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# NASA's Management of Space Launch System Program Costs and Contracts

March 10, 2020

Report No. IG-20-012

# Office of Inspector General

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NASA Office of Inspector General
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# Results in Brief

## NASA's Management of Space Launch System Program Costs and Contracts

March 10, 2020 IG-20-012 (A-18-008-02)

## Why We Performed This Audit

NASA announced the Artemis program in May 2019, setting the ambitious goal of returning American astronauts to the Moon by 2024. Key to achieving this mission is the Space Launch System (SLS)—a two-stage, heavy-lift rocket that will launch the Orion Multi-Purpose Crew Vehicle (Orion) into space. Currently scheduled to launch no earlier than November 2020, Artemis I will serve as a test flight of the integrated SLS/Orion system, sending an uncrewed Orion into orbit around the Moon followed by a return to Earth. Artemis II, scheduled to launch in October 2022, will be the first crewed mission for the new launch system, and plans to orbit the Moon. The Artemis III mission in late 2024 plans to land astronauts on the Moon's south pole to begin creating a sustainable human lunar presence.

In 2011 and 2012, NASA contracted with three commercial companies—The Boeing Company (Boeing), Aerojet-Rocketdyne (Aerojet), and Northrop Grumman—to develop the major elements of the SLS for the first two Artemis missions. Specifically, Boeing would provide the launch system's Core Stage and Upper Stage (also known as the Interim Cryogenic Propulsion Stage or ICPS), Aerojet the RS-25 Engines, and Northrop Grumman the Solid Rocket Boosters (Boosters) that help power the SLS. As of December 2019, NASA had obligated $14.8 billion on the SLS Program and is expected to spend a total of $17.4 billion by the Artemis I launch date. Besides Artemis I costs, these amounts include preparation for Artemis II and III, new engine development, and improved Boosters. However, as of January 2020, NASA anticipates the Artemis I launch date will slip to spring 2021, over 2 years later than its initial planned launch date, with total SLS Program costs rising to $18.3 billion by that time. Moreover, if the Artemis II launch date slips to 2023, total SLS Program costs by then will increase to more than $22.8 billion.

Our October 2018 audit examined cost and schedule challenges related to the Boeing Stages contract. This report updates the status of Stages development and examines the remaining major SLS elements and corresponding contracts with Boeing, Aerojet, and Northrop Grumman. Specifically, we assessed the extent to which (1) the SLS Program is meeting cost and schedule goals for Artemis I, (2) NASA is tracking and appropriately reporting overall cost and schedule goals, and (3) the SLS Program is managing cost and schedule for key contracts. To complete this work, we reviewed SLS Program and contractor cost and budget documentation, interviewed NASA and contractor personnel, and conducted site visits at NASA and contractor facilities.

## What We Found

NASA continues to struggle managing SLS Program costs and schedule as the launch date for the first integrated SLS/Orion mission slips further. Rising costs and delays can be attributed to challenges with program management, technical issues, and contractor performance. For example, the structure of the SLS contracts limits visibility into contract costs and prevents NASA from determining precise costs per element. Specifically, rather than using separate contract line item numbers (CLIN) for each element's contract deliverables, each of the contracts have used a single CLIN to track all deliverables making it difficult for the Agency to determine if the contractor is meeting cost and schedule commitments for each deliverable. Moreover, as NASA and the contractors attempt to accelerate the production of the SLS Core Stages to meet aggressive timelines, they must also address concerns about shortcomings in quality control.

Based on our review of SLS Program cost reporting, we found that the Program exceeded its Agency Baseline Commitment (ABC)—that is, the cost and schedule baselines committed to Congress against which a program is measured—by at least 33 percent at the end of fiscal year 2019, a figure that could reach 43 percent or higher if additional delays push the launch date for Artemis I beyond November 2020. This is due to cost increases tied to development of Artemis I and a December 2017 replan that removed almost $1 billion of costs from the Program's ABC without lowering the baseline, thereby masking the impact of Artemis I's projected 19-month schedule delay from November 2018 to June 2020. Since the replan, the SLS Program now projects the Artemis I launch will be delayed to at least spring 2021 or later. Further, we found NASA's ABC cost reporting only tracks Artemis I-related activities and not total SLS Program costs. Overall, by the end of fiscal year 2020, NASA will have spent more than $17 billion on the SLS Program—including almost $6 billion not tracked or reported as part of the ABC.

Each of the major element contracts for building the SLS for Artemis I—Stages, ICPS, Boosters, and RS-25 Engines—have experienced technical challenges, performance issues, and requirement changes that collectively have resulted in $2 billion of cost overruns and increases and at least 2 years of schedule delays. We reported in October 2018 that Core Stage production is the primary factor contributing to overall SLS launch delays due to its position on the critical path and corresponding management, technical, and infrastructure issues driven mostly by Boeing's poor performance. Boeing's software development for the ICPS is also an ongoing concern as final modification of the software cannot be made until NASA finalizes the Artemis I mission requirements. Additionally, with regard to Northrop Grumman's Boosters contract, numerous incremental contract modifications and the lack of a NASA appointed on-site technical monitor have contributed to an administrative burden on NASA management and issues with monitoring contractor performance. Moreover, both Northrop Grumman and Aerojet have experienced technical issues, with problems related to the Booster's Propellant Liner and Insulation and development of RS-25's new Engine Controller Unit proving difficult to overcome. While NASA has addressed many of the problematic issues in Core Stage, ICPS, Booster, and RS-25 Engine development, we expect additional cost increases totaling approximately $1.4 billion—$1.3 billion for Stages, $107 million for Boosters, and $41 million for ICPS—before the Artemis I launch. That said, NASA is positioned to gain efficiencies in future production of its Core Stage, Upper Stage, Boosters, and RS-25 Engines if they apply lessons learned from the current development phase.

## WHAT WE RECOMMENDED

To increase the sustainability, accountability, and transparency of NASA's efforts to manage the five major SLS element contracts to achieve its goal of landing astronauts on the Moon by 2024, we made the following recommendations to NASA management: (1) notify Congress that the SLS Program has exceeded its ABC by at least 30 percent; (2) review Human Exploration and Operations Mission Directorate and NASA program management policies, procedures, and ABC reporting processes to provide greater visibility into current, future, and overall cost and schedule estimates for the SLS Program and other human space flight programs; (3) for new acquisitions of SLS deliverables, develop a cost accounting model that separates each deliverable into its own CLIN for tracking costs, performance, and award fees; (4) for large award fee contracts where NASA has on-site personnel, ensure selected personnel are clearly assigned the task of monitoring and reporting on the performance of the contractor; and (5) conduct a thorough review of each contract's scope of work and technical requirements needed to complete the period of performance to assist in eliminating incremental contract value increases and lessening contract management burden. We provided a draft of this report to NASA management who concurred with all of our recommendations. We consider management's comments responsive for four of the five recommendations; as such, these recommendations will be closed upon completion and verification of the proposed corrective actions. In Recommendation 3, management only addressed the Core Stage and Upper Stage CLINs, and not future acquisitions of Boosters and RS-25 Engines. Therefore, this recommendation is unresolved pending further discussions with the Agency.

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# Acronyms

| | |
|---|---|
| ABC | Agency Baseline Commitment |
| CLIN | contract line item number |
| DCMA | Defense Contract Management Agency |
| ECU | Engine Controller Unit |
| EUS | Exploration Upper Stage |
| FAR | Federal Acquisition Regulation |
| FY | fiscal year |
| GAO | Government Accountability Office |
| HEOMD | Human Exploration and Operations Mission Directorate |
| ICPS | Interim Cryogenic Propulsion Stage |
| IDIQ | indefinite-delivery, indefinite-quantity |
| KDP | Key Decision Point |
| NFS | NASA FAR Supplement |
| NPR | NASA Procedural Requirements |
| OIG | Office of Inspector General |
| PLI | Propellant Liner and Insulation |
| SLS | Space Launch System |

# INTRODUCTION

In May 2019, NASA announced the Artemis program, setting the ambitious goal of returning American astronauts to the Moon by 2024.[1] Key to achieving this goal is the Space Launch System (SLS)—a two-stage, heavy-lift rocket that will launch the Orion Multi-Purpose Crew Vehicle (Orion) into space.[2] The SLS represents the largest development of space flight capabilities NASA has attempted since the Space Shuttle Program began almost 50 years ago.

In 2011 and 2012, NASA contracted with three commercial companies to develop the major elements of the SLS for the first two Artemis missions: The Boeing Company (Boeing) would provide the Core Stage and Upper Stage, Aerojet-Rocketdyne (Aerojet) the RS-25 Engines, and Northrop Grumman the Solid Rocket Boosters (Boosters). NASA complied with congressional guidance to develop the SLS by incorporating elements from the retired Space Shuttle Program and the canceled Constellation Program.[3] As of December 2019, NASA had obligated $14.8 billion to the SLS Program and is expected to spend a total of $17.4 billion by the Artemis I launch date, currently scheduled for late 2020.[4] Besides Artemis I costs, these amounts include preparation for Artemis II and III, new engine development, and improved Boosters. However, NASA anticipates that the Artemis I launch date will slip to spring 2021, more than 2 years after its initial planned launch date, with total SLS Program costs rising to $18.3 billion. Moreover, if the Artemis II launch date slips to 2023, total SLS Program costs will increase to more than $22.8 billion.

In October 2018, we reported on cost and schedule challenges related to the Boeing Stages contract.[5] This report updates the status of Stages development and examines the remaining major SLS elements and the corresponding contracts with Boeing, Aerojet, and Northrop Grumman. Specifically, we assessed the extent to which (1) the SLS Program is meeting cost and schedule goals for Artemis I, (2) NASA is tracking and appropriately reporting overall cost and schedule goals, and (3) the SLS Program is managing costs and schedule for these contracts. See Appendix A for details on the audit's scope and methodology.

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[1] NASA renamed its planned Space Launch System/Orion Multi-Purpose Crew Vehicle lunar exploration missions the Artemis program to signify the return of U.S. astronauts to the Moon by 2024. In Greek mythology, Artemis—the twin sister of Apollo—is the goddess of the Moon.

[2] Orion is a spacecraft composed of a crew module capable of transporting four crew members, a service module that provides in-space propulsion and storage, a spacecraft adapter for connecting the vehicle to the SLS or other launch vehicles, and a launch abort system that can pull crew members to safety in the event of an anomaly during launch.

[3] National Aeronautics and Space Administration Authorization Act of 2010, Pub. L. No. 111-267, 124 Stat. 2805 (2010). In July 2011, after 30 years and 135 crewed missions to low Earth orbit, the Space Shuttle Program completed its final flight.

[4] The $14.8 billion in obligations includes $354 million in program integration and support.

[5] NASA Office of Inspector General (OIG), *NASA's Management of the Space Launch System Stages Contract* (IG-19-001, October 10, 2018).

# Background

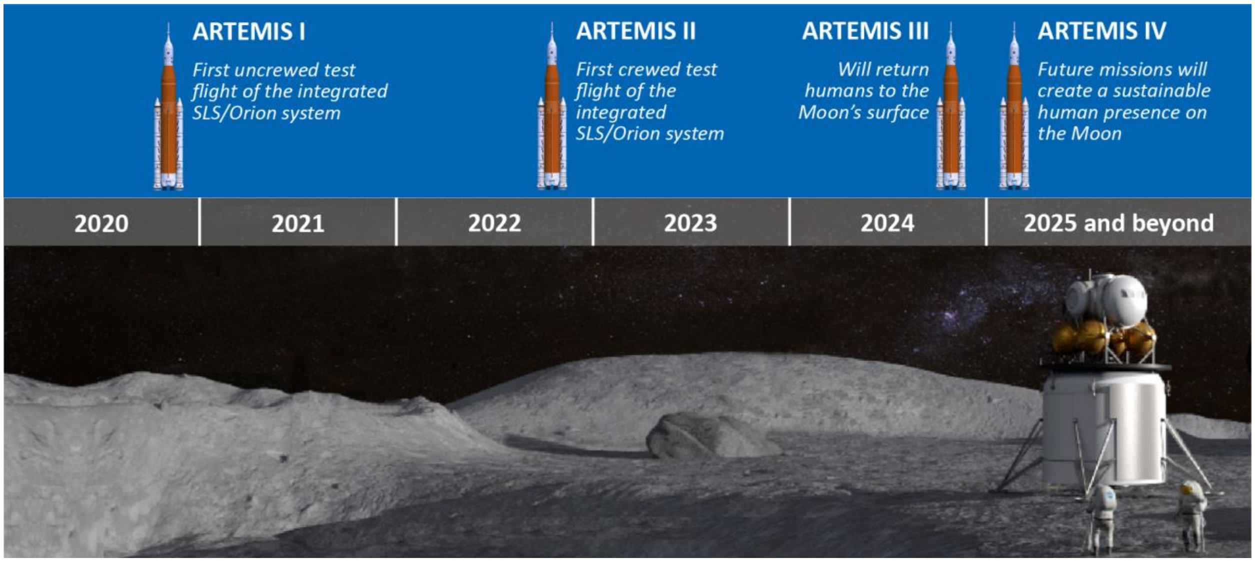
For decades, NASA has been working towards the goal of landing the first humans on Mars. The Artemis program intends to set the stage for achieving this goal by returning humans to the Moon in 2024 and creating a sustainable human presence by 2028, with the ultimate goal of exploring Mars in the 2030s. To meet these objectives, NASA has spent the past 8 years not only developing the SLS and Orion, but also the Exploration Ground Systems, which provides ground processing and launch facilities for the integrated SLS/Orion system.[6] Currently scheduled to launch in November 2020, Artemis I will serve as a test flight of the integrated SLS/Orion system, sending an unmanned Orion into orbit around the Moon followed by a return to Earth. Artemis II, scheduled to launch in October 2022, will orbit the Moon and be the first crewed mission for the launch system. With the launch of Artemis III, scheduled for late 2024, NASA plans to return humans to the surface of the Moon.

For the first three Artemis missions, NASA plans to use the SLS Block 1 configuration, which has an expected capability to lift 70 metric tons to low Earth orbit. The Agency may also rely on the SLS Block 1 configuration to launch the Europa Clipper mission in late 2025, a planetary science mission also known as Science Mission-1.[7] By Artemis IV, NASA anticipates using the SLS's Block 1B configuration, which includes the Exploration Upper Stage, to increase lift capability to 105 metric tons. After these initial four launches, the Artemis program expects to continue sending regular missions to the Moon using the SLS Block 1B configuration. NASA plans to again upgrade the launch vehicle to the Block 2 configuration by 2029, replacing the current boosters with new evolved solid rocket boosters enabling the SLS to send over 130 metric tons of cargo to low Earth orbit and 37 metric tons to Mars. Figure 1 depicts the planned launch cadence of the SLS Program.

[6] Orion development for the Constellation Program began with the contract award to Lockheed Martin in 2006.

[7] The Europa Clipper mission is a science mission that plans to send a spacecraft to Europa, one of Jupiter's moons, to determine whether the icy moon could harbor conditions suitable for life. Congress directed the use of the SLS for the Europa mission in Consolidated Appropriations Act, 2019, Pub. L. No. 116-6 (2019). On August 27, 2019, the OIG sent a letter to Congress highlighting cost and schedule issues associated with mandating use of the SLS for the Europa Clipper mission given Artemis launch schedule priorities.

**Figure 1: SLS Program Launch Cadence**




Source: NASA OIG depiction of Agency program information.

Note: The Europa Clipper mission is currently an alternative fourth launch of the SLS.

## SLS Development and Capabilities

After cancellation of the Constellation Program in 2010, Congress directed NASA, through the National Aeronautics and Space Administration Authorization Act of 2010, to build an SLS rocket designed to meet the Agency's long-term goal of human exploration of Mars.[8] While the Act set an initial operational date of December 31, 2016, NASA's original development plan for the SLS established a launch readiness of December 2017. In 2014, after completion of the SLS's preliminary design work, NASA committed to Congress a launch readiness date of November 2018 at a cost of nearly $9.7 billion. However, since then NASA has delayed the launch readiness window for Artemis I to late 2020. As of December 2019, NASA had spent $14.8 billion developing the initial capability for Artemis I, as well as initiating future configurations of the SLS rocket, and preparing for long-term production using separate contracts for the Upper Stage, Core Stage, Boosters, and RS-25 Engines.

To reduce costs and utilize technologies already in development, Congress directed NASA to incorporate components from the Space Shuttle and Constellation programs, modify existing capabilities, and utilize existing contracts where possible during SLS development.[9]

- *Upper Stage.* The original Upper Stage—also known as the Interim Cryogenic Propulsion Stage (ICPS)—will serve as the second stage for the first three Artemis launches. Based upon a similar design used on the Delta IV Heavy rocket, the ICPS is a liquid-oxygen/liquid-hydrogen system

[8] Constellation was designed to replace the Space Shuttle and provide a deep space cargo and crew capability. However, the Program was canceled in 2010, well before its first mission. Pub. L. No. 111-267.

[9] Pub. L. No. 111-267, 124 Stat. 2805.

with a single RL-10 engine.[10] The ICPS will initially propel an uncrewed Orion using a translunar injection burn sending Orion to the Moon for Artemis I, before transitioning to a crewed configuration for Artemis II and III and a cargo configuration to Jupiter for the Europa Clipper mission.[11] For Artemis IV and beyond, the Upper Stage will be upgraded from the ICPS to the Exploration Upper Stage (EUS), which uses four RL-10 engines.

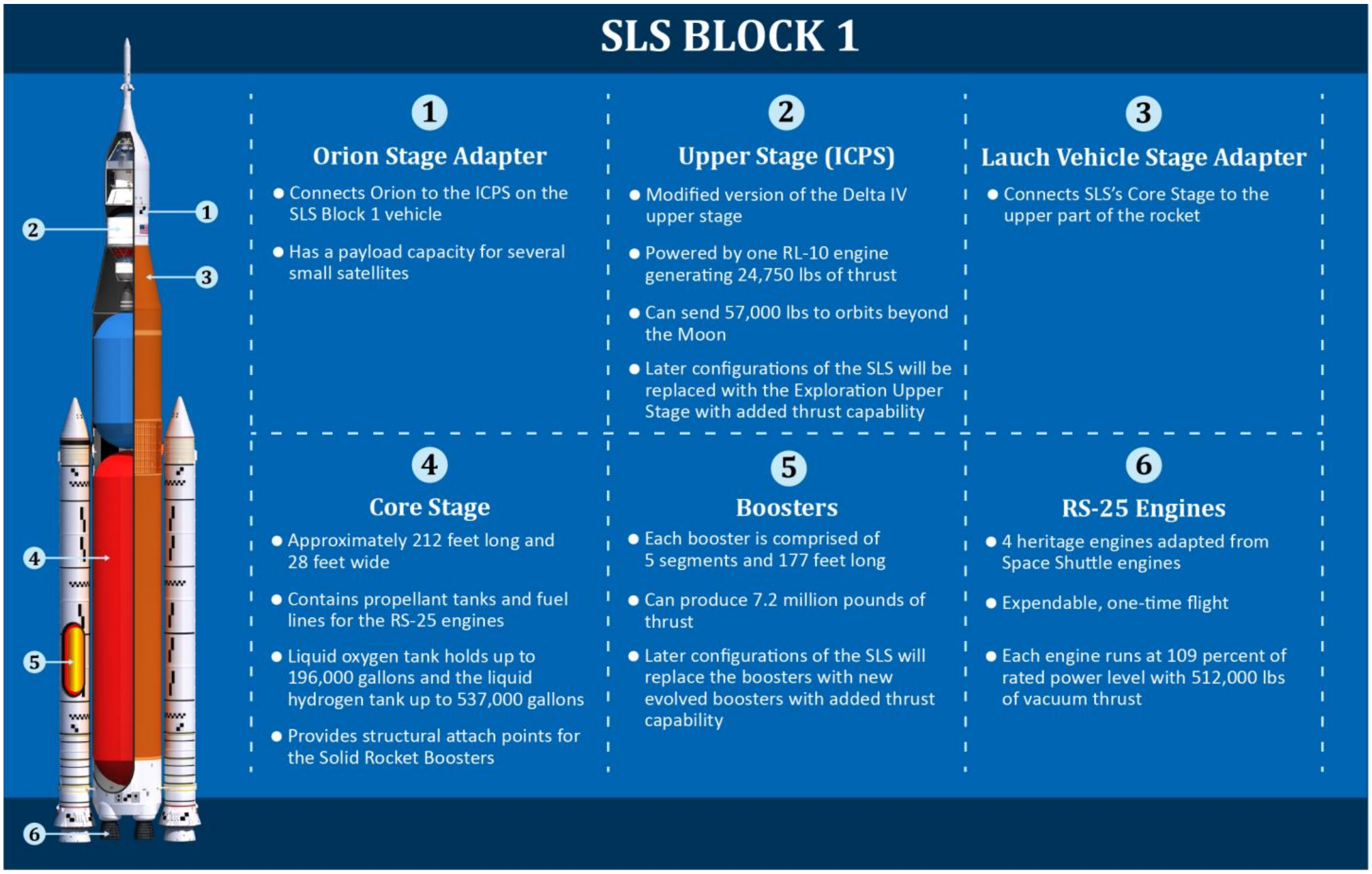
- *Core Stage.* The Core Stage, when combined with the Boosters, is the first stage of the SLS. Planned for use on all SLS configurations, the Core Stage serves as the backbone of the rocket, supporting the weight of the payload, Upper Stage, and crew vehicle, as well as the thrust of its four RS-25 Engines and two, five-segment Boosters attached to the engine and intertank sections. The Core Stage is composed of five key elements: (1) engine section, (2) liquid hydrogen tank, (3) intertank, (4) liquid oxygen tank, and (5) forward skirt.
- *Boosters.* The Boosters are being constructed from components of the Space Shuttle and Constellation programs. Each SLS will require two Boosters comprised of solid rocket motors, an aft skirt, a forward skirt, and nose piece. The length of the Boosters was extended by adding a fifth segment that increases the amount of solid rocket fuel the Boosters can hold, thereby increasing thrust capabilities by 25 percent.
- *RS-25 Engines.* The first four flights of the SLS will each use four RS-25 Engines originally designed, built, and used during the Space Shuttle Program. Unlike the Space Shuttle Program where the engines were built to be reusable, the SLS engines beginning with the fifth flight will be expendable with improved performance to operate at a higher thrust level.[12] Developed by Aerojet, these newly manufactured RS-25 Engines are being redesigned and produced using new manufacturing techniques to reduce costs. Figure 2 shows a breakdown of the major SLS Block 1 elements.

[10] The Delta IV Heavy rocket, developed by United Launch Alliance, first launched in 2004. Due to its proven capability, the Delta Cryogenic Second Stage will be used on SLS Block 1 launches until the more powerful Exploration Upper Stage is developed.

[11] A translunar injection burn is a maneuver that results in the spacecraft entering a trajectory between the Earth and the Moon.

[12] The RS-25 Engines, originally developed in the 1970s for the Space Shuttle Program, produced specific rated levels of thrust during Shuttle launches. Since then, NASA and the contractors have made performance improvements, and the RS-25 Engines can now operate above their originally rated thrust levels. For the SLS Program, the refurbished engines for the first four flights will operate at 109 percent thrust as compared to the 104.5 percent thrust at the end of the Space Shuttle Program. The new engines, starting with the fifth flight, will run at 111 percent thrust.

**Figure 2: SLS Block 1 Elements**




Source: NASA OIG analysis of Agency information.

## SLS Element Contracts

The SLS Program is currently managing eight prime contracts totaling $1.6 billion in obligations for fiscal year (FY) 2019 alone that represents 76 percent of the SLS Program's FY 2019 budget.[13] Collectively, the five major element contracts—Boeing's Core Stage (Stages) contract, Boeing's ICPS contract, Northrop Grumman's Boosters contract, Aerojet's RS-25 Engine Adaptation (RS-25 Adaptation) contract, and Aerojet's RS-25 Engine Restart (RS-25 Restart) contract—compose 71 percent of total funding spent in FY 2019 on all SLS contracts.[14] Table 1 provides a summary of these contracts, including scope of work, required deliverables, performance period, and contract value.

[13] Prime contractors work directly with the government. They manage any subcontractors, and are responsible for ensuring that the work is completed as defined in the contract.

[14] The remaining three contracts not included in the scope of this audit are Teledyne Brown's Launch Vehicle Stage Adapter contract ($8 million obligated in FY 2019), Dynetics Universal Stage Adapter contract ($25 million obligated in FY 2019), and Aerojet Rocketdyne's RL-10 engines contract ($48 million obligated in FY 2019).

**Table 1: Summary of Major SLS Element Contracts (as of December 2019)**

| Contract | Contractor | Deliverables | Performance Period | Contract Type[a] | Contract Value, as of December 2019[b] | Obligated Amount (Percentage) |
|---|---|---|---|---|---|---|
| Stages | Boeing | Design, build, test, and evaluate 2 Core Stages, 1 EUS, and test articles | 11/01/2012–12/31/2021 | Cost-plus-award-fee, IDIQ, and firm-fixed-price | $6,681,774,882 | $5,874,479,500 (88%) |
| ICPS | Boeing/ United Launch Alliance | 3 ICPS, 1 structural test article, and flight software | 10/01/2012–12/31/2023 | Firm-fixed price, cost-plus-award-fee, and IDIQ | $527,312,931 | $425,137,858 (81%) |
| Boosters | Northrop Grumman | Produce 35 Booster segments and upgrade the Boosters for future flights by replacing outdated parts | 12/16/2011–12/31/2023 | Cost-plus-award-fee, incentive-fee, and fixed-fee | $2,422,194,489 | $1,986,193,733 (82%) |
| RS-25 Adaptation | Aerojet | Adaptation of 16 Space Shuttle-era RS-25 Engines and development of new engine controller units used for communicating with the vehicle | 12/01/2011–03/31/2020 | Cost-plus-award-fee, incentive-fee, and IDIQ with fixed-fee | $572,732,597[c] | $572,732,597 (100%) |
| RS-25 Restart | Aerojet | Restart production and certification of 6 new RS-25 Engines | 11/01/2015–09/30/2024 | Cost-plus-award-fee and incentive fee | $1,718,118,754 | $935,892,850 (54%) |

Source: NASA OIG presentation of Agency information.

Note: Indefinite-delivery, indefinite-quantity (IDIQ).

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

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

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

### *Stages*

The Stages contract was initially awarded to Boeing in 2007 under the Constellation Program, and due to the congressional direction to use existing contracts, two SLS Core Stages were added to the contract in 2012 and the EUS in 2017. Boeing is currently contracted to build two Core Stages and one EUS—Core Stage 1 for the Artemis I launch, Core Stage 2 for Artemis II, and EUS for a future Artemis launch—and is also responsible for integrating and testing the Core Stage with the four RS-25 Engines and government-provided flight control software. The current contract utilizes a combination of contract types, including cost-plus-award-fee; cost-plus-incentive-fee; indefinite-delivery, indefinite-quantity (IDIQ); and a small amount of firm-fixed-price contract work. Total value of the contract as of December 2019 is approximately $7 billion through December 2021, of which $375 million was obligated under the Constellation Program. As of November 2019, Boeing has also started purchasing some long-lead materials for a third Core Stage under an undefinitized contract action on the current Stages contract, meaning the final terms and prices were not yet agreed to before Boeing began the purchases. NASA has approval authority over these purchased materials to ensure they are necessary and meet technical requirements. In October 2019, NASA issued a separate letter contract—another type of undefinitized contract action—authorizing Boeing to begin building the Core Stage 3 and order material for up to an additional 10 Core Stages and 8 EUSs.[15] NASA placed an initial value of $1.9 billion on the letter contract through September 2020 so that work can begin while NASA and Boeing finalize the full contract action. NASA officials noted this interim contract action was needed in order to meet the President's direction to land U.S. astronauts on the Moon by 2024.

In our October 2018 audit, we reported that Boeing's poor performance developing and building the first SLS Core Stage led to unsustainable cost increases and schedule delays for the SLS Program.[16] We found Boeing officials in prior years had consistently underestimated the scope of work to be performed and the size and skills of the workforce required. In addition, Boeing did not fully understand the requirements necessary to complete development of the stage controller—that is, the command and control hardware and software needed to conduct an important test known as the Green Run—resulting in approximately an 18-month delay of the stage controller system. Further, and in parallel to the stage controller delays, contaminated rocket fuel tubing in the engine section, a misaligned welding machine, inadequate weld strengths, and a tornado at Michoud Assembly Facility (Michoud) resulted in significant delays to the delivery of the Core Stage flight hardware from Michoud to Stennis Space Center (Stennis).[17] We found these and other issues would result in the first two Core Stages and an EUS costing at least $4 billion more than originally planned and falling behind schedule by 2.5 years.[18]

[15] A cost cap of $100 million is in place on the letter contract while the contract is negotiated.

[16] IG-19-001.

[17] During the Green Run test, the Core Stage will be mounted on a test stand and its four RS-25 Engines fired to simulate an actual launch. The test is designed to check the combined system's compatibility and functionality and will be the only time the RS-25 Engines are test fired as an integrated group.

[18] In our October 2018 Stages audit, we reported a $4 billion increase in costs based on obligations as of August 2018 and our cost projections through the 2021 period of performance of $8.9 billion.

### ICPS

NASA initiated the ICPS contract with Boeing in September 2012 with United Launch Alliance as the major subcontractor building the ICPS element. Upon contract definitization in 2014, the contract scope included the manufacture and engineering support for one ICPS with an option for a second unit, along with flight navigation software.[19] NASA's contract for the ICPS includes a firm-fixed-price element for the hardware, whereas the support is billed to NASA under a separate cost-plus-award-fee IDIQ element. The initial contract was definitized at $89 million; however, due to underestimating the actual cost to modify United Launch Alliance's Delta IV upper stage and integrate the ICPS into the SLS configuration, the contract value increased to $323 million by the time the ICPS was delivered to Kennedy Space Center (Kennedy) in October 2017. With mounting schedule pressures, significant development remaining for the more powerful EUS, and ongoing development of a second Mobile Launcher to support SLS Block 1B configuration, NASA decided to rely on the ICPS for more than just the Artemis I mission. Since the option to order a second ICPS had expired, in October 2018, NASA issued an undefinitized contract action to procure two additional ICPSs and a payload fairing system, increasing the total contract value to $412 million. As of December 2019, the contract value has increased to $527 million with additional increases anticipated after negotiations with Boeing are finalized for the two additional ICPSs. The ICPS for Artemis I is at Kennedy awaiting attachment to Core Stage 1 while additional work to complete the flight software qualification testing remains ongoing.

### Boosters

Northrop Grumman is building the Boosters from components used by the Space Shuttle and Constellation programs under a contract with cost-plus-award-fee, incentive-fee, and fixed-fee elements.[20] The contract was definitized in April 2013 at a cost of approximately $2.8 billion. At that point, the contract only included the production of four Boosters for the first two SLS missions, but in September 2016, NASA purchased three additional Boosters, increasing the contract value by $561 million to a total of $3.4 billion. The contract now includes the delivery of six Boosters for Artemis I, Artemis II, and Artemis III; the delivery of one flight test Booster; and funding for the Booster Obsolescence Life Extension to identify any issues with the design and manufacturing of upgraded and more capable boosters for future missions. Similar to the Stages and RS-25 Adaptation contracts, the Boosters contract was initially awarded in 2007 under the Constellation Program and the SLS requirements were added to the contract in 2012. Each Booster consists of five segments loaded with propellant and an aft skirt, a forward skirt, and nose piece. As of December 2019, Northrop Grumman had 20 of the 35 segments finished and in storage. The contract's value totals $4.1 billion through December 2023, which includes $1.6 billion obligated under the Constellation Program and spent prior to 2012.

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[19] To "definitize" a contract is to write the specific requirements of a program or project into the contract.

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

### *RS-25 Adaptation*

The RS-25 Adaptation contract with Aerojet provides for the retrofitting of Space Shuttle main engines for use on the SLS under a cost-plus-award-fee and incentive-fee structure. This contract began in 2006 under the Constellation Program to develop J-2X engines for use on the Ares I rockets.[21] In 2011, the SLS work was added to retrofit and certify 16 RS-25 Engines for the first four Artemis missions. Fourteen of the 16 RS-25 Engines have successfully flown on previous Space Shuttle missions, while the remaining two engines were assembled using a combination of new and leftover space hardware components from the Shuttle Program. The contract also included the development of Engine Controller Units (ECU)—that is, the "brain" of the engine. The ECU actively controls the engine during flight while monitoring engine operation for anomalous conditions. The ECU also communicates with the vehicle, monitors engine operation, and transmits data back to the vehicle. The $2.06 billion contract will end in March 2020, of which $1.4 billion was spent on development of the J-2X engine for the Constellation Program. Remaining work at approximately $10.9 million was added to the RS-25 Restart contract for flight engine processing, engine delivery, engine acceptance, and flight preparations in support of Artemis II through IV. As of December 2019, four RS-25 Engines were installed on Core Stage 1 for the Artemis I launch, while the remaining 12 engines are stored at Stennis for use on future Artemis missions.

### *RS-25 Restart*

The RS-25 Restart contract was initiated in November 2015 and provides for a recertification program for restarting the RS-25 production line and the production of six new RS-25 Engines. The recertification program includes restarting the supply base and in-house fabrication processes, and addressing hardware obsolescence. The project also includes implementing modern fabrication processes and affordability improvements, engine testing, and final certification for the production of new RS-25 Engines. The engines, scheduled for delivery in 2023 and 2024, will be used on the fifth SLS flight but will also serve as contingency engines for the fourth flight. In addition, Aerojet recently presented to NASA a follow-on proposal to the current contract for an additional 18 RS-25 Engines at a production rate of four engines per year. While the RS-25 Restart contract currently extends through September 2024 at a contract value of $1.72 billion, funding for the recertification portion of the contract ends in December 2021 when final engine certification is scheduled for completion.

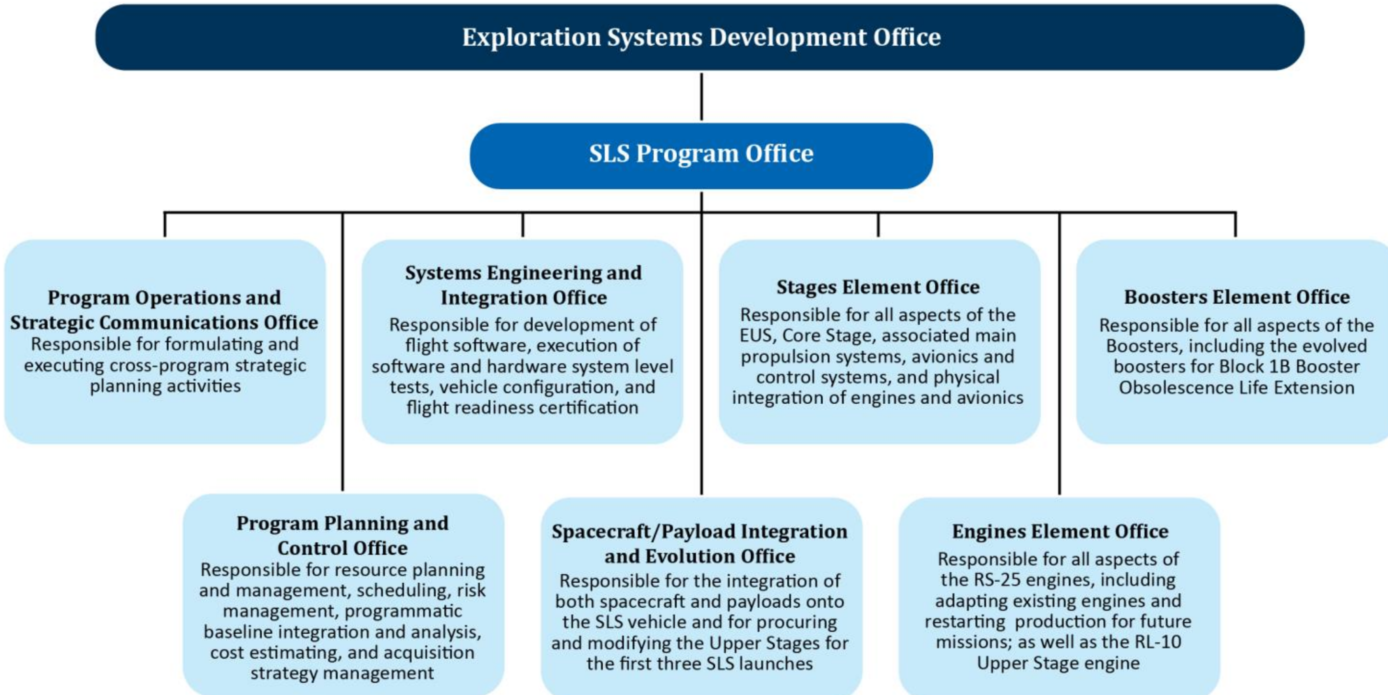
## SLS Program Management

The SLS Program is part of the Exploration Systems Development Office within the Human Exploration and Operations Mission Directorate (HEOMD).[22] Managed out of Marshall Space Flight Center (Marshall), the SLS Program is comprised of multiple "element" offices that develop, manage, and execute the different components of the SLS (see Figure 3).

[21] The Ares I was a two-stage crew launch vehicle developed in 2005 as part of NASA's Constellation Program for missions to the International Space Station and the Moon. The Ares I Upper Stage was designed to use one J-2X engine.

[22] The Exploration Systems Development Office also manages the Orion and Exploration Ground Systems programs.

**Figure 3: SLS Program Offices**




Source: NASA OIG presentation of Agency information and SLS Program Plan.

## Contractor Performance Assessments and Award Fees

For award fee contracts, each contractor's performance is evaluated periodically by NASA to determine the amount of award fees they earn during each assessment period. The contractors can earn anywhere from 0 to 100 percent of the award fees available for that period based on their performance rating. Figure 4 shows the numerical and adjectival ratings for award fee performance ratings.[23] These fees are in addition to the amounts NASA pays the contractors to reimburse them for actual costs incurred. The award fee earned during each performance period is determined by whether the contract is classified as a "service" or "end-item" contract.[24] Whereas Boeing's Stages and Upper Stage contracts and Aerojet's RS-25 Restart contract are service contracts, Aerojet's RS-25 Adaptation and Northrop Grumman's

[23] Marshall Work Instruction 5116.1, *Evaluation of Contractor Performance under Contracts with Award Fee Provisions* (June 2, 2015). For each evaluation period, Marshall guidance requires the SLS Contracting Officer Representatives to provide both a numerical rating and an adjectival (descriptive) rating to the Performance Evaluation Board for its consideration. Upon review, the Performance Evaluation Board provides its recommendations on the amount of award fee to the Fee Determination Official for final approval. A contracting officer representative is appointed in writing by a contracting officer with specific duties to help manage the contract, while technical monitors are appointed by the contracting officer representative to monitor and provide feedback on the contractor's performance. The Performance Evaluation Board is responsible for evaluating the contractor's overall performance for each award-fee evaluation period based on input from the technical monitors, contracting officer representatives, contracting officer, and applicable element program manager.

[24] Federal Acquisition Regulation (FAR) § 37.101, *Service Contracts* (2015), states a service contract "directly engages the time and effort of a contractor whose primary purpose is to perform an identifiable task rather than to furnish an end item of supply." Per the FAR, each evaluation is final for service contracts while for end-item contracts only the last evaluation is final, when the overall quality of contract performance can be measured after the item is delivered. NASA FAR Supplement (NFS) § 1816.405-273, *Award Fee Evaluations* (2018). At that point, the total contract award-fee pool is available for consideration and the contractor's total performance is evaluated against the award-fee plan to determine the award fee.

Boosters are end-item contracts. In service contracts, the award fees earned by the contractor during each evaluation period are final and the federal government cannot recoup those fees even if poor performance issues are subsequently traced back to that period. Similarly, any award fee not paid during a performance period cannot later be claimed by or awarded to the contractor. For end-item contracts, interim or provisional payments are made, but the overall award fee amounts can be adjusted during the evaluation phase in the final performance period.

**Figure 4: Award-Fee Performance Ratings**

| | |
|---|---|
| **91% to 100%** | **EXCELLENT**<br>Contractor ***exceeded almost all*** of the significant award-fee criteria and has met overall management, cost management, technical performance, and small business/small disadvantage business subcontracting 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. |
| **76% to 90%** | **VERY GOOD**<br>Contractor ***exceeded many*** of the significant award-fee criteria and has met overall management, cost management, technical performance, and small business/small disadvantage business subcontracting 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. |
| **51% to 75%** | **GOOD**<br>Contractor ***exceeded some*** of the significant award-fee criteria and has met overall management, cost management, technical performance, and small business/small disadvantage business subcontracting 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. |
| **No greater than 50%** | **SATISFACTORY**<br>Contractor has ***met*** overall management, cost management, technical performance, and small business/small disadvantage business subcontracting 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. |
| **0%** | **UNSATISFACTORY**<br>Contractor has ***failed to meet*** to meet overall management, cost management, technical performance, and small business/small disadvantage business subcontracting 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 OIG presentation of Agency award fee criteria.

## NASA's Program Management 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 5).[25] 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

[25] NASA Procedural Requirements (NPR) 7120.5E, *NASA Space Flight Program and Project Management Requirements with Changes 1-17 (*August 14, 2012) and NASA/SP-2014-3705, *NASA Space Flight Program and Project Management Handbook* (September 2014).

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 5: NASA Project Life Cycle**

| PREFORMULATION | FORMULATION | | APPROVAL/KDP-C | IMPLEMENTATION | | | |
|---|---|---|---|---|---|---|---|
| **Pre-phase A** Preformulation | **Phase A** Concept and technology | **Phase B** Preliminary design and technology completion | NASA sets Agency Baseline Commitments for cost and schedule | **Phase C** Final design and fabrication | **Phase D** System assembly, integration, test, launch, and checkout | **Phase E** Operations and sustainment | **Phase F** Closeout |
| | *Formulation costs* | | | *Development costs* | | *Operations* | |

Source: NASA OIG presentation of Agency information.

## SLS Program Cost and Schedule Tracking and Reporting Requirements

NASA is required to create, track, and report on the life-cycle costs and schedule commitments for any program with a budget exceeding a life-cycle cost of $250 million.[26] Life-cycle costs include all costs related to a program—regardless of funding source or management control—over its planned lifespan. NASA policy further requires space programs to set a formal Agency Baseline Commitment (ABC) at KDP-C for cost and schedule after formulation is complete but before development begins.[27] Total ABC costs consist of past formulation costs and the estimated development costs to achieve operational readiness through Phase D. ABC costs are used both internally and externally to help track a program's progress against specific scope and schedule assumptions. Once set, a program tracks its status against the commitments and submits quarterly reports for vetting by NASA management, including the Office of the Chief Financial Officer, before being sent to Congress and the Office of Management and Budget. NASA also manages the cost and schedule of programs through the Agency's annual budget formulation process, which reflects program and technical updates and changes during development.

[26] Baselines and Cost Controls, 51 U.S.C. § 30104(a)(3) (2010). NPR 7120.5E.

[27] NPR 7120.5E.

Agency program managers must immediately notify the NASA Administrator if there is reasonable cause to believe that a cost or ABC threshold is likely to be exceeded.[28] Once notified, the Administrator must determine what tracking and reporting actions are required. For a program likely to exceed 15 percent of development costs or be delayed by 6 months, the Administrator must notify Congress and then submit an updated cost and schedule status for the program within 7 months of the Agency's determination.[29] If the Administrator determines that a program will exceed 30 percent of development costs, NASA must notify Congress and may not spend any additional money beyond 18 months unless the program is subsequently reauthorized by law and the Agency completes and submits to Congress a rebaseline of program scope, expected costs, and schedule commitments. Additionally, the Agency may formulate an independent review board to evaluate the program's status, ensure the Agency's approach is appropriate, and make recommendations to improve the program. In May 2019, NASA updated its program management policy to require updated Joint Cost and Schedule Confidence Level estimates for any program valued over $1 billion if a rebaseline occurs.[30]

Instead of following the standard requirement for setting the ABC based on all life-cycle costs and activities for the SLS Program, NASA decided to only include costs related to Artemis I and a schedule based on the Artemis I launch date.[31] Based on this scope limitation, the Program's ABC was set at $9.7 billion split between $2.7 billion in formulation costs and $7 billion in development costs. This tailored approach to cost reporting meant that cost increases or schedule delays not tied to Artemis I activities would not be tracked or reported to Congress and the Office of Management and Budget through the ABC process. NASA officials explained the scope of the ABC was limited to just the first Artemis mission because the rest of the program, including subsequent missions, assumed launch cadence, and launch vehicle variants, had not been fully formulated at the time of the initial ABC in 2014. Based on this Artemis I ABC, a rebaseline would only be required if development costs directly tied to Artemis I—initially set at $7 billion—increased by 30 percent or other events and scope changes necessitate a rebaselining. A summary of the initial scope of the ABC costs at KDP-C is shown in Table 2.

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[28] 51 U.S.C. § 30104(d)(1).

[29] 51 U.S.C. § 30104(e).

[30] NASA Interim Directive 7120.122, *Joint Cost and Schedule Confidence Level Requirements Updates* (May 24, 2019). A Joint Cost and Schedule Confidence Level analysis is a tool used by NASA for program management to help determine the likelihood a project will achieve its objectives within budget and on time.

[31] We have reported on the SLS Program's decision to limit the scope of the ABC to only Artemis I activities in past reports: IG-19-001 and NASA OIG, *NASA's Plans for Human Exploration Beyond Low Earth Orbit* (April 13, 2017, IG-17-017).

**Table 2: Initial Scope of SLS Program ABC Costs**

| SLS Program Office | SLS Vehicle Development (including testing) | Production for Artemis I | ABC Cost Commitment |
|---|---|---|---|
| Stages Element Office | SLS Core Stage (including qualification unit, functional testing, and Green Run test) | 1 Core Stage | $3,138,700,000 |
| Boosters Element Office | Five-segment Boosters | 2 Boosters | $1,198,300,000 |
| Engines Element Office | • New RS-25 Engine Controller Units<br>• RS-25 Engine installation with Core Stage<br>• Sustainment to restart RS-25 production line | • Refurbishment of 4 RS-25 Engines and 4 spares<br>• Production of 6 new RS-25 Engines (beyond Artemis I) | $1,090,300,000 |
| Other offices[a] | • ICPS<br>• Stage adapters for SLS Block 1 configuration<br>• Systems engineering and integration<br>• Integration of avionics and software<br>• Program management<br>• Safety and mission assurance<br>• Construction of facilities | • 1 ICPS<br>• 1 Orion stage adapter<br>• 1 launch vehicle stage adapter<br>• Integration of vehicle avionics and software | $1,594,200,000 |
| Subtotal Development Cost Commitment (FY 2014 to FY 2019) | | | $7,021,400,000[b] |
| Formulation Cost Commitment (FY 2012 and FY 2013) | | | $2,674,000,000 |
| **Total ABC Costs (At KDP-C in August 2014)** | | | **$9,695,400,000** |

Source: NASA OIG presentation SLS Program KDP-C Memorandum and Agency information.

[a] Other offices include the Spacecraft/Payload Integration and Evolution Office, Program Management Office, Safety and Mission Assurance Office, and Systems Engineering and Integration Office.

[b] The total of the SLS Program Office development costs are $100,000 higher compared to the $7,021,400,000 development cost subtotal due to rounding in NASA documentation.

# SLS PROGRAM COSTS CONTINUE TO RISE AS ARTEMIS I LAUNCH FACES ADDITIONAL DELAYS

NASA continues to struggle managing SLS Program costs and schedule as the launch date for the first integrated SLS/Orion mission slips further.[32] Rising costs and delays can be attributed to challenges with program management, technical issues, and contractor performance. Going forward, expected delays resulting from upcoming testing and integration events, along with new Artemis lunar plans, may hinder NASA's ability to meet the Agency's mid- and longer-term space exploration goals, including landing on the Moon in 2024 and reaching Mars in the 2030s. Moreover, as NASA and the contractors attempt to accelerate production of SLS Core Stages to meet new timelines, they must address concerns about shortcomings in quality control.

## SLS Costs Will Continue to Rise Significantly Before Artemis I Launch

As of December 2019, costs for the SLS Program have reached $14.8 billion, and based on the work remaining, the earliest launch date for Artemis I will be November 2020. By that time, costs are projected to grow to more than $17 billion—a 60 percent increase from the Agency's original $10.2 billion scope and cost projection in 2014. Leading up to 2019, NASA had significantly increased the workforce to complete Core Stage fabrication and integration at Michoud. Nonetheless, even though Core Stage 1 remains a high priority and shipment to Stennis was completed in January 2020, it is unlikely that NASA will be able to complete the scheduled 6-month long Green Run test and integrate the elements of the rocket with the Orion crew capsule in time to meet the currently scheduled launch date of November 2020. In fact, NASA's current schedule assessment shows that the period of Core Stage integration, testing, and refurbishment could last until fall 2020. As a result, we expect costs to rise beyond the projected $17 billion as the launch schedule continues to slip. See Appendix B for a historical summary of Artemis I launch dates and associated costs. Figure 6 shows how the launch dates have changed since December 2016, the first SLS launch date mandated by Congress.

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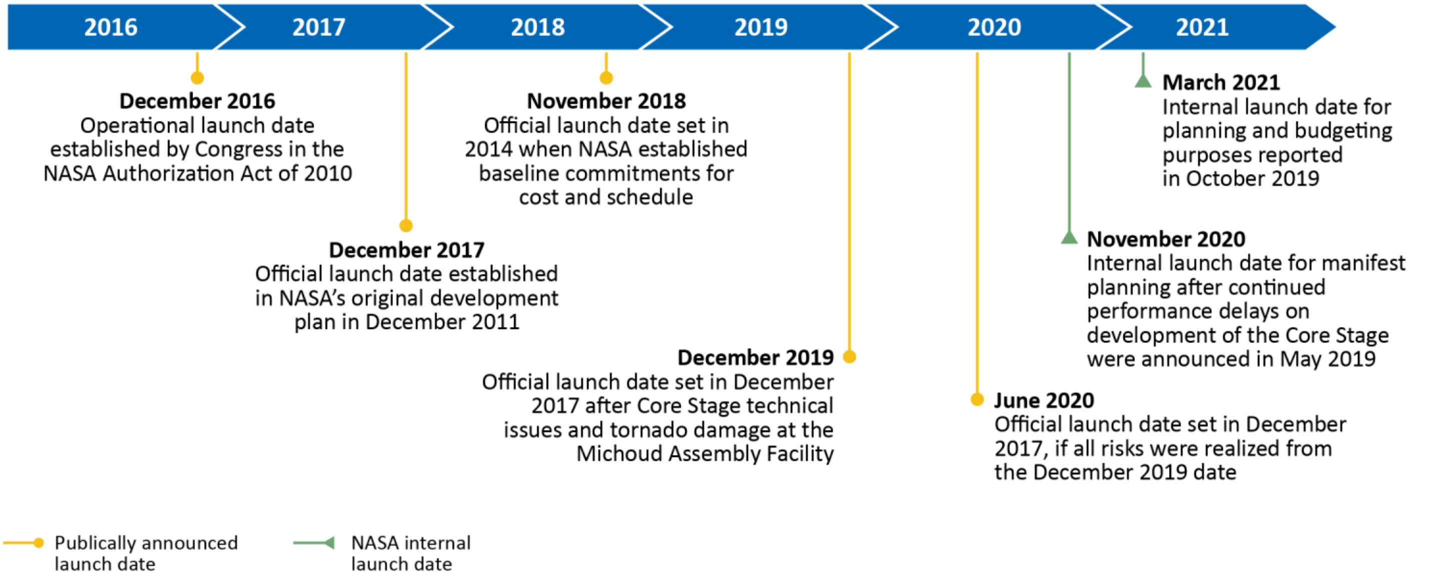
[32] IG-19-001 and IG-17-017. Government Accountability Office (GAO), *NASA Human Space Exploration: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs* (GAO-19-377, June 19, 2019).

**Figure 6: Shifting Artemis I Launch Dates**




Source: NASA OIG summary of Agency information.

With NASA's current plan to launch Artemis II by October 2022, the SLS Program is projected to have spent nearly $22 billion. Combining Orion and Exploration Ground Systems costs with SLS, NASA is projected to spend more than $50 billion by 2024 on the integrated system.

# Management, Technical, and Performance Issues Primary Drivers of Increasing Costs and Schedule Delays

## Using Existing Constellation-Era Contracts and Heritage Equipment Had Drawbacks

In 2010, Congress directed NASA to incorporate SLS requirements into the preexisting Constellation-era contracts after the Program was canceled. Specifically, contracts for Boeing's ICPS, Aerojet's J-2X engine, and Northrop Grumman's Boosters were updated to incorporate SLS requirements. Since the heritage equipment would be modified under existing Constellation contracts, NASA allowed the contractors to continue working, shifting from Constellation tasks to those for SLS before the new contract requirements could be definitized. However, determining firm SLS requirements became a challenge as evidenced by the 1 to 2 years that elapsed before NASA definitized the contracts—far exceeding NASA's own guidance that provides for a 6-month definitization period.[33] Moreover, since

[33] In 2014, GAO concluded that employing SLS contractors for extended periods of time without contract definitization led to increased government risk of rising costs and limited the program's ability to monitor contractor progress. GAO, *Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability* (GAO-14-631, July 23, 2014). The NFS provides that the NASA goal is to definitize contracts within 180 days, or approximately 6 months, of issuance. NFS § 1843.7005(a), *Definitization* (2018).

these contracts were already awarded, modifying them with additional requirements increased costs since the original contracts were not competed among multiple contractors but awarded to the only contractors NASA deemed capable of performing the work, a situation that provided NASA less leverage to negotiate prices.

# Program Management

Throughout the SLS's 8 years of development, program management has been a continuous challenge for the Agency, an outcome we attribute primarily to four factors: mission configuration and scope, award fees, contract structure, and schedule and funding margin.

## *Mission Configuration and Scope*

The SLS Program underwent several mission configuration and scope changes regarding the rocket's Upper Stage. Although NASA had originally planned to use a modified version of the off-the-shelf ICPS for the first two Artemis missions, in December 2015, Congress directed the Agency to develop and utilize the EUS instead of the ICPS for Artemis II. However, the time available to develop and build the EUS and modify the existing Mobile Launcher was not sufficient to meet the Artemis II launch window. Ultimately, the Agency committed to build a second Mobile Launcher at a projected cost of $486 million to accommodate the extra height the EUS added to the SLS.[34] Because of the slowdown in EUS development to help fund completion of Core Stages 1 and 2 and the requirement to build a second Mobile Launcher to support SLS Block 1B configuration, NASA decided in October 2018 to revert to using an ICPS for Artemis II to avoid a significant anticipated delay between the first two Artemis missions. NASA has spent more than $500 million on EUS development, but Boeing has shifted production resources to focus on completing Core Stage 1 and 2, and as of December 2019, the contractor was only conducting design work on the EUS. During this period, NASA missed an opportunity to buy the hardware for a second ICPS for $29 million and instead plans to spend at least $42 million.[35]

## *Award Fees*

Contract award fees are designed to incentivize contractors and reward high performance. Both NASA OIG and the Government Accountability Office (GAO) have previously reported on the Agency's inappropriate use of award fees on the Boeing's Stages contract.[36] Despite continued cost and performance issues on SLS element contracts, NASA officials did not adhere to established guidance and awarded high fee amounts, disincentivizing the contractors to improve performance.[37] To date, for contracts with cost overruns and schedule delays—Stages, Boosters, and RS-25 Adaptation—award fees provided to the contractors average 84 percent, 72 percent, and 90 percent, respectively. Following our October 2018 report, NASA provided Boeing only 58 percent of available award fees on the Stages contract during the 2018 evaluation period compared to 89 percent the Agency awarded on average to

[34] The SLS Block 1 will be assembled on the Mobile Launcher, which will provide structural and logistics support up to and during launch. A second Mobile Launcher is required for the Block 1B capability when the EUS replaces the ICPS.

[35] By the time NASA internally agreed upon an updated configuration for Artemis II, the original contract option for a second ICPS had expired.

[36] In IG-19-001 we identified unsupported award fees in the amount of $64 million. See also GAO-19-377.

[37] Marshall Work Instruction 5116.1.

the Stages contract during the previous seven evaluation periods.[38] Subsequently, Boeing's performance improved, and they earned 82 percent of available award fees in the evaluation period covering the first half of 2019. However, the recently completed RS-25 Adaptation contract has interim award fees of 90 percent, despite major technical issues that resulted in more than 2.5 years of schedule delay.[39] As of the time of this report, the final award determination has not been made.

### *Contract Structure*

The structure of the SLS contracts limits visibility into contract costs and prevents NASA from determining specific costs per element (i.e., Core Stage, ICPS, EUS, Boosters, and RS-25 Engines). As a result, it is difficult to determine the actual cost of building the SLS, which in turn makes it difficult to determine total costs of the Artemis I mission. Specifically, current Federal Acquisition Regulation (FAR) guidance requires each contract deliverable to have its own contract line item number (CLIN) in order to track costs and evaluate a contractor's performance. However, when NASA definitized these contracts in 2013 and 2014, individual CLINs were recommended but not required by the FAR.[40] Consequently, in each of the element contracts, NASA used a single CLIN to track all deliverables.[41] However, since July 2019, NASA is tracking each deliverable item for the Stages contract.[42] In addition, NASA established separate financial codes to track EUS development costs. These actions will provide greater fidelity for the SLS Program when tracking the costs of each major deliverable.

### *Schedule and Funding Margin*

Prior to FY 2019, NASA had routinely built in only $25 to $50 million annually—approximately 1 to 2 percent of the program's development budget—as a management reserve for the SLS Program to handle unexpected expenses. This reserve amount stands in stark contrast to Marshall guidance that recommends programs set aside 10 to 30 percent of their budget as reserve.[43] However, according to the SLS Program Office, in FYs 2018, 2019, and 2020, NASA has made progress in increasing its reserves to 7, 10, and 14 percent, respectively. That said, NASA currently has little schedule reserve for many outstanding tasks that contain inherent technical risk, including the Green Run testing at Stennis and final assembly of the SLS at Kennedy. According to Marshall guidance, the SLS Program should carry 30 days of schedule margin per year leading up to launch. With a projected launch date in late 2020, the

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[38] IG-19-001.

[39] Aerojet's RS-25 Adaptation contract does not include cost as a factor in the award fee evaluation but instead is considered part of the incentive fee structure. If both award and incentive fees are combined, the amount Aerojet has received to date totals 83 percent of the available fees.

[40] When the contract requirements were set in 2014, the FAR stated CLINs should provide unit prices or lump sum prices for separately identifiable contract deliverables and associated delivery schedules or performance periods, FAR § 4.1001, *Administrative Matters—Policy* (2014).

[41] For the Stages contract, the costs to build Core Stage 1, Core Stage 2, and the EUS were combined into CLIN 9; for Boosters, the costs for six Boosters and a flight support booster were combined into CLIN 5; and for RS-25 Adaptation, the costs for refurbishment of all 16 engines was combined into CLIN 3. For the ICPS, although each end item has its own separate CLIN, software development and engineering support are comingled.

[42] In IG-19-001, we found all three deliverables for the Boeing contract—two Core Stages and the EUS—were comingled into the same CLIN which made it difficult to track the progress and costs of each deliverable. In response to our recommendation, beginning in July 2019, NASA revised the contract to start tracking each deliverable through separate CLINs.

[43] Marshall Procedural Requirements (MPR) 7120.1, *MSFC Engineering and Program/Project Management Requirements* (October 20, 2016), provides guidance on standard cost and schedule margins for launch vehicle programs and projects.

Program should have at least 60 days of schedule margin.[44] However, even as SLS development lost schedule margin, NASA failed to build additional margin back into the schedule, making projections for launch dates unreliable. Although NASA officials are adding more funding reserves back into the program, the schedule will continue to have little or no margin, making the current launch date of November 2020 unrealistic.

## Technical Challenges

The SLS Program's Core Stage, ICPS, Boosters, and RS-25 Engines have all experienced substantial technical challenges, which are expected for such a large, complex space flight program. However, the impact on the SLS Program's schedule of addressing these technical issues turned out to be far greater than anticipated. For example, as detailed later in this report, officials represented that seemingly straightforward modifications for improved ECUs and rocket casing liners took approximately 6 years to qualify for production. Furthermore, even if Core Stage 1 had been completed in time for the originally planned Artemis I launch date of November 2018, the Boosters and RS-25 Engines would not have been ready. While the Core Stage 1 schedule is still the primary driver of delays due to its position on the "critical path," the upcoming integration of the Core Stage with other SLS elements will likely result in additional launch delays given that integration is traditionally where programs encounter multiple technical challenges.[45]

## Contractor Performance

We and other oversight entities have consistently identified contractor performance as a primary cause for the SLS Program's increased costs and schedule delays, and quality control issues continue to plague Boeing as it pushes to complete the rocket's Core Stage. Both NASA and contractor officials explained that nearly 50 years have passed since development of the last major space flight program—the Space Shuttle—and the learning curve for new development has been steep as many experienced engineers have retired or moved to other industries. In addition, Boeing officials noted that the U.S. industrial base is not as robust as it used to be, making it difficult to find qualified technicians and suitable suppliers, particularly for production of the Core Stage. Furthermore, according to some contractor officials, it has been difficult to implement new manufacturing processes and introduce improved materials.

Despite these challenges, both NASA and the contractors have made process changes over the past year that, in our judgment, should help better control cost and schedule outcomes of future SLS rocket-builds. For example, NASA has improved its insight into contractor production challenges and improved processes for tracking contractor costs through contract restructurings. Specifically, on Boeing's Stages contract, NASA has increased the frequency of production improvement status updates and, as previously discussed, implemented procedures to separate costs for each Core Stage. For its part, Boeing has made personnel changes to management at Michoud to ensure challenges are addressed in a timelier manner. In addition, Boeing has instituted a horizontal joining process of major components at Michoud that has reduced the Core Stage's production timeline by approximately 4 months. This involved modifying equipment to hold and rotate the rocket and adding a device to position the wiring harnesses on the rocket.

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[44] MPR 7120.1.

[45] A critical path activity has the most work left to do and least amount of time remaining to complete.

Although Boeing has made improvements in the Core Stage production rate, we have concerns about its ability to remedy corrective action requests prepared by Defense Contract Management Agency (DCMA) officials.[46] NASA's Core Stage contract requires Boeing to maintain a system of quality assurance, system safety, and reliability. This includes reporting and tracking significant nonconformances, attending material review boards, and participating in mandatory government inspections during production. In October 2019, DCMA deemed Boeing's corrective action system ineffective. This resulted from DCMA finding repeated safety-related quality assurance nonconformances, including:

- foreign objects found in various parts of the Core Stage,
- bypassing mandatory inspection points,
- loss of traceability of nonconforming hardware, and
- unauthorized work on and moving of hardware.

As a result, Boeing conducted a production pause at the Michoud plant for 2 days in October 2019 while the contractor brought in additional personnel and prepared a formal corrective action plan for submission to NASA. NASA accepted the proposed plan, but it will take at least a year to assess the effectiveness of Boeing's actions due to the scope of corrective actions required.

[46] DCMA assists NASA at Michoud by providing quality assurance specialists that monitor the contractor's compliance with quality management procedures as outlined in the Stages contract.

# SLS Program Exceeded Rebaseline Threshold

Based on our review of SLS Program cost reporting, we found that the Program exceeded its Agency Baseline Commitment (ABC) by at least 33 percent at the end of FY 2019, a figure that could reach 43 percent or higher if additional delays push the launch date for Artemis I beyond November 2020. This is due to cost increases tied to Artemis I and a December 2017 replan that removed almost $1 billion of costs from the ABC without lowering the baseline, thereby masking the impact of Artemis I's projected 19-month schedule delay from November 2018 to a June 2020 launch date. Since the replan, the SLS Program now projects the Artemis I launch will be delayed to at least spring 2021 or later. Further, we found NASA's ABC cost reporting only tracks Artemis I-related activities and not additional expenditures of almost $6 billion through FY 2020 that are not being reported or tracked through the official congressional cost commitment or the ABC.

## SLS Program Removed Development Costs from the ABC without Lowering the Original Baseline

When NASA approved the SLS Program in 2014 to start development activities, the Agency established the ABC for Artemis I at $9.7 billion, which included $7.02 billion for development costs. However, as a result of delaying Artemis I up to 19 months to June 2020, NASA conducted a replan of the SLS Program in 2017 and removed $889 million in Booster and RS-25 Engine-related development costs because SLS Program officials determined those activities were not directly tied to Artemis I.[47] NASA stated the evolved Booster development activities and the acceleration of the RS-25 Restart contract allowed larger portions of SLS Program funding to be accounted for as non-Artemis I activities. This in turn allowed some Booster and RS-25 Engine fixed costs, which had been included in the ABC, to be reallocated to non-Artemis I activities. NASA told Congress that this removal allowed for more cost increases tied to Core Stage and other development activities to be accounted for under Artemis I costs without substantially increasing the overall reported ABC costs.

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[47] A replan is a process initiated if development costs increase by 15 percent or more or if there is a schedule delay of 6 months or more. According to NASA, the December 2017 replan for the SLS Program was triggered due to the more than 6 months of delays tied to the Artemis I launch date and was not because the Program's development costs increased more than 15 percent. A replan does not require a new project baseline to be established. A rebaseline is a process initiated if development costs increase by 30 percent or more. Both processes require NASA to submit a report to relevant congressional committees.

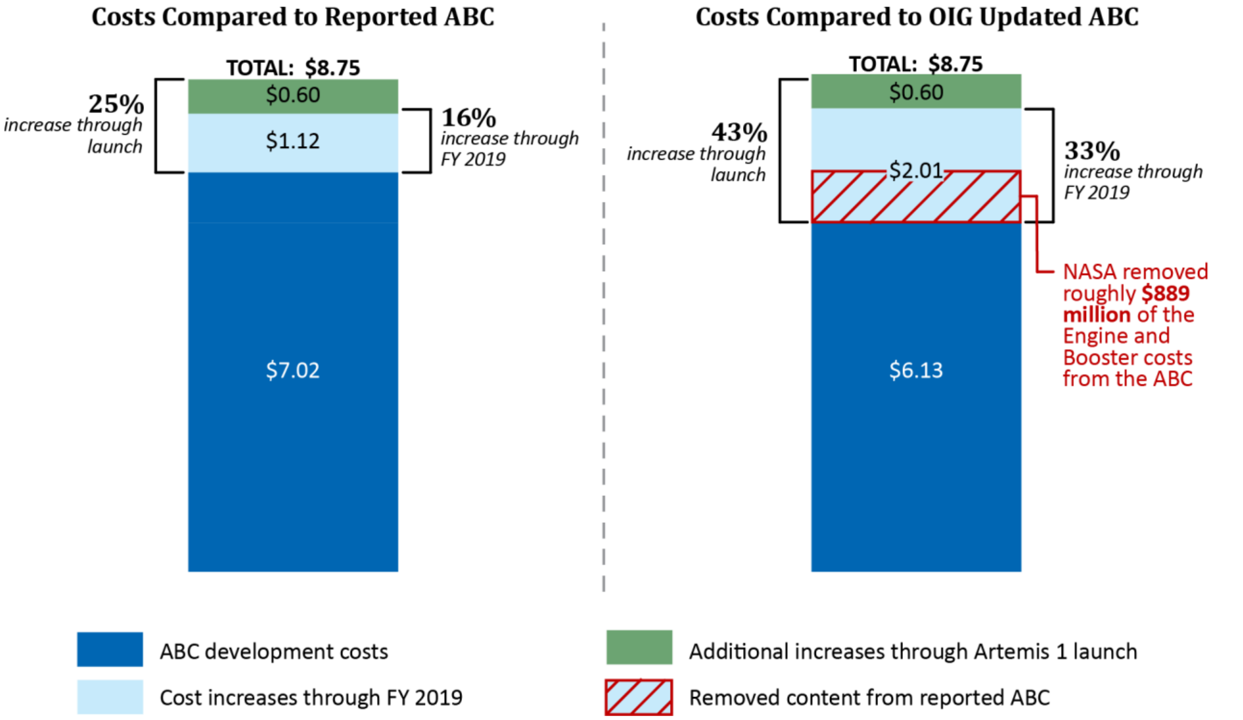
In our judgement, the removal of these costs should have reduced the SLS Program's ABC development costs from $7.02 billion to $6.13 billion.[48] According to SLS Program's Program Plan and NASA's Space Flight Program and Project Management Requirements, the SLS Program must be rebaselined when the NASA Associate Administrator judges the scope defined in the ABC has been changed. While the NASA Associate Administrator did not determine the removal of $889 million in the 2017 replan was a change in scope, in our judgment, a reduction of more than 10 percent of the ABC costs was a significant enough change in scope to require adjusting the ABC baseline. SLS Program and HEOMD officials disagreed with our assessment and stated the SLS Program's change in cost estimates for the Booster and Engines element offices were not a removal of costs but rather a reallocation of those activities to appropriately account for them as non-Artemis I costs. SLS Program officials also stated the HEOMD Associate Administrator did not require a rebaseline in 2017 based on this reallocation. Further, SLS Program officials stated the original ABC commitment—$7.02 billion for development costs—is the appropriate baseline for tracking and reporting percentage increases to ABC costs. However, in April 2018, NASA officials wrote Congress explaining that some Booster and RS-25 Engine costs originally in the ABC baseline were reallocated as non-ABC costs, and this decision resulted in actual costs within the ABC scope being reduced. NASA officials also stated that the reduction allowed for the absorption of other cost increases due to a 13-month to 19-month schedule delay and development and production challenges without substantially increasing the overall reported ABC costs.

As of October 2019, NASA reported total Artemis I costs at $10.8 billion through FY 2019. Of those costs, development spending reached $8.1 billion. Therefore, based on the Agency's reporting, we determined NASA exceeded the ABC by approximately $2.0 billion, or 33 percent, compared against the revised baseline of $6.13 billion. Through the Artemis I launch date, the SLS Program estimates ABC costs will be at least $8.75 billion, which will exceed the ABC by $2.6 billion, or 43 percent.[49] If the original baseline of $7.02 billion is used as recommended by SLS Program officials, then development costs exceeded the baseline by 16 percent in FY 2019 and will increase to 25 percent by an Artemis I launch date. Appendix C provides a comparison of the original baseline, the revised baseline, and the ABC cost estimates by NASA as of October 2019. Figure 7 shows the impact of the removed costs on the percentage increases even though the estimated total development costs are $8.75 billion for both the original ($7.02 billion) and revised ($6.13 billion) baselines.

[48] In June 2019, GAO reported concerns about the removed costs from the 2017 replan and stated SLS Program's ABC would be $6.24 billion when the baseline is revised lower to account for the removed Booster and RS-25 Engine costs. GAO-19-377. We used a similar methodology as GAO, but we determined the revised ABC should be $6.13 billion, or about $100 million lower than what GAO reported. For our determination, we used SLS Program's replan assumptions set as of December 2017. GAO used NASA's reported numbers as of September 2018, which included roughly $100 million in cost increases above the replan baseline.

[49] NASA's revised ABC cost estimates assumed a launch date of March 2021 for planning and reporting purposes.

**Figure 7: NASA Reported ABC Development Costs Compared to OIG Updated ABC through FY 2019 and Artemis I Launch (Dollars in Billions)**




Source: NASA OIG analysis of SLS Program ABC baseline from 2014, ABC replan in 2017, and updated SLS Program estimates from October 2019. NASA's October 2019 cost estimates are based on a March 2021 launch date for Artemis I.

Note: As of October 2019, NASA estimated total ABC costs tied to Artemis I were $11.42 billion with $8.75 billion in development costs and an additional $2.67 billion in formulation costs that occurred prior to setting the Program's baseline in 2014.

Federal law requires that any time Agency program managers have reasonable knowledge that development costs are likely to exceed the ABC by more than 30 percent, they must notify the NASA Administrator.[50] Once the Administrator determines the SLS Program will exceed the development cost baseline by 30 percent or more, NASA is required to notify Congress and rebaseline program costs and schedule commitments. If the Administrator notifies Congress of the need to rebaseline, NASA is required to stop funding program activities within 18 months unless Congress provides approval and additional appropriations.

In our judgement, using NASA's cost estimates from October 2019 and accounting for the removed costs from the replan, the SLS Program was required to rebaseline when the program exceeded its ABC by 33 percent at the end of FY 2019, an increase that could reach 43 percent or higher by the Artemis I launch date.[51] While NASA did not agree with our conclusion that the rebaselining and reporting threshold was triggered, the Agency plans to rebaseline the SLS Program due to changes in scope as a result of the accelerated plans to put humans on the Moon by 2024. NASA policy prescribes that if a program experiences a significant change in scope—such as from added requirements, manifest

[50] 51 U.S.C. § 30104, *Baselines and Cost Controls* (2010).

[51] In June 2019, GAO used cost estimates from September 2018 and similar analysis to find the SLS Program's development costs had increased by 29 percent compared to the SLS Program's ABC. GAO-19-377.

changes, or accelerated timetables—program management requirements allow NASA to rebaseline even if the program has not exceeded the 30 percent ABC threshold.[52] NASA officials stated that if their rebaselining of the Program due to scope changes finds that costs have exceeded the 30 percent threshold, the Agency will follow applicable notification and reporting requirements.

# Billions of Dollars in SLS Program Costs Not Captured in the ABC

The SLS Program does not have a full life-cycle cost estimate as required by NASA's Space Flight Program and Project Management Requirements, a shortcoming attributable to a decision approved by the SLS Program, Office of the Chief Engineer, HEOMD, and the NASA Associate Administrator to tailor requirements at the beginning of the program.[53] This tailoring was a deviation from program requirements and federal law for cost reporting that both require a life-cycle cost estimate of the entire program and the setting of an ABC based on all formulation and development costs.[54] As a result of the deviation, NASA has not established a cost commitment for Artemis II activities and beyond nor is the Agency tracking these costs as part of the SLS ABC, meaning cost increases for those activities are not reported through the ABC process. Overall, by the end of FY 2020, NASA will have spent more than $17 billion on the SLS Program—about $5.9 billion of which is not tracked as part of the ABC. NASA's decision to limit ABC tracking to only Artemis I activities will result in more than 34 percent of all program spending not being reported or tracked within official cost commitments through FY 2020.[55] Accordingly, these additional costs were not considered when determining if a replan or rebaseline of the Program was required. Further, given this decision to tailor the scope of the ABC estimates through a deviation, costs after the Artemis I launch are not currently subject to ABC tracking or reporting requirements. Figure 8 summarizes the $5.9 billion in spending through FY 2020 that will not be subject to a cost commitment or required tracking and reporting under ABC requirements.

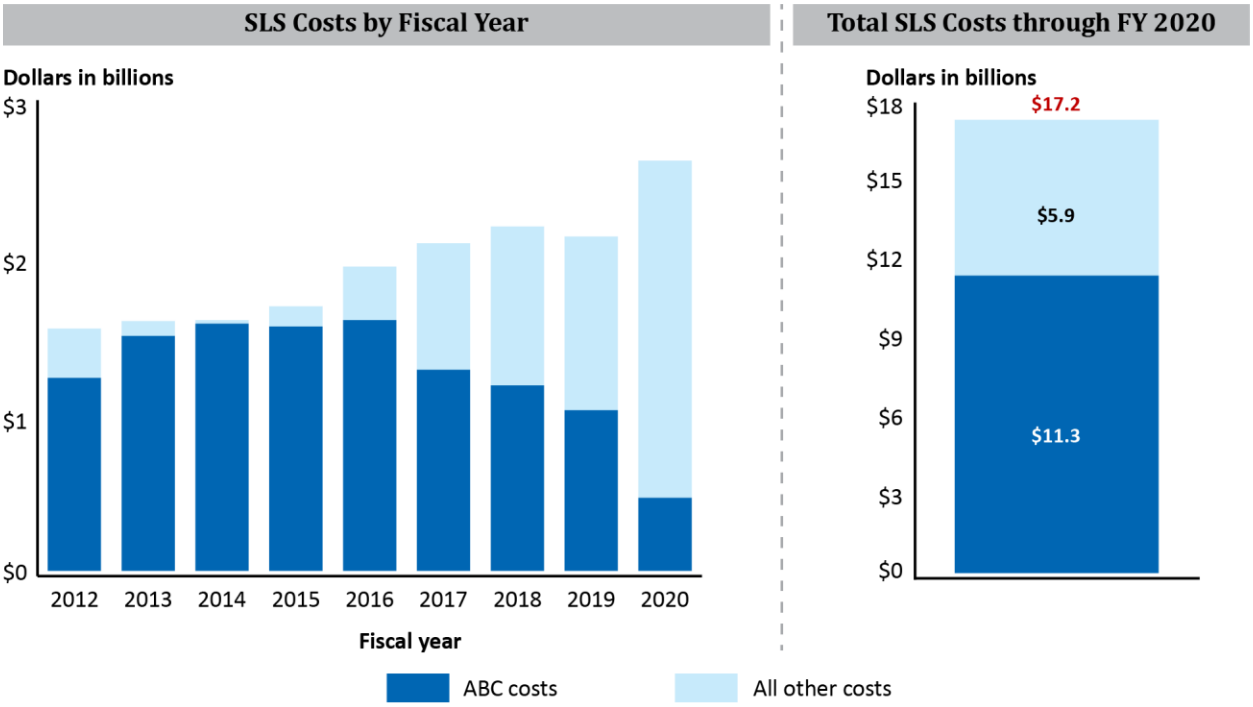
[52] NPR 7120.5E, Chapter 2.4.1.7, *Approving and Maintaining Program and Project Plans, Baselines, and Commitments* (2012). A revised rebaseline based on a change in scope does not require congressional notification according to 51 U.S.C. § 30104 if it does not exceed the existing ABC thresholds of 15 or 30 percent of development costs or a 6-month delay. However, the revised baseline must be reported and tracked through quarterly reports to Congress and the Office of Management and Budget.

[53] NPR 7120.5E, Chapter 2.4.1.5 and Appendix A - Definitions (2012). A life-cycle cost estimate is the total of the direct, indirect, recurring, nonrecurring, and other related expenses both incurred and estimated to be incurred in the design, development, verification, production, deployment, prime mission operation, maintenance, support, and disposal of a project including closeout, but not extended operations. The life-cycle costs of a project or system can also be defined as the total cost of ownership over the project or system's planned life cycle from Formulation (excluding Pre-Phase A) through Implementation (excluding extended operations). The life-cycle costs also include any launch vehicle costs. See also 51 U.S.C. § 30104(a)(3).

[54] NPR 7120.5E, Chapter 2.4.1.5, and 51 U.S.C. § 30104(a). It is NASA policy that all program requirements must be complied with unless relief is formally granted. Tailoring is the process used to adjust or seek relief from a program requirement to meet the needs of a specific program or project and is both an expected and accepted part of establishing proper requirements. NPR 7120.5E, Chapter 3.5, *Principles Related to Tailoring Requirements* (2012). A deviation is an authorization releasing a program from meeting a requirement before its baseline configuration is established whereas a waiver is an authorization after the baseline configuration requirements have been set by the program. In this case, the tailoring involved a deviation.

[55] While there is no official cost commitment for those activities, all SLS costs are reported as part of the annual budget submission process to Congress and the Office of Management and Budget.

**Figure 8: NASA Reporting of ABC SLS Costs through FY 2020**




Source: NASA OIG analysis of Agency information.

Note: NASA's current Artemis I launch date is November 2020 (the beginning of FY 2021) and may be subject to additional delays. To simplify our analysis, we measured the amount of costs spent outside the ABC through FY 2020 and did not include program spending for FY 2021 or later, almost none of which is subject to tracking or reporting against the ABC.

SLS Program and HEOMD officials acknowledged that the SLS Program's current approach for tracking ABC costs only through Artemis I is not a good fit for managing a long-term human exploration program with multiple planned missions over decades. SLS program managers stated that NASA's program management requirements and ABC process were not designed for a long-term, multi-mission, multi-capability human space flight program and said these policies are a better fit for a single-project program such as a one-time science mission. NASA officials explained the SLS Program had to choose a point to baseline its cost commitments and decided early in the program to deviate from existing program management requirements to track and report the ABC status based solely on Artemis I costs. Further, these officials explained this deviation was approved by NASA management and that future missions beyond Artemis I had not been authorized at the time, which made it difficult to estimate costs or schedules at the time of setting the baseline.

Although NASA is updating its ABC baselines for Artemis I, the SLS Program does not have plans to update its existing ABC to include all life-cycle costs for other Artemis missions nor does the Program plan to develop new ABCs for each mission. While we understand the difficulty of setting baselines long into the future, total SLS Program cost increases will not be readily transparent because NASA is not tracking and reporting all costs against an official baseline. Further, although SLS Program budget requests and past costs will be reported through the annual budget planning process, total costs beyond Artemis I will have no baselines against which to measure progress because those activities are not within the scope of the ABC reporting process. For example, NASA currently does not have a cost estimate for Artemis II and is not tracking or reporting cost impacts caused by schedule delays or technical challenges for that mission. NASA officials acknowledged the difficulty of setting baselines for long-term programs and stated they are considering setting cost and schedule baselines for specific capability upgrades, such as the future SLS Block 1B and Block 2 configurations. NASA officials further stated they plan to use best cost estimating and cost management practices to track and report production and operations costs by mission.

## Weaknesses Identified in SLS Program Tracking of ABC Costs

We identified weaknesses in the Agency's accounting process for ABC tracking and reporting caused by cost comingling in NASA's accounting system by mission or CLIN. When questioned about cost allocation to ABC and non-ABC activities, NASA officials explained that the SLS Program's prime contracts support multiple Artemis missions and current contract structures do not allow for separation of costs by mission. This was partly due to the limits of using heritage contracts from the canceled Constellation Program that were not structured to track costs by CLIN or mission. Therefore, SLS Program officials judgmentally categorized costs by estimating the percentages of contract costs allocable to Artemis I and non-Artemis I activities. In the absence of clearly delineated accounting metrics to track ABC cost estimates, this methodology for tracking and separating costs included subjective CLIN analysis and periodic meetings between NASA and contractors to determine cost allocations for Artemis I and non-Artemis I activities. The totals by element are reported to the NASA Office of the Chief Financial Officer and the Office of Management and Budget quarterly without any detailed documentation explaining SLS Program calculations. See Appendix D for details on the ABC costs for SLS Program funding by year and office.

We found that NASA's past reporting and tracking of ABC costs using this methodology contained inaccurate fluctuations. At the time of the replan in December 2017, the SLS Program calculated that the effect on ABC development costs from the planned 13-month delay—from November 2018 to December 2019—was a $38 million, or 1 percent, increase. For the 19-month delay to June 2020, the replan projected a total increase of $147 million, or 2 percent. In our judgment, this analysis masked the full impact of the delays because it did not take into account the removal of $889 million in Booster and RS-25 Engine development costs or the historical spending rate for the SLS Program. At the time, the SLS Program was spending more than $2 billion a year and the Stages Element Office, which was primarily focused on Core Stage 1 development and production, was spending about $90 million a month. Almost 2 years later, in October 2019, NASA identified an additional $2.5 billion in increases against the ABC baseline as a result of an additional 9-month delay from June 2020 to March 2021. This disparity between the initial and updated estimates raises questions about whether the SLS Program's methodology for tracking Artemis I costs accurately incorporated real-time accounting data, such as monthly reporting of Stages contract performance.[56] For example, the Stages Element Office's ABC allocations for Artemis I funding in FY 2019 started at $456 million, dropped to $374 million 6 months later, and then subsequently increased to $693 million, or 80 percent of annual costs, by the end of the fiscal year. This was despite the fact that NASA knew throughout 2019 that the majority of the Stages work was tied directly to Artemis I.[57]

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[56] For example, the final Booster segment for Artemis I was completed in January 2019, 4 months into FY 2019, but ABC cost allocations assumed Booster Office costs of only 10 percent and 3 percent for FYs 2018 and 2019, respectively.

[57] In April 2018, 5 months before the beginning of FY 2019, NASA directed Boeing to prioritize its efforts to complete Core Stage 1 for Artemis I and to de-emphasize non-ABC activities such as Core Stage 2 production and EUS development. While efforts were refocused to address production challenges for Core Stage 1 in FY 2019, the ABC cost estimates for Artemis I did not reflect this change until the end of FY 2019, almost 1.5 years later.

# Key SLS Contracts Experienced Cost, Schedule, and Performance Issues

Each of the major element contracts for developing and building the SLS for Artemis I—Stages, ICPS, Boosters, RS-25 Adaptation, and RS-25 Restart—have experienced numerous technical challenges, performance issues, and requirement changes that have resulted in $2 billion of cost overruns and increases and at least 2 years of schedule delays. We previously reported that Core Stage production is the primary factor contributing to overall SLS launch delays due to its position on the critical path and corresponding management, technical, and infrastructure issues driven mostly by Boeing's poor performance.[58] Additionally, Boeing's software development for the ICPS is an ongoing concern as final preparations in the software cannot be made until NASA finalizes the Artemis I mission's flight profile.[59] Further, Northrop Grumman and Aerojet have experienced performance issues with the Booster Propellant Liner and Insulation and the RS-25 ECUs, respectively, that had proven difficult to overcome. While NASA has addressed many of the major technical issues in Core Stage, ICPS, and Booster development, we expect additional cost increases totaling approximately $1.4 billion—$1.3 billion for Stages, $41 million for ICPS, and $107 million for Boosters—to support the contracts' scope of work.[60] However, with a successful Core Stage 1 Green Run test followed by launch of Artemis I in late 2020 or spring 2021, NASA is positioned to gain efficiencies in future production of its Core Stage, Upper Stage, Boosters, and RS-25 Engines if they apply lessons learned from this development phase.

## Boeing Core Stage Performance Has Improved, but Cost Overruns and Schedule Pressures Still Remain

As of December 2019, Boeing's spending for the first two Core Stages reached $5.4 billion, an increase of $1.2 billion from contract definitization in June 2014.[61] In addition, delivery of the Core Stage 1 to Stennis for testing was completed in January 2020—more than 2 years after an initial contracted delivery date of September 2017. Core Stage 1 remains on the critical path for the SLS; therefore, any delay has a direct impact on the Artemis I launch schedule. We reported in October 2018 that NASA expected Boeing to reach the contract's value by early 2019—nearly 3 years before the contract was

[58] IG-19-001.

[59] In July 2019, the NASA Administrator reassigned the Associate Administrator for HEOMD to a new role. In a September 2019 congressional testimony, the Acting Associate Administrator stated that NASA would not commit to an updated official launch date for Artemis I until after a new Associate Administrator was selected and had an opportunity to become familiar with the Program. In October 2019, the NASA Administrator named the new Associate Administrator for HEOMD, and he began work in early December 2019.

[60] On January 24, 2020, NASA increased the Stages contract value by $2 billion, bringing the total to $9.1 billion, and extended the period of performance by 4 years. As a result, NASA has increased the contract value by $3.5 billion since 2017 to accomplish development of two Core Stages and one EUS.

[61] As of December 2019, NASA has obligated $6.25 billion on the Boeing Stages contract. Of the $6.25 billion, approximately $375 million was spent on the Constellation Program prior to 2012 and $516 million was spent on development of the EUS. The remaining $5.4 billion was spent on development of the two Core Stages.

supposed to end—without final delivery of a single Core Stage or EUS.[62] However, before that threshold could be reached, NASA increased the contract's value in February 2019 by $630 million to prevent a stoppage in work. Since our report, the contract value had increased to $7.06 billion in September 2019 to accommodate additional cost overruns and additional work. Further, most of the work on the EUS remained suspended to ensure Boeing's efforts are focused on Core Stage production. Going forward, based on Boeing's current spending rate on the Stages contract, we estimated NASA will need to add at least $1.3 billion to the contract value to complete development of Core Stages 1 and 2, and continue work on the EUS through December 2021.[63]

In our October 2018 report, we found cost overruns on the Stages contract were unsustainable, and future spending would surpass $8.9 billion through 2021 with a 2.5-year delay in schedule. We primarily attributed these cost overruns and schedule delays to Boeing's poor performance. Specifically, Boeing initially underestimated the number and skill of the workforce required to develop the Core Stage, experienced issues with the command and control hardware and software, and suffered a series of equipment-related mishaps. Nonetheless, for six evaluation periods since 2012, NASA provided Boeing with "excellent" and "very good" performance ratings, resulting in award fee payments totaling $323 million, or 89 percent of the available award and incentive fees.[64] In the rating period that immediately followed issuance of the report, Boeing received significantly lower ratings that more accurately reflected their actual performance.[65]

**Core Stage and EUS (Boeing)**

Development, production, and integration of two Core Stages and one EUS, including integration of engines, and core and second stages for the SLS rocket.

**Cost increases:** At least $2.5 billion through December 2021

**Delays:** More than 2 year delay with first Core Stage, ongoing delays for the second Core Stage, and pause in development and production of the EUS

**Reason:** Contractor performance challenges with the Stage Controller; engine section tubing and wiring, welding; and consistently underestimating the scope of the work

| | Deliverable | Status |
|---|---|---|
| **Test Articles** | Core Stage structural test articles | ✓ |
| **Artemis I** | Core Stage 1 | ⚠ |
| **Artemis II** | Core Stage 2 | ⚠ |
| **Artemis III** | EUS | ⚠ |

✓ Completed ⚠ In progress ⊗ Not started

[62] IG-19-001. As of October 2018, the total contract value was $6.2 billion, including early Constellation work and SLS transition of approximately $674 million.

[63] The $1.3 billion cost increase considers the remaining contract value and is calculated based on Boeing's spend rate of $65 million a month for Core Stage development through December 2021 and $500 million in additional EUS costs. The spend rate is the average of costs reflected on Boeing's monthly financial reports from July through September 2019 and excludes Core Stage 3 material purchases.

[64] IG-19-001.

[65] Furthermore, during the negotiation of modification 286, NASA determined $1.8 billion of the added contract value to be cost overruns and therefore Boeing would not receive any award fees on that amount.

According to NASA officials, Boeing's performance has improved over the past year, which we confirmed during an on-site visit to Michoud in August 2019. We observed Boeing officials saving time by performing work on the Core Stage after placing it in a horizontal rather than vertical position. This allowed the remaining work and testing on the engine section to be done concurrently. In fall 2018, Boeing also repositioned personnel to physically work alongside their assigned hardware instead of in offices spread throughout the facility, thereby increasing coordination with workflow and among offices. Figure 9 shows some of the process improvements at Michoud, including horizontal work and rotating stands and platforms with related personnel working directly alongside their responsible areas.

**Figure 9: Core Stage Process Improvements at Michoud**

Assembled core stage resting on horizontal rotational assembly and transportation tools showcasing new wiring tray, with NASA and Boeing "ship-side" work area visible to the left. In the background, the engine section sits on the "quad pods" custom support structure.

Source: NASA.

As of January 2020, Core Stage 1 remained the highest priority for the SLS Program with its fabrication at Michoud and shipment to Stennis now completed. In September 2019, NASA and Boeing completed the final join of the Core Stage 1 structure by adding the engine section to the bottom of the stage. The engine section had been one of the most complicated pieces of hardware to complete. In November 2019, Boeing and Aerojet successfully completed the installation of the four RS-25 Engines to the main propulsion systems inside the engine section. Additionally, Boeing had started the final testing of the completed Core Stage 1 prior to shipping to Stennis. Although schedule margin has been exhausted, Boeing and NASA officials had been working toward shipping Core Stage 1 to Stennis for the Green Run test by the end of December 2019, and NASA officials extended the current performance evaluation period to capture this delivery milestone for award fees. Although the Green Run test was originally planned for a minimum of 6 months, the actual duration is highly dependent on the results of this first time testing of the integrated propulsion and avionics of the new Core Stage design.[66] Current schedule assessments show that the period for Core Stage 1 integration, testing, and refurbishment could last until fall 2020. To accelerate the overall development schedule, NASA considered skipping the Green Run test and shipping the Core Stage directly to Kennedy for launch preparations. However, the NASA Administrator ultimately decided that since it would be the only test of the Core Stage in test-like-you-fly conditions, the Green Run test requirement would remain.

[66] Upon arrival at Stennis and before the Green Run can begin, several deferred production tasks such as connecting the fuel lines must be completed, an activity anticipated to take between 2 to 3 months.

Going forward, Boeing is already building Core Stage 2 for the Artemis II mission. NASA has decided that this Core Stage will not require a Green Run test and expects to ship it to Kennedy for launch preparations in March 2022. Given the improvements in Michoud processing capabilities, NASA anticipates that Core Stage 2 will proceed at a much faster rate compared to Core Stage 1, showing a 25 percent improvement in work process metrics including labor hours, discrepancies found, and rework required.

# ICPS Costs Increase Due to Underestimating Modification Costs and Launch Date Uncertainty

The cost of the ICPS scheduled to fly on Artemis I has more than doubled from initial estimates in 2014. We estimate NASA will spend $358 million through the launch of Artemis I for the first ICPS, exceeding the $157 million estimated at KDP-C in 2014 by $201 million.[67] While this first ICPS flight unit and associated structural test unit cost $46 million, the KDP-C estimate did not fully consider the total costs associated with modifications needed to adapt the ICPS to SLS and Artemis I mission requirements. As of December 2019, the flight unit is in storage at Kennedy.

In October 2018, NASA issued an undefinitized contracting action to Boeing to purchase two additional ICPS flight units and a payload fairing. By October 2019, the contract value stood at $527 million. However, this amount is expected to increase by the time the two ICPS units are delivered. NASA needs to negotiate the final contract amount with Boeing and plans to definitize the contract in spring 2020 with the period of performance extending through 2025. This contract does not include the cost of two RL-10 engines worth $40 million total, including development costs, procured from Aerojet under an existing NASA contract and provided to Boeing as government furnished equipment.

**ICPS (Boeing)**

Purchase and modification of ICPS for SLS Upper Stage

**Cost increases:** $201 million over cost estimate for first ICPS

**Delays:** None

**Reason:** Requirements added over time instead of robust planning process upfront

| | Deliverable | Status |
|---|---|---|
| **Test Articles** | 1 structural test article; engineering analysis and special studies | Completed |
| **Artemis I** | 1 ICPS | In progress |
| **Artemis II** | 1 ICPS (no RL-10 engine) | In progress |
| **Artemis III** | 1 ICPS (no RL-10 engine) | In progress |
| **Cargo** | 1 payload fairing | In progress |

Completed · In progress · Not started

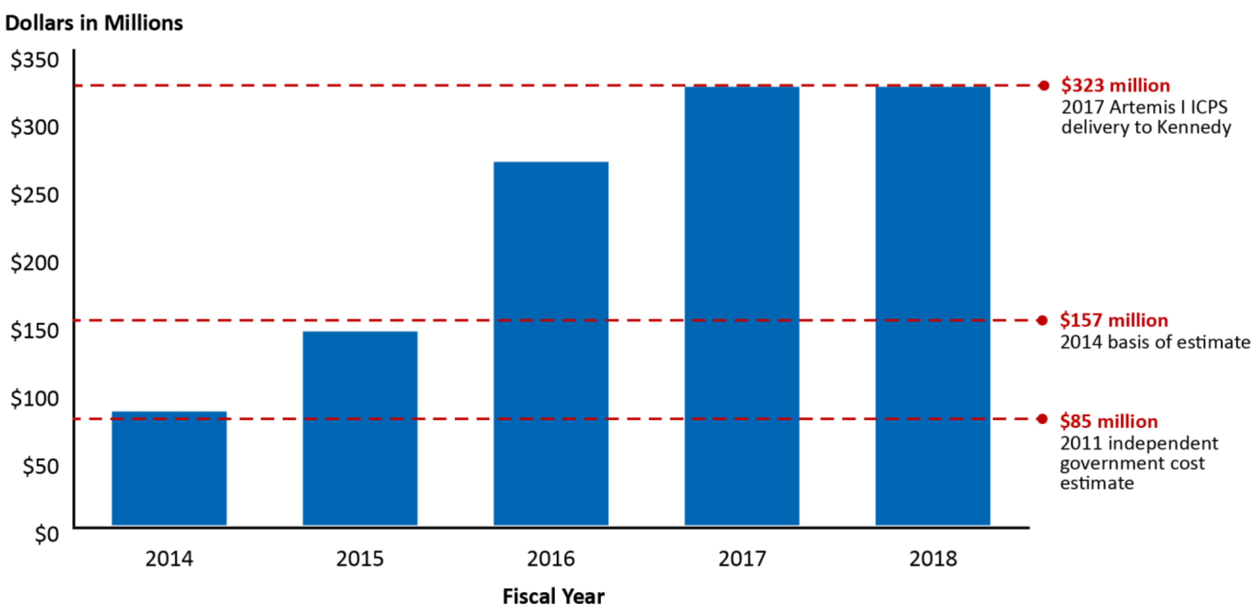
Boeing's ICPS contract allows NASA to procure both the flight and test unit hardware at fixed prices. However, to get the ICPS ready to fly on an SLS, task orders must be issued against a separate, cost-plus-award-fee contract line item. Work conducted under these task orders is based on requirements set forth in the contract's performance work statement and includes structural testing, incorporating unique mission requirements, and configuring navigation software. Certain tasks were added as new or maturing requirements were identified, but other tasks that, for example, rely on flight information from the SLS Program Office need to be reworked each time a launch is delayed.

[67] The $201 million cost increase includes $160 million spent as of December 2019 and $41 million projected through the launch of Artemis I.

Between October 2014 and August 2019, the task order portion of the ICPS contract increased from $5 million to $377 million as NASA continued to add tasks to get the ICPS ready to integrate with the SLS. The ICPS uses its own flight software to navigate, and development of that software, including final mission analysis and trajectory, relies on information from NASA supplied during the Flight Readiness Analysis Cycle.[68] Each time the launch date is delayed, NASA must furnish new information to Boeing. As of October 2019, ICPS navigation software development is on track to support a November 2020 launch date.

Figure 10 summarizes the growth of ICPS contract value during Artemis I ICPS production compared to the independent government cost estimate from 2011 and the updated estimate from 2014. As shown, the contract value had already reached $89 million by the time it was definitized in 2014. By October 2017, when the Artemis I ICPS was delivered to Kennedy, contract value had reached $323 million, more than double the 2014 basis of estimate. The value of the contract remained constant through 2018 as less effort is required leading up to the launch date.

**Figure 10: Contract Value Growth of Artemis I ICPS Compared to Estimates**




Source: NASA OIG analysis of Agency information.

[68] The Flight Readiness Analysis Cycle includes mission-specific information, such as mass properties, Booster burn rates, and launch window, to determine performance of the system. SLS planned for this cycle to begin 15 months prior to launch.

# Boosters Experienced Technical Issues and Cost Increases

As of December 2019, Boosters contract with Northrop Grumman has experienced at least a 1-year delay on the delivery of the Booster segments and a 2-year delay on the Booster hardware (forward assemblies and aft skirts), and will have approximately $568 million in cost overruns and increases through 2023 due to technical and performance issues and requirement changes. According to NASA officials, $355 million of these cost overruns through 2019 can be attributed to technical issues with the SLS's Propellant Liner and Insulation (PLI) and contractor performance problems. Moreover, NASA is still negotiating with Northrop Grumman officials about an additional amount of approximately $50 million related to remaining cost overruns for the PLI. Further, per NASA officials, requirement changes and administrative costs have resulted in multiple contract modifications that increased contract value by approximately $56 million. In October 2019, NASA added approximately $107 million in program support funding to extend Northrop Grumman's Booster support from September 2019 through January 1, 2023. The $568 million in cost overruns and increases does not include the cost of replacing six Booster segments for Artemis III due to the PLI issues.

**Boosters (Northrop Grumman)**

Design, development, testing, and evaluation of 3 development and 2 qualification Boosters. Production of 6 flight Boosters and a flight test Booster for 35 segments total.

| | |
|---|---|
| **Cost increases and overruns:** | At least $568 million through 2023 |
| **Delays:** | At least 1 year associated with PLI insulation on 6 segments but the delay did not affect the SLS schedule |
| **Reason:** | PLI technical issues, 73 modifications changing the contract value, and other performance issues |

| | Deliverable | Status |
|---|---|---|
| **Test Articles** | 3 development Boosters, 2 qualification Boosters, and 1 flight test Booster | In progress |
| **Artemis I** | 2 Boosters | In progress |
| **Artemis II** | 2 Boosters | In progress |
| **Artemis III** | 2 Boosters | In progress |

Completed · In progress · Not started

## Technical Issues

Northrop Grumman's primary technical challenge has been with the PLI, which protects the Booster's metal casing from the extreme heat and pressure created by burning propellant. During the Space Shuttle Program, the Boosters used an asbestos-based insulation material; however, due to the health hazards of asbestos, a new material was required for the SLS Boosters. While this new liner mitigates these health concerns, the material has the potential to off-gas and create voids or gaps between layers in the PLI ranging from less than 1 to 6 inches in length. Hot combustion gases could then penetrate through these voids and impact the metal casing surrounding the PLI, which in turn could lead to a Booster failure. After the voids were found during inspection, Northrop Grumman undertook several redesigns and conducted additional testing, steps that delayed completion of qualification testing and the start of the Booster production. As of August 2019, both NASA and Northrop Grumman are confident the issue has been fully resolved for Artemis II. However, the Boosters for Artemis I still contain material with microvoids that can crack and therefore do not meet overall SLS requirements. After an extensive safety review, NASA approved a waiver for the Artemis I Boosters based on a low likelihood of failure during the uncrewed mission. As a result of the PLI issue, NASA has increased the Boosters contract value by approximately $205 million and is under negotiations with Northrop Grumman to add roughly $50 million more.

## Contractor Performance

In addition to the technical challenge of the new material in the PLI system, Northrop Grumman also faced two other major performance challenges that contributed to cost overruns.

- *Assembly of the Forward and Aft Assemblies in the Booster Fabrication Facility at Kennedy*. This work was previously done by another contractor under the Ares and Space Shuttle programs, and moving those activities into Northrop Grumman's system required a greater effort than expected. These tasks included (1) translating work instructions from a heritage format into Northrop Grumman's electronic shop instructions; (2) making sure all the heritage hardware components would meet SLS requirements; and (3) establishing two major facilities for acceptance testing of the aft and forward assemblies. Formal SLS Program reviews were eventually held to confirm those facilities were in fact ready.
- *Delayed Completion of the Design Certification Review.*[69] Northrop Grumman originally projected that the review could be accomplished in 1 year, but encountered delays in avionics qualification and PLI design analyses, and late changes to avionics harnesses that also failed humidity testing. The contractor was then required to modify and requalify both the existing harnesses to prevent moisture intrusion and also redesign and qualify another set of harnesses before they were built. This caused the Design Certification Review to be divided into four separate reviews spread over 2 years.

As a result of these performance cost overruns, NASA increased the contract value by approximately $150 million. In addition, for this overrun, Northrop did not receive any performance award fees.

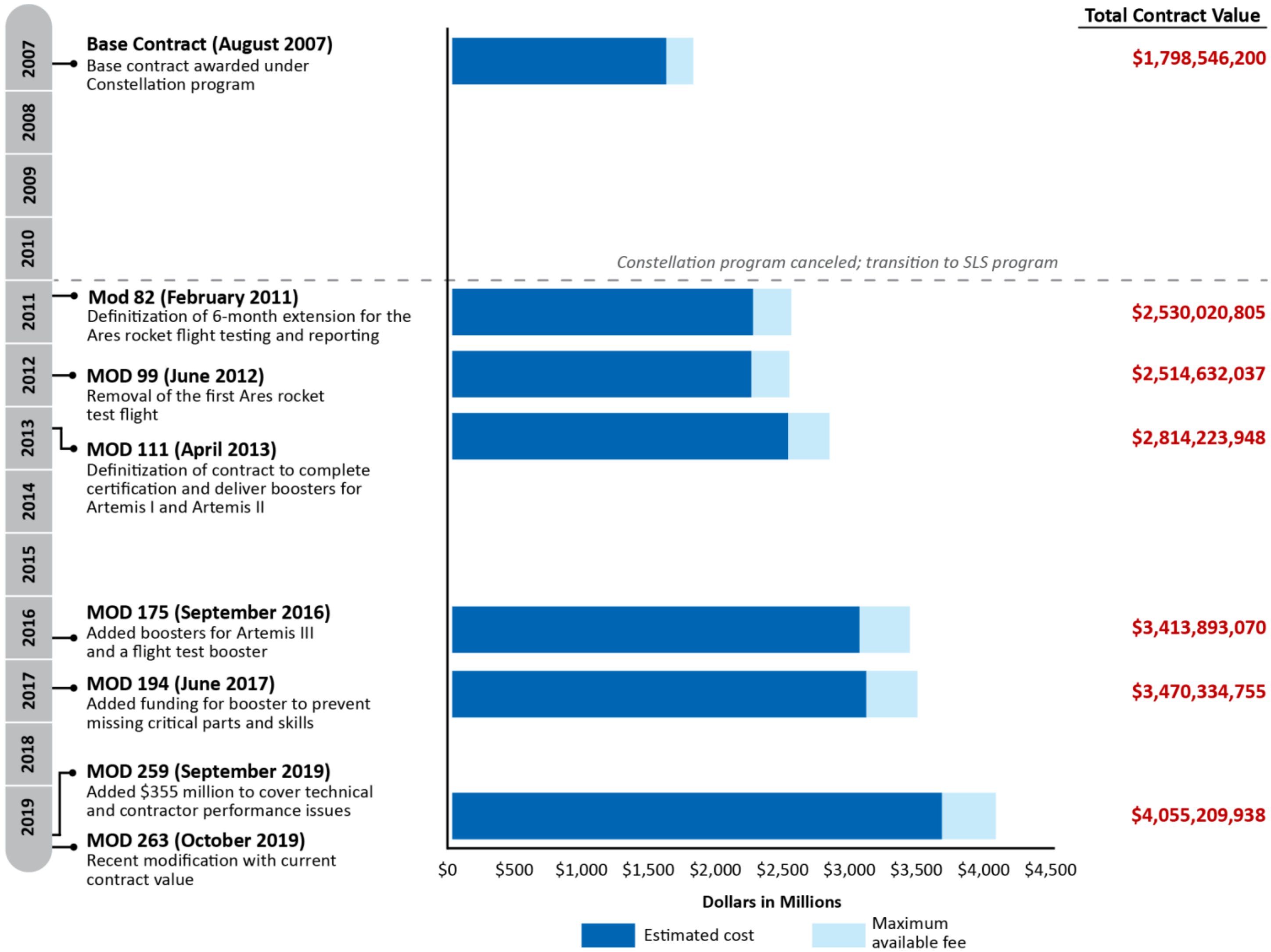
## Contract Modifications

Since contract definitization in 2013, NASA has increased the Booster contract value by nearly $1.24 billion through 73 different contract modifications, occurring nearly every month over the last 5 years. Even though the largest modification added $561 million of additional scope to produce two Boosters for a third SLS mission and one test Booster, we consider 36 of these modifications worth $56 million to be cost increases to the original scope of work. Specifically, the modifications related to requirement changes ($34.1 million), additional technical issues related to PLI not included in the negotiated cost overruns ($7.3 million), and administrative changes such as funding for special studies ($14.8 million). The requirement changes included redesign of the forward separation bolt (heritage hardware from the Space Shuttle Program) to accommodate increased loads on the SLS vehicle from what the hardware encountered on the Space Shuttle, certification of mechanical and electrical vehicle to ground interfaces, and additional avionics hardware. Additionally, another modification added $107 million for Northrop Grumman to continue providing program support for the Boosters through

[69] During the Design Certification Review, the design is evaluated against its requirements to determine if the hardware is certified for space flight.

January 1, 2023. NASA officials also stated that this contract includes a clause stating any increase above $500,000 requires a request for proposal, which provides another rationale for the multiple modifications with contract value increases. Figure 11 summarizes the major contract modifications from inception in 2007 until October 2019, along with the contract value at the time of each modification.

**Figure 11: Major Modifications to the Boosters Contract, 2007 through 2019**




Source: NASA OIG analysis of Agency information.

As we have previously reported, NASA has a history of entering into development contracts without fully understanding all of a program's requirements. Even though the FAR accommodates uncertainty through cost-reimbursement contracts, these types of situations often result in rising costs, schedule delays, and multiple contract modifications that, apart from adding significant value to a contract, create an administrative burden on management. In addition, over the last decade, our work and that of GAO have cited the importance of NASA setting realistic requirements and conducting early analyses of requirements, working closely with industry to ensure requirements are clearly defined, and if necessary, making "trade-offs" or deciding early that one capability is more important than another.[70]

## CLIN Tracking and Contractor Performance Assessment Process Contributing to Increased Costs

NASA and Northrop Grumman do not track per unit costs for the Boosters by CLIN, making it difficult to determine the actual cost for each Booster produced. Per the FAR, CLINs should provide unit prices or lump sum prices for separately identifiable contract deliverables and associated delivery schedules or performance periods.[71] Similar to what we reported in October 2018 regarding the Boeing Stages contract, when requirements for the Boosters were set in 2014, individual CLINs were recommended but not required by the FAR.[72] Without tracking individual unit costs, NASA is unable to determine the exact cost of a single Booster; therefore, it is difficult to develop a total cost for each Artemis mission. Greater visibility into unit costs can also help NASA determine whether Northrop Grumman is meeting cost targets for performance award fees and assist in negotiations for additional units. We estimated the current cost per Booster at roughly $200 million, based on the average of the seven requested Boosters in the production CLIN. However, NASA's Boosters Element Office noted that for future missions beyond Artemis III the average cost per Booster is expected to be approximately $125 million due to reduced development costs.

In addition, between November 2012 and February 2019 NASA had no appointed on-site technical monitors at the Northrop Grumman facility in Promontory, Utah. Technical monitors are critical for providing performance feedback and thus help determine the amount of award fees provided to the contractor. Instead, NASA relied on its on-site personnel to provide informal feedback to the SLS technical monitors located at Marshall. After this omission was brought to the Agency's attention by the OIG, in February 2019, NASA assigned the responsibility to on-site DCMA personnel reporting on cost, but not in providing technical performance feedback to NASA.[73] Subsequently in December 2019, the Boosters Element Office officially added the NASA on-site manager to the list of appointed monitors. On-site monitors are needed to ensure fair and accurate descriptions of the contractor's strengths and weaknesses are reflected in the award fee performance evaluations.

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[70] NASA OIG, *NASA's Strategic Assessment Contract* (IG-19-015, March 28, 2019); *Audit of Commercial Resupply Services to International Space Station* (IG-18-016, April 26, 2018); and *Construction of Test Stands 4693 and 4697 at Marshall Space Flight Center* (IG-17-021, May 17, 2017). GAO, *NASA: Assessments of Major Projects* (GAO-18-280SP, May 1, 2018); *Additional Cost Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects* (GAO-11-364R, March 3, 2011); and *Best Practices: Increased Focus on Requirements and Oversight Needed to Improve DOD's Acquisition Environment and Weapon System Quality* (GAO-08-294, February 1, 2008). FAR, Subpart 16.3, *Cost-Reimbursement Contracts*.

[71] FAR § 4.1001, *Uniform Use of Line Items–Policy* (2018).

[72] IG-19-001.

[73] Technical monitors are integral to the award fee process as they are the specialists most intimately familiar with the assigned areas who provide daily oversight and assessment of contractor performance to the contracting officer representative. Marshall Work Instruction 5116.1 and NASA's Award Fee Contracting Guide.

# ECU Development Increased Costs and Caused Schedule Delays for RS-25 Adaptation

The adaptation of 16 Space Shuttle-era RS-25 Engines for the SLS has experienced approximately $228 million in contract cost increases and more than 2.5 years of schedule delays and contract extensions. This delay would have affected the SLS schedule if Core Stage 1 had not already been behind schedule. NASA management primarily attributed the costs increases and schedule delays to the development of a new ECU.

Both NASA and Aerojet officials stated that the development of the ECU was more complicated than originally planned. Specifically, Aerojet anticipated reworking the Constellation Program's J-2X ECU for the SLS Program, but found instead they needed to develop a completely new ECU, which added time and cost to the contract. According to SLS Program officials, this occurred because Aerojet's early technical assumptions for the ECU were incorrect and their lack of understanding of controller design requirements resulted in significant design and technical issues. Further, contract documentation states that Aerojet did not seek direction or additional contract value from NASA when they decided to alter the ECU design.

Despite these performance issues, since December 2011, Aerojet has earned an average of 83 percent of the award and incentive fees for the in-scope work performed, equivalent to a "very good" score, for its work on the SLS Program even though the contractor has experienced millions of dollars in cost overruns and several years of schedule delays related to its performance issues.[74] However, unlike the Stages contract, the RS-25 Adaptation contract is an end-item contract, meaning award fees are not finalized until the contract's period of performance ends in March 2020, with the final award fee assessment completed by that time. Up until this time, NASA retains the ability to recoup any excessive fees paid based on a re-evaluation of Aerojet's performance.

**RS-25 Adaptation (Aerojet )**

Refurbishment of 16 Shuttle-era RS-25 engines and development of a new ECU

**Overruns:** $228 million

**Delays:** 2 years and 7 months of schedule delays but did not affect the SLS schedule

**Reason:** Technical issues with the ECU resulting from SLS requirements that made it difficult to adapt the generic Constellation Program controller and resulted in the need to create a new ECU. Contractor underestimation of work.

| | Deliverable | Status |
|---|---|---|
| **Test Articles** | 2 test Engines for ECU development | Completed |
| **Artemis I** | 4 Engines and 4 ECUs | Completed |
| **Artemis II** | 4 Engines and 4 ECUs | Completed |
| **SM-1**[a] | 4 Engines and 4 ECUs | In progress |
| **Artemis III**[a] | 4 Engines and 4 ECUs | In progress |
| **Beyond Artemis III**[a] | 2 ECUs | In progress |

Completed In progress Not started

[a]As of January 2020, even though all of the engine and ECU hardware are on hand and completed acceptance testing, the ECUs have yet to be installed on 7 of the 16 engines.

74 Cost management is the only evaluation factor for the incentive fee, whereas technical performance and project management are the evaluation factors for the award fee. As of May 2019, NASA had provided Aerojet with 90 percent of the award fees available and 48 percent of the target incentive fees.

As of September 2019, Aerojet has completed all planned acceptance testing on all of the flight engines and ECUs. Aerojet shipped the four flight engines for Artemis I to Michoud, and two of the four backup engines for Artemis I are ready. In addition, all 18 of the ECUs have completed certification testing with 10 installed on the engines.

In June 2019, NASA transferred approximately $10.9 million of work from the RS-25 Adaptation contract to the RS-25 Restart contract to complete flight engine processing, engine delivery, engine acceptance, and flight preparations in support of SLS flights 2, 3, and 4. With this transfer of funds, NASA will have spent nearly $238 million more than originally planned on the scope of work for the 16 engines. According to SLS management, completing the remaining engine prep work in concert with other RS-25 Restart engine and test operations allowed for the most efficient use of the contractor's resources. However, we found flaws in the technical evaluation and proposal for the transfer of work that could impact program costs. Specifically, the costs were not aligned with the work remaining on the RS-25 Restart contract, and pay rates by workforce skill mix were not included in the contract.[75] Therefore, we anticipate additional funds will be required to cover the remaining work.

## RS-25 Restart Faces Likely Cost Overruns Due to Schedule Delays

The RS-25 Restart contract is currently on budget but behind schedule for final certification of a new RS-25 Engine. Specifically, as of December 2019, Aerojet has spent approximately $936 million of its $1.72 billion contract value to restart the RS-25 Engine production line and provide backup engines for SLS flight 4 and new engines for SLS flight 5. The contractor's spend rate currently meets expectations, but due to the schedule delays, cost overruns are likely to occur.

Aerojet is experiencing a 2-year delay developing the nozzle for the certification Engine given the technical challenges and learning curve associated with using new manufacturing equipment and processes. However, due to task rearrangement, Aerojet is only expecting the nozzle delays to result in a 3-month delay of final RS-25 Engine certification—from December 2021 to March 2022. Nonetheless, the funding for certification ends in December 2021, and additional funding will be required to address this delay. As of December 2019, Aerojet expects to deliver the required two backup RS-25 Engines for SLS flight 4 and four flight RS-25 Engines for SLS flight 5 as scheduled in FY 2023 and FY 2024.

[75] Skill mix refers to the range of types and levels of ability of the workforce. For example, education and experience of an individual affect the pay level, such as the range from junior engineer to senior engineer status.

Compared to the Space Shuttle-era RS-25 Engines, Aerojet anticipates a 33 percent reduction in costs per engine starting with production of the RS-25 Restart contract's seventh engine. This cost reduction is attributable in part to manufacturing process improvements such as 3D printing.[76] In addition, Aerojet is expected to reduce the number of required welds and thus the amount of production time associated with each new RS-25 Engine. Another key aspect of this affordability is maintaining an efficient test program. Specifically, 56 tests are planned as part of the recertification program, which will use two existing development RS-25 Engines and allow Aerojet to test individual components as they are developed. Aerojet's cost reduction strategy is expected to lead to almost $35 million in costs savings for each future RS-25 Engine when compared to the $104.5 million cost (in FY 2015 dollars) associated with producing one of the Space Shuttle-era RS-25 Engines.

**RS-25 Restart (Aerojet)**

Development and production of six new RS-25 engines with plans to purchase more for future SLS missions

**Overruns:** None

**Delays:** 2 years behind on nozzle development

**Reason:** Contractor performance challenges with nozzle development. Learning curve regarding "additive manufacturing," also known as 3-D printing

| | Deliverable | Status |
|---|---|---|
| **Test Articles** | 1 certification Engine | In progress |
| **SLS Flight 4** | 2 backup Engines | In progress |
| **SLS Flight 5** | 4 Engines | In progress |

Completed | In progress | Not started

[76] 3D printing, also known as additive manufacturing, is a process in which materials are joined together to make objects or parts from 3D model data as opposed to common subtractive manufacturing techniques in which objects are made by cutting away from a solid block of material.

# CONCLUSION

Since the SLS Program was established 8 years ago, NASA and its supporting contractors have been designing, building, and testing elements of its new heavy-lift rocket to support the Agency's lunar and Mars ambitions, including landing astronauts on the Moon's south pole by 2024. Although many of the significant technical challenges the Program has faced over the years, such as getting Michoud up and running efficiently, propulsion insulation issues with the Boosters, and ECU for the RS-25 Adaptation have been corrected, collectively, they have contributed to the Program's significant cost increases and schedule delays.

NASA's continued struggle with managing SLS Program costs and schedule has the potential to impact the Agency's ambitious goals for the Artemis program. Furthermore, the SLS Program exceeded its ABC by at least 33 percent at the end of FY 2019, over a year before the November 2020 scheduled launch date for Artemis I, and consequently the Program will need to be rebaselined. Because the original baseline only focused on Artemis I costs, almost $6 billion in SLS spending through FY 2020 is not reflected in the Agency's cost commitment. While we acknowledge that NASA does track total SLS Program costs through its annual budget process, without transparent and accurate reporting on its cost commitments it will be difficult for the Agency, Congress, and external stakeholders to make informed decisions about the future of the human space flight program.

Technical and management problems have affected the building of SLS Core and Upper stages, adaptation of the RS-25 Engines, and the building of the Boosters to meet SLS requirements. Looking forward, the SLS Program faces the critical Green Run test of Core Stage 1, integration of all the SLS elements, and integration of the SLS with the Orion capsule and service module. Since each of these are first-time events, further delays in the current Artemis I launch date of November 2020 are likely.

# RECOMMENDATIONS, MANAGEMENT'S EVALUATION, AND OUR RESPONSE

To increase the sustainability, accountability, and transparency of NASA's efforts to manage the five major SLS element contracts to achieve the Agency's 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 Marshall Center Director, Marshall Office of Procurement, and SLS Program, undertake the following actions:

1. Notify Congress that the SLS Program has exceeded its ABC by at least 30 percent.
2. Review HEOMD and NASA program management policies, procedures, and ABC reporting processes to provide greater visibility into current, future, and overall cost and schedule estimates for the SLS Program and other human space flight programs. This review shall include the following:
    a. rebaselining Artemis I costs to appropriately and transparently track costs that include SLS development costs and activities tied to the first SLS launch;
    b. establishing methodologies and processes to track and set cost commitments for Artemis II; and
    c. determining reporting and tracking procedures for setting cost and schedule commitments, and monitoring progress throughout the entire life cycle of the SLS Program (through at least 2030).
3. For new acquisitions of SLS deliverables, develop a cost accounting model that separates each deliverable into its own CLIN for tracking costs, performance, and award fees.
4. For large award fee contracts where NASA has on-site personnel, ensure they are appointed in writing and clearly assigned the task of monitoring and reporting on the performance of the contractor.
5. Conduct a thorough review of each major SLS contract's scope of work and technical requirements needed to complete the period of performance to assist in eliminating incremental contract value increases to the contract and lessen contract management burden, as in the case of the Boosters contract.

We provided a draft of this report to NASA management who concurred with all of our recommendations. We consider management's comments responsive for four of the five recommendations and these will be closed upon completion and verification of the proposed corrective actions. However, for Recommendation 3 management only addressed the Core Stage and EUS CLINs, and not future acquisitions of Boosters and RS-25 Engines. Therefore, this recommendation is unresolved pending further discussions with the Agency. In its response, the Agency also noted that it had identified information in the draft report that should not be publicly released. We revised the report as appropriate.

Major contributors to this report include Ridge Bowman, Space Operations Directorate Director; Kevin Fagedes, Project Manager; Susan Bachle; Daniel Fenzau; Frank Martin; Robert Proudfoot; Karlo Torres; Sarah McGrath; 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: SCOPE AND METHODOLOGY

We performed this audit from November 2018 through January 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 determined that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. The scope of this audit was the SLS Program from 2011 through January 2020.

This report is the second in a series of reviews examining NASA's management of the SLS Program. In the first report, we assessed to what extent Boeing is meeting its cost, schedule, and performance goals for the development of the Core Stages 1 and 2 and the EUS and the SLS Program's compliance with acquisition regulations, policies, and procedures regarding the Stages contract.[77] In this report, we assessed to what extent the remaining major SLS element contractors—Boeing, Aerojet, and Northrop Grumman—are meeting their cost, schedule, and performance goals for the development of the ICPS, RS-25 Engines, and Boosters, respectively. We also provided an update to the Stages contract report by evaluating Boeing's spending and progress made since the publication of our first report in October 2018. In addition, we assessed to what extent NASA is tracking, reporting, and meeting its overall cost goals for the SLS Program. Our review was conducted at Marshall, Michoud, NASA Headquarters, Northrop Grumman, and Aerojet. In preparation for the audit, we conducted routine coordination with the Associate Counsel to the Inspector General and the OIG Office of Investigations.

To assess NASA's performance for acquiring and subsequently integrating the ICPS into the SLS, we reviewed SLS Program and contractor cost and budget documentation, to include financial management reports, budget documents, and estimates. We also reviewed the contract file, modifications, and negotiation documents. We interviewed personnel from the NASA Spacecraft/Payload Integration and Evolution Office, including the Office Manager, Business Manager, ICPS Technical Representative, and ICPS Contracting Officer, as well as the Boeing ICPS Project Lead to understand the costs and development issues involved with acquiring the ICPS and then modifying the hardware to fly on the SLS.

To assess the performance of NASA's contractors for developing the Boosters and RS-25 Engines, we reviewed SLS Program, NASA Office of the Chief Financial Officer, and contractor cost and budget documentation, to include the contract files, modifications, and negotiations documents. Additionally, we reviewed contractor financial management reports and Earned Value Management System cost estimates. We also evaluated award fees earned by reviewing the performance evaluation plans for the evaluation factors as compared to our assessment of the contractors' performance, schedule, and cost. To determine cost overruns on the contracts, we only included the overruns negotiated between the contractors and NASA. To determine cost increases on the contracts, we evaluated the value for the original scope of work as compared to the current value as it relates to the same scope of work. We did not include any additional scope added for future missions. We interviewed NASA SLS Program officials, contracting officers from the Marshall Office of Procurement, and officials from the SLS Program Planning and Control Office to determine the status of the Program's cost, schedule and performance. We also interviewed the Northrop Grumman and Aerojet program managers and contracting staff regarding the cost and schedule performance of Booster and RS-25 Engine contracts, respectively. In

[77] IG-19-001.

addition, we interviewed the DCMA representatives embedded at Northrop Grumman concerning their roles and responsibilities regarding the Booster contract. Finally, we interviewed the NASA Resident Office Manager at Aerojet to gain their perspective concerning the performance of the RS-25 Engine contracts.

To provide an update to the OIG's 2018 Stages report we reviewed financial management reports, contract modifications, and negotiation documents occurring over the past year—September 2018 through September 2019. We assessed current spending as compared to the remaining contract scope to determine additional cost increases. We interviewed the Stages Element Program Manager; Stages procurement representatives, including the Stages Procurement Manager; and contracting officers to determine the cost, schedule, and performance status of the Stages contract.

To assess NASA's performance in tracking, reporting, and meeting its overall cost goals for the SLS Program, we reviewed cost reporting data, budget documentation, Agency decision memorandums, the ABC, replan from 2017, federal law for baselines and cost controls, and space flight program management policies for the Program. We also interviewed NASA personnel from the Office of the Chief Financial Officer, Office of Chief Engineer, and the SLS Program Planning and Control Office to gain their perspective concerning NASA's ability to track and report its schedule and cost goals for the SLS Program.

## Use of Computer-Processed Data

We used computer-processed data to perform this audit, and that data was used to materially support findings, conclusions, and recommendations. First, we reviewed and analyzed NASA obligation and disbursement data for FYs 2012 through 2019 in NASA's financial accounting system for the entire SLS Program, each SLS Element Office, and each contract—Core Stage, ICPS, Boosters, RS-25 Adaptation, and RS-25 Restart. Then, we compared these results with data provided by the SLS Program in the form of briefing charts and Excel spreadsheets. In addition, for each contract we obtained monthly and quarterly contractor financial management reports from Boeing, Northrop Grumman, and Aerojet for November 2017 through October 2019.

## Review of Internal Controls

We evaluated the internal controls associated with NASA's management of the SLS, specifically the extent to which NASA's contractors are meeting their cost, schedule, and performance goals for the development of the Core Stage, ICPS, Boosters, and RS-25 Engines. The control weaknesses we found were identified and discussed previously in this report. Our recommendations, if implemented, will correct the identified control weaknesses.

## Prior Coverage

During the last 7 years, the NASA Office of Inspector General (OIG) and the Government Accountability Office (GAO) have issued 14 reports of significant relevance to the subject of this report. Unrestricted 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 the Space Launch System Stages Contract* (IG-19-001, October 10, 2018)

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

*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)

*NASA's Launch Support and Infrastructure Modernization: Assessment of the Ground Systems Needed to Launch SLS and Orion* (IG-15-012, March 18, 2015)

*NASA's Decision Process for Conducting Space Launch System Core Stage Testing at Stennis* (IG-14-009, January 8, 2014)

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

### Government Accountability Office

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

*Priority Open Recommendations: National Aeronautics and Space Administration* (GAO-19-424SP, April 12, 2019)

*NASA Major Projects: Portfolio Is at Risk for Continued Cost Growth and Schedule Delays* (GAO-18-576T, June 14, 2018)

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

*NASA: Assessments of Major Projects 2017* (GAO-17-303SP, May 16, 2017)

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

*Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability* (GAO-14-631, July 23, 2014)

# Appendix B: Projected Artemis I Launch Dates and Associated SLS Costs

**Table 3: Projected Artemis I Launch Dates and Associated SLS Costs**

| Decision Points (Year) | Projected Artemis I Launch Date | Dollars in Billions | |
|---|---|---|---|
| | | Projected Program Costs for Artemis I Only | All SLS Costs Projected through the Artemis I Launch Date |
| Report to Congress (2011) | December 2017 | $9.5 | $9.5 |
| Commitment to Congress (2014) | November 2018 | 9.7 | 9.7 |
| Key Decision Point C (2014) | November 2018 | 9.7 | 10.2 |
| Critical Design Review (2015) | November 2018 | 9.7 | 12.9 |
| Initial Program Replan (2017) | December 2019 | 9.7 | 15.2 |
| Update to Program Replan (May 2018) | June 2020 | 9.8 | 16.4 |
| NASA Estimate (September 2018) | June 2020 | 10.7 | 16.4 |
| NASA Updated Estimate (October 2019) | March 2021 (Unofficial Planning Date) | 11.4 | 18.3 |

Source: NASA OIG summary of Agency information.

# Appendix C: SLS Program Costs Compared to the Original ABC and Revised ABC

**Table 4: SLS Program Costs as of Original ABC, 2017 Replan, and the October 2019 ABC Updated Compared to the Original and Revised ABC Baselines**

| SLS Program | Dollars in Billions | | | | |
|---|---|---|---|---|---|
| | 2014 KDP-C ABC Costs | December 2017 Replan | Removed Costs from 2017 Replan | October 2019 ABC Update | Percent Increase From ABC Costs |
| **Total Program Costs** | **$9.695** | **$9.733** | | **$11.424** | **18%** |
| Formulation | 2.674 | 2.674 | | 2.674 | 0% |
| Development Costs | 7.021 | 7.059 | | 8.750 | 25% (from original ABC) |
| - Stages | 3.139 | 3.708 | | 4.947 | 58% |
| - Engines | 1.198 | 0.402 | *-$0.796* | 0.487 | 21% (from 2017 replan) |
| - Boosters | 1.090 | 0.998 | *-0.092* | 0.988 | *-1%* (from 2017 replan) |
| - All other – subtotal | 1.594 | 1.886 | | 2.328 | 46% |
| Total value of costs removed from ABC | | | *-$0.889* | | |
| Revised development cost ABC | | | $6.133 | | |
| Total increase of development costs from updated ABC ($8.750–$6.133) | | | | 2.617 | 43% (from revised ABC) |

Source: SLS Program reporting for tracking and reporting ABC costs through the Artemis I launch.

Note: All other costs include other SLS elements, construction of facilities, supporting activities, and other ABC-related costs.

# Appendix D: Breakout of SLS Program Costs by Fiscal Year and ABC Allocations

**Table 5: SLS Program Costs By Fiscal Year, ABC-Related Activities, and Percentage Allocations to ABC Costs**

| | Dollars in Millions | | | | | | | | | | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Projected | | | |
| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | |
| **Total SLS Program Costs** | **$1,527** | **$1,574** | **$1,580** | **$1,667** | **$1,917** | **$2,064** | **$2,170** | **$2,107** | **$2,586** | **$2,257** | **$19,449** |
| ABC costs | 1,216 | 1,480 | 1,558 | 1,540 | 1,580 | 1,267 | 1,168 | 1,012 | 460 | 144 | 11,424 |
| Attributable to ABC costs | 80% | 94% | 99% | 92% | 82% | 61% | 54% | 48% | 18% | 6% | 59% |
| **Total Stages** | **$541** | **$682** | **$765** | **$774** | **$996** | **$1,003** | **$1,095** | **$867** | **$1,157** | **$1,020** | **$8,900** |
| ABC costs | 476 | 682 | 758 | 743 | 891 | 734 | 836 | 693 | 237 | 55 | 6,105 |
| Attributable to ABC costs | 88% | 100% | 99% | 96% | 89% | 73% | 76% | 80% | 20% | 5% | 69% |
| **Total Boosters** | **$287** | **$212** | **$235** | **$258** | **$274** | **$281** | **$300** | **$279** | **$386** | **$366** | **$2,849** |
| ABC costs | 228 | 212 | 235 | 258 | 274 | 182 | 29 | 9 | 1 | 0 | 1,428 |
| Attributable to ABC costs | 79% | 100% | 100% | 100% | 100% | 65% | 10% | 3% | 0% | 0% | 50% |
| **Total Engines** | **$340** | **$165** | **$225** | **$216** | **$248** | **$381** | **$324** | **$384** | **$456** | **$389** | **$3,128** |
| ABC costs | 247 | 165 | 225 | 125 | 36 | 44 | 56 | 0 | 0 | 0 | 898 |
| Attributable to ABC costs | 73% | 100% | 100% | 58% | 15% | 12% | 17% | 0% | 0% | 0% | 29% |
| **Total SPIE** | **$51** | **$113** | **$91** | **$152** | **$143** | **$151** | **$182** | **$94** | **$218** | **$202** | **$1,397** |
| ABC costs | 33 | 32 | 60 | 123 | 133 | 103 | 65 | 18 | 27 | 27 | 621 |
| Attributable to ABC costs | 65% | 28% | 67% | 81% | 93% | 68% | 35% | 20% | 12% | 13% | 44% |
| **Total Other (PM, SMA, SIE, etc.)** | **$307** | **$402** | **$264** | **$268** | **$257** | **$247** | **$268** | **$485** | **$368** | **$311** | **$3,177** |
| ABC costs | 232 | 389 | 279 | 291 | 245 | 203 | 182 | 292 | 195 | 61 | 2,369 |
| Attributable to ABC costs | 76% | 97% | 106% | 109% | 95% | 82% | 68% | 60% | 53% | 20% | 75% |

Source: SLS Program reporting for tracking and reporting ABC costs through the Artemis I launch and NASA's FY 2021 Budget Request for FYs 2020 and 2021 budget assumptions.

Notes: The following acronyms are defined as: Spacecraft/Payload Integration and Evolution Office (SPIE); Program Management Office (PM); Safety and Mission Assurance Office (SMA); and Systems Engineering and Integration Office (SEI). FY 2019 costs are preliminary. The FY 2021 budget is based on NASA's FY 2021 Budget Request. NASA OIG adjusted SLS Program Office budget assumptions to account for the recently passed FY 2020 budget and the FY 2021 Budget Request. For FYs 2014 through 2016, ABC allocations exceeded the annual PM budget (within Total Other costs listed above) due to additional funding required for Michoud operations. Total costs may not add up exactly due to rounding.

# APPENDIX E: MANAGEMENT COMMENTS

National Aeronautics and Space Administration
**Headquarters**
Washington, DC 20546-0001

March 5, 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 Mission Directorate

Acting Deputy Associate Administrator for Exploration Systems Development

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of Space Launch System Program Costs and Contracts" (A-18-008-02)

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 Space Launch System Program Costs and Contracts" (A-18-008-02), dated January 30, 2020.

Over the past year, NASA has continued to implement recommendations from the 2018 OIG report on the management of Space Launch System (SLS) Stages contract. NASA has made significant improvements since 2018, and the Agency is committed to continuing improvements in sustainability, accountability, and transparency in its Exploration Systems Development (ESD) programs.

In the draft report, the OIG makes five recommendations addressed to the Associate Administrator for Human Exploration and Operations Mission Directorate and the Deputy Associate Administrator for Exploration Systems Development, in conjunction with the Marshall Space Flight Center Director, Marshall Space Flight Center Office of Procurement, and Space Launch System Program, intended to increase the sustainability, accountability, and transparency of NASA's efforts to manage the five major SLS element contracts to achieve the Agency's goal of landing astronauts on the Moon by 2024.

Specifically, the OIG recommends the following:

**Recommendation 1:** Notify Congress that the SLS Program has exceeded its Agency Baseline Commitment (ABC) by at least 30 percent.

**Management's Response:** NASA concurs. The Artemis I and II launch dates are under review pending completion of several assessments. NASA is conducting a Program Status Assessment of the overall Artemis effort, of which SLS and Exploration Ground Systems

(EGS) are key components. This assessment includes review of the schedule and technical approaches as well as systems engineering integration and program management. In parallel, NASA is performing an independent technical and programmatic assessment, including a joint cost and schedule confidence level analysis of the SLS and EGS programs.

NASA leadership will review the results of these assessments and then rebaseline the SLS program. NASA will communicate the results of these reviews to Congress and will comply with all applicable reporting requirements.

**Estimated Completion Date:** April 30, 2020.

**Recommendation 2:** Review HEOMD and NASA program management policies, procedures, and ABC reporting processes to provide greater visibility into current, future, and overall cost and schedule estimates for the SLS Program and other human space flight programs. This review shall include the following:

a. rebaselining Artemis I costs to appropriately and transparently track costs that include SLS development costs and activities tied to the first SLS launch;

b. establishing methodologies and processes to track and set cost commitments for Artemis II; and

c. determining reporting and tracking procedures for setting cost and schedule commitments, and monitoring progress throughout the entire life cycle of the SLS Program (through at least 2030).

**Management's Response:** NASA concurs. NASA has already begun implementing improvements to better track cost and schedule and to report progress against baselines, including separating each deliverable item into its own contract line item number (CLIN) in the renegotiation of the Stages Contract and committing to do so in new acquisitions. In addition, NASA is evaluating changes to NASA Procedural Requirements (NPR) 7120.5, "Space Flight Program and Project Management Requirements," to better enable the necessary insight into program affordability and efficient monitoring of total program costs and execution for multi-year, multi-cadence type programs. NASA is also investigating plans to redefine formal reporting requirements for multi-decade programs while maintaining visibility to entire plan.

**Estimated Completion Date:** September 30, 2020.

**Recommendation 3:** For new acquisitions of SLS deliverables, develop a cost accounting model that separates each deliverable into its own CLIN for tracking costs, performance, and award fees.

**Management's Response:** NASA concurs. NASA has already addressed this recommendation with the renegotiation of the Stages Contract. For new acquisitions of SLS deliverables, NASA will separate each flight set into its own CLIN, with per-unit delineation at the Sub-Contract Line Item Number (SLIN) when a flight set is comprised of more than a single unit, for tracking costs, performance, and award fees.

**Estimated Completion Date:** Complete. The current Core Stage contract separates each core stage and Exploration Upper Stage into unique CLINs and new acquisitions will conform to the recommendation.

**Recommendation 4:** For large award fee contracts where NASA has on-site personnel, ensure they are appointed in writing and clearly assigned the task of monitoring and reporting on the performance of the contractor.

**Management's Response:** NASA concurs. All award fee-type contracts with on-site personnel now have appointment letters identifying assigned technical monitors and monitoring and reporting tasks.

**Estimated Completion Date:** Complete.

**Recommendation 5:** Conduct a thorough review of each major SLS contract's scope of work and technical requirements needed to complete the period of performance to assist in eliminating incremental contract value increases to the contract and lessen contract management burden, as in the case of the Boosters contract.

**Management's Response:** NASA concurs. The Booster Obsolescence and Life Extension (BOLE) contract example is unique; BOLE upgrades are intended to be incrementally implemented on the current design until existing heritage hardware is exhausted, at which point final design changes, including new propellant formula and case material, will be incorporated. A similar contractual approach to incremental fielding of improvements does not exist elsewhere in the program. NASA has already started to implement a plan that will meet the intent of this recommendation with the current deep dive assessment to achieve the Artemis I, II and III missions, reconciling technical requirements with existing contract scope.

**Estimated Completion Date:** April 30, 2020.

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

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.

Douglas Loverro

Thomas Whitmeyer

# APPENDIX F: REPORT DISTRIBUTION

## National Aeronautics and Space Administration

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## Non-NASA Organizations and Individuals

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 Deputy Associate Director, Energy and Space Programs Division

Government Accountability Office
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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

**(Assignment No. A-18-008-02)**