

# NASA

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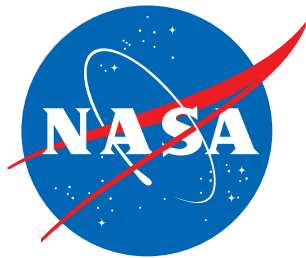


### NASA's Management of Space Launch System Block 1B Development



August 8, 2024

IG-24-015



## Office of Inspector General

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# RESULTS IN BRIEF



## NASA's Management of Space Launch System Block 1B Development

August 8, 2024

IG-24-015 (A-23-08-01-HED)

### WHY WE PERFORMED THIS AUDIT

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Scheduled to launch in September 2028, Artemis IV will be the first flight of NASA's more powerful heavy-lift rocket—the Space Launch System (SLS) Block 1B. The rocket is designed to increase the amount of cargo the SLS can deliver to the Moon. A critical component of this upgrade is The Boeing Company's (Boeing) development of the SLS's new upper stage, the Exploration Upper Stage (EUS). Once completed, the EUS will give the SLS a 40 percent upgrade in capability to send the Orion Multi-Purpose Crew Vehicle capsule and large cargos to the Moon, from 27 metric tons under Block 1—the SLS rocket's first iteration—to 38 metric tons with Block 1B.

The SLS Block 1B has been under development since 2014 and has faced changing technical requirements and competing funding priorities. These factors, along with congressional directives to accelerate the rocket's development, have led to increased costs and schedule delays. Originally intended for the Artemis II mission, Block 1B's first flight was moved to Artemis IV, extending the development timeline and increasing costs. Boeing's EUS contract has grown from \$962 million to over \$2 billion through 2025, contributing to the overall SLS Block 1B cost increase.

In this audit, we examined NASA's management of the SLS Block 1B development, focusing on the EUS. To complete this work, we interviewed officials from NASA Headquarters, Marshall Space Flight Center, Michoud Assembly Facility (Michoud), Boeing, and the Defense Contract Management Agency (DCMA). We also reviewed NASA and contractor cost and budget documentation, contracts for each SLS element, contract obligations and disbursements, Boeing financial management reports, and Earned Value Management System (EVMS) cost estimates. Additionally, we assessed past and current schedules and quality control documents for SLS core and upper stage production.

### WHAT WE FOUND

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While NASA requires its aerospace contractors to have quality assurance programs that comply with SAE International's AS9100D standards on quality management systems, we found Boeing's quality management system at Michoud does not adhere to these standards or NASA requirements. NASA engages DCMA to conduct surveillance of Boeing's core and upper stage manufacturing efforts at Michoud, and when deficiencies in quality are found, DCMA issues Corrective Action Requests (CAR) to the contractor. CARs are labeled Level I through IV, with Level I the least serious deficiency. From September 2021 to September 2023, DCMA issued Boeing 71 Level I and II CARs, as well as a draft Level III CAR. According to DCMA officials, this is a high number of CARs for a space flight system at this stage in development and reflects a recurring and degraded state of product quality control. Boeing's process to address deficiencies to date has been ineffective, and the company has generally been nonresponsive in taking corrective actions when the same quality control issues reoccur.

Quality control issues at Michoud are largely due to the lack of a sufficient number of trained and experienced aerospace workers at Boeing. To mitigate these challenges, Boeing provides training and work orders to its employees. Considering the significant quality control deficiencies at Michoud, we found these efforts to be inadequate. For example, during our visit to Michoud in April 2023, we observed a liquid oxygen fuel tank dome—a critical component of the SLS Core Stage 3—segregated and pending disposition on whether and how it can safely be used going forward due to welds that did not meet NASA specifications. According to NASA officials, the welding issues arose due to Boeing's

inexperienced technicians and inadequate work order planning and supervision. The lack of a trained and qualified workforce increases the risk that Boeing will continue to manufacture parts and components that do not adhere to NASA requirements and industry standards.

We project SLS Block 1B costs will reach approximately \$5.7 billion before the system is scheduled to launch in 2028. This is \$700 million more than NASA's 2023 Agency Baseline Commitment, which established a cost and schedule baseline at nearly \$5 billion. EUS development accounts for more than half of this cost, which we estimate will increase from an initial cost of \$962 million in 2017 to nearly \$2.8 billion through 2028. Boeing's delivery of the EUS to NASA has also been delayed from February 2021 to April 2027, and when combined with other factors, suggests the September 2028 Artemis IV launch date could be delayed as well. Factors contributing to these cost increases and schedule delays include redirection of EUS funds to the core stage during Artemis I production, changing Artemis mission assignments, maintaining an extended workforce 7 years more than planned, manufacturing issues, and supply chain challenges.

NASA delayed establishing the Block 1B Agency Baseline Commitment until December 2023, after 10 years of development and much later in the project life cycle than NASA's standard practice. Without a formal cost and schedule baseline at critical milestones, the Agency was limited in its ability to assess adherence to budgets and timelines, and Congress and other stakeholders lacked visibility into the Block 1B's increasing costs and schedule delays. Additionally, Boeing Defense, Space & Security's EVMS, used by NASA for its Stages contract to measure cost and schedule progress, has been disapproved by the U.S. Department of Defense since 2020. DCMA has issued several Level II and III CARs for this EVMS, including a Level III CAR related to visibility into cost, schedule, and resource needs for several Boeing contracts, including Stages.

## WHAT WE RECOMMENDED

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To improve the safety and sustainability of the SLS Program, we recommended the Associate Administrator for Exploration Systems Development Mission Directorate (ESDMD) in conjunction with the Assistant Administrator for Procurement and the Chief, Safety and Mission Assurance: (1) coordinate with Boeing, the SLS Stages prime contractor, to develop a quality management system training program that is compliant with AS9100D and reviewed by the appropriate NASA officials and (2) institute financial penalties for Boeing's noncompliance with quality control standards. To minimize the impact on the Artemis campaign's timeline and achieve sustainability, we recommended the Associate Administrator for ESDMD: (3) perform a detailed cost overrun analysis on Boeing's Stages contract for EUS development. To provide greater visibility into cost and schedule estimates for SLS upgrades, we recommended the Associate Administrator for ESDMD: (4) coordinate with DCMA to ensure contractual compliance with EVMS clauses.

We provided a draft of this report to NASA management who concurred with three of the four recommendations and described planned actions to address them. We consider the proposed actions responsive to Recommendations 1, 3, and 4 and will close them upon completion and verification. The Agency non-concurred with Recommendation 2, and we find its proposed actions unresponsive. Consequently, this recommendation will remain unresolved pending further discussions with the Agency.

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# Acronyms

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ABC	Agency Baseline Commitment
CAR	Corrective Action Request
CDR	Critical Design Review
DCMA	Defense Contract Management Agency
DOD	Department of Defense
EUS	Exploration Upper Stage
EVMS	Earned Value Management System
IRT	Independent Review Team
JCL	Joint Cost and Schedule Confidence Level
KDP	Key Decision Point
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
SLS	Space Launch System

# INTRODUCTION

Artemis IV will be the first flight of NASA’s more powerful heavy-lift rocket—the Space Launch System (SLS) Block 1B—which is designed to increase the amount of cargo the SLS can deliver to the Moon. During the Artemis IV mission, scheduled to launch in September 2028, the SLS Block 1B must lift the Orion Multi-Purpose Crew Vehicle (Orion) capsule and its co-manifested payload, the International Habitation Module, and put them on a path to the Moon’s orbit. There, Orion will link with the lunar orbiting Gateway station and Human Landing System to transport astronauts from lunar orbit to the Moon’s surface. Key to achieving this capability upgrade is The Boeing Company’s (Boeing) development of the SLS’s new upper stage—the Exploration Upper Stage (EUS). The EUS gives the SLS a 40 percent upgrade in capability to send Orion and large cargos to the Moon, from 27 metric tons under Block 1—the SLS rocket’s first iteration—to 38 metric tons for the new Block 1B system. An upgrade of this complexity requires diligent oversight to ensure the contractor delivers a quality space flight system that meets the Agency’s requirements.

Under development since 2014, the SLS Block 1B has experienced changing technical requirements and competing funding priorities. Rework of critical components and previous Artemis mission launch delays have led to increased costs and schedule delays. Furthermore, congressional direction to accelerate Block 1B development while the Agency was focused on supporting near-term Artemis missions resulted in a stop-start effort that also extended the timeline for Block 1B development and delayed its first flight. Originally intended to fly as part of Artemis II (then scheduled for 2021), the Block 1B was subsequently moved to the Artemis IV mission. This extended timeline along with supply chain challenges have contributed to increasing Block 1B costs, with Boeing’s EUS contract growing from \$962 million to over \$2 billion through 2025. Further compounding the issue, for its first 10 years of development, Congress and other stakeholders have had limited visibility into the Block 1B’s projected costs and any risks that may impact its schedule for completion. This resulted from NASA adjusting traditional project management procedures by delaying the establishment of its Block 1B cost and schedule baseline until December 2023.

In this audit, we examined NASA’s management of the development of the SLS Block 1B, with a particular focus on the EUS. See Appendix A for details of the audit’s scope and methodology.

## Background

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NASA's Moon to Mars Program seeks to return humans to the Moon using a combination of heavy-lift rockets from the Agency and its commercial partners to propel the Orion, Gateway, and Human Landing System to lunar orbit.<sup>1</sup> The SLS Block 1 is the first iteration of NASA's heavy-lift rocket that will be used on the first three Artemis missions; this version of the rocket can transport 27 metric tons—the weight of Orion—to the Moon. Artemis I, launched in November 2022, was the first uncrewed flight of the integrated SLS/Orion system. It flew on a trajectory that included a series of orbits around the Moon and ended with the successful return of the Orion capsule to Earth. The second mission and first crewed flight—Artemis II, scheduled for 2025—will also orbit the Moon and prepare the way for Artemis III in 2026. In this third mission, the Orion capsule will dock directly to Space Exploration Technologies Corp.'s (SpaceX) Human Landing System in lunar orbit to transport astronauts to and from the Moon's surface.

Subsequent Artemis mission goals include a longer-term presence on the Moon that incorporates the use of the Gateway station in lunar orbit, ground infrastructure on the lunar surface such as a habitat, and surface transportation like a lunar rover. To accomplish these goals, the Agency requires an upgrade to the SLS—the Block 1B.<sup>2</sup> NASA will debut this more powerful rocket as part of the Artemis IV mission in 2028. In preparation for Artemis IV, the Gateway's initial elements—the Power and Propulsion Element and Habitation and Logistics Outpost—will be launched into lunar orbit, along with multiple SpaceX Starships.<sup>3</sup> Then, the SLS Block 1B will launch the Orion spacecraft and its co-manifested International Habitat to the Moon's orbit.<sup>4</sup> There, Orion will link with the Gateway and Human Landing System to transport astronauts from lunar orbit to the Moon's surface. See Figure 1 for Artemis IV's mission profile.

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<sup>1</sup> The Moon to Mars Program focuses on hardware development, mission integration, and risk management for programs critical to NASA's exploration approach that uses Artemis missions to the Moon to prepare for human missions to Mars. This includes the SLS rocket, Orion spacecraft, supporting ground systems, Human Landing Systems, spacesuits, and the lunar orbiting Gateway station.

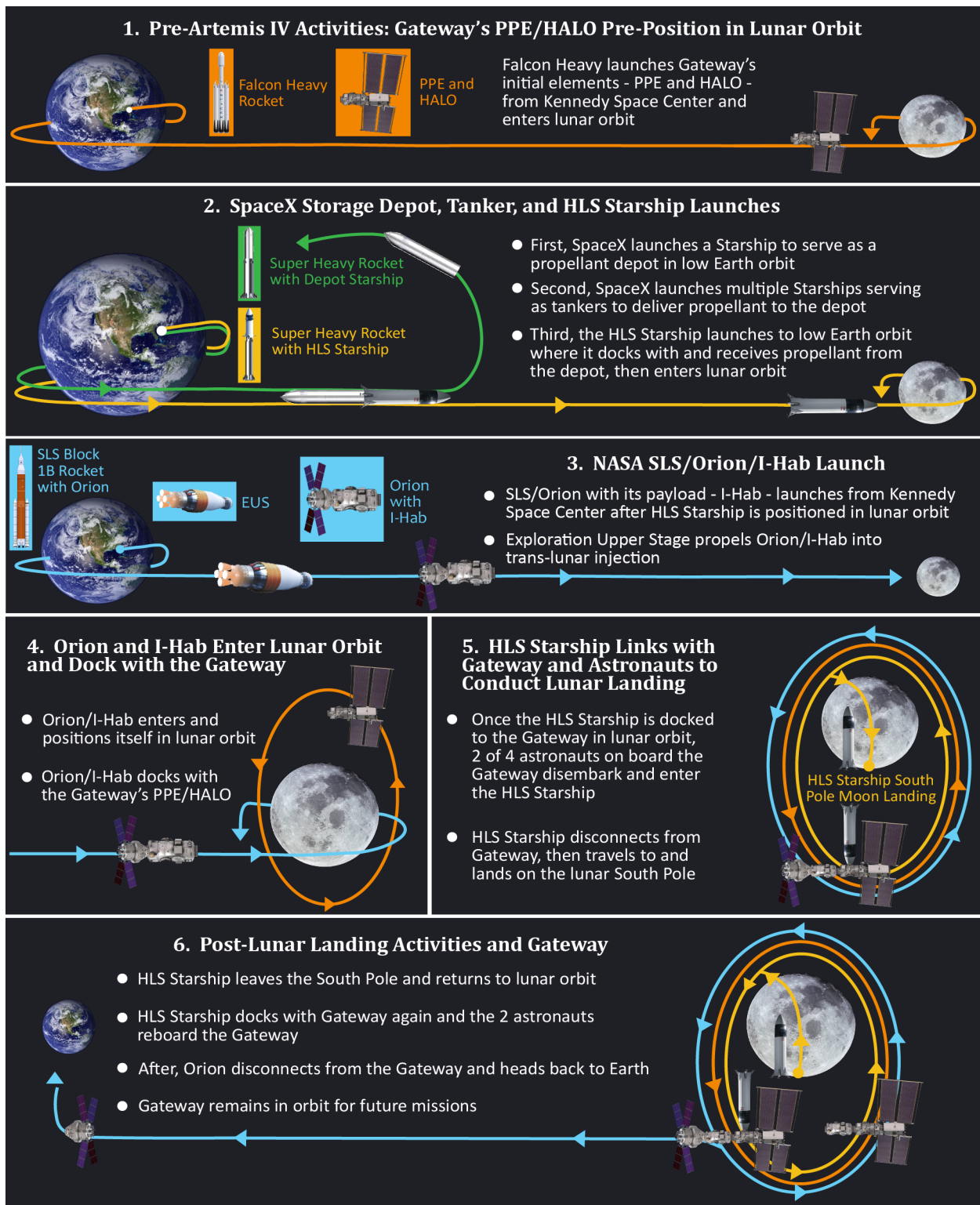
<sup>2</sup> Besides Block 1B, NASA intends to produce a third version of the SLS—the Block 2—which will be another upgrade in the rocket's space flight systems to include more powerful solid rocket boosters.

<sup>3</sup> The Power and Propulsion Element will power and propel the Gateway in orbit while the Habitation and Logistics Outpost will provide a docking location for the Orion capsule and living and working spaces for crewmembers staying less than 30 days.

<sup>4</sup> The International Habitation Module, or International Habitat, will dock between NASA's Habitation and Logistics Outpost module and the Orion capsule. Provided by NASA's partners the European Space Agency and Japan Aerospace Exploration Agency, the International Habitat includes crew living quarters that will house life support systems, cameras, and scientific research facilities.



**Figure 1: Planned Artemis IV Mission Profile (as of March 2024)**

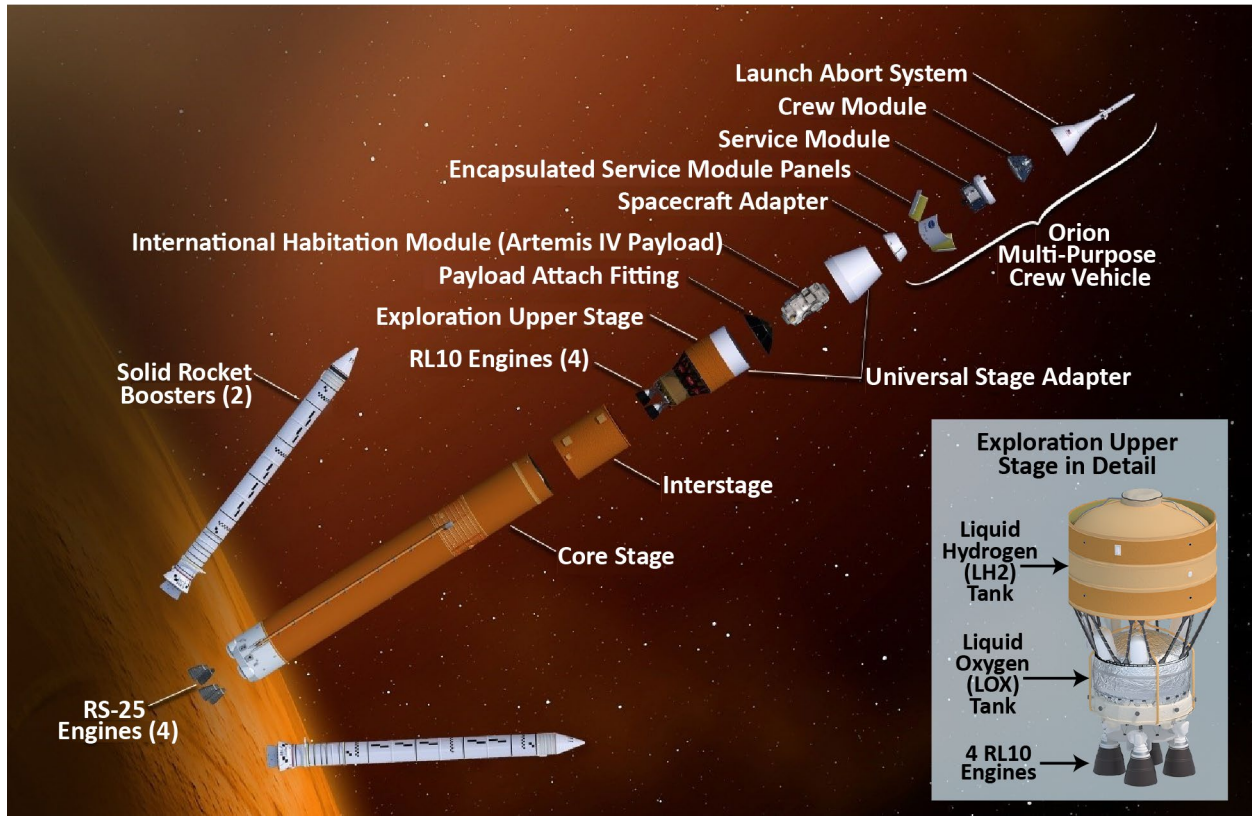


Source: NASA Office of Inspector General (OIG) presentation of Agency data.

Note: Power and Propulsion Element (PPE), Habitation and Logistics Outpost (HALO), Human Landing System (HLS), Space Launch System (SLS), Exploration Upper Stage (EUS), and International Habitat (I-Hab).

The SLS Block 1B can transport 38 metric tons to the Moon and is powered during launch by the core stage’s four RS-25 engines and two solid rocket boosters.<sup>5</sup> The Block 1B’s more powerful upper stage, the EUS, with its four RL10 engines, will replace the Block 1’s Interim Cryogenic Propulsion Stage with its one RL10 engine. Figure 2 shows a breakout of the elements of the SLS Block 1B rocket.

**Figure 2: Space Launch System Block 1B Elements**



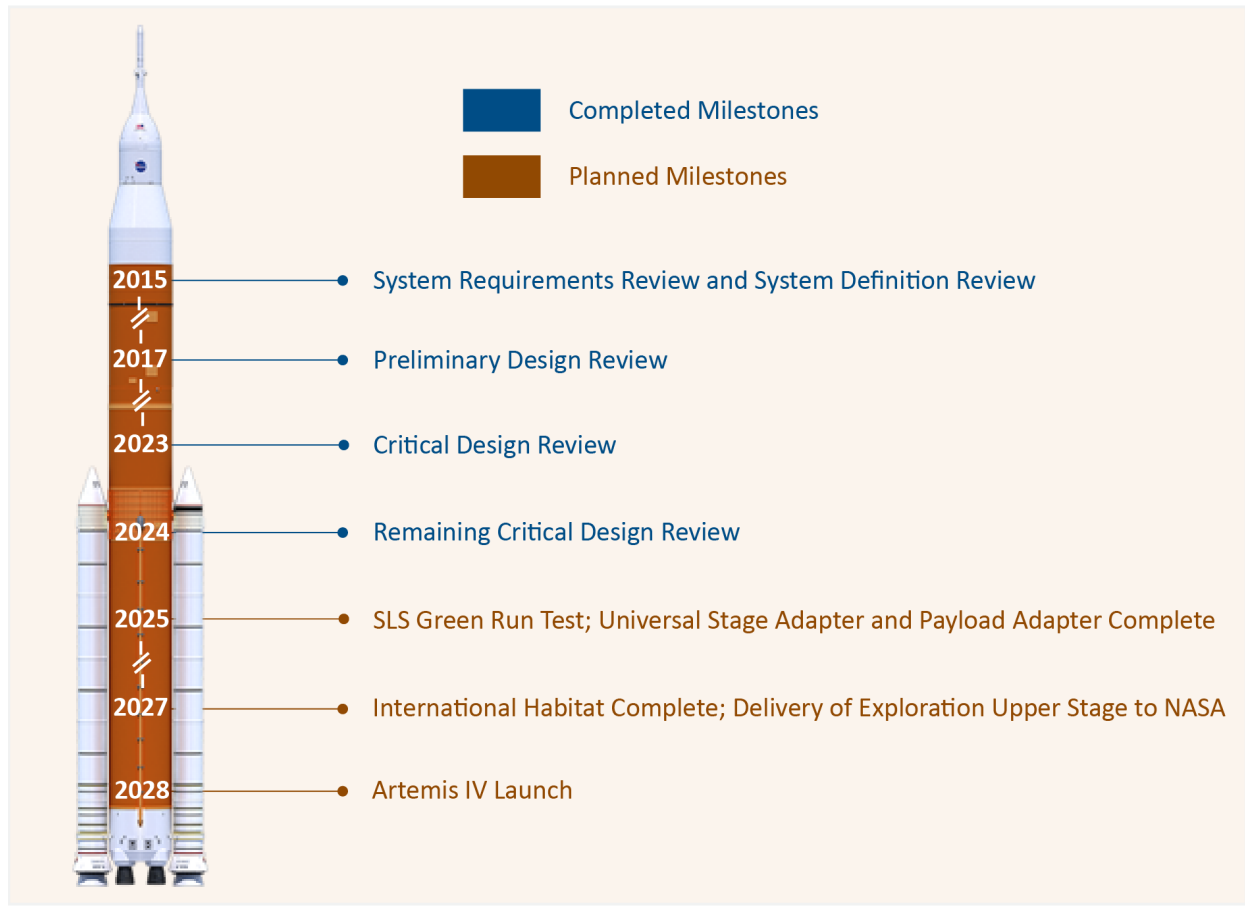
Source: NASA OIG presentation of Agency information.

The SLS Block 1B, including the EUS, is currently in the final design and fabrication phase of development. Boeing is the prime contractor for EUS development and production while Aerojet Rocketdyne provides the RL10 engines. In addition, Dynetics is providing a new stage adapter—the Universal Stage Adapter—that will connect the EUS to the Orion spacecraft. The Block 1B upgrade team has completed several required project life-cycle reviews, including its Critical Design Review (CDR) in 2023, and is fabricating the core stage and EUS fuel tanks at NASA’s Michoud Assembly Facility

<sup>5</sup> The SLS rocket delivers propulsion in stages to send the Orion spacecraft and its cargo to the Moon for the Artemis missions. At liftoff, the core stage—which stores liquid hydrogen and liquid oxygen and the systems that feed the stage’s four RS-25 engines—and twin solid rocket boosters fire to propel the SLS off the launch pad into low Earth orbit. Once in orbit, the upper stage provides the in-space propulsion to set the spacecraft on a precise trajectory to the Moon.

(Michoud).<sup>6</sup> NASA is also planning a Green Run test for Artemis IV's EUS and its RL10 engines at Stennis Space Center in 2025.<sup>7</sup> Figure 3 shows the current timeline for Block 1B development.

**Figure 3: NASA's Block 1B Development Timeline (as of July 2024)**



Source: NASA OIG presentation of Agency data.

<sup>6</sup> Reviews include the (1) System Requirements Review to evaluate whether functional and performance requirements for the system are responsive to the program's requirements on the project and can be achieved; (2) System Definition Review to evaluate the credibility and responsiveness of the proposed system architecture to program requirements and constraints including available resources; (3) Preliminary Design Review to evaluate the planning, technical, cost, and schedule baselines developed during the project's formulation and assess the preliminary design to determine if the project is sufficiently mature to begin final design and fabrication; and (4) Critical Design Review to evaluate the ability of the project's design to meet mission requirements with appropriate margins and acceptable risk within defined project constraints including available resources.

<sup>7</sup> During the Green Run test, the EUS is mounted on a test stand and its four RL10 engines fired to simulate an actual launch. The test is designed to check the combined system's compatibility and functionality.

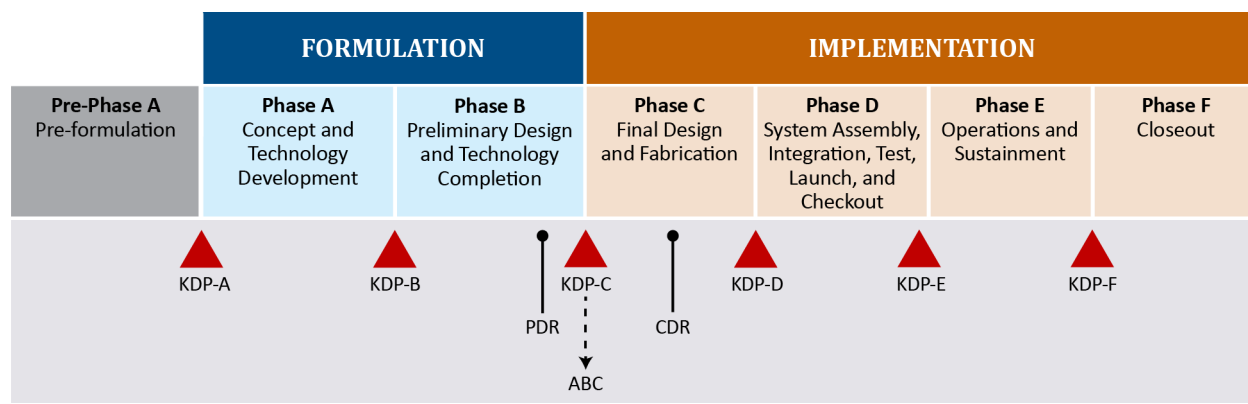
NASA estimates that SLS Block 1B costs will total nearly \$5 billion, including the first flight of the EUS during Artemis IV. This includes development of new systems—the EUS, Universal Stage Adapter, and Payload Adapter—as well as software modifications and integration with the core stage and boosters. It does not include the costs for the boosters, Core Stage 4, and the RS-25 engines. According to the Agency, the obligated funds spent on Block 1B development from fiscal year 2014 through fiscal year 2023 and NASA’s projected total costs for the next five fiscal years total nearly \$5 billion.

## NASA Program and Project Management

Guidance for managing NASA programs and projects, controlling development costs, and congressional reporting requirements are described in U.S. law, namely Title 51.<sup>8</sup> The Agency implements its major activities through NASA Procedural Requirements (NPR) in accordance with Title 51, including federal requirements on transparency and accountability. Specifically, NASA manages the SLS under NPR 7120.5F, *NASA Space Flight Program and Project Management Requirements*, with the goal of developing and successfully executing cost-effective and efficient programs and projects.<sup>9</sup>

NASA divides the program and project life cycle into two main phases: Formulation and Implementation (see Figure 4). Subsequent life-cycle phases within Formulation (Phases A and B) and Implementation (Phases C through F) allow the Agency to progress to the next major milestone in the program or project. The readiness of a program or project to continue to the next phase of the life cycle is determined at various “gates” or Key Decision Points (KDP). Within Phases A through F, multiple life-cycle reviews must be met to satisfy KDP requirements and move to the next phase. During the Formulation Phase, the Agency emphasizes defining the complexity and scope of the program or project and increasing understanding of programmatic requirements.

**Figure 4: NASA Program and Project Life Cycle**



Source: NASA OIG presentation of information contained in NPR 7120.5F.

Note: Preliminary Design Review (PDR) and Agency Baseline Commitment (ABC).

<sup>8</sup> Public Law 111-314 (2010) is known as Title 51 of the United States Code, “National and Commercial Space Programs.” Title 51 created specific controls for NASA programs with a life-cycle cost over \$250 million including a requirement to provide Congress a Major Program Annual Report. The annual report must include a Baseline Report that, at a minimum, gives an estimate of the life-cycle cost for the program including a detailed breakout of the development cost and program reserves as well as an estimate of the annual costs until development is completed.

<sup>9</sup> NPR 7120.5F, *NASA Space Flight Program and Project Management Requirements w/Change 3* (August 3, 2021).

For example, the life-cycle gate that allows the program or project to proceed from Phase B in Formulation to Phase C, the start of Implementation, is KDP-C. Known as the Decision Memorandum for Implementation, KDP-C requires program and project managers to document the life-cycle cost and schedule estimates, which become the Agency Baseline Commitment (ABC).<sup>10</sup> The ABC is the cost and schedule baseline against which progress and performance are measured throughout the Implementation Phase. This is also the only official baseline for a program or project sent to Congress and the Office of Management and Budget.

After the ABC is established, the program or project progresses from the Formulation Phase to the Implementation Phase and prepares for the CDR, the life-cycle review that determines if the design is sufficiently mature for final design and fabrication. Flexibility in the timing, number, and content of the life-cycle reviews is allowed as long as equivalent information—such as the ABC resulting from KDP-C—is provided at each KDP to satisfy its requirements. Under federal law and NPR 7120.5F, development cost growth exceeding 15 percent requires official notification to Congress, whereas any growth more significant than 30 percent requires a rebaseline.<sup>11</sup> NASA is required to notify Congress in the event of a rebaseline, and congressional reauthorization is necessary to continue the program or project.

In addition, a Joint Cost and Schedule Confidence Level (JCL) is required for all single-project programs at KDP-C, regardless of life-cycle cost.<sup>12</sup> A JCL is a probabilistic analysis of cost and schedule to measure the likelihood of completing the remaining work on time and at the budgeted levels. In accordance with NPR 7120.5F, the Exploration Systems Development Mission Directorate must plan and budget single-project programs based on a 70 percent JCL or confidence level, meaning a 70 percent likelihood that the cost and schedule will be completed within budget and on time or as approved by the Decision Authority.

An Earned Value Management System (EVMS) is an additional tool NASA uses to assess program and project cost and schedule performance with timely and accurate data for effective decision-making.<sup>13</sup> Earned value management measures program and project progress by integrating technical, cost, schedule, and risk management data at a work performance level. NPR 7120.5F requires single-project programs and projects with an estimated life-cycle cost greater than \$250 million to perform earned value management for all in-house and contracted portions of the work as soon as the contract begins to develop its Work Breakdown Structures and Integrated Master Schedules.<sup>14</sup> NASA requires an EVMS

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<sup>10</sup> A life-cycle review is complete when the governing Agency Program Management Council and Decision Authority—the NASA Associate Administrator or delegated Mission Directorate Associate Administrator—sign the Decision Memorandum.

<sup>11</sup> 51 U.S.C. § 30104(e) and (f). A rebaseline is the process that results in a change to a program's or project's ABC.

<sup>12</sup> Single-project programs generally have long development and operational lifetimes and represent a large investment of Agency resources. Multiple organizations or agencies contribute to them. Single-project programs have one project and implement their program objectives and requirements through one of two management approaches: (1) separate program and project structures or (2) a combined structure.

<sup>13</sup> Use of an EVMS to assess program and project cost and schedule performance is required by Federal Acquisition Regulation Subpart 34.2, *Earned Value Management System* (2019) and NPR 7120.5F.

<sup>14</sup> A Work Breakdown Structure identifies the hardware, software, services, and all other deliverables required to achieve an end project objective. The purpose of a Work Breakdown Structure is to subdivide the project's work content into manageable segments to facilitate planning and control of cost, schedule, and technical content. It identifies the total project work to be performed, including all in-house work by NASA as well as all work by contractors, international partners, universities, and other performing entities. An Integrated Master Schedule is the complete, time-phased schedule necessary to accomplish a program or project that incorporates all activities and planned work, including contractor and subcontractor efforts, as well as the necessary resources and associated budgets.

on cost-type and fixed-price incentive contracts for development and production work, including work for flight and ground support systems.<sup>15</sup> For contracts and subcontracts valued at \$20 million but less than \$50 million, compliance with EVMS industry standards is determined by the cognizant contracting officer.<sup>16</sup> For contracts and subcontracts valued at \$50 million or more, the contractor must have an EVMS in compliance with industry standards as determined by the cognizant federal agency.

A certified EVMS ensures contractor performance measurement data provided to NASA is valid, accurate, and timely to support informed decision-making. It also allows NASA to plan contract scope to completion; integrate the contract's cost, schedule, and technical aspects into a detailed baseline plan; objectively measure progress; and forecast achievement of milestones. The Integrated Program Management Data and Analysis Report is the contractor's primary means of communicating contractually required earned value management-related data to the government.

The Defense Contract Management Agency (DCMA) typically reviews EVMS plans and verifies continued compliance with industry guidelines.<sup>17</sup> However, NASA can conduct a compliance review of a contractor's EVMS plans at the time the contract is awarded if the EVMS is nonexistent or determined to be noncompliant with EVMS guidelines. According to the NASA Federal Acquisition Regulation Supplement, if the contractor does not correct all deficiencies identified in the review, the contracting officer may take remedial action, which may include but is not limited to, a reduction in fee in the event of noncompliance.<sup>18</sup>

## SLS Quality Management System and Quality Assurance Responsibilities

NASA's aerospace contractors are required to have a quality assurance program that complies with SAE International's AS9100D, *Quality Management Systems—Requirements for Aviation, Space, and Defense Organizations*.<sup>19</sup> These standards are designed to produce a quality space flight system that meets customer requirements and applicable statutory and regulatory requirements. NASA has prescribed aerospace standards for quality management in the SLS Block 1B element contracts. For example, in its Stages contract with Boeing to provide the core stages for Artemis I and II and the EUS for Artemis IV,

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<sup>15</sup> A cost-type contract reimburses the contractor for all legitimate expenses up to a set limit plus additional payment to allow for a profit. A fixed-price incentive contract provides for adjusting profit and establishing the final contract price by application of a formula based on the relationship of the total final negotiated cost to the total target cost.

<sup>16</sup> Electronic Industries Alliance Standard 748, *Earned Value Management Systems*, is the standard for U.S. Department of Defense (DOD) earned value management programs and was adopted in August 1999 for application to major defense acquisition programs, including NASA. The standard helps provide integrated program management information using the organization's resources and an EVMS to meet the needs of a project.

<sup>17</sup> Electronic Industries Alliance Standard 748. A part of DOD, DCMA is responsible for determining EVMS compliance. NASA has a Memorandum of Understanding with DCMA for EVMS acceptance and surveillance. Under this agreement, DCMA is expected to provide NASA with evidence supporting its acceptance of a contractor's EVMS.

<sup>18</sup> NASA Federal Acquisition Regulation Supplement 1852.234-2(b), *Earned Value Management System* (2015).

<sup>19</sup> SAE International is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial vehicle industries with a focus on life-long learning and voluntary consensus standards development. AS9100D, *Quality Management Systems—Requirements for Aviation, Space, and Defense Organizations* (September 20, 2016), includes International Organization for Standardization ISO 9001:2015 quality management system requirements and specifies additional aviation, space, and defense industry requirements, definitions, and notes. Specifically, Chapter 10, *Improvement*, states the organization shall determine and select opportunities for improvement and implement any necessary actions to meet customer requirements and enhance customer satisfaction.

NASA requires that the contractor's quality management system shall comply with AS9100D standards. To determine whether the quality management system complies with these standards, the contractor supports the government's post-award verification audit of its quality management system to assess compliance with AS9100D and supplemental requirements imposed by SLS-RQMT-014, *Space Launch System Program Safety and Mission Assurance Requirements*.<sup>20</sup>

NASA's Office of Safety and Mission Assurance is responsible for development, implementation, and oversight of agency-wide safety, reliability, assurance, and space environment sustainability policies and procedures, including fostering early integration and life cycle implementation of quality assurance into NASA's programs and operations. DCMA assists NASA by providing quality assurance specialists at Boeing manufacturing facilities located at Michoud and Kennedy Space Center (Kennedy). Along with NASA officials and third-party registrars, DCMA specialists monitor the contractor's compliance with quality management system procedures.<sup>21</sup>

At Michoud, DCMA has approximately 30 employees working 24 hours a day, seven days a week, overseeing core stage and EUS production. Core stage production, including installation of the RS-25 engines for Artemis I and II, was completed at Michoud. However, beginning with the production for Artemis III, NASA will ship the core stage's components from Michoud to Kennedy for final assembly. The engine section structure is shipped first, followed by the remaining four of five major stage elements that are preassembled at Michoud. At Kennedy's Vehicle Assembly Building, these elements will be vertically integrated with the engine section and the RS-25 engines installed in the core stage. While the engines are installed, Kennedy's quality assurance specialists will perform surveillance.<sup>22</sup> Upon completion of its Green Run testing at Stennis Space Center, the EUS will also be shipped to Kennedy and stacked with the other elements of the SLS in the Vehicle Assembly Building.<sup>23</sup>

When deficiencies in quality are found, DCMA—in consultation with NASA—issues Corrective Action Requests (CAR) to the contractor. DCMA identifies the contractual nonconformity and the severity of the deficiency by labeling the CAR Level I through IV, with Level I the least serious (see Figure 5). In response, the contractor must take action to correct the deficiencies, and for Level II and above, reply in writing to DCMA of the corrective action taken. Levels III and IV are the most serious issues which require notification to the contractor's top management due to repeated, uncorrected nonconformances and can involve reductions in contract payments, or in the case of a Level IV, suspension of payments. Because Level III and IV CARs are subject to potential contracting actions, DCMA submits a draft CAR to the SLS Program to determine the appropriate course of action before issuing the CAR to the contractor.

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<sup>20</sup> The scope of the post-award verification audit is tailored based on certification and registration status and coordinated with the contractor prior to scheduling the audit. NASA SLS-RQMT-014, Revision E, *Space Launch System Program Safety and Mission Assurance Requirements* (November 16, 2017).

<sup>21</sup> A third-party registrar is an independent organization that certifies a contractor's quality management system has been assessed and approved against the provisions of SAE International's quality management standards and requirements.

<sup>22</sup> Surveillance consists of activities to review and analyze contractor plans, financials, schedules, policies, procedures, systems, processes, process outputs, products, and services. Surveillance includes reviews to determine adequacy (when applicable) and compliance to contractual, statutory, regulatory, or contractor requirements. Surveillance activities apply primarily to post-award activities but may apply to some pre-award activities as well.

<sup>23</sup> The first EUS is being built at Michoud but will undergo testing at Stennis Space Center before being shipped to Kennedy.

**Figure 5: DCMA Corrective Action Request Levels**

<b>CAR Level I</b>	Issued for contractual nonconformity that can be corrected on the spot and where no further corrective action response is necessary. Level I CARs shall be documented and issued to the supplier management level responsible for taking corrective actions.
<b>CAR Level II</b>	Issued when contractual nonconformity cannot be corrected on the spot. At a minimum, nonconformity associated with Critical Safety Item critical characteristics and Safety of Flight characteristics shall be issued at this level. Level II CARs should be directed to the supplier management level responsible for initiating corrective actions.
<b>CAR Level III</b>	Issued to the supplier's top management to call attention to severe contractual nonconformity. Repeat nonconformities found within 1 year for the same single point failure Safety of Flight characteristics shall be issued at this level. A Level III CAR may be coupled with contractual remedies such as reductions of progress payments, cost disallowances, and business management disapprovals. A Level I or II CAR need not be issued before a Level III CAR is generated. All Level III CARs shall be coordinated with the contracting officer.
<b>CAR Level IV</b>	Issued to the supplier's top management when a Level III CAR has been ineffective or the contractual nonconformity is of such a severe nature to warrant contractual remedies such as suspension of progress payments or product acceptance activities, by applicable Federal Acquisition Regulation/Defense Federal Acquisition policies.

Source: NASA OIG presentation of DCMA CAR information.



# BOEING'S INEFFECTIVE QUALITY MANAGEMENT SYSTEM AND INEXPERIENCED WORKFORCE INCREASE POTENTIAL RISKS

## Boeing's Quality Management System for Core Stage Production at Michoud Does Not Meet Industry Standards

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NASA requires its aerospace contractors to have quality assurance programs that comply with AS9100D standards. However, we found that Boeing's quality management system at Michoud does not effectively adhere to industry standards or NASA requirements, resulting in production delays to the SLS core and upper stages and increased risk to the integrated spacecraft. To ensure Boeing's quality management system meets AS9100D standards, the Agency engages DCMA to conduct surveillance of Boeing's core and upper stage manufacturing efforts at Michoud. According to DCMA officials, Boeing's process for addressing contractual noncompliance has been ineffective, and the company has generally been nonresponsive in taking corrective actions when the same quality control issues reoccur.

We analyzed 2 years of DCMA CAR reports (September 2021 to September 2023) that detailed Boeing's nonconformances with AS9100D found during quality control surveillance and the performance of government-mandated inspections.<sup>24</sup> During this period, DCMA reported Boeing was issued 71 Level I and Level II CARs, of which 24 were the more serious Level II CARs. According to DCMA officials, this is a high number of CARs for a space flight system at this stage in development. For example, in September 2021, a Level II CAR noted that foreign object debris was identified inside the SLS Core Stage 2 liquid hydrogen fuel tank.<sup>25</sup> DCMA found contamination of metal shavings, Teflon, and other debris on and underneath the entry platform and ladder assembly on the forward dome panels inside of the tank. Foreign object debris can damage hardware and potentially injure flight crew when entrapped within crewed flight articles. DCMA concluded that Boeing's foreign object debris clean-as-you-go policy did not comply with AS9100D, Section 8.5.1, "the provision for the prevention, detection, and removal of foreign objects."<sup>26</sup> The liquid hydrogen fuel tank was subsequently cleaned, reinspected, and found to meet standards.

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<sup>24</sup> Government mandatory inspection points are points in the workflow at which the government executes a quality assurance surveillance activity that must be completed before continuing the production flow. The surveillance activity can include an engineering documentation review, a product inspection, a process witness, or review of verification data.

<sup>25</sup> Foreign object debris is a substance, debris, or article alien to the hardware that would potentially cause damage. Examples include metal shavings, wire clippings, construction debris, dropped tools or fasteners, oil drips, and water spills. Flight piece parts can be debris if they are dropped or lost in flight hardware where they do not belong.

<sup>26</sup> Clean-as-you-go is an operations approach in which an area is cleaned after each planned operation and before the end of each work shift to remove unnecessary items and prevent damage from foreign object debris.

Furthermore, in May 2023, the NASA Stages Chief Safety Officer asked DCMA to draft a Level III CAR to consolidate the data from 20 stamp warranty Level I and II CARs issued to Boeing from January 2022 to April 2023, where the company's corrective actions were inadequate to prevent further recurrence. Stamp warranty is a critical process where a company inspector certifies that all work instructions have been complied with. For example, Boeing officials incorrectly approved hardware processing under unacceptable environmental conditions, accepted and presented damaged seals to NASA for inspection, and used outdated versions of work orders. DCMA also found that Boeing personnel made numerous administrative errors through changes to certified work order data without proper documentation and retention of historical information necessary to trace the changes. DCMA reported that it continued to issue multiple Level I and II CARs for stamp warranty issues over the 11-month period while the Level III CAR remained in a draft status.

NASA ultimately decided not to issue a Level III CAR. However, in an effort to correct the identified stamp warranty issues, NASA continues to use alternate corrective action methods including Monthly Management Reviews, Contractual Areas of Emphasis, a Technical Directive Letter, and feedback to the Performance Evaluation Board.<sup>27</sup> Nonetheless, according to both DCMA and NASA Safety and Mission Assurance officials, the unusually high number of stamp warranty CARs reflects the seriousness of the nonconformity, and changing certified work order data without retention of historical information could increase the risk to the flight vehicle. With the large number of nonconformances identified during the manufacturing process and Boeing's ineffective quality management system, we are concerned that critical nonconformities may not be identified and corrected.

As part of the Agency's ongoing efforts to streamline production for the Artemis campaign, starting with core stage production for Artemis III, NASA has moved assembly of the engine section's internal components from Michoud to Kennedy. This move, while strategically intended to improve assembly processes, introduces additional complexities and potential risks to the SLS production line according to DCMA officials at Michoud. For example, the production processes developed over the past 10 years at Michoud are being established at Kennedy, where Boeing has relocated some of its production workforce. In addition, NASA plans to delegate surveillance duties currently performed by DCMA to a contractor that provides inspections and surveillance for projects at this facility. While we appreciate the Agency's efforts to improve SLS assembly processes, these changes introduce uncertainties and potential inconsistencies into the oversight and quality control processes.

## **Boeing's Michoud Workforce Lacks Sufficient Aerospace Production Experience, Training, and Instruction**

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According to Safety and Mission Assurance officials at NASA and DCMA officials at Michoud, Boeing's quality control issues are largely caused by its workforce having insufficient aerospace production experience. Michoud officials stated that it has been difficult to attract and retain a contractor workforce with aerospace manufacturing experience in part due to Michoud's geographical location in New Orleans, Louisiana, and lower employee compensation relative to other aerospace competitors.

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<sup>27</sup> Monthly Management Reviews are meetings conducted by NASA management to assess the status of the SLS, identify challenges, and make informed decisions. Contractual Areas of Emphasis are critical provisions identified by NASA and its contractors, such as Boeing, that are essential for SLS success, encompassing quality control standards, safety protocols, technical specifications adherence, and delivery schedule compliance. Technical Directive Letters are issued to the contractor to furnish additional instruction. The Performance Evaluation Board works with the SLS Program to evaluate contractor performance and determine award fees.

Safety and Mission Assurance officials advised that Boeing provides training and work orders to its employees to mitigate the challenges associated with an inexperienced workforce and help ensure that its workers comply with quality control standards. However, given the significant quality control deficiencies discussed above and our observations during a site visit to Michoud, we found both these efforts to be inadequate.<sup>28</sup>

For example, during our visit to Michoud in April 2023, we observed quality control issues with the production of the SLS Core Stage 3 liquid oxygen fuel tank dome for Artemis III. Specifically, we saw that the dome was segregated and pending disposition due to welds that did not meet NASA specifications (see Figure 6). DCMA reported that Boeing wrote a nonconformance for the dome. The company is currently evaluating the dome to determine whether and how it can safely be used going forward. The liquid oxygen tank dome is a critical component of Core Stage 3, and according to NASA officials, the welding issues arose due to Boeing’s inexperienced technicians and inadequate work order planning and supervision.

**Figure 6: Improperly Welded Core Stage 3 Liquid Oxygen Tank Dome at the Michoud Assembly Facility (April 26, 2023)**



Source: Manufacturing Technical Solutions, Inc.

Boeing is working to establish a more robust hands-on training program, including model-based instructions and a mock-up of the EUS equipment shelf that houses avionics and flight computers. However, it is too early to determine if the new training alone will result in a notable decrease in

<sup>28</sup> According to AS9100D, Section 7.2, *Competence*, the organization shall (a) determine the necessary competence of person(s) doing work under its control that affects the performance and effectiveness of the quality management system; (b) ensure that these persons are competent on the basis of appropriate education, training, or experience; (c) where applicable, take actions to acquire the necessary competence and evaluate the effectiveness of the actions taken; and (d) retain appropriate documented information as evidence of competence.

nonconformances and CARs issued. According to a NASA official, further quality assurance challenges related to the workforce stem from work instructions that lack explicit details on how to perform the task and with what tools. Some technicians reported they had to hunt through layers of documentation to identify required instructions and documentation of work history and key decisions related to the hardware. Especially with inexperienced technicians, the challenge of finding and interpreting deficient work orders increases the risk of stamp warranty violations and quality control deficiencies.

The lack of a trained and qualified workforce increases the risk that the contractor will continue to manufacture parts and components that do not adhere to NASA requirements and industry standards. While NASA has processes in place to assess, document, and mitigate identified nonconformances to ensure that risks are well understood, communicated, and dispositioned, the rework of parts and components can contribute to increased costs and schedule delays for the SLS core and upper stages.<sup>29</sup> For example, Boeing's unsatisfactory welding operations at Michoud, a critical path item in EUS development, resulted in fuel tanks that did not meet the required specifications and caused a 7-month delay in EUS completion. Moreover, quality control deficiencies, if not identified and corrected, could increase safety risk to the integrated spacecraft.

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<sup>29</sup> We did not independently assess these processes as part of this review.

# SLS BLOCK 1B CONTINUES TO EXPERIENCE COST INCREASES AND SCHEDULE DELAYS

## Block 1B Cost Increases and Schedule Delays Driven by EUS Development

We project the SLS Program’s Block 1B development costs will reach approximately \$5.7 billion before the system is scheduled to launch in 2028. This is \$700 million more than the Block 1B cost and schedule baseline, or Agency Baseline Commitment (ABC), that NASA formally established in December 2023 at nearly \$5 billion. The EUS accounts for more than half of the cost of Block 1B development. We estimate EUS development costs will reach nearly \$2.8 billion through 2028, roughly three times the initially agreed-upon cost of \$962 million in 2017.

Given the workforce Boeing needs to complete remaining work on the EUS through its expected delivery to NASA in 2027 and the Agency’s subsequent integration and testing efforts leading up to a 2028 launch, we project Block 1B annual costs will remain at 2023 levels through at least 2026 before tapering off in the out years until the Stages contract closes out. NASA officials disagree with our analysis and expect a reduction in Boeing’s workforce will result in reduced labor costs—an outcome the Agency is still evaluating.<sup>30</sup> It is our view, as we previously reported, that development costs for large space flight programs increase rather than decrease once integration and testing occur and new problems are identified.<sup>31</sup> Regardless, NASA’s fiscal year 2024 SLS Program budget projections do not account for the additional funds needed for EUS development in fiscal years 2024 through 2027. Without additional funding, scheduled work will continue to be pushed into subsequent years as has been the case for the EUS over the last decade, leading to further cost increases and schedule delays. This has already contributed to \$200 million in cost overruns on Boeing’s Stages contract for the EUS for Artemis IV—with more expected.

Boeing’s delivery of the EUS to NASA has been postponed 6 years from an initial February 2021 date established in 2016 to April 2027 (see Figure 7). NASA is currently tracking EUS schedule risks and development challenges that could lead to further delays.<sup>32</sup> For example, as of October 2023, the EUS stage controller—command and control hardware and software needed for the EUS Green Run test—and avionics have potential risks which could extend the delivery up to an additional 14 months. Although development of Block 1B is not on the Artemis IV critical path, further delays in earlier Artemis

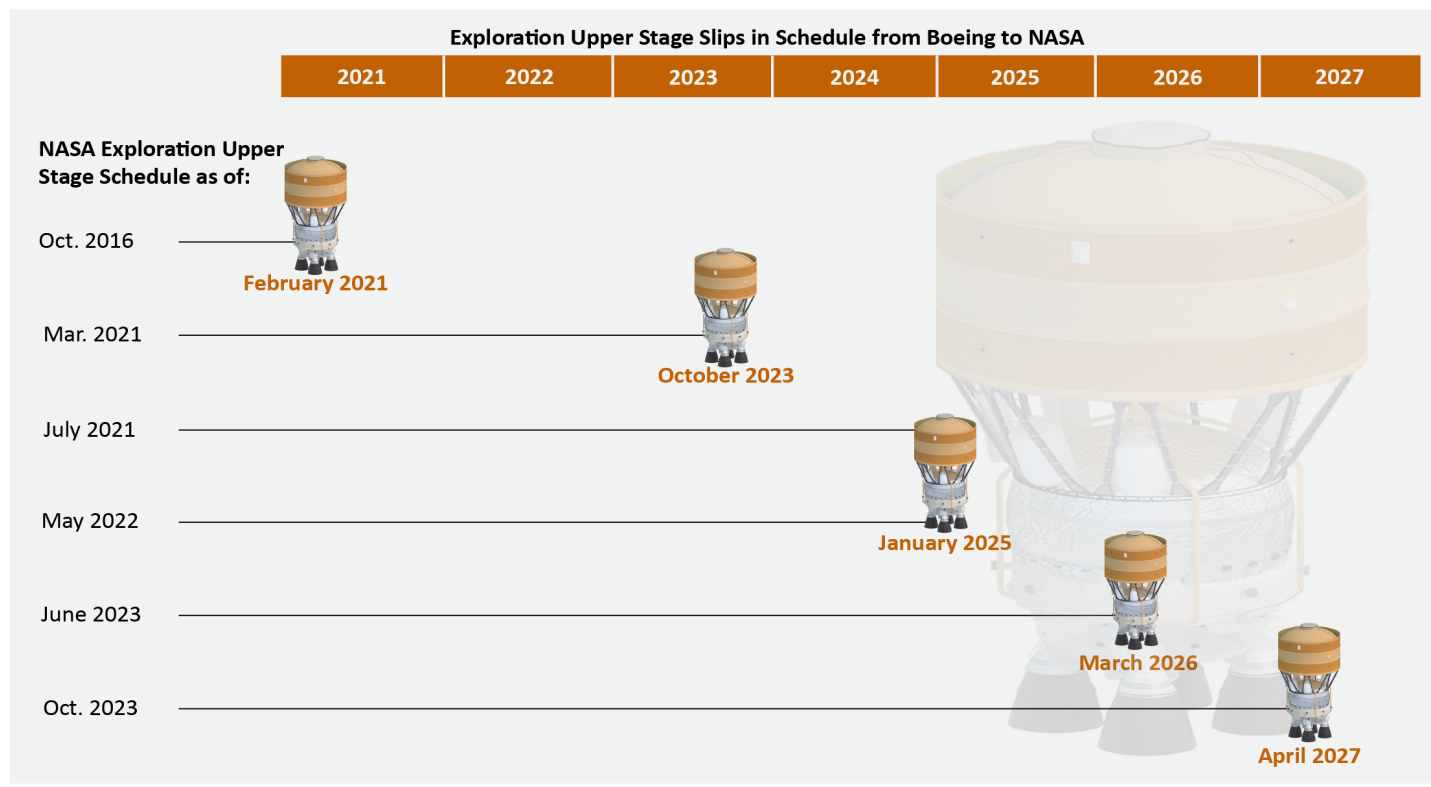
<sup>30</sup> We were not able to independently verify the Agency’s claims that Boeing plans to reduce its workforce.

<sup>31</sup> NASA Office of Inspector General (OIG), *NASA’s Management of the Space Launch System Stages Contract* ([IG-19-001](#), October 10, 2018).

<sup>32</sup> NASA originally planned to use off-the-shelf Interim Cryogenic Propulsion Stages for the first two Artemis missions; however, Congress directed the Agency to develop and utilize the EUS, initially planned for use on the SLS Block 1B, instead for Artemis II. For a period of time, the Agency focused on building the EUS to satisfy the direction of Congress, but in October 2018 NASA directed Boeing to shift resources from EUS production to complete the core stage for Artemis I after numerous delays and challenges, and the Agency shifted use of the EUS to Artemis IV.

missions combined with potential EUS delivery delays and pending development milestones suggest the Artemis IV launch, planned for September 2028, may be delayed as well.<sup>33</sup>

**Figure 7: Exploration Upper Stage Schedule Slips (as of December 2023)**



Source: NASA OIG presentation of Agency data.

## Multiple Factors Contribute to EUS Cost Increases and Schedule Delays

Development of the EUS for the SLS Block 1B has been marked by a host of interrelated challenges, which have led to significant cost increases and schedule delays:

- Redirection of EUS Funding to Core Stage Development.** During Artemis I production, Boeing’s contract funds for the core stage ran out before completion of the work because the company underestimated the complexity of the project. As a result, funding meant for the EUS was redirected to the core stage. This ultimately led to a nearly one-year delay in EUS work and an additional \$4 billion in funding to Boeing to cover the costs for the core stage development work.

<sup>33</sup> The critical path refers to the sequential path of tasks in a schedule that represents the longest overall duration from the present time through project completion. Any slippage of these tasks will increase the project’s duration. In the case of Artemis IV, completion of the Mobile Launcher 2—the ground structure that will be used to assemble, process, transport to the launch pad, and launch the SLS/Orion system—is the critical path with completion of the International Habitat as the secondary driver.

- **Changing Mission Dates.** The SLS Program has grappled with the effects of changing requirements from Congress as to which Artemis mission the Block 1B should first fly. This has resulted in a mission assignment shift from Artemis II to Artemis IV once Congress agreed with NASA's change to a later date. These changing mission dates posed costly challenges to the Program's development timeline, such as the reallocation of resources, increased impact of higher inflation rates, and contract revisions involving contractors and suppliers.
- **Maintaining EUS Workforce.** A significant factor contributing to the high costs of the Block 1B upgrade has been sustaining an EUS workforce over the past 10 years. The EUS workforce will have worked on the system for 14 years by the time of the projected first flight—an effort intended to be completed in 7 years. From February to August 2023, Boeing spent on average \$26 million a month on its EUS workforce, contractors, and related costs. We expect Boeing to continue this level of spending on workforce hours until it delivers the EUS to NASA in 2027 due to major outstanding schedule milestones such as software installation, liquid oxygen fuel tank installation, Forward Adapter integration and testing, and final integrated functional testing.
- **Boeing's Manufacturing Issues.** Multiple Boeing manufacturing issues necessitated costly and time-consuming rework of critical components. These issues span from production inefficiencies to workforce and quality control deficiencies discussed earlier in this report. As noted earlier, Boeing's unsatisfactory welding operations resulted in a 7-month delay in EUS completion.
- **Supply Chain Challenges.** A variety of supply chain issues related to component sourcing, material acquisition, and supplier management resulted in schedule setbacks and increased costs of materials and components.<sup>34</sup> According to NASA officials, many supply chain challenges were exacerbated by Boeing's late negotiations and contract agreements with its suppliers.

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<sup>34</sup> In 2023 we reported on challenges in NASA's management and visibility into its supply chain necessary to meet its Artemis goals. NASA OIG, *NASA's Management of the Artemis Supply Chain* ([IG-24-003](#), October 19, 2023).

# DELAYED COST AND SCHEDULE BASELINE COUPLED WITH BOEING'S INSUFFICIENT EVMS HINDERS BLOCK 1B ACCOUNTABILITY AND TRANSPARENCY

## NASA Spent More than \$3 Billion over 10 Years without a Cost and Schedule Baseline

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Despite spending over \$3 billion since 2014, NASA continued to develop the SLS Block 1B upgrade and its associated capabilities without a required ABC until December 2023.<sup>35</sup> According to the ABC, the capability upgrade will be ready by January 2028 at a cost of nearly \$5 billion. The ABC is a critical part of NASA's program and project management, serving as the cost and schedule baseline against which progress and performance are measured throughout the Implementation Phase and is the only official baseline sent to Congress and the Office of Management and Budget. Without this ABC, the ability to effectively monitor and manage the cost and schedule for the SLS Block 1B upgrade was significantly hindered.

NASA considers the Block 1B to be a capability upgrade from the first version of the SLS rather than a new single-project program or separate project. To date, the Block 1B has incurred costs of over \$3 billion, which exceeds NASA's threshold to be classified as a Category 1 project.<sup>36</sup> As such, it is subject to NPR 7120.5F requirements applicable to single-project programs and capability upgrades.<sup>37</sup> Specifically, capability upgrades that meet the criteria for a major project must adhere to the standard project life cycle and develop an ABC. Therefore, the Block 1B's ABC must be distinct from the SLS Program's overall Phase E (the operations and sustainment phase) cost estimate, reflecting its status and financial scope as a major project. NASA maintains that tracking costs on a mission-by-mission basis is not the only sufficient mechanism for ensuring accountability and transparency nor does the Agency believe that such mission-level commitments are required by NASA policy or law.

To NASA's credit, the SLS Program Plan did acknowledge that while the Exploration Upper Stage and Associated Capabilities is not a standalone project, a Joint Cost and Schedule Confidence Level (JCL)-based ABC must be developed to fund the design, development, testing, and evaluation of the Block 1

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<sup>35</sup> NPR 7120.5F.

<sup>36</sup> According to NPR 7120.5F, projects are classified as Category 1 if any of the following are applicable: a life-cycle cost of more than \$2 billion, the inclusion of significant radioactive material onboard the spacecraft and/or launch vehicle, or if the system being developed is for human space flight.

<sup>37</sup> According to NPR 7120.5F, upgrades that meet the criteria for a major project shall be treated as projects and produce an ABC that is different from the overall SLS Program's Phase E (operations and sustainment) cost estimate.



evolution to Block 1B.<sup>38</sup> NASA officials, however, deferred the establishment of an ABC for the SLS Block 1B until after its Critical Design Review (CDR)—the life-cycle review evaluating the design’s ability to meet mission requirements within defined program and project constraints, including available resources—in November 2022, citing difficulties in accurately predicting manufacturing costs. While this decision was based on lessons learned from cost estimation challenges with the SLS Block 1, it circumvents NASA’s project management policies designed to avoid excessive delays and budget overruns. Typically, the baseline is established *before* conducting the CDR. As such, the absence of established cost and schedule baselines raises questions about whether the Agency had all the key information needed to properly conduct the CDR.

To this point, an Independent Review Team (IRT) raised concerns about the Agency’s readiness for the CDR. Specifically, the team found deficiencies with the Block 1B upgrade during its assessment in the lead-up to and at the November 2022 CDR Board review. The IRT identified shortcomings in six of nine critical criteria for a successful CDR, highlighting issues such as inadequate risk margins and the lack of a comprehensive testing approach. The IRT also made several requests for action to the SLS Program to address these issues. The IRT did not, however, assess cost and schedule criteria related to the JCL during this time due to receiving data later than expected.

A final IRT evaluation in May 2023 concluded that while the SLS Program made significant progress on addressing CDR requirements, and sufficient plans were in place to close the remaining requests for action, the SLS Block 1B upgrade still lacked flight software and JCL-based cost and schedule metrics. Nevertheless, the Agency proceeded with the CDR closeout in May 2023. Five months later, a post-CDR assessment by the IRT found the JCL model was sufficiently mature to establish the ABC, and in November 2023, the Agency held a separate CDR for Block 1B flight software.

In December 2023, the SLS Program completed its Block 1B ABC after 10 years of development with no baseline and much later in the project life cycle than NASA’s standard practice. Without a formal cost and schedule baseline at critical junctures, such as before the CDR, the Agency was limited in its ability to assess adherence to budgets and timelines and stakeholders lacked visibility into the Block 1B’s estimated cost and schedule.

## **Boeing Defense EVMS Has Been Disapproved since 2020**

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Using a certified Earned Value Management System (EVMS) is a critical part of program and project management, serving as a key tool to measure cost and schedule progress, and is required on all NASA projects with a life-cycle cost greater than \$250 million.<sup>39</sup> However, we found that Boeing Defense, Space & Security (Boeing Defense)—the division of Boeing responsible for defense and aerospace contracts—has struggled for years with its EVMS, which has been in a disapproved status by the U.S. Department of Defense (DOD) since 2020. Multiple agencies that use Boeing Defense’s EVMS are impacted by DOD’s disapproved status including NASA and its Stages contract.

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<sup>38</sup> The SLS Program Plan is the controlling document defining the programmatic and management processes of the SLS Program and is considered a live document—able to be updated, as necessary, when funding or other significant changes impact the plan’s content. The Exploration Upper Stage and Associated Capabilities include the EUS and its four RL10 engines, the Universal Stage Adapter, the Payload Adapter, and other engineering, integration, and management tasks.

<sup>39</sup> NPR 7120.5F.

For a DOD contractor's EVMS to be disapproved, a DOD contracting officer must determine the existing EVMS has one or more significant deficiencies as defined in Electronic Industries Alliance Standard 748. The DOD contracting officer may then use discretion to disapprove the EVMS and withhold payments. DCMA has issued several Level II and III CARs related to material deficiencies in Boeing Defense's EVMS, including deficiencies in identifying management reserves, maintaining estimates at completion, and maintaining the baseline. In particular, DCMA issued a Level III CAR to Boeing Defense in late 2020, notifying them of several material deficiencies in their EVMS—which impacted NASA's Stages contract with Boeing—including visibility into cost, schedule, and resource needs for the contract's remaining work. DCMA requested Boeing Defense correct the significant deficiencies or provide a corrective action plan. DCMA also withheld requests for payment on a small percentage of the affected DOD contracts until Boeing implemented an effective plan.

While Boeing has begun implementing corrective actions to address its EVMS deficiencies impacting the SLS Program, there remains one active Level III EVMS CAR and one Level II EVMS CAR, both undergoing the verification and validation process that is not expected to be complete until late 2024. Until then, Boeing's EVMS cannot produce meaningful data that can be used to make informed decisions and produce credible forecasts. According to NASA contracting officials, Boeing cannot produce a realistic baseline delivery date for the EUS due to continuing deficiencies in its EVMS. In August 2023, NASA sent Boeing a letter noting that performance concerns observed during core stage development have continued during work on the EUS and offered corrective solutions such as optimizing manufacturing techniques and increasing labor efficiencies. As of March 2024, Boeing had not responded to this letter. NASA officials are also engaging with other users of Boeing Defense's EVMS and reviewing options to better evaluate the company's performance.

# CONCLUSION

The Block 1B version of the SLS provides a 40 percent upgrade in the amount of cargo that can be transported to the Moon using NASA's heavy-lift rocket. This upgraded capability is needed to achieve NASA's Artemis goals, with the Block 1B's first mission transporting both the International Habitat and astronauts to the Moon during Artemis IV. Despite progress to date, expected delivery of the EUS has slipped 6 years as cost and schedule rebaselines for the contract were ongoing, and original contract costs more than doubled to over \$2 billion. As the result of multiple production issues, we expect costs for the Block 1B to increase significantly, reaching approximately \$5.7 billion by 2028. Further, given the workforce needed to complete remaining work on the EUS and subsequent integration and testing efforts leading up to a 2028 launch, we project that annual costs will remain higher than NASA has currently budgeted, likely leading to further delays.

Given the importance of the SLS Block 1B to NASA's future Artemis crewed missions, it is critical that the Agency effectively manage this development effort. However, we found an array of issues that could hinder SLS Block 1B's readiness for Artemis IV including Boeing's inadequate quality management system, escalating costs and schedules, and inadequate visibility into the Block 1B's projected costs. For example, we found that Boeing's quality management system does not meet industry standards in core stage production at Michoud. Given Boeing's quality management and its related workforce challenges, we are concerned these factors could potentially impact the safety of the SLS and Orion spacecraft including its crew and cargo.

In December 2023, the SLS Program completed its Block 1B ABC after 10 years of development with no baseline and much later in the project life cycle than NASA's standard practice. The absence of a formal cost and schedule baseline at critical junctures, such as before the CDR, contributed to a lack of visibility and challenges in the Agency's ability to assess progress and adherence to cost and timelines. As we have repeatedly reported, it is critical that NASA establish timely, credible, complete, and transparent cost and schedule estimates from which it can measure success and be accountable to Congress and other stakeholders. In the end, failure to address these issues may not only hinder the Block 1B's readiness for Artemis IV but also have a cascading impact on the overall sustainability of the Artemis campaign and NASA's deep space human exploration efforts.

# RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To improve the safety and sustainability of the SLS Program, we recommended the Associate Administrator for Exploration Systems Development Mission Directorate in conjunction with the Assistant Administrator for Procurement and the Chief, Safety and Mission Assurance:

1. Coordinate with Boeing, the SLS Stages prime contractor, to develop a quality management system training program that is compliant with AS9100D and reviewed by the appropriate NASA officials.
2. Institute financial penalties for Boeing's noncompliance with quality control standards.

To minimize the impact on the Artemis campaign's timeline and achieve sustainability, we recommended the Associate Administrator for Exploration Systems Development Mission Directorate:

3. Perform a detailed cost overrun analysis on Boeing's Stages contract for EUS development.

To provide greater visibility into cost and schedule estimates for SLS upgrades, we recommended the Associate Administrator for Exploration Systems Development Mission Directorate:

4. Coordinate with DCMA to ensure contractual compliance with EVMS clauses.

We provided a draft of this report to NASA management who concurred with three of the four recommendations and described planned actions to address them. We consider the proposed actions responsive to Recommendations 1, 3, and 4 and will close them upon completion and verification.

The Agency non-concurred with Recommendation 2, and we find its proposed actions unresponsive. Consequently, this recommendation will remain unresolved pending further discussions with the Agency. Recommendation 2 addresses the need to institute financial penalties for Boeing's noncompliance with quality control standards. In its response, NASA stated that the OIG's recommendation falls "outside the bounds of the contract." The Agency further noted that it already has the authority to enforce quality control standards through existing contractual vehicles. We agree that these contractual mechanisms may be a sufficient means for imposing financial penalties. Our recommendation was written to allow the Agency latitude to use the most appropriate mechanisms practicable to impose financial penalties on Boeing for not complying with required quality control standards.

Management's comments are reproduced in Appendix B. Technical comments provided by management and revisions to address them have been incorporated as appropriate.

Major contributors to this report include Ridge Bowman, Human Exploration Audits Director; Kevin Fagedes, Assistant Director; Deanna Lee, Assistant Director; Moriah Lee; Tyler Mitchell; Rachel Pierre; Robert Rose; Michele Schaeffer; and Lauren Suls.

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](mailto:laurence.b.hawkins@nasa.gov).

George A. Scott  
Deputy Inspector General

## APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from August 2023 through May 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

This report is the second in a series of audits examining NASA's development of space flight systems for its Artemis IV and future missions. In this report we evaluated NASA's development cost, schedule, and performance of the SLS Block 1B, with a particular focus on the EUS. Our review included interviews with officials at NASA Headquarters, Marshall Space Flight Center, Boeing, and DCMA. As part of our work published in the Office of Inspector General's October 2023 report on the Exploration Production and Operations Contract, we visited the Michoud Assembly Facility in New Orleans, Louisiana, to observe SLS core stage and EUS production and incorporated the information we learned into this report as appropriate.<sup>40</sup>

To assess Boeing's cost and schedule performance for developing the Block 1B core stage and EUS, we reviewed SLS Program, NASA Office of the Chief Financial Officer, and contractor cost and budget documentation. We also reviewed past and current budget planning documents from the SLS Stages Element Office and SLS Program. Additionally, we reviewed Boeing's financial management reports and EVMS cost estimates. We analyzed the Stages Element Office and Boeing Stages contract obligations and disbursements through NASA's financial accounting system. We also examined NASA's program management policies and internal and external EVMS requirements. To determine the status of Boeing's Stages contract, we interviewed NASA contracting officers from the Marshall Office of Procurement; officials from the SLS Program, Planning, and Control Office; and managers from the Stages Element Office. To establish baseline costs for each SLS element, we examined the contract files for the major SLS contracts—Stages, Stages Production and Evolution Contract, Boosters Production and Operations Contract, RS-25 Restart and Production, RL10 Engines, and Universal Stage Adapter.

Additionally, we reviewed past and current schedules to assess whether Boeing was meeting its schedule milestones and goals. Specifically, we reviewed contract milestones, past and current Integrated Master Schedules, and quarterly program status reviews. We also interviewed Boeing and NASA Technical Management Personnel at Michoud to gain their perspective on whether they will be able to meet current schedule milestones for the Block 1B.

Due to several nonconformances in current SLS Block 1B production, we reviewed quality control documents for SLS core and upper stage production and interviewed DCMA and NASA Safety and Mission Assurance representatives. We also interviewed NASA personnel from the Exploration Systems Development Mission Directorate, Office of the Chief Engineer, and Office of Procurement to understand the quality, costs, development issues, and contractual options for applying financial penalties resulting from quality and performance issues related to core and upper stage production.

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<sup>40</sup> NASA OIG, *NASA's Transition of the Space Launch System to a Commercial Services Contract* ([IG-24-001](#), October 12, 2023).

## Assessment of Data Reliability

We used computer-processed data to perform this audit, and that data was used to support our findings, conclusions, and recommendations materially. We reviewed and analyzed NASA cost data for fiscal years 2007 through 2023 in NASA’s financial accounting system for the entire SLS Program, each SLS Element Office, and each contract—Stages, Stages Production and Evolution Contract, Boosters Production and Operations Contract, RS-25 Restart and Production, RL10 Engines, and Universal Stage Adapter. The data derived from the financial accounting system was previously tested and found to be reliable. We also compared our results with data provided by the SLS Program in the form of briefing charts and Excel spreadsheets, and to monthly and quarterly contractor financial management reports for each contract. No discrepancies were noted. We determined the data was sufficiently reliable and could be used to support our audit objectives.

Additionally, DCMA provided information from the CAR module of its Product Data Reporting and Evaluation Program—Automated Information System. We reviewed the details of DCMA’s CAR reports and compared them to documentation confirming the number of records and content of selected records in the CAR reports. No discrepancies were noted. We determined the data was sufficiently reliable for the purpose of quantifying and describing quality management issues within the SLS Block 1B manufacturing process.

## Review of Internal Controls

We evaluated the internal controls associated with NASA’s management of SLS Block 1B development, specifically their cost, schedule, and performance during production at Michoud, as well as the evaluation of program controls. In addition, we reviewed program documents designed to manage cost, schedule, and performance for the production of the core stage, EUS, boosters, RS-25 and RL10 engines, and Universal Stage Adapter. The control weaknesses we found were identified and discussed in this report. Our recommendations, if implemented, will improve the identified control weaknesses. However, because our review was limited to these internal control components and underlying principles, it may not have disclosed all internal control deficiencies that may have existed at the time of this audit.

## Prior Coverage

During the last 5 years, the NASA Office of Inspector General and Government Accountability Office have issued 22 reports of significant relevance to the subject of this report. Reports can be accessed at <https://oig.nasa.gov/audits/> and <https://www.gao.gov>, respectively.

### ***NASA Office of Inspector General***

*Key Challenges Facing NASA’s Artemis Campaign* ([Testimony-2024](#), January 17, 2024)

*NASA’s Management of the Artemis Supply Chain* ([IG-24-003](#), October 19, 2023)

*NASA’s Transition of the Space Launch System to a Commercial Services Contract* ([IG-24-001](#), October 12, 2023)

*NASA’s Management of the Space Launch System Booster and Engine Contracts* ([IG-23-015](#), May 25, 2023)

*2022 Report on NASA's Top Management and Performance Challenges* ([MC-2022](#), November 2022)

*NASA's Management of the Mobile Launcher 2 Contract* ([IG-22-012](#), June 9, 2022)

*NASA's Cost Estimating and Reporting Practices for Multi-Mission Programs* ([IG-22-011](#), April 7, 2022)

*NASA's Management of the Artemis Missions* ([IG-22-003](#), November 15, 2021)

*Artemis Status Update* ([IG-21-018](#), April 19, 2021)

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

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

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

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

### **Government Accountability Office**

*NASA Artemis Programs: Lunar Landing Plans Are Progressing, but Challenges Remain* ([GAO-24-107249](#), January 17, 2024)

*Space Launch System: Cost Transparency Needed to Monitor Program Affordability* ([GAO-23-105609](#), September 7, 2023)

*NASA: Assessments of Major Projects* ([GAO-23-106021](#), May 31, 2023)

*NASA Lunar Programs: Improved Mission Guidance Needed as Artemis Complexity Grows* ([GAO-22-105323](#), September 8, 2022)

*NASA: Lessons from Ongoing Major Projects Could Improve Future Outcomes* ([GAO-22-105709](#), February 9, 2022)

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

*High-Risk Series: Dedicated Leadership Needed to Address Limited Progress in Most High-Risk Areas* ([GAO-21-119SP](#), March 2, 2021)

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

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



# APPENDIX B: MANAGEMENT'S COMMENTS

National Aeronautics and Space Administration

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



Reply to Attn of: Exploration Systems Development Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Exploration Systems Development Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of Space Launch System Block 1B Development" (A-23-08-01-HED)

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 Block 1B Development" (A-23-08-01-HED), dated June 24, 2024.

With the first crewed Artemis mission in lunar orbit clearly on the horizon, NASA programs in the Exploration Systems Development Mission Directorate (ESDMD) are tasked with one of humanity's most challenging and unique endeavors: to send human explorers into deep space as a means of enabling discovery, scientific progress, and inspiration. The mandate to do so is not one taken lightly by the Agency. The Space Launch System (SLS) Program, responsible for the development of the launch vehicles that will ultimately enable the return of astronauts to the lunar surface, is structured and managed to ensure these responsibilities are met and goals fulfilled.

ESDMD acknowledges the crucial role played by the OIG in assessing instances of waste, fraud, or abuse within the Federal Government. ESDMD is dedicated to transparency and accountability. The Agency's goal is to fully cooperate with the OIG, providing access to all relevant information and documentation necessary for their audits, evaluations, and investigations. As OIG notes in Appendix A of the report, ESDMD has been audited 22 times in the past five years regarding this subject matter. During this specific audit, ESDMD provided 366 products, attended 7 requested meetings, and participated in 17 hours of interviews. Altogether, this activity incurred an estimated 140 hours of work by our ESDMD team. This commitment to transparency underscores our dedication to upholding the highest standards of integrity and ethics in all aspects of our work.

In this draft report, the OIG examined NASA's management of the SLS Block 1B development, focusing on the Exploration Upper Stage (EUS). The OIG found that The Boeing Company's (Boeing) quality management system at NASA's Michoud Assembly Facility (Michoud) does not adhere to SAE International's AS9100D standards on quality

management systems or the Agency's requirements. The OIG also reported on SLS Block 1B's cost increases and schedule delays.

Specifically, the OIG states that it found an array of issues that could hinder SLS Block 1B's readiness for Artemis IV including potential safety risks, escalating costs and schedules, and inadequate visibility into the Block 1B's projected costs, resulting in costs for Block 1B to increase significantly and reach approximately \$5.7 billion by 2028. Additionally, the OIG states its view that Boeing's quality management system does not meet industry standards in core stage productions at Michoud. The OIG also states its view that the absence of a formal cost and schedule baseline contributed to a lack of transparency and challenges in NASA's ability to assess progress and adherence to cost and timelines.

The OIG states it is concerned that, with the large number of nonconformances identified during the manufacturing process at Michoud and Boeing's ineffective quality management system, critical nonconformities may not be identified and corrected. OIG notes concern specifically with the quality control deficiencies and asserts that this could "increase safety risk to the integrated spacecraft." While it is recognized that the contractor has encountered quality issues, it is important to avoid making assumptions that this will result in substandard parts being used in the spacecraft. NASA maintains specific processes to ensure quality issues are not flowed to flight hardware. NASA closely monitors its contractors through a variety of mechanisms to ensure they meet the Agency's standards and requirements. This includes regular reviews of contractor performance, financial audits, and quality inspections of hardware, facilities, and processes.

NASA is dedicated to ensuring that its workforce and associated contractors are qualified and properly trained to ensure the safety of its missions. This includes employing project managers and technical experts who work closely with contractors to provide guidance and ensure compliance with contractual obligations. NASA holds all its programs to the highest technical and programmatic standard levied on the spaceflight community, and ESDMD bears the responsibility of equipping Artemis astronauts with safe, reliable hardware to enable the most ambitious of engineering and scientific goals.

The aerospace industry is facing significant supply chain disruptions, similar to, and in some cases in a more acute scale, to the broader economic supply chain issues. These disruptions have been exacerbated by various factors, including labor shortages, transportation delays, and raw material shortages. These disruptions have had a profound impact on the aerospace industry, leading to production delays, increased costs, and challenges in meeting customer demand. ESDMD's buying power is decreasing each year and escalating. These unforeseen challenges, including technical issues, are all contributing factors to cost and schedule impacts. NASA is working to adapt through proactive management strategies and understanding the interconnected factors shaping the aerospace market's dynamics.

NASA continues to recognize OIG's critical role in promoting Artemis accountability and transparency. NASA is committed to meeting the Agency Baseline Commitment (ABC). The delay in the ABC reflects NASA's commitment to thorough planning, risk management, and stakeholder engagement to maximize the likelihood of mission success. By taking the

time to address technical, budgetary, and stakeholder considerations, NASA aims to ensure that its projects are well-positioned for success and deliver value to the Nation and the world.

NASA uses an array of tools to track quality, progress, and performance against cost and schedule targets, which include, but are not limited to, Government mandatory inspection points, project-level cost and schedule joint confidence level informed commitments (including for major developmental upgrades), independent reviews at major life-cycle reviews and associated key decision points, documented and configuration-controlled mission definition baselines, risk assessments, independent Agency financial auditing (including a thirteenth consecutive unmodified or “clean” audit opinion in 2023), and Agency-led baseline performance and major program reviews. There are also independent reviews by the NASA Advisory Council, Aerospace Safety Advisory Panel, and various other ongoing reviews from Governmental oversight entities. This rigorous monitoring helps NASA maintain accountability and quality in its programs and projects.

NASA’s commitment to Artemis IV and beyond is underscored by its dedication to exploration, innovation, collaboration, and public engagement. By building on the achievements of previous lunar missions and leveraging cutting-edge technologies and partnerships, NASA aims to establish a sustainable human presence on the Moon and propel humanity toward new frontiers of space exploration.

The OIG makes four recommendations addressed to the Associate Administrator (AA) for ESDMD.

Specifically, the OIG recommends the AA for ESDMD, in conjunction with the Assistant Administrator for Procurement and the Chief, Safety and Mission Assurance:

**Recommendation 1:** Coordinate with Boeing, the SLS Stages prime contractor, to develop a quality management system training program that is compliant with AS9100D and reviewed by the appropriate NASA officials.

**Management’s Response:** NASA concurs. The SLS Stages contract contains the requirements associated with quality management systems compliant with AS9100D in EUS Statement of Work paragraph 5. The SLS Program, in consultation with the Office of Safety and Mission Assurance, will enforce the contract requirements as well as work with Boeing and Michoud, to confirm that Boeing implements a quality management system training program that is compliant with AS9100D for the development of SLS.

**Estimated Completion Date:** July 31, 2025.

**Recommendation 2:** Institute financial penalties for Boeing’s noncompliance with quality control standards.

**Management’s Response:** NASA non-concurs. NASA interprets this recommendation to be directing NASA to institute penalties outside the bounds of the contract. There are already authorities in the contract, such as award fee provisions, which enable financial ramifications for noncompliance with quality control standards. Further, quality issues

and noncompliances are documented in the Contractor Performance Assessment Reporting System. For anything beyond this, OIG's broad recommendation appears inconsistent with NASA Procedural Requirements 8735.2C, Hardware Quality Assurance Program Requirements for Programs and Projects, the Federal Acquisition Regulation (FAR) subparts 46.1 – 46.8, and the NASA FAR Supplement (NFS), which all specify processes for addressing any nonconformances with quality control standards. Instituting financial penalties outside the bounds of the contract subverts the control process of the contract.

NASA considers noncompliance with quality control standards as a part of its award fee evaluation process, consistent with contract terms and applicable laws. The Agency's Office of Procurement, Office of the General Counsel, Chief Program Management Officer, the Office of the Chief Financial Officer, and Mission Directorate representatives continue to explore and evaluate options for addressing quality control nonconformances, in a manner consistent with existing NASA policies and applicable laws.

**Estimated Completion Date:** N/A

In addition, the OIG recommends the AA for ESDMD:

**Recommendation 3:** Perform a detailed cost overrun analysis on Boeing's Stages contract for EUS development.

**Management's Response:** NASA concurs. The contract's Limitation of Funds clause requires notification when the contractor believes it will be in a cost overrun position. The SLS Program evaluates the prime contractor's performance continuously and prepares independent assessments of the contractor's schedule, cost, risk, and technical progress. On a quarterly basis, the SLS Program evaluates the estimate to complete.

**Estimated Completion Date:** December 31, 2024.

**Recommendation 4:** Coordinate with the Defense Contract Management Agency (DCMA) to ensure contractual compliance with Earned Value Management System (EVMS) clauses.

**Management's Response:** NASA concurs. The SLS Program maintains robust relations with DCMA, engaging in regular meetings to thoroughly review and discuss contract status and performance. The contract clause NFS 1852.234-2 states that NASA will ensure that the requirements are enforced. Although Boeing's EVMS is disapproved by DCMA, NASA will continue to ensure compliance with the terms and conditions of the contract.

SLS commits to conducting monthly reviews with DCMA representatives to rigorously ensure that all proposed corrective action plans are implementable and there are no additional costs to the SLS Program. It is worth noting that the Boeing EVMS compliance is an issue extant throughout numerous Government contracts and crossing several Government agencies. NASA will work the Boeing EVMS issues to the extent that they apply to the Agency-specific contracts.

**Estimated Completion Date:** October 31, 2024.

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 communicated such to the OIG.

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 Christine Solga at (202) 358-1238.

**CATHERINE** Digitally signed by  
**KOERNER** CATHERINE KOERNER  
Date: 2024.07.24  
15:14:27 -05'00'

Catherine A. Koerner

cc:

Chief, Safety and Mission Assurance/Mr. Deloach  
Assistant Administrator for Procurement/Ms. Smith Jackson

# APPENDIX C: REPORT DISTRIBUTION

## National Aeronautics and Space Administration

Administrator  
 Deputy Administrator  
 Associate Administrator  
 Chief of Staff  
 Associate Administrator for Exploration Systems Development Mission Directorate  
 Assistant Administrator for Procurement  
 Chief, Safety and Mission Assurance  
 Moon to Mars Program Manager  
 Space Launch System Program Manager

## Non-NASA Organizations and Individuals

Office of Management and Budget  
     Deputy Associate Director, Climate, Energy, Environment, and Science Division  
 Government Accountability Office  
     Director, Contracting and National Security Acquisitions  
 The Boeing Company

## Congressional Committees and Subcommittees, Chair and Ranking Member

Senate Committee on Appropriations  
     Subcommittee on Commerce, Justice, Science, and Related Agencies  
 Senate Committee on Commerce, Science, and Transportation  
     Subcommittee on Space and Science  
 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 Accountability  
     Subcommittee on Government Operations and the Federal Workforce  
 House Committee on Science, Space, and Technology  
     Subcommittee on Investigations and Oversight  
     Subcommittee on Space and Aeronautics

**(Assignment No. A-23-08-01-HED)**