dates for Artemis I and Artemis II are under review. November 2021 is the internal launch date for Artemis I pending a final decision by HEOMD/ESD leadership.

[a] Notional launch plans indicate an Artemis IX mission launch for Summer 2029 even though at the time of our review no missions beyond Artemis VIII were under contract.

[18] Another system in the Crew Module filters carbon dioxide from the crew out of the cabin.

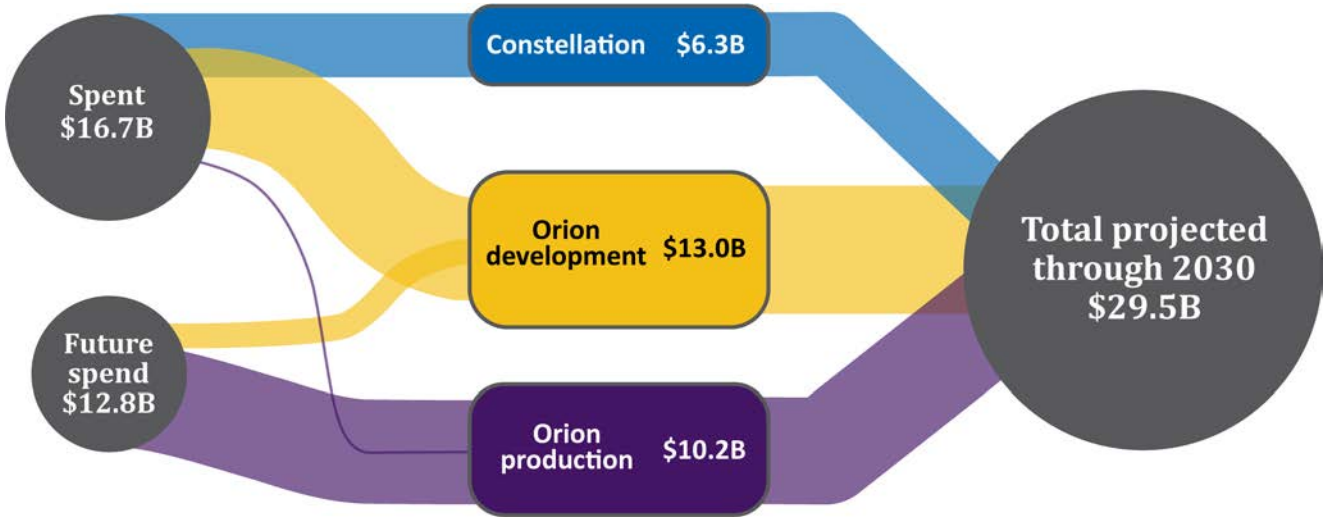
[19] On April 30, 2020, NASA awarded contracts to Blue Origin Federation, LLC, Dynetics, Incorporated, and Space Exploration Technologies Corporation (SpaceX) for design of a Human Landing System. At the end of the 10-month period, NASA plans to select up to two vehicles to fly demonstration missions.

Orion Contracts and International Agreement

Development and Production Contracts

Through January 2020, NASA spent $16.7 billion for the development of the Orion spacecraft, averaging about $1.1 billion annually, or about 6 percent of the overall Agency budget.[20] Figure 3 summarizes the spending on the program as of January 2020.

Figure 3: Orion Financial Summary as of January 2020



Source: NASA OIG presentation of program information.

Note: These figures do not include the cost of the European Service Module. Numbers are rounded. As of June 2020, program financial data was only available through January 31, 2020. In addition, the financial data used in this report does not include any impacts of COVID-19.

Development. Initiated as part of the Constellation Program, the Orion spacecraft development contract was awarded to Lockheed in August 2006 and has been updated through a series of modifications. The original contract value—$3.9 billion—was to fund a crewed mission to the ISS by no later than 2014, while the current $13.7 billion contract value funds development of the spacecraft through the Artemis II test flight targeted for August 2023.[21] This contract utilizes a combination of contract types: cost-plus-award fee for the Design, Development, Test, and Evaluation (DDT&E) portion of the contract; cost-plus-incentive-fee for a test lab program and software verification; and indefinite-delivery indefinite-quantity task orders for work such as sustaining engineering and operations

[20] The $16.7 billion through January 2020 includes $6.3 billion spent on Orion under the Constellation Program which was canceled in 2010.

[21] Based on the target launch date for Artemis II of August 2023, the Development contract (NNJ06TA25C) will require an extension of at least 8 months to incorporate one fiscal quarter of post-Artemis II flight data analysis. The financial impact of this contract extension was not yet quantified at the time of our writing.

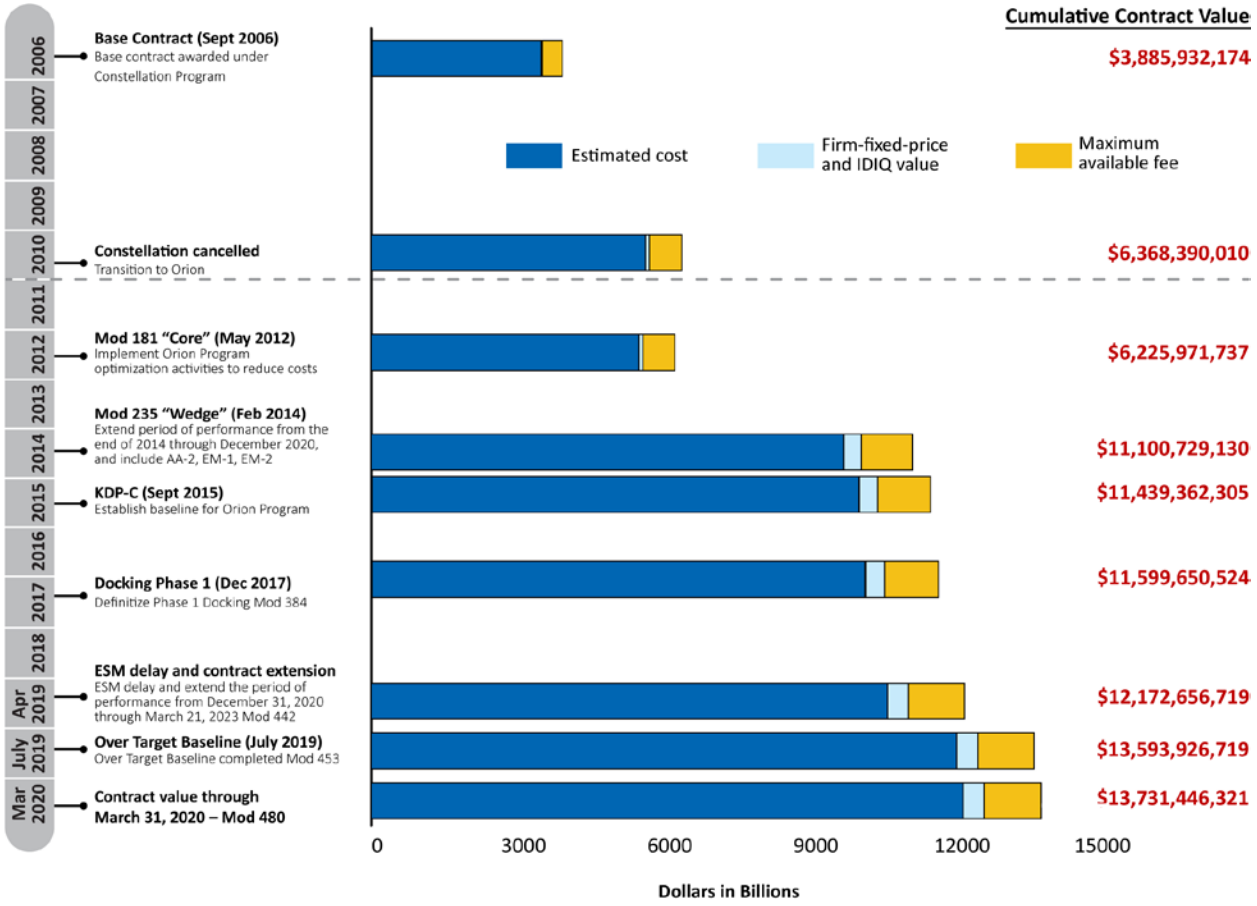
support.[22] Under this hybrid contract structure, NASA is required to reimburse Lockheed for all allowable costs and, in addition, pay applicable award and incentive fees. Award fees are based on a set period of performance or are paid in conjunction with completion of key milestones such as test flights (like EFT-1 and AA-2) and mission completion (Artemis I and II), while incentive fees are based on meeting targets for deliverables such as certifications and verifications.[23] Through March 2020, Lockheed had been paid $863 million in fees—91.4 percent of the total available—of which $352.1 million was for period of performance award fees, $388.9 million was for milestone award fees, and $122 million was for incentive fees.[24] Figure 4 provides a summary of the current contract value and major modifications to the contract from 2006 through March 2020.

[22] The DDT&E portion of the contract includes all design, development, test and evaluation activities to certify the EFT-1, Artemis I, and Artemis II vehicles as well as the production activities for the Artemis I and Artemis II flight vehicles. Cost-plus-award-fee and cost-plus-incentive fee contracts give NASA maximum control over the contractor's design and final product but the majority of the cost, schedule, and outcome risks are borne by the federal government. An indefinite-delivery indefinite-quantity contract allows NASA to issue an undefined number of task orders for services up to a specified amount of money.

[23] For the verification metric Lockheed must demonstrate continued progress toward meeting program verification requirements to support the Artemis I schedule.

[24] The available fee associated with the Orion DDT&E contract is split amongst three pools: 35 percent for period of performance award fee, 40 percent for performance milestone award fee, and 25 percent for performance incentive fee. The period of performance award fee facilitates the evaluation and billing process. The performance milestone award fee establishes milestones and dates associated with each milestone. The performance incentive fee establishes performance incentives with completion criteria and dates associated with each performance incentive.

Figure 4: Major Changes to the Orion Development Contract



Source: NASA OIG presentation of program information.

Note: IDIQ – Indefinite Delivery, Indefinite Quantity; EM-1 and-2 – Exploration Missions 1 and 2 are now renamed Artemis I and II; KDP-C – Key Decision Point-C; ESM – European Service Module.

Production. In support of the 2024 lunar landing (Artemis III) directive, in June 2019 NASA awarded Lockheed what is known as a "letter contract" designating $57.3 million to procure hardware for Artemis III.[25] The letter contract provided NASA additional time for ongoing negotiations on the final production contract while also supporting the production schedule for the Orion spacecraft. In September 2019, using a *justification for other than full and open competition*, NASA awarded Lockheed the Orion Production and Operations Contract (OPOC)—a follow-on production contract worth $4.6 billion for six Artemis missions (Artemis III through VIII), $2.2 billion of which is projected to be spent by August 2023 when Artemis II is slated to launch.[26] OPOC will support the production of the

[25] FAR 16.603-1 A letter contract is a written preliminary contractual instrument that authorizes the contractor to begin immediately manufacturing supplies or performing services. FAR 16.603-2(a) A letter contract may be used when (1) the Government's interests demand that the contractor be given a binding commitment so that work can start immediately, and (2) negotiating a definitive contract is not possible in sufficient time to meet the requirement. The value of the letter contract increased on June 18, 2019, to $478.3 million, and again on August 12, 2019, to the final value of $805.9 million.

[26] This justification provides the rationale for awarding the contract to Lockheed without competition. Other contractors did not have the opportunity to submit sealed bids or competitive proposals on this procurement.

Orion spacecraft, as well as sustaining engineering, flight operations support, and mission support packages to support up to 12 Artemis missions, with a minimum of six missions guaranteed.[27] OPOC is an indefinite-delivery indefinite-quantity contract with the first six missions being cost-plus incentive fee orders with the ability to order up to six additional missions (Artemis IX through XIV) under to-be-negotiated firm-fixed price orders. As of September 2019, Lockheed had authority to proceed with the first three missions, Artemis III through V, which are projected to cost an average of approximately $900 million for each Orion spacecraft, while missions VI through VIII (which include plans to reuse some components) are projected to cost an average $630 million each.[28]

Partnership with the European Space Agency

In addition to the Orion development and production contracts, NASA has a partnership with the European Space Agency (ESA) to provide the European Service Module as an offset to ESA's portion of operating costs for the ISS. ESA had previously offset ISS operating costs through the use of its cargo delivery spacecraft—the Automated Transfer Vehicle—which ferried supplies to the ISS. When ESA discontinued use of this spacecraft due to high costs and the desire to further the Agency's exploration goals, ESA agreed to provide the European Service Module for Artemis I and other hardware components for Artemis II to meet its obligation for common system operations costs.[29] While there have been significant delays in development of the European Service Module, the terms of this agreement have grown to include complete European Service Modules for Artemis I and II, with negotiations for the Artemis III European Service Module anticipated to be complete in summer 2020.[30] Contract negotiations between ESA and its prime contractor, Airbus Defence and Space, for the Artemis IV through VI European Service Modules are expected to be completed by fall 2020.[31]

[27] Mission support packages refer to potential spacecraft augmentations. To accommodate additional capabilities beyond those required for the initial crewed mission, the Orion may be augmented to meet the needs of specific missions.

[28] NASA will purchase missions in batches of three allowing the Agency to benefit from economies of scale.

[29] The fifth and final mission of the Automated Transfer Vehicle launched to the ISS in July 2014.

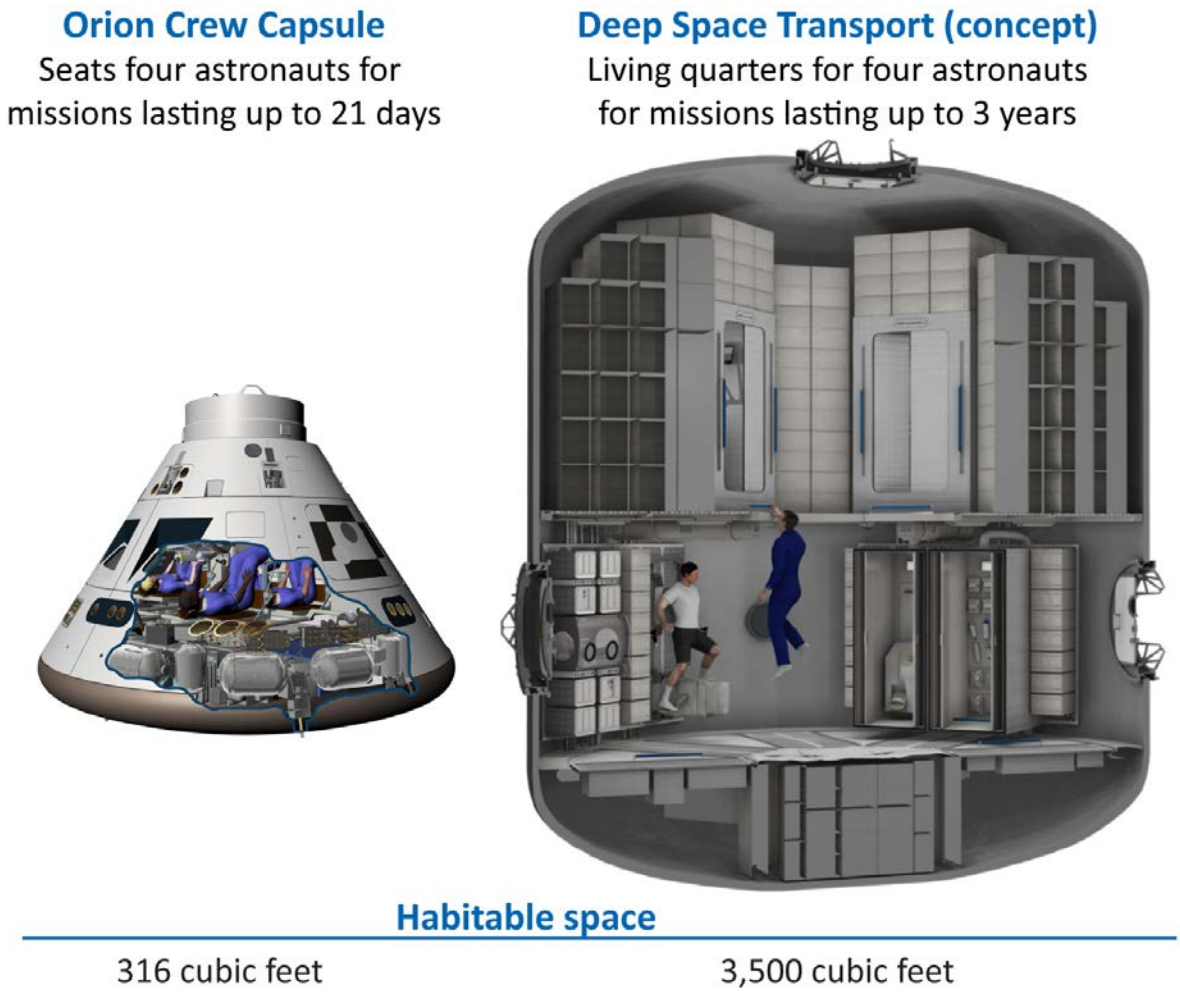
[30] The European Service Module main engine, the Orbital Maneuvering System engine, is a refurbished engine from NASA's Space Shuttle Program that will be replaced by new engine builds beginning with Artemis VI. The engine is provided by NASA to ESA as part of the barter agreement. NASA expects the new engine development contract to be awarded in late 2020.

[31] Airbus Defence and Space is headquartered in Ottobrunn, Germany; construction of the European Service Module takes place in Bremen, Germany.

Orion's Limited Utility as a Deep Space Vehicle

Orion's primary purpose is to provide crew transportation to and from the Moon's orbit. However, NASA plans to use Orion as the building block for future, crewed deep space missions. In this concept, Orion would be combined with habitation modules or additions to propulsion systems to extend the length of stay or broaden access to Mars or other deep space locations. The current crew module can accommodate up to four astronauts for 21 days in its 316 cubic feet of habitable space—similar in size to a minivan—and thus will not be suitable on its own for Mars missions. In contrast, NASA's notional Mars architecture, called Deep Space Transport—similar in size to a large two-bedroom apartment—will support a crew of four in 3,500 cubic feet of habitable space for a 3-year mission, with private and public crew spaces, a galley, medical and exercise systems, and research stations. Orion's involvement in a Mars mission would thus be limited to transport of astronauts to and from the Gateway at the beginning and conclusion of the mission. Figure 5 compares the Orion capsule to the Deep Space Transport and illustrates the additional space and equipment envisioned for a Mars mission.

Figure 5: Orion Interior Compared to Deep Space Transport's Habitation Module Interior



Source: NASA.

EXCLUSION OF MORE THAN $17 BILLION IN ORION-RELATED COSTS HINDERS TRANSPARENCY OF CREW VEHICLE'S LIFE CYCLE COST

Both federal law and NASA policy call for a Life Cycle Cost estimate for all major science and space programs costing more than $250 million, and for the Agency Baseline Commitment (ABC) to be based on all formulation and development costs.[32] The Orion Program received approval from the NASA Associate Administrator to deviate from those requirements, resulting in exclusion of $17.5 billion in Orion-related costs from fiscal year (FY) 2006 to FY 2030 due to the Agency's tailored approach to program management and cost reporting. Although these exclusions have been approved, the tailoring of cost reporting requirements significantly limits visibility into the total amount spent on development and production efforts.

Orion Program is Using a Tailored Approach to Cost Reporting

NASA is required to create, track, and report Life Cycle Costs and schedule commitments for any program with a budget exceeding a Life Cycle Cost of $250 million.[33] NASA policy further requires space programs to set a formal ABC at Key Decision Point C for cost and schedule after formulation is complete but before development begins.[34] Total ABC costs consist of past formulation costs and the estimated development costs to achieve operational readiness through Phase D.[35] ABC costs are used both internally and externally to help track a program's progress against specific scope and schedule assumptions. Once the ABC is set, a program tracks its status against the commitments and submits quarterly reports for review by NASA management, including the Office of the Chief Financial Officer, before sending the reports to Congress and the Office of Management and Budget (OMB). NASA also manages the cost and schedule of programs through its annual budget process, which reflects program and technical updates and changes during development.

Instead of following the standard requirement for setting the ABC based on all Life Cycle Costs and activities for the Orion Program, NASA tailored the ABC to only include costs related to Artemis I and II

[32] National Aeronautics and Space Administration Authorization Act of 2005, Pub. L. No. 109-155, 119 Stat. 2895 (2005) and NASA Procedural Requirements (NPR) 7120.5E *NASA Space Flight Program and Project Management Requirements* (2012).

[33] National Aeronautics and Space Administration Authorization Act of 2005.

[34] NPR 7120.5E. Key Decision Point C is a program milestone at which the Agency approves a project to begin implementation and baselines the project's official schedule and budget. See Appendix C for further detail on NASA's Program Life Cycle.

[35] Project Phase D includes system assembly, integration and test, and launch.

and a schedule based on the proposed Artemis II launch date.[36] Based on these limitations, in 2015 the Agency set the program's ABC at $11.3 billion, split between $4.5 billion in formulation costs and $6.8 billion in development costs, with Artemis II launch readiness expected by April 2023. This tailored approach meant that cost increases or schedule delays not directly attributable to Artemis I and II activities would not be tracked or reported to Congress and OMB through the ABC process.[37] NASA officials explained they used this approach because of the difficulty in estimating a full Life Cycle Cost for a long-term human exploration program that is likely to last for multiple decades. Table 2 summarizes ABC costs and status of the program through the second quarter of FY 2020.

Table 2: Orion Project Life Cycle, Development Costs, and Threshold for Notifying Congress

	Agency Baseline Commitment	FY 2020 Second Quarter Estimate	Congressional Notification
	Dollars in Millions		
Phases A & B (Formulation)	$4,515	$4,511	Not applicable
Phases C & D (Development Costs)	$6,768	$7,687	$7,783
ABC Life Cycle Costs	$11,283	$12,197	$12,299

Source: NASA OIG presentation of Orion Program information.

Note: Numbers are rounded. These figures do not include $6.3 billion in expenditures for the Constellation Program. These figures also do not include the cost of the European Service Module.

Over $17 Billion in Costs Not Captured in Orion Program Life Cycle Cost

As of March 2020, Orion's Life Cycle Cost estimate totaled $12.2 billion. Approximately $7.7 billion of this amount is for development costs (a 13.6 percent increase over the original $6.8 billion estimate as shown in Table 2)—a total that falls $97 million below the 15 percent increase in cost that would trigger a Congressional notification with roughly three years to go before the planned Artemis II launch.[38] Our review of Orion Program cost data found that significant expenses are not included in the tailored Life Cycle Cost of $12.2 billion and thus are either excluded from the quarterly ABC reports or are not fully represented in the annual budget process. In our view, this limits the transparency of program expenditures. We acknowledge that it may not be practicable to include certain costs—for example, sunk costs associated with Orion development under the Constellation Program—when evaluating the program's tracking of ABC costs against the Congressional notification thresholds. However, a complete picture of Life Cycle Costs should include all costs related to a program, regardless of funding source or management control, over its planned lifespan. As such, we have divided these non-ABC costs—which

[36] NASA policy allows for the formal tailoring of cost and schedule reporting requirements.

[37] Some of the costs are instead tracked as part of the annual Planning, Programming, and Budgeting Execution process.

[38] These cost estimates include contractor Management Reserve and government Unallocated Future Expenses. Management Reserve is an amount withheld for management control purposes rather than designated for the accomplishment of a specific task or set of tasks. Unallocated Future Expenses are costs that are expected to be incurred but cannot yet be allocated to a specific work breakdown structure sub-element of a program's plan.

total $17.5 billion—into four general categories: (1) Constellation Program; (2) post-Artemis II development; (3) other "non-life cycle"; and (4) production.[39]

- *Constellation Program Costs.* The Orion Program does not currently include in its cost reporting any of the $6.3 billion expended on the Orion Crew Exploration Vehicle under the Constellation Program even though the work performed under that contract from 2006 to 2011 served as the foundation for the current program. NASA was directed by Congress to utilize existing contracts when Constellation was cancelled; program officials state this saved approximately 18 months—the time it would have taken to recompete and award a new contract.[40] These costs were included in external reporting to the Office of the Chief Financial Officer, Congress, and OMB through June 2019, but were then removed. Program officials explained that the change in external reporting in 2019 was done because Constellation costs are publicly available elsewhere, and because the Constellation and Orion programs are two separate programs per an Agency decision made in 2012. However, in our judgment, since the Constellation work was essential to achieving current program goals, the $6.3 billion is relevant when calculating the total cost of Orion development.

- *Post-Artemis II Development.* The program is planning for an additional $819.6 million in development costs not included in the baseline related to missions beyond Artemis II. These include costs for development of key requirements such as docking, European Service Module Orion main engines, and other development costs and upgrades related to the spacecraft including vehicle thrust, optical communication, and propulsion. The program classifies development of these capabilities as "Mission Support Packages" in order to distinguish these efforts from costs that are directly related to baseline core vehicle development costs.

  The Orion spacecraft for Artemis missions III to V will cost on average nearly $900 million each—a cost that does not include the expense for development of the docking system or additional per-mission pricing for docking hardware.[41] NASA procurement officials explained docking requirements were too immature at the time the production contract was being negotiated to include docking as part of the spacecraft's base capabilities. In addition, they noted that Artemis II has no docking capability because the objective of the mission is a lunar fly-by.

- *Other "Non-Life Cycle" Costs.* The program has excluded approximately $181.5 million in other costs (summarized in Appendix E) that are also not reported as part of the program's Life Cycle Cost. Program officials told us they excluded these costs because they are tied to either missions after Artemis II or to requirements levied after the 2015 baseline was set. For example, over 40 percent of these costs ($75.6 million) pertain to avionics because the program accelerated the procurement of avionics for Artemis III in order to decrease schedule pressure and reduce reliance on avionics reuse from previous missions. Other smaller amounts are tied to activities such as Orion requirements changes driven by whether SLS will use the Interim Cryogenic Propulsion Stage or the Exploration Upper Stage, delayed billing and work under the

[39] This figure includes costs totaling $168.8 million for program integration and support at the Headquarters level that are excluded from Life Cycle Cost reporting by Program officials because the Orion Program does not manage or budget for these funds. These funds were also not included in the 2015 ABC baseline.

[40] Public Law 111-267, dated October 11, 2010 "National Aeronautics and Space Administration Authorization Act of 2010."

[41] Although the NASA Authorization Act of 2010 requires the Agency to use the vehicle to conduct regular in-space operations, such as docking and extra-vehicular activities, none of these capabilities are included as a base capability for Artemis III.

Constellation Program, and facility or Government shutdowns resulting from hurricanes or funding lapses.[42] In a more recent example, the Coronavirus (COVID-19) pandemic resulted in suspension of production and testing of SLS and Orion beginning in March 2020, with the cost and schedule impact of this suspension unknown.

- *Production Costs.* While NASA policy dictates that Life Cycle Cost typically includes production and operations in Phases E and F—which for Orion encapsulates missions beyond Artemis II—NASA's Associate Administrator approved the customized approach that excluded funding for these activities (which fall under the OPOC contract) from total Life Cycle Cost.[43] Therefore, these costs are excluded from ABC cost reporting, and are instead reported through the annual budget process. This approach understates the overall Life Cycle Cost of Orion by approximately $10 billion through FY 2030.[44]

In our judgement, reporting these cost categories as separate from the Life Cycle Cost—which includes both ABC and non-ABC costs—gives an incomplete picture of total program costs. Since only a portion of these costs are currently tracked through the established quarterly Life Cycle Cost reporting process, outside stakeholders are limited in their ability to track progress and determine whether a replan or rebaseline of program funding and schedule expectations is required. Furthermore, without a complete and comprehensive picture of Orion's Life Cycle Cost, it is difficult for Congress and other stakeholders to have the information necessary to inform strategic decisions regarding future human exploration priorities.

[42] The Interim Cryogenic Propulsion Stage is the second stage of NASA's Space Launch System that will be used to boost the first three Artemis mission into orbital attitude. Starting with Artemis IV, NASA plans for the Exploration Upper Stage to replace the Interim Cryogenic Propulsion Stage.

[43] NPR 7123.1B. *NASA Systems Engineering Processes and Requirements* (2013).

[44] We have reported on HEOMD Program decisions to limit the scope of the ABC in past reports: *NASA's Management of Space Launch System Program Costs and Contracts* (IG-20-012, March 10, 2020), *NASA's Management of the Space Launch Systems Stages Contract* (IG-19-001, October 10, 2018), and *NASA's Plans for Human Exploration Beyond Low Earth Orbit* (IG-17-017, April 13, 2017). During implementation of a project or program, NASA policy allows extended operations, such as any potential continuation of a satellite operation beyond the expected mission timeframe, to be excluded from Life Cycle Cost estimates. Past human exploration programs, like the Space Shuttle and ISS programs, are examples of long-duration programs that have extended operations beyond an initial mission.

ORION PROGRAM CONTINUES TO EXPERIENCE COST INCREASES AND SCHEDULE DELAYS

Since Orion's cost and schedule baseline was set in 2015, the program has experienced over $900 million in cost growth through 2019, a figure expected to rise to at least $1.4 billion through 2023. At the same time, the program's schedule for Artemis I has slipped more than 3 years, while the schedule for Artemis II has slipped 2 years. Additional delays are likely as both Orion and SLS complete development efforts for Artemis I in the next 16 months and prepare for Artemis II. Meanwhile, Orion is proceeding with production of crew capsules for later Artemis missions before completing key development activities, increasing the risk of additional cost growth and schedule delays as issues are discovered late in the development effort, potentially requiring costly rework.

Cost Overruns and Schedule Delays Continue as Development Approaches Completion

Lockheed's Performance Shortcomings Resulted in Program Costs Exceeding Target Baseline by over $1 Billion

Since the Constellation Program was cancelled and Orion became the Multi-Purpose Crew Vehicle in FY 2012, NASA has spent almost $10 billion (through FY 2019) on formulation and development with the Agency projecting to spend an additional $2.2 billion between FY 2020 and FY 2023 to complete development of Artemis II. To date, the program is reporting 13.6 percent development cost growth since the Orion Program baseline was established in 2015. Part of this cost growth is attributable to a July 2019 Over Target Baseline (OTB) adjustment that increased the total contract value by $1.4 billion.[45] The OTB incorporated $900 million in cost overruns incurred from 2015 to 2019 when Lockheed encountered technical challenges including valve design and procurement, display units, and flight software.

The OTB also included $520 million for expected cost growth based on additional work needed on the side hatch, Launch Abort System, software, and the spacecraft's life support and propulsion systems; and schedule margin for Artemis I (2 months), schedule margin for Artemis II (3 months), and replenishment of Lockheed's management reserves.[46] In a 2016 report, we found that Lockheed was expending its management reserves at a higher rate than both the program and the company expected and that, if continued, would deplete its reserve account almost a year before the planned launch of

[45] An Over Target Baseline (OTB) is a new performance measurement baseline resulting from failure to meet the original objectives.

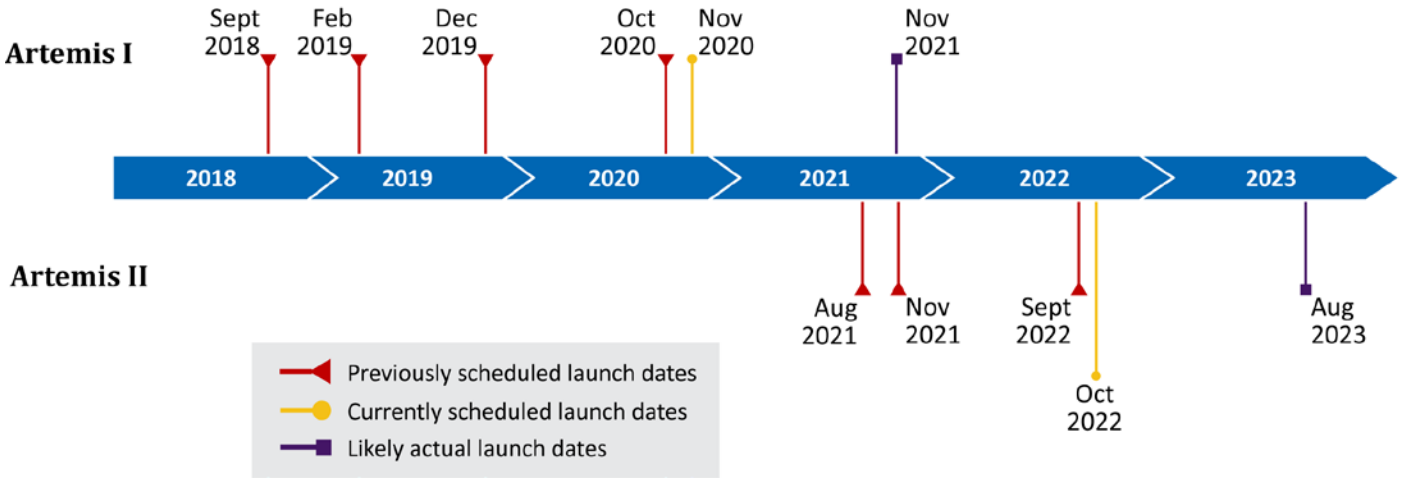
[46] Management Reserve is an amount withheld for management control purposes rather than designated for the accomplishment of a specific task or set of tasks. The Reserve is typically used when there is newly identified work, unanticipated redesign, remakes or retests, adjustments related to buying a component rather than making it in-house, and adjustments in labor or overhead rates.

Artemis I.[47] At that time, program officials acknowledged the depletion rate was high, but believed that if the reserve was depleted before the Artemis II launch, Lockheed could cover the costs or NASA could draw on other Agency funds. Contrary to that assumption, Lockheed's management reserves were depleted to such a degree as to require the OTB at least 28 months ahead of the planned Artemis I launch.[48]

Recent Schedule Slips Attributable to Launch Vehicle and European Service Module Delays

Since the baseline was set in 2015, Orion's schedule for Artemis I has slipped multiple times, from the original estimated launch of September 2018 to the recent estimate of November 2021—a cumulative 38-month delay.[49] In turn, the Orion schedule for Artemis II has slipped from August 2021 to the current anticipated launch date of August 2023—a 24-month change. This current launch date is four months past Orion's April 2023 baseline commitment date for launch readiness. (Figure 6 shows the history of launch date slips since 2015). Although Orion has experienced significant schedule delays, the program has continued to benefit from the more substantial delays experienced by the SLS Program. As we recently reported, the SLS core stage will not be ready in time for the currently scheduled November 2020 launch, and as such the Exploration Systems Development (ESD) division is now anticipating a launch in November 2021.[50] As a result, program officials do not expect that Orion will further impact the Artemis I launch date.

Figure 6: Orion Launch Dates History Since ABC



Source: NASA OIG presentation of program information.
Note: The 2015 baseline launch readiness date for Artemis II is April 2023.

[47] IG-16-029. We also reported NASA had not monitored the impact of this possibility on the Orion Program. We recommended that the Orion Program Manager designate and manage depletion of Lockheed's reserve as a cost risk to the Program. NASA was responsive to the recommendation and it was closed in January 2018.

[48] In anticipation of the pending OTB, the Orion program issued a contract modification in December 2018 to replenish Management Reserve 7 months before the OTB was finalized.

[49] SLS, not Orion, was the driver of the most recent 12-month slip from November 2020 to November 2021.

[50] *NASA's Management of Space Launch System Program Costs and Contracts* (IG-20-012, March 10, 2020). ESD's mission is to design and build the capability to extend human existence to deep space. The Enterprise consists of three Programs: SLS, Orion, and Exploration Ground Systems.

Delays in the Orion program can be primarily attributed to a 22-month slip in the European Service Agency's (ESA) delivery of the Artemis I European Service Module. ESA joined the program 2 years after Lockheed began working on the revamped spacecraft and faced challenges typical of a new development program. For example, ESA's prime contractor, Airbus Defence and Space, experienced supplier issues and test failures of valves in the propulsion system. As a result of these difficulties, the program is tracking a high risk of potential delays of 3 to 6 months to the Artemis II schedule.

According to program officials, Artemis II launch date slips are mostly attributable to delays for Artemis I. According to NASA, the program needs about 20 months between launches to integrate the re-used, non-core avionics from mission I to mission II. Moving forward, in order to reduce schedule dependencies and keep Artemis missions on track, program officials are planning not to reuse avionics between Artemis II and III.

Concurrent Development and Production Increases Risk

Orion is conducting qualification testing after the Artemis I spacecraft has been completed, which could result in additional cost and schedule delays if a technical issue is discovered that requires rework.[51] The program is also proceeding with production before finishing development, increasing the risk of additional cost growth and schedule delays as issues are discovered late in the development effort.

Concurrency of Qualification and Spacecraft Assembly on Artemis I and II Foreshadow Potential Cost Increases and Schedule Delays for Artemis III

Qualification testing formally verifies that a design meets the requirements. Traditionally, qualification testing is completed utilizing a dedicated flight test article between Critical Design Review and the vehicle's first flight.[52] The Orion Program, however, is following a qualification approach that uses multiple pieces of hardware—including the Artemis I flight vehicle, a structural test article, and an environmental test article—to complete qualification of the design prior to the launch of Artemis II.[53] This strategy dates to 2016, when program officials baselined an approach to rely more on qualification testing of components and subsystems in lieu of having a dedicated test article.[54] Instead, the Artemis I flight vehicle will be used to complete environmental testing. As changes and design upgrades are made from mission I to II and from II to III, qualification will be completed following the same approach.

[51] This is similar to the approach we found for the SLS Core Stage 1. In a 2018 report, we noted that the liquid fuel tanks for the Artemis I launch had already been constructed; however, a separate set of fuel tanks constructed for testing had yet to be shipped to Marshall for structural qualification testing. We concluded that any significant issues with these tanks identified during testing would necessitate modification of the tanks already constructed for the Artemis I launch, resulting in costly rework and delays. *NASA's Management of the Space Launch System Stages Contract* (IG-19-001, October 10, 2018).

[52] Qualification inspects and verifies the materials, design, performance, and long-term reliability of these systems. During the Critical Design Review, program officials determine if the integrated design is appropriately mature to continue with final design and fabrication.

[53] All components will be qualified prior to the Artemis II flight, but additional testing in the flight environment will continue for Artemis III and beyond.

[54] From 2012 to 2017, the Program addressed risks associated with earlier programmatic decisions to defer system level testing from Artemis I to Artemis II, and eliminate some additional testing from Artemis I. As part of the mitigation approach for these risks, Program officials adjusted the test plan to move testing from Artemis II to either Artemis I or the Structural Test Article in order to complete qualification of the Orion design earlier. The Orion Program began following the "distributed qualification approach," using multiple pieces of hardware as described, following Critical Design Review in 2016.

Table 3 highlights several of the key changes that will be made to Artemis II and III based on preceding missions in order to satisfy mission requirements and test objectives. These changes include robust launch abort and life support systems to support crew members on missions after Artemis I, as well as the addition of docking capability and enhanced propulsion capability needed for crewed lunar missions.

Table 3: Selected Spacecraft Changes from Artemis I to Artemis III

Mission profiles and vehicle specifications	Artemis I	Artemis II	Artemis III
Crew size	Uncrewed	Up to four astronauts	
Mission duration	21 to 42 days (no crew)	21 days (with crew)	84 days (with crew)
Docking capability	None		With the Gateway or a Lunar Lander[a]
Abort Capability	Does not include Launch Abort System with active abort capability	Includes fully active Launch Abort System	
Life Support	Partial pressure control of crew cabin and potable water system	Includes full pressure control, potable water, air revitalization, waste management, and fire detection and suppression systems, and flight crew equipment	
European Service Module Propulsion	Four tanks (two fuel, two oxidizer), almost 19,000 pounds of propellant, and heritage Shuttle engine for maneuvering	Artemis I capabilities plus valves and seals that are one-fault tolerant with additional measures of robustness	Artemis II capabilities plus upgraded thrust vector control
Return entry velocity	Over 36,000 feet per second		

Source: NASA OIG presentation of Orion Program information.

Note: This table includes selected spacecraft changes and is not an all-inclusive list of all differences between the missions.

[a] As of March 2020, NASA may not dock Orion with the Gateway for the Artemis III mission in 2024. Orion could instead dock directly with a lunar lander.

In the absence of a dedicated test article, the program is conducting component qualification tests at the same time as integrating Artemis I.[55] At the integrated system level, the program is implementing a testing approach called protoqualification (protoqual).[56] In the aerospace industry, protoqual is more commonly used for one-of-a-kind spacecraft such as a satellite that are to be launched without a flight crew. Therefore, in order to mitigate the risks of this testing approach, the program plans to complete integrated system level qualification after Artemis I using the Crew Module from that mission to qualify the module design at abort load levels for Artemis II.[57] Further, program officials will review test and other data from Artemis I flight instrumentation to identify which tests are required for protoqual of Artemis II.

[55] Integration is defined as the process by which flight systems or subsystems are assembled or otherwise interconnected.

[56] At NASA, protoqual testing is a variation of qualification testing that involves reduced test duration and levels from the baseline qualification test program.

[57] In aeronautics, a load factor is the ratio of the lift of an aircraft to its weight that measures the stress (load) on the structure of the aircraft. For the Orion spacecraft, the abort load level is the load factor anticipated in the event of an abort.

Program officials acknowledged the risks of this testing approach in 2014, estimating potential cost increases of $63 million and schedule delays of 6 months for Artemis I and II due to potential test failures and required design updates.[58] However, officials at the time reasoned that the risks were outweighed by the advantage of staying on schedule. Nonetheless, 6 years later these risks are being realized. For example, the Artemis I crew module experienced a 5-month schedule delay when the program discovered issues with avionics boxes during qualification testing, which resulted in several boxes being removed and reinstalled in the Crew Module three times as problems were addressed.[59] In another instance, between June 2018 and November 2019, the integrated Crew and Service Module experienced 8 months of schedule slippage due to European Service Module delays in hardware delivery and testing failures with the propulsion system.[60]

Production Contract Awarded Despite Incomplete Development Work

In support of the Artemis III mission objective to land on the Moon in 2024, NASA awarded the OPOC contract to Lockheed in September 2019. Stating that Lockheed had unique qualifications to perform production under OPOC, the follow-on contract was awarded without competition using a *justification for other than full and open competition*.[61] According to NASA, these qualifications, developed under the current development contract, uniquely positioned Lockheed to support effective, timely, and safe transition from development to initial production without substantial duplication of cost and schedule delay.

Artemis I integrated Crew and Service Module testing at Plum Brook

Source: NASA

As of March 2020, 23 of 58 risks the Orion program is tracking are linked to concurrent development and production activities, with a combined estimated cost threat of $52 million and schedule threats of up to 6 months.[62] Given these risks and the current average cost of $900 million per spacecraft, by the time additional capabilities such as docking are added, any issues discovered during qualification and testing over the next three years could increase the price of the spacecraft to more than $1 billion for Artemis missions III and IV.

[58] Officials estimated that the maximum cost impact of this decision could be as much as $100 million.

[59] According to Program officials, these delays had no effect on the Artemis I critical path.

[60] Ultimately a software workaround was identified for Artemis I, but a hardware change for Artemis II and subsequent missions was recommended by a team consisting of NASA, ESA, Airbus, and Lockheed personnel.

[61] This justification provides the rationale for awarding the contract to Lockheed without competition. Other contractors did not have the opportunity to submit sealed bids or competitive proposals on this procurement.

[62] These risks may be realized concurrently meaning that 23 risks with a schedule threat of up to 6 months each does not necessarily equal a total threat of 138 months. Excluding low likelihood risks with a probability of 25 percent or less, the combined estimated cost threat is $30.1 million with schedule threats of up to 6 months.

We found that concurrent development and production—similar to the program's protoqual testing approach—could exacerbate cost and schedule risks. Our analysis shows Orion will have already spent approximately $3 billion on production of spacecraft for Artemis III through V by the time the Artemis II mission launches. Moreover, program officials stated the minimum time required between Artemis I and II is 20 months, meaning that the baseline launch date of April 2023 for Artemis II launch readiness necessitates the Artemis I launch by August 2021. Since the current Artemis I launch date may be delayed until November 2021, this latest schedule slip puts a strain on NASA's schedule margin.

As of March 2020, a significant amount of work remains for Artemis I and II. The program is completing final integration and testing for the Artemis I Crew and Service Module; manufacturing of critical components for Artemis II continue; and Lockheed is in the early stages of building the spacecraft pressure vessel for Artemis III. Testing of the Artemis I integrated Crew and Service Module was completed at Plum Brook and returned to Kennedy in March 2020 and the spacecraft will be handed over to the Exploration Ground Systems Program in December 2020 for integration with the Launch Abort System and SLS. Meanwhile life support system and avionics component fabrication are underway for the Artemis II crew module, while the European Service Module is being assembled in Bremen, Germany with an anticipated delivery date to Kennedy of November 2020. Once received, the European Service Module for Artemis II will be mated to the NASA Crew Module Adapter and then integrated with the Crew Module in summer 2021.

NASA's Award Fee Practices Have Hindered the Orion Program's Control of Contract Costs

Given the Orion Program's significant cost increases and schedule delays, we found that NASA has been overly generous with award fees provided to Lockheed.[63] From contract inception in 2006 through January 2020, Lockheed received $740.9 million in award fees or 90.2 percent of the total fee available.[64] We attribute these overly generous award fees to the subjective nature of award fee evaluations coupled with nebulous and dated criteria used by the program. The result, for both the Orion Program and frequently other NASA programs, is that adjectival ratings—such as "Excellent"—given to the contractor often do not accurately reflect performance shortfalls. At a minimum, we question $27.8 million in fees awarded from September 2006 to April 2015. In addition, we found the continued use of the "Award Fee for End-Item Contracts" clause can serve as a disincentive to contractor performance because of the second opportunity to collect unearned fees once the end-item (in this case, the Orion capsule) is delivered.[65]

NASA Guidance Allows Significant Subjectivity for Final Award Fee Scores

The NASA FAR Supplement (NFS) best practice for award fee evaluations uses evaluation factors to determine the total award fee score. For example, the evaluation factors in the Orion contract are weighted by Technical (45 percent), Program Management (20 percent), Cost Management (25 percent), and Small Business/Small Disadvantaged Business Subcontracting Goals (10 percent).[66] At

[63] In accordance with Federal Acquisition Regulation (FAR) 16.305, a cost-plus-award-fee contract is a cost-reimbursement contract that provides for a fee consisting of a base amount fixed at inception of the contract and an award amount, based upon a judgmental evaluation by the Government.

[64] Lockheed received over $863 million in total fees; $122 million was for incentive fees separate and apart from the award fees. Although $740.9 million is 90.2 percent of the total fee available, it is noteworthy that Lockheed was awarded 95 percent of fee available in the first eight evaluation periods (Award Fee Period 1), and the maximum amount of 80 percent of fee available in the subsequent four interim periods (half of Award Fee Period 2)—a figure which could rise when the fee is finalized for all of Award Fee Period 2.

[65] The term "look-back" clause is commonly used by procurement officials in reference to the NFS 1852.216-77 *Award Fee for End Item Contracts* clause.

[66] *Technical performance* includes factors such as safety and mission assurance, requirements definition and flow down, risk management, margin management, innovation, and Life Cycle Cost; *Program Management* includes schedule management, subcontract management, responsiveness, innovation, Life Cycle Cost management, and corporate commitment to capital investments and personnel; *Cost Management* includes Earned Value Management System data using cost performance reports and other cost data sources; and *Small Business/Small Disadvantaged Business* is where the contractor's performance will be evaluated against contract goals. (Innovation is defined as measures that reduce cost, benefit schedule both from a current and future perspective, or result in improved design, coordination, or communication without adverse effects on performance, cost, or schedule.)

the beginning of an award fee evaluation, performance monitors score each factor from 0 to 100.[67] The numerical score for each factor is then multiplied by the weight for that factor to determine a weighted score. The weighted scores are then added to determine the total recommended award fee score for that evaluation period.[68] Once complete, the performance monitors present a recommended score to the Program Evaluation Board (PEB).[69] Next, the PEB evaluates the contractor's overall performance, considering the performance monitors' recommendations and other considerations, and presents their recommended score to the Fee Determination Official (FDO). The FDO considers the recommendation from the PEB as well as Agency-wide priorities and requirements, and has the final say regarding the overall award fee score for the period.[70]

We found that the final scores for the Lockheed contract were consistently higher than the composite of the individual factor scores. A review of the technical evaluations revealed Lockheed struggles with two areas in particular—program management (which includes schedule management) and cost management. For both evaluation factors, 8 of the 12 periods (from 2006 to 2019) contained scores below "Excellent." For example, in 2013 Lockheed received "Good" scores of 78 percent for program management and 76 percent for cost management due to the late delivery of critical items causing 5 to 6 months of schedule delays for EFT-1.[71] When Technical and Small Business/Small Disadvantaged Business Subcontracting Goals were evaluated, the total weighted score for the period was 83 percent. However, NASA treats the weighted scores as merely a starting point. In this example, as the award fee evaluation passed through multiple layers of review—from the performance monitors to the PEB, and ultimately to the FDO—the final award fee score increased by 8 percentage points to a final interim score of 91 percent, an "Excellent" rating.[72] In fact, for 11 of the 12 completed award fee evaluation periods, the final award fee score consistently increased by a range of less than 1 percent to 8 percent, maintaining "Excellent" ratings for Lockheed while, according to the performance monitor weighted scoring system, only 6 of the 12 evaluation periods rose to the level of "Excellent."[73]

According to NASA guidance, the FDO, who makes the final decision on the award fee, can increase award fees as long as there is rationale for the adjustment and this rationale is documented. Program officials explained award fee scores typically increase because performance monitors—who are most familiar with the day-to-day activities for the contract—do not take into account high-level issues that affect contractor performance such as an aggressive schedule or operating under a continuing funding

[67] The performance monitors, along with the Contracting Officer's Technical Representative, collectively make up the Program Evaluation Board Integration Team.

[68] NFS 1816.405-275 (d) "Award fee evaluation rating."

[69] The PEB is established by the Fee Determination Official. The purpose of the PEB is to evaluate the contractor's overall performance for the award-fee evaluation period and result in a recommended award fee score to the Fee Determination Official. The contractor also provides a self-evaluation for each evaluation period.

[70] On May 14, 2019, the NASA Assistant Administrator for Procurement issued Procurement Notice (PN) 19-01 which revises NFS 1816.405-273 to require an independent review of the award fee determination process for contracts over $1 billion.

[71] Program officials noted that from 2012 to April 2019, Lockheed's cumulative Cost Performance Index—a measure of the financial effectiveness and efficiency of a project—was 0.88, meaning that the total budget is 88 cents to every financed dollar. According to Program officials, this is considered "very good."

[72] This example in which the award fees score grew from an initial calculated score of 83 to an FDO-awarded final score of 91 was the most extreme instance of increasing scores that we evaluated. Excluding this instance, the average growth in award fee score from the performance monitor's initial calculated score to the final FDO-awarded score was just over 3 percent.

[73] Our calculations of the ranges of scores are based on the performance monitor-calculated scores rather than the recommended score to emphasize the subjective nature of the scoring process.

resolution. In addition, program officials noted other issues that affected Lockheed performance, such as the Service Module work that was transferred from Lockheed to ESA, and the additional complexity that comes with working with an international partner. Nonetheless, in our judgment the Agency's decision to award Lockheed 95 percent of the available award fees and deeming its work consistently "Excellent" appears overly generous given the program's longstanding cost and schedule growth.[74] At a minimum, we question $27.8 million of the $543.6 million in fees awarded from September 2006 to April 2015—the difference between the performance monitors' weighted score and the final score given to Lockheed—because in our assessment, the weighted score generally appeared to better reflect contractor performance.[75]

Imprecise and Outdated Criteria Allow for Inflated Award Fees

Because the Orion contract was issued almost 15 years ago, the program is often contractually "grandfathered" out of more restrictive award fee guidance that has been updated over time. In particular, the 2006 NFS provided the language that is used in the contract, which defines "Excellent" as "Of exceptional merit… very minor (if any) deficiencies…" However, from 2010 to date, the NFS deferred to the language in the FAR to provide adjectival ratings and associated numerical scores to include descriptions that are significantly more objective. "Excellent" is now defined as, "Contractor has exceeded almost all of the significant award fee criteria and has met overall cost, schedule, and technical performance requirements..." This updated language more closely resembles the individual weighted evaluation factors. Moreover, the NFS has consistently stated that in order to be rated ''Excellent,'' the contractor must be under cost, on or ahead of schedule, and have provided excellent technical performance. Table 4 outlines the updated FAR performance descriptions compared to language in the 2006 Orion contract. While NASA consistently rated Lockheed performance as "Excellent" under the prior FAR guidance, these ratings are even more questionable when compared to the revised performance standards.

[74] The Lockheed development contract is comprised of two award fee periods consisting of eight interim evaluation periods each. Award Fee Period 1 spanned from September 2006 to April 2015 and yielded a final score of 95 percent. Award fees paid to Lockheed since April 2015 are considered interim until the end of Award Fee Period 2 in March 2023.

[75] Historically, we have found NASA's award fee practices to be overly generous in light of programs' significant cost increases and schedule slippages, and in past reports have recommended reforms to ensure poor contractor performance is reported to the award fee rating officials. For example, our October 2018 audit of the SLS Stages Contract found flaws in NASA's evaluation of The Boeing Company's performance, resulting in NASA inflating the contractor's scores and leading to overly generous award fees. Considering the SLS Program's cost overages and schedule delays, we questioned nearly $64 million of the $323 million paid to Boeing in award fees. *NASA's Management of the Space Launch System Stages Contract* (IG-19-001, October 10, 2018). See Appendix F for details of the Questioned Costs. The performance monitors' average weighted score for evaluation periods 1 through 8 was 90 percent.

Table 4: Federal Performance Standards from 2006 and 2010

	2006 Criteria[a]	2010 Revised Criteria[b]
Excellent	Of exceptional merit; **exemplary performance** in a timely, efficient and economical manner; **very minor (if any) deficiencies** with no adverse effect on overall performance.	Contractor **has exceeded almost all** of the significant award fee criteria and has met overall cost, schedule and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award fee plan for the award fee evaluation period.
Very Good	**Very effective performance**, fully responsive to contract requirements; accomplished in a timely, efficient, and economical manner for most part; **only minor deficiencies**.	Contractor **has exceeded many** of the significant award fee criteria and has met overall cost, schedule and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award fee plan for the award fee evaluation period.
Good	**Effective performance**, fully responsive to contract requirements; **reportable deficiencies**, but **with little identifiable effect** on overall performance.	Contractor **has exceeded some** of the significant award fee criteria and has met overall cost, schedule and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award fee plan for the award fee evaluation period.
Satisfactory	**Meets or slightly exceeds minimum acceptable standards**; adequate results; **reportable deficiencies** with identifiable, but **not substantial**, effects on overall performance.	Contractor **has met** overall cost, schedule and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award fee plan for the award fee evaluation period.
Unsatisfactory	**Does not meet minimum acceptable standards** in one or more areas; remedial action required in one or more areas; **deficiencies** in one or more areas **which adversely affect** overall performance.	Contractor **has failed to meet** overall cost, schedule and technical performance requirements of the contract in the aggregate as defined and measured against the criteria in the award fee plan for the award fee evaluation period.

Source: NASA FAR Supplements (NFS) (NFS 1816.405-275 (b), October 1, 2005; NFS 1816.405-275 (b), October 1, 2011) and FAR (16.401, Table 16-1, October 14, 2009) excerpts with NASA OIG emphasis in bold.

Notes:

[a] The October 1, 2005 edition of the NFS was in effect until October 2006, one month after the Orion contract was signed.

[b] Prior to October 1, 2010, the FAR provided no language for adjectival ratings and associated numerical scores; this language was provided in the NFS.

Continued Use of "Look-Back" Clause May Disincentivize Contractor Performance

The Orion contract contains a clause, unique to end-item deliverable contracts, informally known as a "look-back" clause. This clause gives the contractor the opportunity to earn, in a final evaluation period, previously unearned award fees.[76] This practice is allowable under the NFS. NASA procurement officials have stated in the past that, for an end-item contract, interim evaluations are conducted to give contractors feedback throughout contract performance. Because development contracts for large programs can span many years, NASA also wanted the ability to go back and retrieve money if there was a product or performance failure. Essentially, the clause was developed as a way to protect NASA by ensuring that, regardless of how well a contractor performed throughout the contract, there was a way to penalize the contractor should the end-item fail during or after launch.

In October 2009, 3 years after the Orion contract was signed, the Civilian Agency Acquisition Council, in conjunction with the Defense Acquisition Regulations Council, revised the FAR to prohibit rollover fees.[77] This change was made because the councils found that the use of unearned award fee from one evaluation period to another evaluation period diminishes the effectiveness of the award fee rating given for a specific evaluation period, since the unearned award fee could be earned by the contractor in a subsequent period. Moreover, the councils found that "rollover" of unearned award fee does not incentivize contractors throughout the contract, and that instead, the use of "rollover" acts as a disincentive to a consistently high level of performance.[78]

In a 2013 report, we examined NASA's use of fees awarded as part of the "look-back" process, concluding that the fees are similar enough to the FAR-prohibited practice of rollover fees to warrant NASA's re-assessment of its practice of using them.[79] We recommended that NASA revise the NFS so that award fees not earned in a specific evaluation period were not available to contractors at the end of contract performance, or to use the end-item contract final evaluation only for downward adjustments following catastrophic events or failures. We suggested that, alternatively, NASA should

[76] NASA applies a clause unique to end-item deliverable contracts informally known as the "look-back" clause. The Agency developed the *Award Fee for End-Item Contracts* clause in response to negative publicity in the media and scrutiny from the OIG and Government Accountability Office. For contracts with this clause, NASA evaluates contractor performance and makes interim award-fee payments throughout the course of the contract, but the amount of award fee the contractor ultimately receives is based upon demonstrated performance of the end-item deliverable. However, NASA includes in the final award pool any funds not awarded to the contractor in interim periods.

[77] The Defense Acquisition Regulations Council is overseen by the Department of Defense (DoD). The Civilian Agency Acquisition Council assists the Administrator of the General Services Administration in developing and maintaining the FAR System by developing or reviewing all proposed changes to the FAR, and coordinates its activities with the Defense Acquisition Regulations Council. The group is composed of representatives from each U.S. military department, the Defense Logistics Agency, and NASA.

[78] Award fee is structured to incentivize contractors to perform throughout the contract. Therefore, rollover of unearned award fee provides a disincentive for contractors to perform throughout the entire period of performance. If a contractor did not perform adequately during an award-fee rating period and was rated appropriately and then allowed to recover that unearned award fee in a subsequent period, the incentive for the contractor to perform consistently throughout the entire contract would be reduced. Federal Register / Vol. 75, No. 188/Wednesday, September 29, 2010/Rules and Regulations ([FAC 2005-46; FAR Case 2008-008; Item IV; Docket 2009-0036, Sequence 1]).

[79] *NASA's Use of Award-Fee Contracts* (IG-14-003, November 19, 2013). FAR 16.001 Definitions. *Rollover of unearned award fee* means the process of transferring unearned award fee, which the contractor had an opportunity to earn, from one evaluation period to a subsequent evaluation period, thus allowing the contractor an additional opportunity to earn that previously unearned award fee. Federal Register / Vol. 74, No. 197 / Wednesday, October 14, 2009 / Rules and Regulations.

designate a specific percentage of the total award pool that will be available for the final performance evaluation. The Agency non-concurred with that recommendation, stating that "look-back" is distinctly different from rollover. For rollover, all evaluations are final, and the contractor keeps the fee earned in any period regardless of the evaluations of subsequent periods; any unearned fee is added to a subsequent period, giving the contractor multiple chances at earning the previously unearned fee. For "look-back", all interim award fee payments are treated as provisional and are superseded by the fee determination made in the final evaluation at contract completion, thus unearned fees for interim periods are pooled at the end of the award fee period for a second chance to earn previously unearned fees when the outcome of the program is known.

In our judgement, although NASA officials view the two approaches differently, rollover and "look-back" can often have the same result. For example, at the end of the first award fee period from FY 2006 to FY 2015, NASA paid Lockheed an estimated $3.4 million in "look-back" fees. This payment coincided with Lockheed's successful completion of the EFT-1 test. Looking ahead, although Lockheed experienced significant performance issues from 2015 to 2019 and overran the contract value to such a degree as to require NASA's approval for the $1.4 billion OTB mentioned earlier in this report, award fee scores nonetheless were "Excellent" with the most recent period score being "Very Good" to reflect the OTB. Our concern is that if at the end of the next award fee period the Artemis II mission is successful, the Agency may disregard Lockheed's prior poor performance and give the contractor all or nearly all of the previously unearned fees—up to an additional $14.4 million.[80]

[80] This calculation is based on our assumption that interim and final award fee scores for periods 9 through 16 may be consistent with the scores received thus far for periods 1 through 12. The assumed final award fee earned for periods 9 through 16 is based on the final performance award fee score for Period 8. We used the interim award fee scores recommended by the Performance Evaluation Board to calculate the amount of fee earned for interim award fee periods 9 through 12, and used an average of those fees to forecast potential fee for periods 13 through 16.

NASA Taking Steps to Control Orion's Costs Moving Forward

Looking ahead, the Orion Program has undertaken a series of development, production, and infrastructure initiatives aimed at reducing or controlling costs. These actions include modifications to the contract, award fee restrictions, new software development and cost data tracking initiatives, the use of incentive-fee and firm-fixed-price contracts, batch ordering, spacecraft component reuse, updated facilities, and reduction and consolidation of offices as development ends and production begins. While we view these initiatives as positive steps, most are in the early stages and the extent to which these initiatives will appreciably decrease Orion's costs is unclear.

Development Initiatives are Underway but May Have Limited Impact

The program's development initiatives, which are tied to contracting decisions and adoption of new processes and tools, could save both time and money as Orion transitions from development to production in support of Artemis missions. However, in our assessment one initiative in particular, the decision to use a hybrid contract for development, may actually cost NASA more in fees.

Use of a Hybrid Contract. In February 2014, as a way to incentivize Lockheed and improve performance, NASA procurement officials designated 25 percent of contract funds for a cost incentive, effectively reducing the amount of award fee available by $175.9 million and potentially reducing the amount of fee available for "look-back" by at least $35.2 million.[81] However, we found that since November 2014, NASA paid 100 percent of incentive fee for all but 2 periods, and in those 2 periods the contractor received 95 percent. Program officials stated that the contractor's performance against these objective metrics indicates that the Government received significant value as a result of implementing the incentive fee metric. However, had NASA not reassigned fee from the milestone fee pool to incentive fee, we estimate the Agency could have saved approximately $7.7 million under the original fee plan, even when considering "look-back."[82]

Restriction of Additional Award Fee. The development contract's estimate at completion continued to grow until Lockheed ran out of management reserves, forcing the company to submit a $1.4 billion OTB

[81] NASA procurement officials negotiated a contract modification that effectively changed the contract from a traditional cost-plus award fee—with a 65/35 split between milestone payments and award fee—to a hybrid contract. This hybrid contract offered 40 percent of fee payments as *performance milestone award fee*, 35 percent for *period of performance award fee*, and the remaining 25 percent for a *performance incentive*. According to Program officials, the purpose of the incentive fee metric was to establish a way to incentivize the contractor's performance on the near-term critical program focus areas. This incentive fee metric is not subject to "look-back," and any unearned incentive fee is forfeited.

[82] Our estimate assumes the Final Award Fee Period 2 score will be the same as Award Fee Period 1 (95 percent) and that incentive fees continue to be 100 percent for the remaining periods. The incentive fee portion of the DDT&E contract includes the Artemis I Orion Test lab program, Artemis I Certified Principal Engineer final certifications, Artemis I software verification, and Supply Chain Management.

in May 2019, the result of which was an increase in the contract value to $13.6 billion. Although Lockheed continued to receive "Excellent" scores from 2016 through 2018 and received a score of "Very Good" during the period in which the OTB became apparent, NASA awarded no fee on the OTB. This amounts to a savings of approximately $170.4 million and a decrease in the total development contract fee rate of about 2.25 percent.

Iterative Software Flow Adopted. Software "builds" traditionally take place at the end of a development cycle.[83] However, effectively integrating hardware components and ensuring they function as expected necessitates much earlier involvement. In response to this challenge, the Orion software team designed a continuous integration approach requiring early and frequent software integration, developing software requirements in cooperation with hardware developers, and engaging hardware developers in integration testing. By defining requirements early and designing systems-level tests alongside the hardware team, the Orion program reported savings on the order of 200,000 staff-hours (roughly $40 million) based on the expected efficiencies.

New Business Intelligence Tool. Since July 2017, the Orion program has leveraged the use of a Business Intelligence tool, Tableau, to create the Orion Risk and Cost Assessment (ORCA) database—a "one-stop shop" database for all known and estimable cost data.[84] This unified database integrates budget expenditures and future cost estimates by pulling data from NASA, the prime contractor, Earned Value Management reporting, the Office of the Chief Financial Officer, and estimated cost threats and liens tied to the program's risk register. Traditionally, these various costs were managed using different databases. The use of multiple databases from multiple offices created communication backlogs and increased the workload for Program Planning and Control personnel.[85] According to program officials, this improvement to data compilation has increased efficiency in decision making abilities across the program.

Production Initiatives are Unproven

The program is also moving forward on a number of initiatives aimed at reducing production costs including contract pricing and fee structure, batch ordering, and component reuse although it is too early to tell the extent to which these initiatives will reduce costs.

Transition to a Cost-Plus Incentive Fee Contract for Early Production. For the OPOC contract, the first six Artemis missions (Artemis III to VIII) are under cost-plus incentive fee orders and the contract allows the Government to order up to an additional six missions as firm-fixed-price—the more typical approach

[83] Software builds are created when a certain point in development has been reached or the code has been deemed ready for implementation, either for testing or outright release.

[84] Tableau is a data visualization tool used in the Business Intelligence industry to simplify raw data into a more easily understood format.

[85] The Program Planning and Control (PP&C) discipline can be described as eight interrelated functions: PP&C Integration, Resource Management, Scheduling, Cost Estimation/Cost Assessment, Acquisition and Contract Management, Risk Management, Earned Value Management, and Configuration and Data Management.

to buying production units once a design has stabilized.[86] Unlike the development contract award fee, which is based on subjective criteria, a cost-plus incentive fee is based on objective criteria for evaluation periods. For example, the development contract includes award fees for "responsiveness" and "innovation," whereas the production contract's incentive fees measure cost performance relative to target cost goals and mission success.[87] In early contract negotiations NASA officials expected the incentive fee to be 0.5 percent lower than the final negotiated fee percentage.[88] In our estimation the higher incentive fee could amount to as much as $18.5 million in additional cost. Program officials stated that although the final incentive percentage was higher, Lockheed agreed to take out reopener clauses throughout the contract which, according to program officials, limits potential cost growth and risk to the government.[89] In addition, Lockheed agreed to expanded reuse of hardware, beginning one mission earlier than initially proposed and expanding the amount of hardware to be reused, which resulted in lower unit costs to the program. For these reasons, program officials assessed that the potential costs savings benefits will outweigh the increase in fee percentage.

Anticipated Transition to Firm-Fixed Price Contract Structure after Artemis VIII. Program officials said they had an initial goal of buying production units of the spacecraft under a firm-fixed-price agreement much earlier than Artemis IX, which is NASA's current plan.[90] However, in negotiations with Lockheed the parties could not reach a mutually agreeable firm-fixed price sooner due to uncertainty regarding the cost savings and risks associated with reuse. The program will complete the first instance of light reuse on Artemis V and the first heavy reuse on Artemis VI. To facilitate future firm-fixed price negotiations, each mission under OPOC will have a separate delivery order that will require cost tracking by mission to ensure a well-informed, firm-fixed price as the program works to finalize the design on Artemis missions III through VIII.

Ordering Orion Capsules in Batches of Three for Production. In 2019, NASA officials determined that ordering capsules in batches of three was the most affordable approach for production. With the award of OPOC, the Agency confirmed orders of three Orion spacecraft for Artemis III through V for a total of $2.7 billion for all three spacecraft. The contract also reflects the program's plans to order three additional Orion capsules in FY 2022 for Artemis VI through VIII, at a total of $1.9 billion. According to Lockheed's pricing proposal for the production contract, ordering the spacecraft in groups of three reduces cost by 21 percent because it allows NASA to benefit from economies of scale.

[86] The incentive fee plan contains two elements: a performance incentive and a cost incentive, with the performance incentive representing the majority of the fee available. From Artemis III through V to Artemis VI through VIII the cost incentive will increase by 1 percent, being offset by a 1 percent decrease in the performance incentive. The performance incentive is structured to motivate Lockheed to provide Orion spacecraft that meet mission objectives. Specific mission objectives will be defined on the order level, based on the requirements for that order. The cost incentive is structured to motivate Lockheed to control cost while assuring mission success. This cost incentive fee is based on the Contractor's actual cost performance relative to target cost at the end of each order.

[87] Mission success is based on established mission objectives and success criteria.

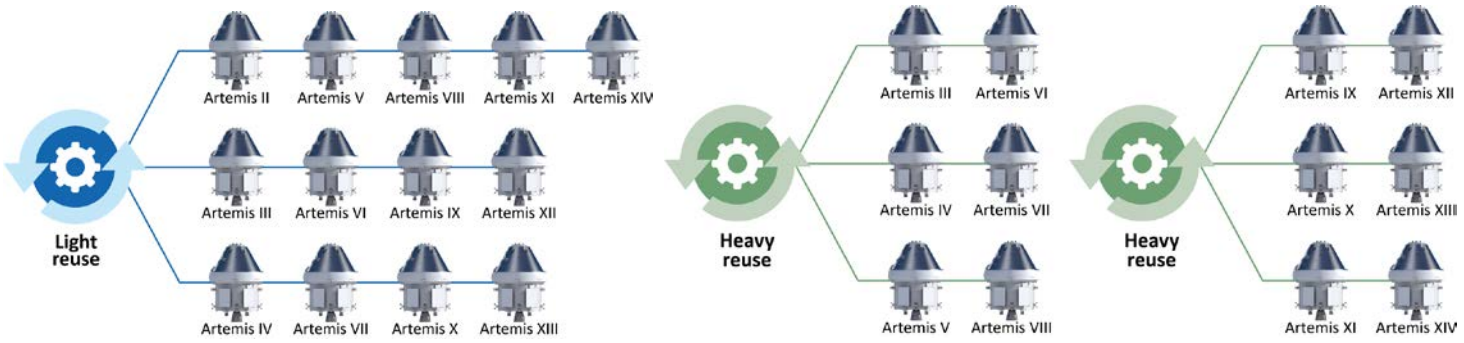
[88] The final negotiated percentages are considered competition sensitive.

[89] A contract reopener clause provides for adjustment of the contract amount after award.

[90] In contrast to a cost-plus contract, a firm-fixed price contract is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. This contract type places upon the contractor maximum risk and full responsibility for all costs and resulting profit or loss.

Reusing Pressure Vessels and Avionics Boxes. The OPOC contract mission costs decrease by 37 percent from Artemis III to Artemis VIII.[91] Reusability falls into two main categories—light and heavy. The Orion Program plans to gain cost efficiencies in production by reusing high-value interior components including avionics, life support systems, and crew systems (light) up to four times (for five total missions) beginning with Artemis V; or reusing the assembled pressure vessels and all interior components (heavy) once (for 2 total missions) beginning with Artemis VI. (See Figure 7.) Program officials expect that Artemis III through V will cost 35.8 percent less than Artemis II due to reuse of components, bulk buying of components and materials, and production efficiencies.[92] As such, NASA expects to save approximately $162 million for light reuse, and $278 million per mission for heavy reuse. In total, NASA expects to save an estimated $2.3 billion through Artemis XIV primarily due to reuse efforts. However, reuse has associated risks. Orion Program officials are assessing and quantifying proposed reuse risks as the program transitions into production. As of March 2020, the program had identified three reuse-related risks with potential schedule impacts of 2 to 5 months each, and a cumulative cost of approximately $17 million.[93]

Figure 7: Orion's Reuse Plans



Source: NASA OIG analysis of notional Agency documentation.

[91] This decrease is predominantly driven by planned Crew Module reuse, but there are also expected production efficiencies. Total cost savings are a forecast because missions for Artemis III through VIII are on a cost-plus contract which could result in cost growth as requirements for the early missions continue to mature.

[92] This calculation is not based on the total cost of Artemis III through V, but is instead based on the estimated production costs of those missions and Program estimates for the cost of Artemis II.

[93] Risks associated with reuse include avionics, power, and wiring reuse from Artemis I to Artemis II, Artemis I reusability "effectiveness", and the new Artemis II components that will experience long vibration duration testing.

Infrastructure Savings are Expected But May Not be Realized for Several Years

Program officials expect its infrastructure initiatives—including facilities updates and consolidation of offices—to save both time and money as Orion transitions from development into production.

Updating facilities to accommodate testing instead of shipping the integrated Crew and Service Modules around the country. For Artemis I, the Crew and Service Module had to be flown aboard NASA's Super Guppy from Kennedy to Ohio's Mansfield Lahm Airport then transported by truck to Plum Brook for qualification testing—a significant endeavor that cost NASA $13.7 million.[94] To maximize efficiency and reduce future costs for final testing of the integrated spacecraft, testing of the integrated spacecraft for Artemis II and beyond will be conducted using new and refurbished equipment at Kennedy facilities, some of which had not been used since the Apollo years and had fallen into disrepair. This equipment will cost the Orion Program a projected $4.8 million through 2021. Agency officials expect this up-front investment will save the program approximately $5.7 million in transportation costs through Artemis VIII. Further, they estimate it will save approximately 18 days of schedule per mission.[95]

Artemis I Orion loaded onto Super Guppy

Source: NASA

Drawdown of capabilities to reduce program footprint. Development efforts for the Orion Program are spread over multiple NASA locations in order to align tasks with the appropriate workforce. As development portions of the spacecraft are completed, offices will close and ongoing work will be consolidated. For example, officials working on the Launch Abort System at Langley will move on to new projects in FY 2021 as their work concludes in advance of the Artemis I launch. In addition, Orion's new Spacecraft Engineering office—comprised of consolidated versions of several of the current development offices—will manage production. Through the consolidation of offices and reduction of personnel from 652 to 369 full time team members (a 43 percent decrease), Agency officials estimate the shrinking footprint of the Orion Program will reduce costs by approximately $500 million through FY 2030.

[94] The Super Guppy is NASA's specialized oversized-transport plane. Qualification testing at Plum Brook included thermal vacuum, thermal balance and electromagnetic testing. Thermal vacuum testing detects material, process, and workmanship defects resulting from vacuum, extreme temperature, and thermal stress conditions. Thermal balance testing verifies the spacecraft's performance at temperatures with an additional margin of what is expected during flight thermal conditions. Electromagnetic testing ensures electrical/electronic equipment will perform properly in its expected electromagnetic environment and demonstrates compatibility between all on-board components and performance through external interference. In addition to NASA's funding, the State of Ohio provided $2.5 million to support creation of the ground transportation corridor between Mansfield and Plum Brook.

[95] The $5.7 million reflects the total per-mission transportation costs multiplied by seven missions (Artemis II through VIII). Per mission costs include Super Guppy flights and other transportation operations and support.

CONCLUSION

NASA has been working since 2006 to develop the Orion spacecraft in support of the goal of returning to crewed spaceflight beyond low Earth orbit. Through January 2020, the Agency spent $16.7 billion on Orion, but will require additional funding to complete development, qualification testing, and integration in preparation for the planned Artemis III lunar mission in 2024.

We acknowledge that the development and production of a new spacecraft comes with many uncertainties and challenges that must be overcome during first-time production, and this understandably leads to increased cost and schedule risk. That said, development of the Orion Crew Module and the European Service Module has cost more and taken longer than NASA, Lockheed, and ESA anticipated. If additional issues arise during qualification and testing over the next 3 years, the work needed to address those issues will result in additional cost and schedule growth, further compressing the timeline in which to complete development and begin production of the spacecraft for future missions.

With respect to tracking program costs, NASA excluded $17.5 billion in Orion-related costs from FY 2006 to FY 2030 due to the Agency's tailored approach to program management, making it difficult for NASA, Congress, and other stakeholders to make informed strategic decisions regarding the Orion program, as well as other Agency priorities.

In addition, despite significant cost increases and schedule delays, Lockheed received nearly all available award fees over a 9-year period due to a variety of factors including the use of an "Award Fee for End-Items" contracts clause that in our judgement disincentivizes contractor performance by offering the contractor the opportunity to, at the end of a final award fee period, earn previously unearned award fees. We calculate that, at a minimum, NASA paid at least $27.8 million in excess award fees to Lockheed throughout development for the "Excellent" performance ratings it received while the Orion Program was experiencing substantial cost increases and schedule delays.

Finally, the program has initiated several efforts to control costs, but it remains too early to determine how successful these efforts will be in making the Orion more affordable as NASA looks ahead to Artemis missions to the Moon and beyond.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To increase the sustainability, accountability, and transparency of the Orion Program as it pursues the goal of landing astronauts on the moon by 2024, we recommend the Associate Administrator for Human Exploration and Operations Mission Directorate and the Deputy Associate Administrator for Exploration Systems Development, in conjunction with the Johnson Center Director, Johnson Office of Procurement, and Orion Program, undertake the following actions:

1. Ensure total development and production contract costs currently not reported as part of the ABC baseline are included in quarterly financial status reporting to the Office of the Chief Financial Officer, OMB, and Congress.

2. To the extent practicable, adjust the production schedules for Artemis IV and V to better align with the successful demonstration of Artemis II to reduce schedule delays associated with potential rework.

To improve NASA's management of award fees, we recommend the Assistant Administrator for Procurement undertake the following action:

3. Ensure procurement officials minimize the availability of award fees when contract modifications and value increases are the result of shortcomings in contractor performance, and require documentation of the rationale for any award fees granted.

We provided a draft of this report to NASA management who concurred with all of our recommendations. We consider management's comments responsive for two of the three recommendations; as such, those recommendations will be closed upon completion and verification of the proposed corrective actions. In its response to Recommendation 1, management stated Orion will include ABC, production and operations, and post-Artemis II costs in regular OCFO reporting starting with the first quarter of fiscal year 2021. However, management further stated that it will only include costs pertaining to the current Orion Program of Record, which would exclude Constellation Program costs incurred under the same development contract. As such, we find management's proposed actions only partially responsive to our recommendation. We acknowledge that it may not be practicable to include the $6.3 billion in sunk costs associated with Orion development under the Constellation Program when evaluating the program's tracking of ABC costs against the Congressional notification thresholds. However, in our judgment a complete picture of Orion's Life Cycle Costs should include all costs related to a program regardless of funding source or management control over its planned lifespan. Therefore, this recommendation is unresolved pending further discussions with the Agency.

Management's comments are reproduced in Appendix G. Technical comments provided by management and revisions to address concerns about proprietary information regarding public release of this report have also been incorporated as appropriate.

Major contributors to this report include Ridge Bowman, Space Operations Director; Letisha Antone, Project Manager; Amy Bannister; Gina Davenport-Bartholomew; Thomas Dodd; Moriah Lee; Matt Ward; Daniel Mills; and Cedric Campbell.

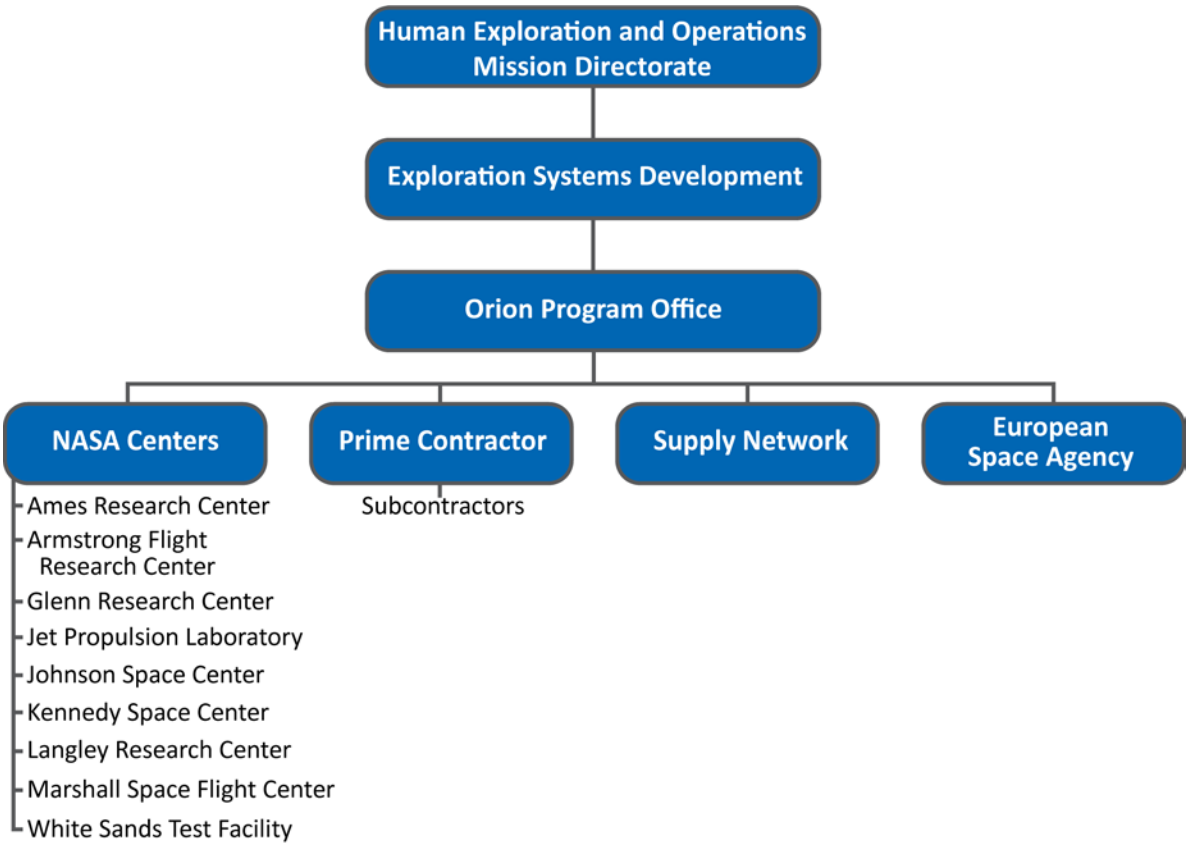
If you have questions about this report or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at 202-358-1543 or laurence.b.hawkins@nasa.gov.

Paul K. Martin
Inspector General

APPENDIX A: PROGRAM ORGANIZATION

The Orion Program consists of NASA organizations and external entities. NASA organizations include the Human Exploration and Operations Mission Directorate, Exploration Systems Development Division, Orion Program Office, and Agency centers and facilities. External entities include the prime contractor, subcontractors, the supply network, and the European Space Agency. Boards and panels are used to control requirements and to make decisions necessary to stay on plan; they generally include both NASA and contractor personnel and may be led by NASA or the contractor. See Figure 8.

Figure 8: Orion Program Organization as of March 2020



Source: NASA.

Exploration Systems Development

The Exploration Systems Development division (ESD), located at NASA Headquarters, provides the program oversight and direction. The Associate Administrator for Human Exploration and Operations has delegated program authority to the ESD Deputy Associate Administrator, including responsibility for the Orion, SLS, and Exploration Ground Systems programs. However, according to NASA policy, the

NASA Associate Administrator is the decision authority for authorizing the program to advance through milestone reviews.[96]

Orion Program Office

The Orion program office, located at Johnson, is responsible for controlling the program's technical objectives, schedule, and cost. The program office is organized by function, including separate offices for Program Planning and Control, the Launch Abort System, Crew and Service Module, avionics and power systems, flight operations, ESA integration, the flight test office, and vehicle integration. The program also has three technical authorities: safety and mission assurance, health and medical, and engineering. Responsibility is delegated to managers of the respective offices. For example, the Launch Abort System Office is led by a manager who independently verifies development of the system and supports integration of the Launch Abort System into the vehicle.

NASA Centers

In addition to officials at NASA Headquarters, over 600 civil servants from nine NASA centers and facilities provide products and services to the program. Civil servants work on tasks such as requirements, testing, and contract oversight. Each civil servant works for a support office that reports directly to the program manager responsible for providing resources and ensuring execution of the assigned tasks and activities.

Prime Contractors and Sub Contractors

Lockheed is the prime contractor. Major subcontractors are Aerojet Rocketdyne, Inc., Honeywell Aerospace, and United Technologies Aerospace Systems. Contractor personnel work collaboratively with NASA personnel on what are called integrated project teams.

Supply Network

The Orion supply chain is comprised of approximately 200,000 parts, provided by more than 2,200 suppliers in 50 states, including participants ranging in size from small businesses to major corporations. The supply chain begins with analysis and proceeds through component engineering, procurement, vendor manufacturing, transportation, and receiving inspection. The program established a joint NASA and Lockheed "Demand Management Team" to provide oversight and manage the Orion Supply Chain processes.

European Space Agency

With the support of 10 European countries and the U.S., ESA, the European counterpart to NASA, provides products and services according to requirements laid out in a partnership agreement. Under the agreement, ESA is responsible for building and delivering a fully qualified European Service Module for both Artemis I and Artemis II and assisting in integrating the European Service Module. In addition,

[96] NPR 7120.5E, *NASA Space Flight Program and Project Management Requirements* (2012).

negotiations for ESA's provision of the European Service Module for Artemis III are anticipated to be complete in summer 2020.

Boards, Panels, and Working Groups

The program is aided by various boards that differ in the scope of their reviews and authority. Program officials use them to help control requirements, evaluate performance, and make decisions necessary to stay on plan. For example, the Standing Review Board conducts key milestone reviews throughout the project and recommends technical, schedule, and programmatic changes as part of their reviews; the Multi-Purpose Crew Vehicle Control Board establishes the program baseline, the approved plan for the program with approved changes, and resolves baseline issues; and the Service Module Control Board approves changes to the European Service Module documents that define the Module's baseline, product changes, schedules, and risks.

APPENDIX B: SCOPE AND METHODOLOGY

We performed this audit from March 2019 through July 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence that provides a reasonable basis for our findings and conclusions. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

The scope of this audit was NASA's management of the Orion Multi-Purpose Crew Vehicle Program. Our review was conducted with the Human Exploration and Operations Mission Directorate at NASA Headquarters, and the Orion Program Offices at Johnson, Kennedy, Glenn, and Langley. We observed on-going Orion efforts at Plum Brook, Kennedy, Langley, and Lockheed Martin's Integrated Test Laboratory and facilities in Littleton, Colorado.

To assess the extent to which NASA is tracking and appropriately reporting overall cost goals for the Orion Program, we reviewed cost reporting data, budget documentation, Agency decision memorandums, the ABC, federal law for baselines and cost controls, and space flight program management policies for the program.[97] We also interviewed NASA personnel from the Orion Program Planning and Control Office to gain their perspective concerning NASA's ability to track and report its schedule and cost goals for the program.

To assess the extent to which NASA met cost, schedule, and performance goals in readying Orion for Artemis I and Artemis II, we reviewed program and Office of the Chief Financial Officer cost and budget documentation and schedules for Orion. Specifically, we analyzed data from NASA's accounting system for FY 2006 through January 2020; information from the Orion Risk and Cost Assessment (ORCA) database for FY 2012 through FY 2030; Defense Contract Management Agency monthly status reports; the Orion Development Contract (NNJ06TA25C) and modifications logs; the Orion Production and Operations Contract (OPOC) (80JSC019C0012); Planning, Programming, Budgeting, and Execution information; the Key Decision Point-C decision memorandum; Orion's Formulation Authorization Document; the program's Risk Register; and Quarterly Program Status Reviews. We also reviewed program documents from decision points such as the Preliminary Design Review and Critical Design Review, planning documents, and Federal and NASA criteria. We further reviewed relevant documents, including strategic planning documents, past presidential budget submissions, and NASA authorization and appropriation bills. We compared cost data from NASA's accounting system to the data obtained from the Orion Program and interviewed program planning and control officials. We interviewed program officials to determine past and expected technical challenges and the impact to schedule. We compared the program's plans for qualification and system-level testing of components to best practices for developing a manned spacecraft. We interviewed Exploration Systems Development (ESD) officials at NASA Headquarters, and Orion Program officials at Johnson, Kennedy, Glenn, and Langley. In addition, we observed the Crew and Service Module assembly and test facilities at Kennedy, the test facilities at Plum Brook, and the Integrated Test Lab and other facilities at the Lockheed Martin facility in Littleton, Colorado.

[97] Anticipated launch dates, as discussed throughout this report, are under review and as of May 2020 have not been formally approved by the NASA Administrator. These dates do not include the impacts of COVID-19. In addition, as of June 2020 Program financial data was only available through January 31, 2020 and also does not include the impacts of COVID-19.

To assess the extent to which NASA managed its development contract with Lockheed to control program costs, we reviewed the Orion Development Contract (NNJ06TA25C) Award Fee Plan, Performance Evaluation Board (PEB) presentations, PEB Performance Determination letters, Fee Determination Official (FDO) Performance Determination letters, award fee payment modifications, Award Fee Evaluation System inputs, Fee Determination Official presentations, the Federal Acquisition Regulation (FAR), the NASA FAR Supplement (NFS), and the NASA Award Fee Contracting Guide. We also evaluated award fees earned by reviewing the performance evaluation plans for the evaluation factors as compared to our assessment of the contractor's cost, schedule, and performance. In addition, we interviewed the Orion Program Manager and Procurement officials at Johnson Space Center and the Associate Administrator for Procurement at NASA Headquarters.

To assess the program's efforts to increase affordability and efficiency, we reviewed administrative strategies beginning in 2004 with the *Vision for Space Exploration* and ending with the 2019 *Space Policy Directive*. We reviewed Orion program documentation on reducing production and operation costs and planning documents related to acquisition strategies and system re-use in addition to assessing Lockheed Martin's re-use plans and batch order savings projections. We also reviewed external budgetary studies such as the one published by the Science & Technology Policy Institute that detailed cost projections and affordability efforts such as re-use and the use of heritage technologies.[98] We further reviewed the Implementing Arrangement with the European Space Agency that details the provision of the European Service Module for Artemis missions and reviewed prior Office of Inspector General (OIG) work on NASA's international partnerships. We interviewed Lockheed officials in Littleton, Colorado, as well as Orion Program Managers and procurement officials at Johnson Space Center, the Orion Productions and Operations Office at Kennedy, and ESD officials at NASA Headquarters.

Assessment of Data Reliability

We used computer-processed data to perform this audit, and that data was used to materially support findings, conclusions, and recommendations. In order to assess the quality and reliability of the data, we verified the information through independent calculations. Primarily, we reviewed and analyzed NASA cost data for FY 2006 through January 2020 in NASA's financial accounting system for the entire Orion Program. Then, we compared these results with data provided by the Orion Program in the form of briefing charts and Excel spreadsheets. Additionally, we used Tableau software to review future cost projection data captured in the program's Orion Risk and Cost Assessment database. We also reviewed computer-processed contract, award fee, incentive fee, Life Cycle Cost, and risk information.

Review of Internal Controls

We assessed internal controls and compliance with laws and regulations associated with NASA's management of space systems needed to support the Orion program. The control weaknesses we identified are discussed in this report. Our recommendations, if implemented, should correct the identified control weaknesses. Because our review was limited to these internal control components and underlying principles, it may not have disclosed all internal control deficiencies that may have existed at the time of this audit.

[98] IDA Science and Technology Policy Institute, *Evaluation of a Human Mission to Mars by 2033*, (February 2019).

Prior Coverage

During the last 7 years, NASA OIG and the Government Accountability Office (GAO) have issued 18 reports relevant to the Orion Program. The reports can be accessed at https://oig.nasa.gov/audits/auditReports.html and http://www.gao.gov.

NASA Office of Inspector General

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

2019 Report On NASA's Top Management and Performance Challenges (MC-2019, November 13, 2019)

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

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

NASA's Management of the Orion Multi-Purpose Crew Vehicle Program (IG-16-029, September 6, 2016)

Audit of NASA's Management of International Space Station Operations and Maintenance Contracts (IG-15-021, July 15, 2015)

Costs Incurred on NASA's Cost-Type Contracts (IG-15-010, December 17, 2014)

NASA's Use of Award-Fee Contracts (IG-14-003, November 19, 2013)

Government Accountability Office

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

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

NASA: Actions Needed to Improve the Management of Human Spaceflight Programs (GAO-19-716T, September 18, 2019)

NASA: Assessments of Major Projects (GAO-19-262SP, May 30, 2019)

NASA: Assessments of Major Projects (GAO-18-280SP, May 1, 2018)

NASA Human Space Exploration: Integration Approach Presents Challenges to Oversight and Independence (GAO-18-28, October 19, 2017)

Defense Contracting: DOD Needs Better Information on Incentive Outcomes (GAO-17-291, July 11, 2017)

NASA Human Space Exploration: Delay Likely for First Exploration Mission (GAO-17-414, April 27, 2017)

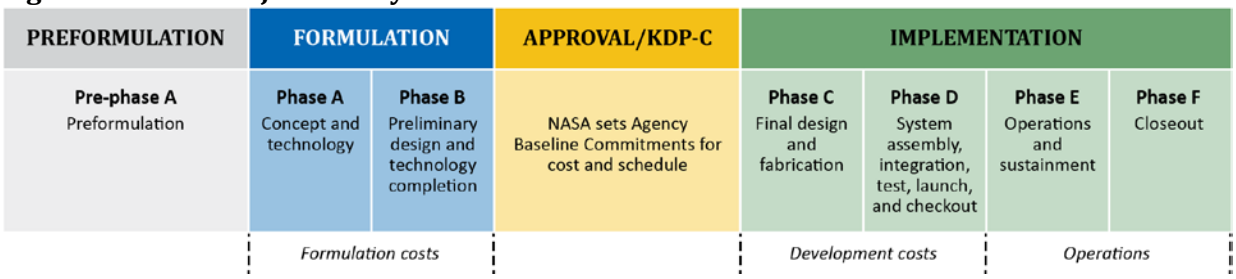
Orion Multi-Purpose Crew Vehicle: Action Needed to Improve Visibility into Cost, Schedule, and Capacity to Resolve Technical Challenges (GAO-16-620, July 27, 2016)

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

APPENDIX C: NASA PROGRAM MANAGEMENT LIFE CYCLE REQUIREMENTS

NASA space flight programs are required to follow a project life cycle that is divided into two phases—Formulation and Implementation—with each further divided into Phases A through F. The life cycle also consists of numerous activities, including preformulation, evaluation, and Key Decision Points (KDP) that allow managers to plan, assess, and review a project's progress (see Figure 9).[99] Preformulation is where mission teams prepare concept studies to provide information on mission costs, risks, and feasibility. The Formulation Phase is divided into Phases A and B, during which mission teams identify how their mission supports NASA's strategic goals and develop technological and preliminary project designs. Formulation costs include program plans, cost and schedule estimates, technical requirements, and acquisition strategies before the Development phase. Once the process outlined in the Formulation Phase is confirmed, the project is approved with a Decision Memorandum at KDP-C, which occurs between Phases B and C, and transitions the program into the Implementation Phase. Divided into Phases C through F, the Implementation Phase is where mission development and operation project plans are executed and control systems are used to ensure they align with NASA's strategic goals. Development costs include all project costs, including construction of facilities and civil servant costs, from the program's approval at the beginning of Phase C through achievement of operational readiness at the end of Phase D. Operations, sustainment, and program closeout costs occur during Phases E and F.

Figure 9: NASA Project Life Cycle



Source: NASA OIG presentation of Agency information.

As of January 2020, the program is in transition from Phase D to E. The total Life Cycle Cost for the Orion Program, including preformulation and formulation costs from the Constellation Program beginning in 2006 and production of at least eight spacecraft (Artemis I through VIII) through FY 2030, is $29.5 billion.

[99] NPR 7120.5E and NASA Space Flight Program and Project Management Handbook (September 2014).

APPENDIX D: ORION VS. APOLLO FUNDING

Fifty-five years after the first moon landing, NASA will attempt another moon landing employing a spacecraft similar to Apollo—including the characteristic gumdrop-shaped capsule. However, there are key differences between the Orion and Apollo capsules, such as number of crew, overall size, component reusability, and price (see Table 5).

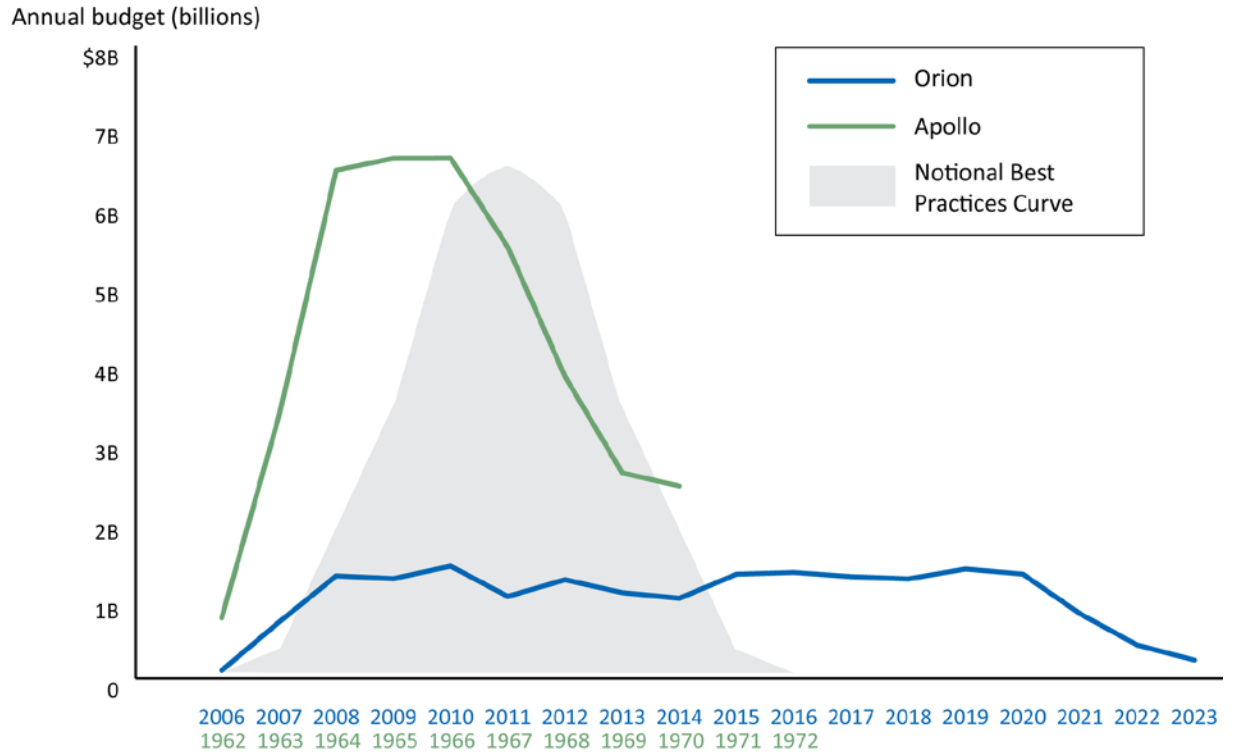
Table 5: Orion vs Apollo

Spacecraft	 Apollo	 Orion
Manufacturer	North American Rockwell, Grumman Aircraft Engineering Corporation	Lockheed Martin, European Space Agency
Beginning of Crew Service Module Development to First Crewed Launch	1960–1968	2006–2023
Lunar Launch Vehicle	Saturn V	SLS
Crew Number	Three	Four
Crewed Area	218 Cubic Feet	316 Cubic Feet
Reusability	N/A	Once per Pressure Vessel
Crew and Service Module Development Cost	$30.9 billion (in 2019 dollars) for six uncrewed and one crewed mission[a]	$18.5 billion for one uncrewed and one crewed mission[b]

Source: NASA OIG presentation of Apollo and Orion Program information.
Notes:
[a] OIG calculation of Apollo Crew and Service Module development cost was adjusted to reflect 2019 dollars; costs exclude launch vehicles. Calculations are approximated and used NASA's New Start Index which is designed to normalize the costs of aerospace projects over time by strongly weighting the changing costs of labor and aerospace materials. Costs presented are through the first crewed mission for each spacecraft.
[b] These figures do not include the cost of the European Service Module.

Part of the success of the Apollo program is attributable to the unprecedented and consistent level of funding allotted for that first moon landing. A typical space system life cycle model shows a bell-shaped funding curve for research, development, testing, and evaluation because more resources are needed as development progresses and programmatic risks are identified and remediated.[100] However, the Orion Program funding has been flat-lined, and overall budgets are lower than Apollo-era funding levels for spacecraft development.[101] Figure 10 compares Orion funding levels since 2006 to Apollo funding from 1962 to 1972, and illustrates what an optimal funding curve might look like in accordance with best practices.[102]

Figure 10: Apollo vs. Orion Funding Levels



Source: NASA OIG Presentation of program data.

Note: Apollo budget data was derived from program-level spending obligations from NASA's congressional budget estimates from FY 1964 to FY 1970. Apollo costs are for the Command and Service module and do not include costs associated with the Saturn V launch vehicle or Lunar Excursion Module.

[100] GAO Cost Estimating and Assessment Guide, March 2009.

[101] Apollo costs presented in this Appendix are for the Command and Service module and do not include costs associated with the Saturn V launch vehicle or Lunar Excursion Module.

[102] GAO Cost Estimating and Assessment Guide, March 2009.

APPENDIX E: SUMMARY OF ADDITIONAL COSTS EXCLUDED FROM LIFE CYCLE COST

The Orion Program has excluded approximately $181.5 million in "other costs" from the program's Life Cycle Cost for Artemis I and Artemis II. Program officials told us they excluded these costs (summarized in Table 6) because they are tied to either missions after Artemis II, or to requirements levied after the Agency Baseline Commitment (ABC) was set. As discussed in this report, in our view, characterizing these additional costs as separate from Life Cycle Cost obfuscates the complete cost of the program.

Table 6: Summary of Additional Costs Excluded from Life Cycle Cost

Description	Cost ($ in millions)	Management Rationale
Costs Tied to Missions After Artemis II		
Core Avionics	$75.6	The total cost for core avionics for Artemis II through V is $100.7 million. The program expects every avionics set to have a life expectancy of four flights and as such has allocated $25.2 million each to Artemis missions III, IV, and V which fall outside the scope of the ABC.
Delay of Production and Operations Charge Codes	$12.1	This was a retroactive adjustment made based on an estimate that 5 percent of the workforce was dedicating time towards production-related activities in FY 2017, and 10 percent in FY 2018.
Abort Motor Obsolescence	$26.5	Due to the complexity and uniqueness of the hardware needed to complete avionics, early procurement of spares and parts expected to become obsolete is essential as a risk mitigation for flights beyond Artemis II.
Manual Pressure Equalization Valve to Side Hatch (non-recurring cost)	$6.0	
Hard Copy 3 (HC3)[103]	$5.0	
Crew Module Long Lead Artemis III Procurements	$1.4	
Orion Inertial Measurement Unit Parts Obsolescence	$0.8	
Main Engine Controllability	$1.8	The existing Thrust Vector Control system must be modified from its current configuration to enhance efficiency and effectiveness in flight units after Artemis II.

[103] Hard Copy 3 is a microchip contained within the Orion avionics.

Table 6 (continued)

Description	Cost ($ in millions)	Management Rationale
Costs Tied to Missions After Artemis II (continued)		
European Service Module Auxiliary Thruster Long Lead Procurements	$1.4	In consideration of experience with Artemis I and II thus far, technical teams have made recommendations to modify the existing design to reduce technical risks and allow future production efficiencies.
Lockheed Support of European Service Module integration for Artemis III and beyond	$0.5	
Support of European Service Module development for Artemis III	$0.3	
European Service Module Auxiliary Engine Testing for Artemis III	$0.2	
Addition of Docking Requirement to System Requirement Documents	$0.5	The ABC did not include docking because the capability will not be required until after Artemis II.
Costs Tied to Requirements Levied after the ABC was Completed		
Artemis II Development Flight Instrumentation	$20.3	These capabilities were added in order to test new capabilities and gather data to reduce technical, safety, schedule, and cost risk while also providing evidence of potential cost reductions for future flights. This addition was not originally part of the ABC.
Exploration Upper Stage (EUS) Flight Operations Directorate; EUS Avionics, Power, and Software; Interim Cryogenic Propulsion Stage (ICPS) Change Request	$12.3	Under the original plan during KDP-C, an ICPS was intended to be used. Due to a change in requirements in 2017, NASA Headquarters directed the SLS Program to replace the ICPS with the EUS. In 2018 requirements were changed again to revert to the original ICPS plan. These changes resulted in cost inefficiencies for the Orion Program. Interface costs associated with the upper stage remain inside the Life Cycle Cost, however, the additional cost burden associated with the change in requirements from external authorities falls outside the ABC.
Constellation Obligation—Past Year Adjustments	$7.5	Prior to the authorization of the Orion Program, the Constellation Program obligated funds towards construction of facilities for future years. Delayed billing and work caused the invoices of this content to fall within the life cycle timeframe of Orion but were paid with pre-FY 2012 funding.

Table 6 (continued)

Description	Cost ($ in millions)	Management Rationale
Costs Tied to Requirements Levied after the ABC was Completed (continued)		
Shutdowns	$4.6	Throughout the development of the Orion capsule there were several shutdowns due to natural disasters at NASA centers on the Gulf and Atlantic coasts and funding lapses with associated Government shutdowns. (This figure includes: $2 million for the 2013 Government Shutdown, $1.3 million for Hurricane Irma, $0.8 million for Hurricane Harvey, and $0.5 million for Hurricane Matthew.)[104]
Non-Demand Labor	$2.8	Civil Service labor is allocated from Headquarters to the program and the program must pay for that allotted work force. As the demands of the program lessen, many civil servants continue charging the program, even though only a portion of their labor hours are spent on Orion-related tasks.
AstroRAD/ESA Active Dosimeter/Space Biology Pathfinder Payloads	$1.0	Due to requirements related to SLS, ESD direction, and other external parties, the Orion Program absorbed new requirements to accommodate payload integration. Although they ride on the Artemis II mission, these requirements were not part of the ABC because they were imposed by external parties.
Payload Integration for Artemis I	$0.9	

Source: NASA OIG presentation of program information.

[104] In a recent example, the 2020 Coronavirus (COVID-19) pandemic resulted in suspension of production and testing of Orion in March 2020. At the time of our writing, the cost impact of this suspension was not known.

APPENDIX F: QUESTIONED COSTS

The evaluation factors in the Orion contract are weighted by Technical (45 percent), Program Management (20 percent), Cost Management (25 percent), and Small Business/Small Disadvantaged Business Subcontracting Goals (10 percent). At the beginning of an award fee evaluation, performance monitors score each factor from 0 to 100. The numerical score for each factor is then multiplied by the weight for that factor to determine the weighted score. The weighted scores for each evaluation factor are then added to determine the total recommended award fee score for that evaluation period. Once complete, the performance monitors present a recommended score to the Program Evaluation Board (PEB). Next, the PEB evaluates the contractor's overall performance and presents their recommended score to the Fee Determination Official (FDO). The FDO, who makes the final decision on the award fee, can adjust award fees as long as the reasons for doing so are documented. Based on the inflated award fee scores we described earlier in this report, we question $27.8 million in fees (as detailed in Table 7) awarded from September 2006 to April 2015—the monetary difference between the performance monitors' weighted score and the final score given to Lockheed.

Table 7: Questioned Award Fees

Award Fee Evaluation Period	Final Award Fee Approved by the FDO	Award Fee Calculated Using Performance Monitor Weighted Scores	Questioned Costs
1	$49,162,860	$47,248,096	$1,914,764
2	37,286,688	35,540,101	1,746,587
3	115,908,179	113,345,998	2,562,181
4	34,238,096	33,967,795	270,301
5	74,585,709	71,994,837	2,590,872
6	64,633,208	56,503,031	8,130,177
7	72,751,723	66,778,424	5,973,299
8	$95,019,445	$90,418,504	4,600,941
Total Questioned Costs			$27,789,122

Source: NASA OIG calculation.

Note: Questioned Costs are calculated by subtracting fees calculated using performance monitor weighted scores from final fees approved by the FDO.

APPENDIX G: MANAGEMENT'S COMMENTS

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

July 10, 2020

Reply to Attn of: Human Exploration and Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations
Assistant Administrator for Procurement

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of the Orion Multi-Purpose Crew Vehicle Program" (A-19-012-00)

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 the Orion Multi-Purpose Crew Vehicle Program" (A-19-012-00), dated June 17, 2020.

NASA remains committed to improving cost and schedule performance in its Exploration Systems Development programs and increasing trust and transparency by demonstrating ability to execute plans and report to external stakeholders. NASA appreciates the thoroughness of the OIG review. Implementing the associated recommendations will strengthen NASA's ability to plan and implement the complex missions that the Agency is undertaking while enhancing cost and schedule transparency.

In the draft report, the OIG makes three recommendations addressed to NASA intended to increase the sustainability, accountability, and transparency of the Orion Program and improve NASA's management of award fees.

Specifically, the OIG recommends the following:

To increase the sustainability, accountability, and transparency of the Orion Program as it pursues the goal of landing astronauts on the Moon by 2024, the OIG recommends the Associate Administrator for Human Exploration and Operations Mission Directorate (AA/HEOMD) and the Deputy Associate Administrator for Exploration Systems Development (ESD), in conjunction with the Johnson Space Center (JSC) Director, JSC's Office of Procurement, and the Orion Program, undertake the following actions:

> **Recommendation 1:** Ensure total development and production contract costs currently not reported as part of the agency baseline commitment (ABC) baseline are included in quarterly financial status reporting to the Office of the Chief Financial Officer (OCFO), Office of Management and Budget, and Congress.

Management's Response: Concur. All Orion costs are included in the annual budget process. In addition to this and other standard reporting processes, the Orion program will report all projected life-cycle costs in its regular status reporting, and OCFO will ensure that this is included in the Major Programs Annual Report (MPAR) to Congress. Constellation costs are not reported because Constellation was a different program, outside of the current Orion Program of Record. Constellation costs are a part of the public record and are available to all via publicly available means.

Estimated Completion Date: Orion will include ABC, production and operations, and post-Artemis II costs in regular OCFO reporting starting with Quarter 1 of Fiscal Year 2021.

Recommendation 2: To the extent practicable, adjust the production schedules for Artemis IV and V to better align with the successful demonstration of Artemis II to reduce schedule delays associated with potential rework.

Management's Response: Concur. It is important to continually balance the risks of proceeding with production efforts while finishing final development and the completion of Artemis I and II flights. The Orion program has made a concerted effort to balance the qualification of components and subsystems with the national priorities for a sustainable exploration cadence to make risk-informed decisions on initiating production. The program's efforts to complete component qualification and the integrated system level tests for Artemis I/II help mitigate the risks in proceeding with production of Artemis IV/V. In addition, certain high-performance and unique aerospace components require long-lead production times which necessitate an overlap between Design, Development, Test, and Evaluation (DDT&E) and production efforts, a common practice in aerospace production. NASA acknowledges there are residual risks inherent in reasonable concurrency between starting production while completing DDT&E, but the risk is manageable. NASA will continue to assess the flight schedules and evaluate opportunities to obtain test and early flight data to inform Orion's production efforts.

Estimated Completion Date: May 31, 2021.

To improve NASA's management of award fees, the OIG recommends the Assistant Administrator for Procurement (OP) undertake the following action:

Recommendation 3: Ensure procurement officials minimize the availability of award fees when contract modifications and value increases are the result of shortcomings in contractor performance and require documentation of the rationale for any award fees granted.

Management's Response: Concur. NASA continually seeks to improve all aspects of its contracting activities and has issued award fee guidance within the last year to

include shorter award fee evaluation periods for design and development programs with a life-cycle cost of $250M or more as well as guidance instituting an independent Agency-level panel check of award fee evaluation period scores for design and development programs with a life-cycle cost of at least $1B or more. This guidance was designed to ensure independence in the award fee determination process and emphasize the need for greater focus on the timely evaluation of contractor performance. The Office of Procurement will provide further guidance to contracting officers reminding them that they should minimize the availability of award fees when contract cost overrun modifications and associated value increases are the result of shortcomings in contractor performance as well as require documentation of action(s) taken in the contract file.

Estimated Completion Date: January 31, 2021.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have not identified any 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 Lynne Loewy on (202) 358-0549.

KATHRYN LUEDERS Digitally signed by KATHRYN LUEDERS Date: 2020.07.10 14:48:19 -04'00'

Kathryn L. Lueders

MONICA MANNING Digitally signed by MONICA MANNING Date: 2020.07.08 15:24:30 -04'00'

Monica Manning

APPENDIX H: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
General Counsel
Associate Administrator for Mission Support Directorate
Associate Administrator for Human Exploration and Operations Mission Directorate
Associate Administrator for Procurement
Deputy Associate Administrator for Exploration Systems Development
Deputy Associate Administrator for Procurement
Director, Johnson Space Center
Director, Kennedy Space Center
Director, Langley Research Center
Director, Glenn Research Center
Director, Johnson Space Center Office of Procurement
Acting Manager, Orion Program Office

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Energy and Space Programs Division

Government Accountability Office
    Director, Contracting and National Security Acquisitions

Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
    Subcommittee on Aviation and Space

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

House Committee on Oversight and Reform
    Subcommittee on Government Operations

House Committee on Science, Space, and Technology
    Subcommittee on Investigations and Oversight
    Subcommittee on Space and Aeronautics

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