United States Government Accountability Office

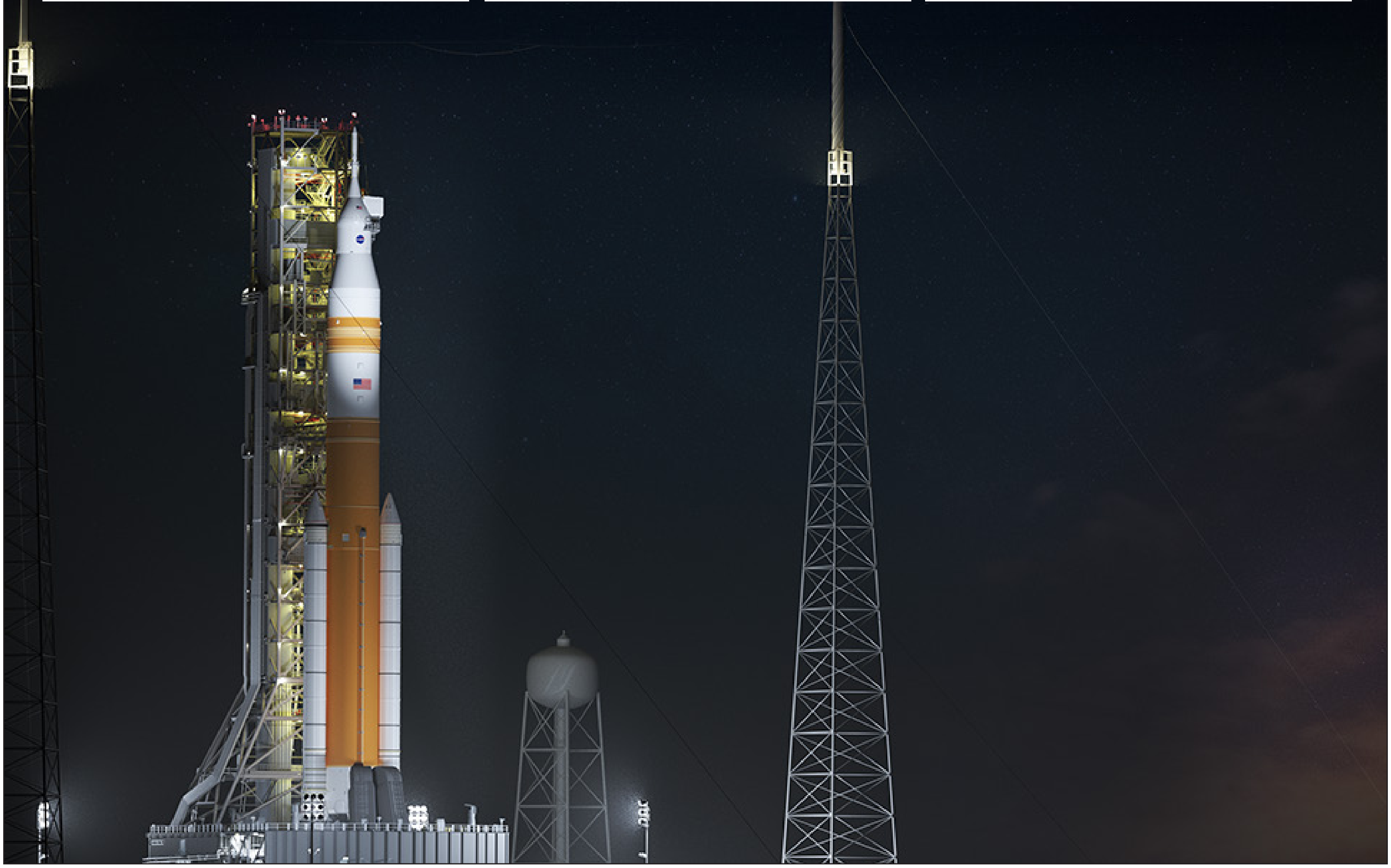
Report to Congressional Committees

June 2024

NASA

Assessments of Major Projects

LUNAR EXPLORATION **ASTROPHYSICS** **PLANETARY SCIENCE** **AERONAUTICS**



GAO-24-106767

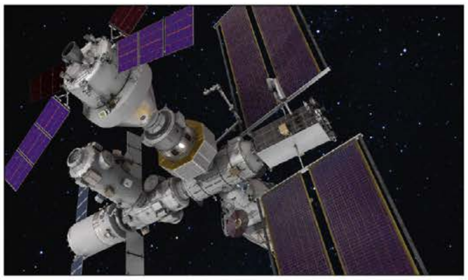
June 2024

NASA

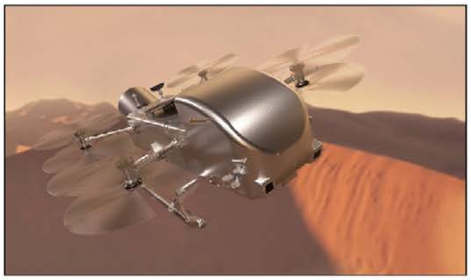
Assessments of Major Projects

GAO
Highlights

Highlights of GAO-24-106767, a report to congressional committees


Gateway – Lunar outpost


Low Boom Flight Demonstrator


Dragonfly – Planetary explorer

Source: NASA, Lockheed Martin, Johns Hopkins University Applied Physics Laboratory. | GAO-24-106767

Why GAO Did This Study

NASA plans to invest more than $81 billion in its portfolio of major projects (i.e., projects over $250 million). A House explanatory statement includes a provision for GAO to prepare status reports on NASA's major projects. This is GAO's 16th annual assessment.

This report describes GAO's assessment of the cost and schedule performance of NASA's major projects, and NASA's assessment of the projects' technology development. GAO also assessed the status of each major project.

GAO collected and analyzed data; reviewed project status reports; and interviewed officials. GAO reviewed projects in the formulation phase (which takes a project through its preliminary design), and those in the development phase (which includes building and launching the system).

What GAO Recommends

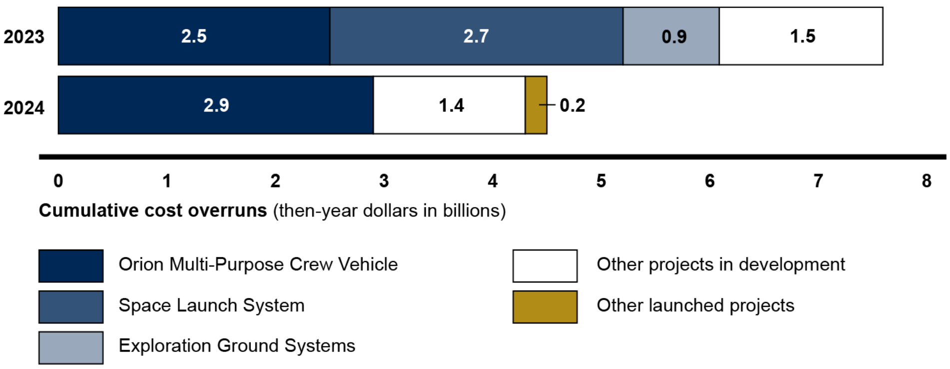
In prior work, GAO made multiple recommendations to improve NASA's management of these projects, and NASA has generally agreed with them. As of April 2024, NASA had not yet fully implemented 39 GAO recommendations, including eight that GAO identified as high priority.

View GAO-24-106767. For more information, contact W. William Russell at (202) 512-4841 or russellw@gao.gov.

What GAO Found

Since 2023, NASA's cumulative cost and schedule performance has improved. Cost overruns decreased from $7.6 billion in 2023 to $4.4 billion in 2024. Schedule overruns decreased from a total of 20.9 years in 2023 to 14.5 years in 2024. These decreases are primarily because two projects, the Space Launch System and Exploration Ground Systems, demonstrated their initial capability and left the portfolio. Previously, these projects accounted for $3.6 billion in cost overruns and each experienced delays of 4 years.

NASA's Cumulative Development Cost Overruns by Project, 2023-2024



Source: GAO analysis of NASA data. | GAO-24-106767

Note: Due to rounding, the numbers in the figure do not sum to the total cumulative cost overruns of $4.4 billion for 2024.

Category 1 projects—NASA's highest priority and most costly—continue to drive NASA's cumulative cost performance. While the departure of the Space Launch System and Exploration Ground Systems from the portfolio improved cumulative performance, the remaining category 1 projects accounted for 81 percent of the portfolio's total cumulative baseline overrun in 2024. One of these category 1 projects, the Orion Multi-Purpose Crew Vehicle (Orion), accounted for 65 percent ($2.9 billion) of the portfolio's total cumulative baseline cost overrun.

NASA's Artemis-related category 1 projects are positioned to shape the agency's cumulative cost performance in the coming years. The Artemis enterprise aims to return U.S. astronauts to the surface of the moon, establish a sustained lunar presence, and ultimately achieve human exploration of Mars. Currently, eight of the 14 category 1 major projects are Artemis-related. In December 2023, NASA set development cost baselines—estimates against which performance on a project is measured—totaling $9.6 billion for three Artemis projects: the Space Launch System Block 1B, Gateway Initial Capability, and Human Landing System Initial Capability. These three projects and Orion, which also supports the Artemis missions, now account for nearly 60 percent, or $19.2 billion, of the portfolio's $32.1 billion development costs. Because these projects' development cost baselines are so large, any overruns could have cascading effects on NASA's broader portfolio of major projects.

Regardless of their category, most of the projects in development did not experience annual cost growth or schedule delays since 2023. Specifically, 11 out of the 16 major projects in development did not experience cost growth in 2024, and 13 out of the 16 reported no schedule delays this year. Below are the five projects that experienced cost growth totaling $477 million since 2023.

Annual Development Cost Growth for Major NASA Projects since GAO's 2023 Assessment

Legend:
LBFD: Low Boom Flight Demonstrator
Orion: Orion Multi-Purpose Crew Vehicle
SEP: Solar Electric Propulsion
SPHEREx: Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer
VIPER: Volatiles Investigating Polar Exploration Rover

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data are as of January 2024. This figure reflects cost increases against what was reported in GAO's May 2023 annual assessment of major projects. This figure does not include projects that reported cost underruns since GAO's last report.

[a]The cost estimates for the Orion and VIPER projects are under review.

NASA has taken steps to improve the performance of its major projects, including those supporting the Artemis missions. In 2023, in response to statute, NASA established the Moon to Mars program office to manage the Artemis programs. It also completed several initiatives to strengthen its cost and schedule estimating capacity. NASA officials reported that they have also established a Chief Program Management Officer who works to strengthen NASA's program and project management policies and best practices in support of increasing performance and enabling long-term mission success for NASA.

GAO previously made recommendations to help NASA demonstrate progress in improving portfolio performance, including for those major projects supporting the Artemis missions. GAO will continue to monitor NASA's efforts in this area.

In addition to its efforts to improve portfolio performance, NASA has also taken steps to mature its critical technologies in its major projects. Of the 11 projects that reported critical technologies in 2024, the projects assessed that nine matured their technologies to technology readiness level 6 by their preliminary design review. Achieving this level involves demonstrating a representative prototype of the technology in a relevant environment. GAO's past work shows that maturing technologies prior to product development can help reduce technology-related cost increases and schedule delays.

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Abbreviations

AEPS	Advanced Electric Propulsion System
AOS	Atmosphere Observing System
APL	Applied Physics Laboratory
ATLO	assembly, test, and launch operations
CCP	Commercial Crew Program
CCRS	Capture, Containment, and Return System
CDR	critical design review
CGI	Coronograph Instrument
CLPS	Commercial Lunar Payload Services
COSI	Compton Spectrometer and Imager
CoDICE	Compact Dual Ion Composition Experiment
DARPA	Defense Advanced Research Projects Agency
DAVINCI	Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging
DRACO	Demonstration Rocket for Agile Cislunar Operations
DSL	Deep Space Logistics
DrACO	Drill for Acquisition of Complex Organics
DragonCam	Dragonfly Camera Suite
EAP	Electrified Aircraft Propulsion
EGS	Exploration Ground Systems
EHP	Extravehicular Activity and Human Surface Mobility Program
EPFD	Electrified Powertrain Flight Demonstration
ESA	European Space Agency
ESO	Earth System Observatory
ESPRIT-RM	European System Providing Refueling, Infrastructure, and Telecommunications Refueler Module
EUS	Exploration Upper Stage

EVA	Extravehicular Activity
FAR	Federal Acquisition Regulation
GE	GE Aviation
GERS	Gateway External Robotic System
GRACE-C	Gravity Recovery and Climate Experiment – Continuity
HALO	Habitation and Logistics Outpost
HLS	Human Landing System
IBR	integrated baseline review
iCDR	integrated critical design review
I-HAB	International Habitat
IMAP	Interstellar Mapping and Acceleration Probe
ISRO	Indian Space Research Organisation
ISS	International Space Station
JAXA	Japanese Aerospace Exploration Agency
JCL	joint cost and schedule confidence level
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
KDP	key decision point
LBFD	Low Boom Flight Demonstrator
LTV	Lunar Terrain Vehicle
LIDAR	light detection and ranging
MCR	mission concept review
MDR	mission definition review
ML2	Mobile Launcher 2
MSR	Mars Sample Return
MUSE	MUlit-slit Solar Explorer
NASA	National Aeronautics and Space Administration
NEO	Near Earth Object
NISAR	NASA- ISRO – Synthetic Aperture Radar
ORR	operational readiness review
Orion	Orion Multi-Purpose Crew Vehicle
OSAM-1	On-Orbit Servicing, Assembly, and Manufacturing 1
PACE	Plankton, Aerosol, Cloud, ocean Ecosystem
PDR	preliminary design review
PMAR	post-mission assessment review
PPE	Power and Propulsion Element
REU	robot electronics unit
Roman	Nancy Grace Roman Space Telescope
RPOD	rendezvous proximity operations and docking
SBG	Surface Biology and Geology
SDR	system definition review
SEP	Solar Electric Propulsion

SFD	Sustainable Flight Demonstrator
SIR	system integration review
SIT-4	System Integration and Test Level 4
SLD	Sustaining Lunar Development
SLS	Space Launch System
SPHEREx	Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer
SPIDER	SPace Infrastructure DExterous Robot
SRL	Sample Retrieval Lander
SRR	system requirements review
TRL	technology readiness level
TBD	to be determined
TIR	Thermal Infrared
VDS	Vehicle Damper System
VIPER	Volatiles Investigating Polar Exploration Rover
VSWIR	Visible Short Wave Infrared
VenSAR	Venus Synthetic Aperture Radar

GAO U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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June 20, 2024

Congressional Committees

Each year, NASA invests billions of dollars in a wide-ranging portfolio of major projects to help execute important missions. These major projects aim to understand climate change and explore Earth and the solar system, among other things. They also intend to extend human presence beyond low-Earth orbit to the lunar surface—an ambitious undertaking known at NASA as the Artemis missions. In fiscal year 2024, NASA plans to invest more than $81 billion in its portfolio of 36 major projects. NASA's major projects have life-cycle costs of at least $250 million and take multiple years to acquire.

NASA's planning and execution of its major projects has been on our high-risk list since 1990 due to the agency's history of persistent cost growth and schedule delays in most of its major projects. In our April 2023 high-risk report, we found that NASA continued to face challenges, particularly with the cost and schedule performance of its most expensive projects.[1] These are known as category 1 projects and have total project life-cycle cost estimates that exceed $2 billion. NASA has taken steps to reduce its acquisition risks and improve project cost and schedule performance. However, NASA is embarking on several new, large projects. These projects are complex and specialized, and often rely on state-of-the-art space technology.

The explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act, 2009 includes a provision for us to prepare project status reports on selected large-scale NASA programs, projects, and activities.[2] The joint explanatory statement accompanying the Consolidated Appropriations Act, 2023 includes a

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[1] GAO, *High-Risk Series: Efforts Made to Achieve Progress Need to Be Maintained and Expanded to Fully Address All Areas*, GAO-23-106203 (Washington, D.C.: Apr. 20, 2023).

[2] See Explanatory Statement, 155 Cong. Rec. H1653, H1824-25 (daily ed., Feb. 23, 2009), on H.R. 1105, the Omnibus Appropriations Act, 2009, which became Pub. L. No. 111-8. In this report, we refer to these projects as major projects rather than large-scale projects since this is the term used by NASA.

similar provision.[3] This is our 16th annual report responding to these provisions.

This report includes our analysis of (1) the cost and schedule performance of NASA's portfolio of major projects; (2) the maturity of NASA's technologies; and (3) the current status of major NASA projects, as reflected in individual project and program assessments. Appendix I includes 24 individual assessments for NASA projects and programs that have either passed key milestones or exceed $2 billion in total life-cycle costs; 12 abbreviated assessments for projects that are early in their life cycles and do not exceed $2 billion in total life-cycle costs; and three summaries that provide additional detail on NASA's Artemis missions and two of its supporting programs. When NASA determines that a project has an estimated life-cycle cost of over $250 million, we include that project in our annual review through its launch or the end of its development. Two projects—Psyche, and Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)—launched in October 2023 and February 2024, respectively. As a result, they are included in our portfolio-level cost and schedule analyses, but we did not provide an individual assessment of either one.

To conduct our analyses, we collected cost, schedule, and technology maturity data via data collection questionnaires sent to NASA headquarters and project offices. We analyzed these data and, where appropriate, compared them against best practices we have identified in our prior work on product development. To complete our individual project assessments, we reviewed monthly status reports, analyzed data obtained through our questionnaires, and interviewed project officials. Appendix II contains detailed information on our scope and methodology.

We conducted this performance audit from April 2023 to June 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 that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

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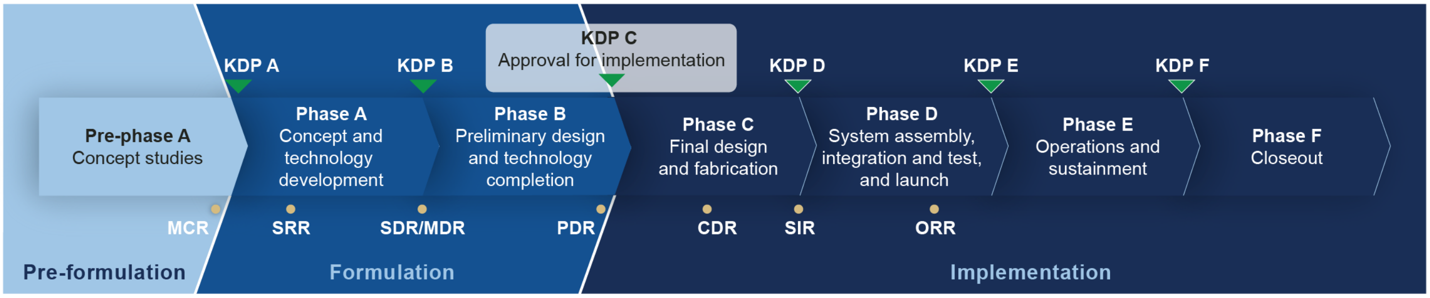
[3] Explanatory Statement, 168 Cong. Rec. S7898 (daily ed., Dec. 20, 2022), accompanying the Consolidated Appropriations Act, 2023, Pub. L. No. 117-328.

Background

NASA's Life Cycle for Major Space Flight Projects

The life cycle for NASA space flight projects consists of two phases: (1) formulation, which takes a project from concept development to preliminary design; and (2) implementation, which includes activities like building, launching, and operating the system. NASA further divides formulation and implementation into phases A through F. Major projects must get approval from senior NASA officials at key decision points before they can enter each new phase. Figure 1 depicts NASA's life cycle for space flight projects.

Figure 1: NASA's Life Cycle for Space Flight Projects



Management decision reviews

▼ KDP = key decision point

Technical reviews

● MCR = mission concept review

● SRR = system requirements review

● SDR/MDR = system definition review/mission definition review

● PDR = preliminary design review

● CDR = critical design review

● SIR = system integration review

● ORR = operational readiness review

Source: GAO analysis of NASA data. | GAO-24-106767

Project formulation consists of phases A and B, during which a project team develops and defines requirements, cost and schedule estimates, and the system's design for implementation. Prior to beginning phase A, NASA conducts a mission concept review to evaluate the feasibility and maturity of proposed mission concepts and associated planning. In phase

A, a project team develops a range of cost and schedule estimates for uses such as budget planning. The agency conducts a system requirements review and system definition review/mission definition review. These reviews ensure that the project's performance requirements and proposed system architecture or technical approach are aligned with the mission's performance requirements. During phase B, the project team also develops programmatic measures and technical leading indicators that track various project metrics, such as requirement changes, staffing demands, and mass and power use. Near the end of formulation, leading up to the preliminary design review, the project team completes technology development and the preliminary design. Formulation culminates in a review at key decision point C, at which point senior leaders determine whether and how the project proceeds into the next phase and approves any additional actions.

Implementation follows key decision point C and consists of phases C, D, E, and F. In this report, we refer to projects in phases C and D as being in development. The project team holds a critical design review during the latter half of phase C to determine whether the design performs as expected and is stable enough to support proceeding with the final design and fabrication. After the critical design review and just prior to beginning phase D, the project team completes a system integration review to evaluate the readiness of the project and associated supporting infrastructure to begin system assembly, integration, and test. In phase D, the project team performs system assembly, integration, test, and launch activities. During the latter half of phase D, the project team holds an operational readiness review to ensure that all system and support hardware, software, personnel, and procedures are ready for operations. Phases E and F consist of operations, sustainment, and project closeout.

NASA Cost and Schedule Commitments

Major NASA projects have two sets of cost and schedule commitments—the management agreement and the agency baseline commitment.

- **Management agreement.** According to NASA policy, the management agreement should be viewed as a contract between NASA and the program or project manager.[4] The executing center's

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[4] NASA's spaceflight program and project management policy describes a program as a strategic investment by a mission directorate or mission support offices with a defined architecture and/or technical approach, requirements, funding, and a management structure that initiates and directs one or more projects. The policy further describes a project as a specific investment identified in a program plan having defined requirements, a life-cycle cost, a beginning, and an end.

project manager has the authority to manage the project within the parameters outlined in this agreement, which includes cost and schedule reserves that the project manager controls.[5] Cost reserves are for costs that projects expect to incur—for instance, risk mitigations—but are not yet allocated to a specific part of the project. Schedule reserves are extra time in project schedules that managers can allocate to specific activities, elements, and major subsystems to mitigate delays or address unforeseen events. If the project requires additional time or money beyond the management agreement, NASA headquarters may allocate headquarters-held reserves, which represent the difference between the agency baseline commitment and the management agreement.

- **Agency baseline commitment.** The agency baseline commitment includes the cost and schedule baselines against which the agency's performance on a project is measured. The baselines generally include life-cycle costs broken out by formulation, development, and operations, and a key schedule milestone event such as a launch readiness date to denote the end of development and the start of operations.[6]

To inform the management agreement and the agency baseline commitment, each project with a life-cycle cost estimate of greater than $250 million must also develop a joint cost and schedule confidence level unless NASA waives the requirement. A joint cost and schedule confidence level is an integrated analysis of a project's cost, schedule, risk, and uncertainty, the result of which indicates a project's likelihood of meeting a given set of cost and schedule targets.[7]

The total amount of cost and schedule reserves held at the project level varies based on where the project is in its life cycle. NASA's policy on whether projects are required or recommended to hold certain levels of cost and schedule reserves at key project milestones also varies by

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[5] NASA refers to cost reserves as unallocated future expenses.

[6] For projects and programs that plan continuing operations and production with an unspecified end point, the operations cost estimate is established as part of the operational readiness review for 5 years and updated and documented annually for the next 5-year period.

[7] NASA, *NASA Cost Estimating Handbook Version 4.0* (February 2015).

NASA center.[8] Projects track their reserves between phases to help ensure they hold reserves consistent with these requirements.

When a project is no longer meeting certain conditions in the agency baseline commitment, NASA replans or rebaselines the project. In certain cases, NASA is required to notify Congress when this occurs. See table 1 for an overview of characteristics of NASA replans and rebaselines.

Table 1: Characteristics of NASA Program or Project Replans and Rebaselines

	Description	Potential congressional reporting requirement
Replan	A replan is a process by which a program updates or modifies its plans. It is driven by changes in program or project cost parameters, such as if development cost growth is 15 percent or more of the estimate in the baseline report or a major milestone is delayed by 6 months or more from the baseline's date. A replan does not require a new project baseline to be established.	When the NASA Administrator determines that development cost growth is likely to exceed the development cost estimate by 15 percent or more, or a program milestone is likely to be delayed from the baseline's date by 6 months or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.[a]
Rebaseline	Rebaselining is the process that results in a change to the project's agency baseline commitment. NASA initiates a rebaseline if the estimated development cost exceeds the baseline development cost estimate by 30 percent or more, or if the NASA Associate Administrator determines other events make a rebaseline appropriate.	In addition to the replan reporting noted above, should a program exceed its development cost baseline by more than 30 percent, the program must be reauthorized by Congress and rebaselined in order to expend funds to continue work beyond a specified time frame.[b]

Source: GAO analysis of NASA policy and 51 U.S. Code Sec. 30104. | GAO-24-106767

[a] 51 U.S.C. § 30104(e)(1).

[b] 51 U.S.C. § 30104(f).

NASA Project Management Policy

The primary policy that guides project management for spaceflight programs and projects is NASA Procedural Requirements 7120.5F, which we refer to throughout this report as NASA's key project management policy.[9] This policy establishes the requirements by which NASA formulates and implements space flight programs and projects. The requirements include a definition of category thresholds that determine the level of internal oversight and approval a project receives depending on its life-cycle cost and other criteria. These category definitions do not

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[8] NASA has 10 centers spread across the United States that execute its major projects.

[9] NASA, *NASA Space Flight Program and Project Management Requirements,* Procedural Requirements 7120.5F (Aug. 3, 2021).

affect NASA's statutory external reporting requirements to report progress against cost and schedule baselines to congressional committees for projects with a life-cycle cost over $250 million.[10] See table 2 for NASA project category cost threshold definitions.

Table 2: NASA Project Category Cost Threshold Definitions

Category	Project life-cycle cost threshold	Decision authority
1	Over $2 billion	NASA Associate Administrator
2	$365 million to $2 billion	Mission Directorate Associate Administrator
3	Less than $365 million	

Source: GAO analysis of NASA Procedural Requirements 7120.5F. | GAO-24-106767

Note: Beside its life-cycle cost estimate, other factors might lead NASA to increase the category level of a project. These factors include the project's level of radioactive material, distinction as a human space flight project, or its priority level. Priority level is determined by the importance of the activity to NASA, the extent of international participation (or joint effort with other government agencies), or level of risk associated with the development of the spacecraft or payload.

NASA designated 14 of the 36 projects we reviewed this year as category 1.

NASA Projects That We Reviewed in Our 2024 Assessment

Of the 36 projects that we reviewed this year, 11 are related to the Artemis missions. The goal of NASA's Artemis enterprise is to return U.S. astronauts to the surface of the moon, establish a sustained lunar presence, and ultimately achieve human exploration of Mars. NASA is now beginning development of the multiple highly complex, interdependent systems required to enable lunar surface exploration. Figure 2 illustrates all 36 projects and programs that we reviewed this year, including designations for those related to the Artemis missions.[11]

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[10] 51 U.S. Code Sec. 30104.

[11] For the purposes of our report, we use the term "project" to refer to capabilities or capability upgrades under single project programs that NASA manages under a discrete baseline such as the Human Landing System (HLS) Initial Capability, HLS Sustaining Capability, and Space Launch System (SLS) Block 1B. We also use the terms "project" and "program" interchangeably when referring to single project programs that include the capability upgrades mentioned above, such as SLS, the Exploration Ground Systems (EGS), and the Orion Multi-Purpose Crew Vehicle (Orion).

Figure 2: Major NASA Projects and Programs in Formulation or Development Reviewed in GAO's 2024 Assessment

Formulation - 19		Compton Spectrometer and Imager (COSI)
		Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI)
		Demonstration Rocket for Agile Cislunar Operations (DRACO)
	1	Dragonfly
	A 1	Extravehicular Activity and Human Surface Mobility Program (EHP) - Extra Vehicular Activity (EVA) Development Project
	A 1	Extravehicular Activity and Human Surface Mobility Program (EHP) - Lunar Terrain Vehicle (LTV)
		Electrified Powertrain Flight Demonstration (EPFD)
		Earth System Observatory (ESO) - Atmosphere Observing System (AOS)
		Earth System Observatory (ESO) - Gravity Recovery and Climate Experiment-Continuity (GRACE-C)
		Earth System Observatory (ESO) - Surface Biology and Geology (SBG)
	A	Gateway - Deep Space Logistics (DSL)
		HelioSwarm
	A 1	Human Landing System (HLS) - Sustaining Lunar Development (SLD)
		Landsat Next
	A 1	Mobile Launcher 2 (ML2)
	1	Mars Sample Return (MSR)
		MUlti-slit Solar Explorer (MUSE)
		Sustainable Flight Demonstrator (SFD)
		Venus Synthetic Aperture Radar (VenSAR)
Development - 16	1	Europa Clipper
	A 1	Gateway Initial Capability - Habitation and Logistics Oupost (HALO) and Power and Propulsion Element (PPE)[a]
	A 1	Human Landing System (HLS) - Initial Capability
		Interstellar Mapping and Acceleration Probe (IMAP)
		Low Boom Flight Demonstrator (LBFD)
		Near Earth Object (NEO) Surveyor
		NASA Indian Space Research Organisation – Synthetic Aperture Radar (NISAR)
	A 1	Orion Multi-Purpose Crew Vehicle (Orion)
	1	On-Orbit Servicing, Assembly and Manufacturing 1 (OSAM-1)
		Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)—Launched
		Psyche—Launched
	1	Nancy Grace Roman Space Telescope (Roman)
	A	Solar Electric Propulsion (SEP)
	A 1	Space Launch System (SLS) Block IB
		Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer (SPHEREx)
	A	Volatiles Investigating Polar Exploration Rover (VIPER)
Other - 1	1	Commercial Crew Program (CCP)[b]

A Artemis-related project 1 Category 1 project

Source: GAO analysis of NASA data. | GAO-24-106767

[a] The Gateway Initial Capability's estimates include the cost and schedule of the PPE and HALO projects—which will launch together—the launch vehicle, and portions of program mission execution

essential for the launch. Therefore, GAO reviewed Gateway Initial Capability as a single project in its cost and schedule analyses, but reviewed Gateway – HALO and Gateway – PPE separately for technology maturity and other programmatic elements in the individual assessments.

[b]The Commercial Crew Program has a tailored project life cycle and project management requirements and did not establish a cost or schedule baseline and is not included in GAO's cost and schedule analyses for the development portfolio.

Appendix I contains a description of the projects and programs in this year's assessment.[12] Appendix III includes all the projects in this year's portfolio with their current cost and schedule estimates. Appendix IV includes a list of all the projects that we reviewed from 2009 to 2023.

Recent GAO Work on Selected NASA Projects

Over the past 10 years, we issued several in-depth reports assessing NASA's progress in acquiring its largest projects and programs.[13] For example, in November 2023, we found that NASA had established ambitious schedules for the Artemis III mission and that the Human Landing System (HLS) program had already experienced schedule delays.[14] In January 2024, we found that NASA shifted the Artemis III mission date from December 2025 to September 2026 to allow additional time to complete testing and remaining technical work.[15]

Since we initially designated NASA's acquisition management as high risk, we have made numerous recommendations to help the agency reduce its acquisition risk. Through these recommendations, we identified multiple areas where NASA should take action to improve the management of its portfolio of major projects. For example, in December 2019, we recommended that NASA create a life-cycle cost estimate for the Artemis III lunar landing mission.[16] NASA agreed with the recommendation but has not yet implemented it. NASA has generally agreed with our recommendations and implemented changes in response to many of them, but it needs to take additional actions to fully address all

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[12] We did not include project assessments for the PACE and Psyche projects because they recently completed their development.

[13] See related GAO products at the end of this report.

[14] GAO, *NASA Artemis Programs: Crewed Moon Landing Faces Multiple Challenges,* GAO-24-106256 (Washington, D.C.: Nov. 30, 2023).

[15] GAO, *NASA Artemis Programs: Lunar Landing Plans Are Progressing, but Challenges Remain,* GAO-24-107249 (Washington, D.C.: Jan. 17, 2024).

[16] GAO, *NASA Lunar Programs: Opportunities Exist to Strengthen Analyses and Plans for Moon Landing,* GAO-20-68 (Washington, D.C.: Dec. 19, 2019).

of them. As of April 2024, NASA had not yet fully implemented 39 of our recommendations, including eight that we identified as high priority.

NASA's Cost and Schedule Performance Continues to Improve for Its Portfolio of Major Projects

The portfolio's cumulative cost and schedule performance improved in 2024, driven by two large category 1 projects demonstrating their initial capabilities and leaving the portfolio. In addition, most of the 16 projects in development did not experience annual cost growth or schedule delays since our last report. More than half of the category 1 projects in development are Artemis-related, and, moving forward, these projects will drive the portfolio's performance due to the scale of their baseline costs. NASA has taken steps to improve the management and cost and schedule performance of all its major projects, including those supporting Artemis missions.

Category 1 Projects Drove Improved Cumulative Cost and Schedule Performance

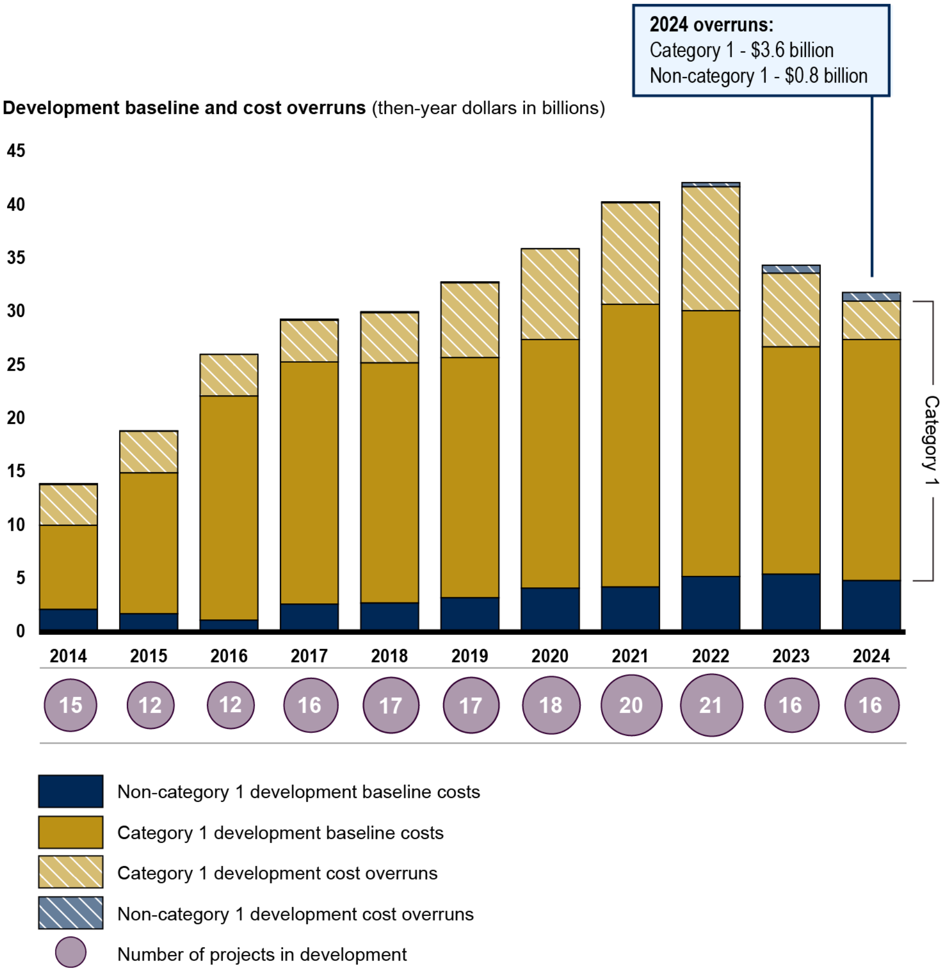
The portfolio's cumulative cost and schedule performance improved in 2024, driven largely by the performance of the category 1 projects.

Cumulative Cost Performance

The portfolio's cumulative baseline cost overruns decreased from $7.6 billion in 2023 to $4.4 billion in 2024, a decrease driven by two large category 1 projects—the Space Launch System (SLS) and the Exploration Ground Systems (EGS). SLS and EGS successfully demonstrated their initial capability during the Artemis I mission and are no longer in the portfolio in 2024. Together, these projects accounted for $3.6 billion, or 47 percent, of the cumulative baseline cost overruns in 2023. Overall, category 1 baseline development cost overruns decreased from $6.9 billion in 2023 to $3.6 billion in 2024, the lowest cost development overruns for category 1 projects since 2014.

Category 1 projects continue to account for most of NASA's cumulative development cost overruns. Specifically, 81 percent of these overruns came from category 1 projects (see fig. 3).

Figure 3: Cumulative Development Cost Overruns for NASA's Portfolio of Major Projects by Category

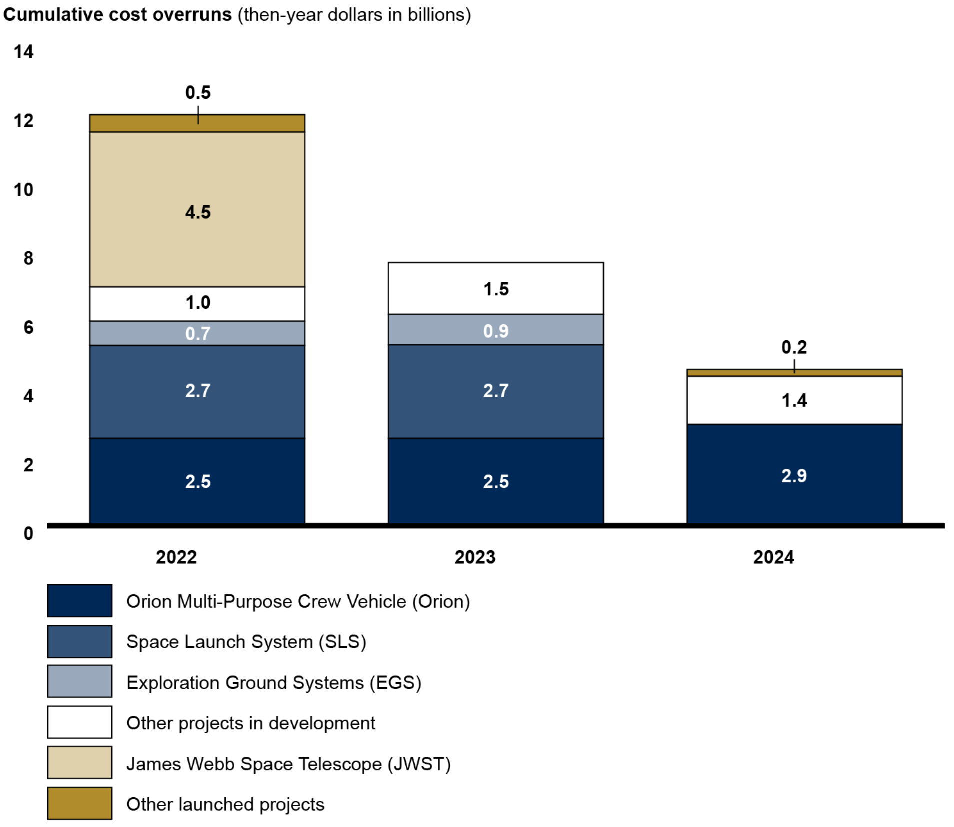


Source: GAO analysis of NASA data. | GAO-24-106767

Notes: The years in the figure are the year that GAO issued its annual assessment of major NASA projects. Data for GAO's current assessment are as of January 2024.

Furthermore, 65 percent of the current portfolio's cumulative baseline cost overruns came from the Orion Multi-Purpose Crew Vehicle project (Orion), a category 1 and Artemis-related project. Orion's cumulative cost overruns ($2.9 billion) exceeded the cumulative overruns from the 15 other development projects combined ($1.6 billion) (see fig. 4).

Figure 4: Comparison of NASA's Cumulative Baseline Development Cost Overruns by Project, 2022-2024



Source: GAO analysis of NASA data. | GAO-24-106767

Notes: The years in the figure denote the year that GAO issued its annual assessment of major NASA projects. Data for GAO's current assessment are as of January 2024. The Orion project's cost is under review. Until the review is complete, information presented is based on the latest estimates that GAO received from NASA. Due to rounding, the numbers in the figure do not sum to the total cumulative cost overruns of $4.4 billion for 2024.

Cumulative Schedule Performance

Following the same trend as the portfolio's cumulative cost performance, the major projects in development improved their cumulative schedule performance in large part due to SLS and EGS, two category 1 projects, leaving the portfolio. Specifically, the portfolio's schedule overruns decreased from 20.9 years in 2023 to 14.5 years in 2024. Prior to leaving the portfolio, SLS and EGS were each delayed by 4 years. This represented 38 percent of the cumulative schedule delays in 2023. Of the 16 projects remaining in the current portfolio, nine contributed to the cumulative schedule overruns.

Most Projects in Development Did Not Experience Annual Cost or Schedule Overruns

Most of the 16 projects in development did not experience annual cost growth or schedule delays since our last report. Specifically, 11 out of the 16 projects in the development portfolio did not experience annual cost growth in 2024, and 13 out of 16 reported no schedule delays this year. Furthermore, two projects—Psyche and PACE—reported lower development costs in 2024.

- We reported last year that the Psyche project increased its development cost estimate by 19.3 percent and delayed its launch by 14 months due to missing its fall 2022 launch window. The project successfully launched on October 13, 2023. NASA subsequently moved $15.6 million of funding planned for development to the operations phase, which decreased the latest development cost estimate by $15.6 million.
- Last year, PACE operated within its revised cost and schedule baselines, which it updated in February 2022. The project launched on February 8, 2024, 3 months ahead of the replanned launch readiness date. Since our last report, PACE reduced its development cost estimate by $31.1 million, attributing $15.9 million to unused cost reserves and $15.1 million to planned funding moving from the development phase to phase E operations.

Five of the 16 projects experienced cost growth since our last report, which increased the development portfolio's estimated overruns by $476.6 million (see fig. 5).[17]

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[17] The $476.6 million annual total does not include projects that reported cost underruns since our 2023 report. Including underruns, the total annual development cost change is $429.9 million. See appendix V for all cost changes since our 2023 report.

Figure 5: Annual Development Cost Growth for Major NASA Projects since GAO's 2023 Assessment (in then-year millions of dollars)

Legend:
LBFD: Low Boom Flight Demonstrator
Orion: Orion Multi-Purpose Crew Vehicle
SEP: Solar Electric Propulsion
SPHEREx: Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer
VIPER: Volatiles Investigating Polar Exploration Rover

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data are as of January 2024. This figure reflects cost increases against what GAO reported in its May 2023 annual assessment of major projects. This figure does not include projects that reported cost underruns since GAO's last report.

[a] The cost estimates for Orion and VIPER are under review.

Three of the five projects that experienced cost growth since our last report also reported schedule delays during this time frame. This added 30 months in estimated collective delays (see fig. 6).[18]

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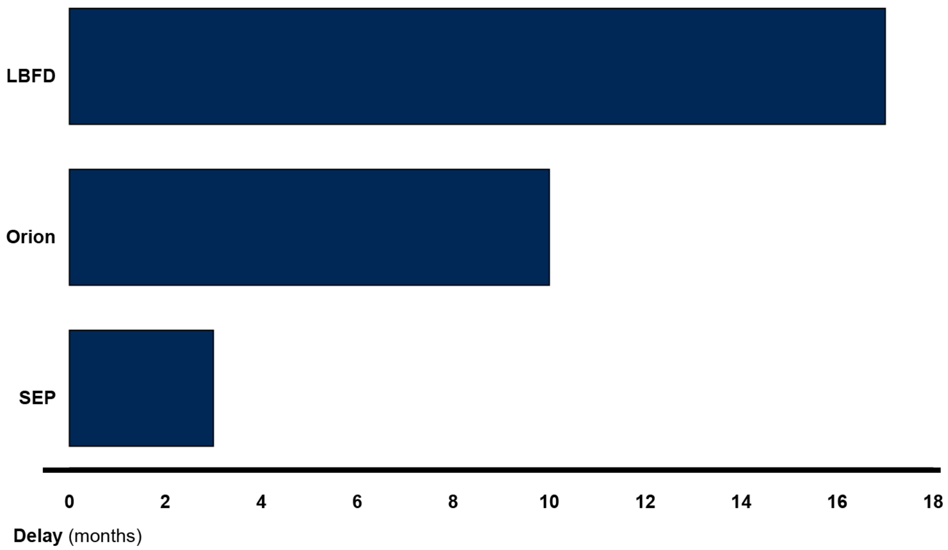
[18] The annual total does not include projects that reported schedule underruns since our last report. One project, PACE, reported a 3-month schedule underrun since our 2023 report. See appendix V for all schedule changes since our 2023 report.

Figure 6: Annual Development Delays for Major NASA Projects in Development since GAO's 2023 Assessment



Legend:
LBFD: Low Boom Flight Demonstrator
Orion: Orion Multi-Purpose Crew Vehicle
SEP: Solar Electric Propulsion

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data are as of January 2024. This figure reflects schedule delays against what GAO reported in its May 2023 annual assessment of major NASA projects. This figure does not include projects that reported schedule underruns since GAO's last report.

The five projects that reported cost growth, schedule delays, or both were Orion; Low Boom Flight Demonstrator (LBFD); Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx); Solar Electric Propulsion (SEP); and Volatiles Investigating Polar Exploration Rover (VIPER):

- Orion cost overruns accounted for 74 percent of the development portfolio's total annual cost growth in 2024. This year, Orion reported $321 million in cost growth and 10 months of schedule delays due to the delay of the Artemis II launch date. According to program officials, the annual cost growth includes costs that were associated with delaying Artemis II from May 2024 to December 2024. These costs were not reflected in last year's estimates due to the agency continuing a review and estimation of associated costs.

  In January 2024, program officials said they are still reviewing the costs associated with the most recent Artemis II launch delay to

September 2025, and, as a result, they expect costs to increase. Because of these schedule changes, the Orion program's cost estimate has been under review since September 2022.

- The LBFD project rebaselined in January 2024 as its costs grew by $101.8 million and its schedule was delayed by almost 1½ years. NASA documentation states that the delay was due to issues with contractor performance and overly optimistic planning. The project is now working toward a first flight date of October 2024, over 2 years later than its original baseline.
- The SPHEREx project experienced cost growth totaling $28.6 million in 2024. In January 2024, at key decision point D, the Science Mission Directorate approved SPHEREx to begin system assembly and integration and testing, and to prepare for launch. At this milestone, the Science Mission Directorate approved a $36.7 million increase to the project's life-cycle costs, which now total $488.1 million. The cost increase was driven by technical and schedule challenges due to payload telescope and spacecraft delivery delays and the rework of the spacecraft's flight computer, among other things.
- The SEP project experienced cost growth totaling $20 million in 2024 and 3 months of schedule overruns. These overruns occurred because the project had to redesign its thruster harnesses—the groupings of wire or cable that transmit signals and electrical power. The project had to redesign the harnesses to address a hardware incompatibility, following reconciliation of conflicting spacecraft requirements with the Gateway – Power and Propulsion Element project that will host the SEP hardware. Harness redesign was the option with the lowest overall schedule effect to the PPE project, which covered the cost of the redesign.
- The VIPER project experienced cost growth totaling $5 million in 2024. In August 2023, at key decision point D, the Science Mission Directorate approved VIPER to begin system assembly and integration and testing, and to prepare for launch. This decision included an increase of $71.9 million to the project's life-cycle costs, which now total $505 million. The Science Mission Directorate also approved the VIPER project's replan to accommodate the 1-year delay to the launch readiness date from November 2023 to November 2024, which we reported on last year.[19]

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[19] GAO, *NASA: Assessment of Major Projects,* GAO-23-106021 (Washington, D.C.: May 31, 2023).

Additional details on cost and schedule performance for each project are included in our individual assessments in appendix I. For a comprehensive list of annual cost and schedule performance by project, see appendix V.

Artemis-Related Category 1 Projects Will Drive Near-Term Portfolio Performance

The cost of NASA's Artemis-related category 1 projects will shape the agency's performance in the coming years. The departure from the portfolio of two of these projects—SLS and EGS—already drove cost and schedule improvements in 2024. Looking ahead, eight of NASA's 14 category 1 major projects are Artemis-related. Five of these eight projects—HLS Initial Capability, HLS Sustained Lunar Development, Gateway Initial Capability, Orion, and SLS Block 1B—have preliminary life-cycle cost estimates or cost baselines that range from $4.9 billion up to $14 billion. Furthermore, for fiscal year 2025, Artemis-related projects comprised 77 percent of NASA's budget request for all major projects.

NASA has faced challenges managing the cost and schedule performance of the Artemis projects. Three category 1 Artemis projects—SLS, EGS, and Orion—rebaselined due to technical issues or scope changes.[20] In addition to these rebaselines, production challenges with the SLS core stage and the Orion crew and service modules, among other things, led NASA to delay the Artemis I mission.

In December 2023, NASA set development cost baselines totaling $9.6 billion for three of the projects noted above: SLS Block 1B, HLS Initial Capability, and Gateway Initial Capability. These three category 1 Artemis projects increased the total development baseline costs for NASA's portfolio of major projects from $18.1 billion to $27.7 billion. All three projects are in, or are approaching, the final design and fabrication phase of development. We previously found that this phase is when projects are

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[20] In August 2021, the Orion program rebaselined due to program cost growth; significant outside influences (COVID-19 effects to NASA facilities at Johnson Space Center, Kennedy Space Center, and Michoud Assembly Facility); schedule and technical issues with the European Space Agency-provided service module; and scope changes (addition of the rendezvous proximity operations and docking; Artemis II core avionics and development flight instrumentation; optical communications; alternative thrust vector control; changes to the exploration upper stage and interim cryogenic propulsion stage; and obsolescence mitigation).

most likely to experience cost and schedule growth.[21] If the newly baselined projects encounter problems similar to what SLS, EGS, and Orion faced during development, they could require additional funding. For example, if each of the three recently baselined projects were to experience developmental cost growth in the range of 15 percent (which could trigger a replan) to 30 percent (which could trigger a rebaseline), it could increase the developmental portfolio costs by $1.4 billion to $2.9 billion.

NASA Continues to Work Toward Improvements to Its Acquisition Management

Considering its decades-long inclusion on our high-risk list and ongoing acquisition management challenges, NASA committed to and has taken steps to improve the management and cost and schedule performance of its major projects, including category 1 projects.

- In 2023, in response to statute, NASA established the Moon to Mars program office to lead and manage the Artemis programs. NASA determined that this office is not subject to NASA's program and project management policy (NASA Procedural Requirements 7120.5F), which generally requires the establishment of cost and schedule baselines to measure program and project performance. NASA reported that the Moon to Mars program office serves to fulfill an integration function, and each program within it is already compliant with NASA Procedural Requirements 7120.5F. NASA officials stated that the Moon to Mars program office is currently formulating its policies and governance approach to manage cost, risk, schedule, and performance factors.
- In our April 2023 High-Risk Update, we found that NASA completed several initiatives to strengthen its cost and schedule estimating capacity.[22] For example, NASA completed initiatives in its action plan to strengthen its cost and schedule estimating workforce and elevated its Chief Acquisition Officer position to the NASA Deputy Administrator to help ensure that appropriate levels of consideration are applied to major acquisitions. By doing so, NASA hopes to better estimate projects' costs and schedules going forward.
- Senior NASA officials told us that that they have made several changes to help improve project performance. For example, they said

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[21] GAO, *NASA Assessments of Major Projects,* GAO-17-303SP (Washington, D.C.: May 16, 2017); and *NASA: Assessments of Major Projects,* GAO-16-309SP (Washington, D.C.: Mar. 30, 2016). We found that projects appear most likely to rebaseline between their critical design review and system integration review—the riskiest point in the development cycle.

[22] GAO-23-106203.

that they delayed setting the baseline for the SLS Block 1B project until the requirements were more stable. As a result, they are confident they can execute the project within the established cost and schedule baseline commitments. Further, to help improve acquisition outcomes, NASA established the Chief Program Management Officer 2 years ago. The Chief Program Management Officer and NASA officials said that this office has used its influence to help projects meet their cost and schedule commitments and establish attainable baselines.

- In March 2024, NASA announced that it was canceling OSAM-1, a category 1 project with a history of poor cost and schedule performance. In late 2023, the Space Technology Mission Directorate that managed OSAM-1 requested an independent continuation review. The review recommended that the OSAM-1 project be discontinued after finding that the mission goal was not perceived to be of value, particularly when paired with the high cost-to-go and pace at which the project was executing. Throughout its life cycle, the OSAM-1 project experienced recurring cost growth and schedule delays due to scope changes, the COVID-19 pandemic, and issues with developing new technologies and supplier quality. Prior to the cancelation, the OSAM-1 project was reviewing its May 2022 rebaselined cost and schedule estimates because it had exhausted its cost and schedule reserves. The explanatory statement to the Consolidated Appropriations Act, 2024, directs NASA to continue with an adjusted OSAM-1 mission.[23]
- NASA delayed setting cost and schedule baselines for the Mars Sample Return (MSR) mission, a category 1 project with a potential life-cycle cost of $8 billion to $11 billion. In May 2023, the Science Mission Directorate stood up an Independent Review Board to assess the mission before setting its baselines due to mounting technical, schedule, and cost concerns. In September 2023, the independent review board issued a broad range of findings and recommendations. In response, NASA is soliciting studies from industry and engaging with NASA experts to investigate innovative architectures that could offer lower annual and life-cycle costs, provide earlier sample return, and reduce mission complexity and risk.

Managing the cost and schedule performance of the new category 1 projects, including Artemis projects, will increasingly play a substantial role in the performance of NASA's portfolio of major projects. Significant

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[23] Explanatory Statement, 170 CONG. REC. S1223, S1412 (daily ed., Mar.5 2024), on H.R. 4366, Consolidated Appropriations Act, 2024, which became Pub. L. No. 118-42.

cost growth on category 1 projects can have a cascading effect on NASA's portfolio of major projects. For example, in 2021, we found that the James Webb Space Telescope project's $4.4 billion development cost growth was one of the main drivers of poor cost and schedule performance in NASA's portfolio of major projects.[24] This project's poor performance was having a cascading effect on other projects. Specifically, at the same time the James Webb Space Telescope was experiencing additional cost and schedule growth, the Nancy Grace Roman (Roman) telescope was struggling to establish itself as a project at NASA. In May 2021, we found that for the third year in a row, the President's budget request proposed canceling the Roman project.[25]

Our recent work indicates that NASA is at a critical juncture and executing improved acquisition management will be important for NASA to achieve its cost and schedule commitments moving forward.[26] For example:

- In our May 2023 assessment of NASA's major projects, we found that the largest projects drive the cost and schedule performance of NASA's development portfolio, and that NASA has identified opportunities to improve the cost and schedule performance of its projects.[27]
- In December 2020, we recommended that NASA establish cost and schedule baselines for SLS Block 1B, SLS Block 2, Mobile Launcher 2, and the Orion Docking System.[28] As of March 2024, NASA established a baseline for the SLS Block 1B capability and incorporated the Orion docking system into the Orion program's baseline. NASA plans to establish a baseline for Mobile Launcher 2 in spring 2024, but it has not yet set a date for the SLS Block 2 capability.
- In May 2014, we recommended that NASA establish cost and schedule baselines for additional SLS and EGS capabilities that

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[24] GAO, *NASA: Assessments of Major Projects*, GAO-21-306 (Washington, D.C.: May 20, 2021).

[25] GAO, *NASA: Lessons from Ongoing Major Projects Can Inform Management of Future Space Telescopes,* GAO-22-105555 (Washington, D.C.: Dec. 1, 2021).

[26] See related GAO products at the end of this report.

[27] GAO-23-106021.

[28] GAO, *NASA Human Space Exploration: Significant Investments in Future Capabilities Require Strengthened Management Oversight*, GAO-21-105 (Washington, D.C.: Dec. 15, 2020).

include all life-cycle costs including operations and sustainment.[29] In spring 2022, NASA established the first 5-year production and operations cost estimate for each program. NASA plans to update these annually, on a rolling basis. However, in September 2023, we found that NASA's new cost estimates were not a substitute for a cost baseline and are poor measures of cost performance over time because they do not track costs by Artemis mission or for recurring production items.[30]

We continue to believe that implementing our recommendations will help NASA reduce its overall acquisition risk. These recommendations will also help NASA demonstrate progress in improving the cost and schedule performance of its portfolio of major projects, including those supporting the Artemis missions. We will continue to monitor NASA's efforts to address our recommendations.

NASA's Portfolio Maintained Its Technology Maturity Performance in 2024

NASA's technology maturity levels in 2024 were generally consistent with the levels that projects reported since 2021. As in recent years, almost all major NASA projects met our Technology Readiness Guide's recommendation to mature their technologies to at least technology readiness level (TRL) 6 upon entering product development or by their preliminary design review. Achieving a TRL 6 involves demonstrating a representative prototype of the technology in a relevant environment.[31] For more information about TRLs, see appendix VI. Our past work shows that including immature technologies in product development before they were mature later contributed to cost increases and schedule delays. NASA's Systems Engineering policies align with our technology maturity best practice for achieving TRL 6 by preliminary design review.[32] Of the

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[29] GAO, *NASA: Actions Needed to Improve Transparency and Assess Long-Term Affordability of Human Exploration Programs*, GAO-14-385 (Washington, D.C.: May 8, 2014).

[30] GAO, *Space Launch System: Cost Transparency Needed to Monitor Program Affordability*, GAO-23-105609 (Washington, D.C.: Sept. 7, 2023).

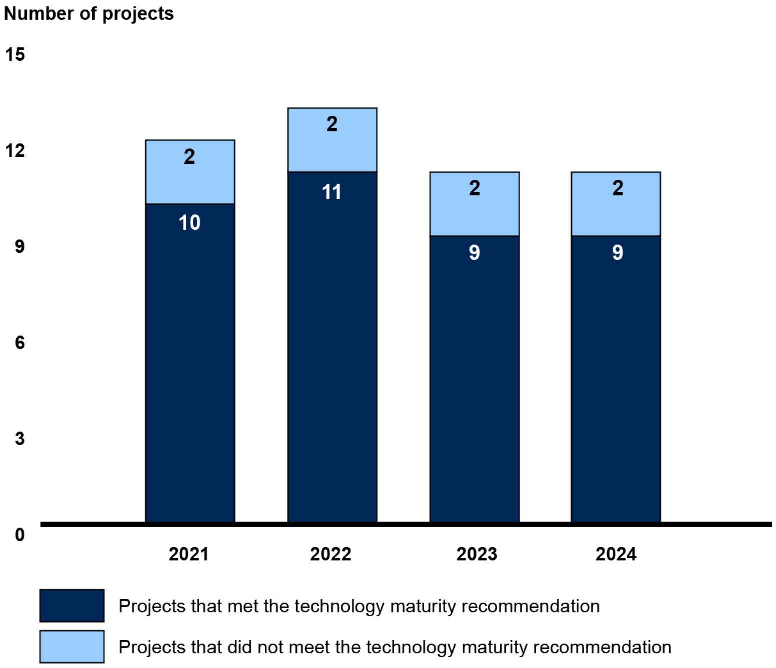
[31] Our guide states that during the product development process, technology readiness assessments are important inputs into systems engineering events—such as a project's preliminary design review and critical design review—and can expose knowledge gaps. If a project has a lower than recommended TRL by its preliminary design review, then it does not have a solid technical basis for its design and could put itself at risk of approving a design that is less likely to remain stable. GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects,* GAO-20-48G (Washington, D.C.: Jan. 7, 2020).

[32] NASA, *NASA Systems Engineering Processes and Requirements,* Procedural Requirements 7123.1C (Feb. 14, 2020).

11 projects that reported critical technologies in 2024, the projects assessed that nine matured their technologies to TRL 6 by their preliminary design review.[33]

The number of projects reporting critical technologies remained the same since last year, but the composition of this part of the portfolio changed during this time frame. Specifically, Surface Water and Ocean Topography exited and Dragonfly entered the portfolio. Dragonfly assessed that it matured all three of its critical technologies to at least TRL 6 ahead of its February 2023 preliminary design review. Figure 7 shows the number of projects that achieved TRL 6 in accordance with our guide since 2021.

Figure 7: Number of NASA's Major Projects Achieving a Technology Readiness Level 6 by Preliminary Design Review



Source: GAO analysis of NASA data. | GAO-24-106767

Notes: The years in the figure are the year that GAO issued its annual assessment of major NASA projects. The 2024 data are current as of January 2024. This assessment includes projects that completed preliminary design review and identified critical technologies and excludes technology demonstration projects from all years.

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[33] GAO-20-48G. Technologies are considered critical if they are new or novel, or used in a new or novel way and needed for a system to meet its operational performance requirements within defined cost and schedule parameters (i.e., cost and schedule targets set at key decision point B or C).

We previously reported on the two projects—Roman and Gateway – Power and Propulsion Element—that did not meet our technology maturity best practice at the time of their preliminary design reviews.

- Roman assessed that it finished maturing the last one of its nine critical technologies to TRL 6 in 2022, over 2 years after its preliminary design review and after the project had held its critical design review. Roman is continuing to make progress on building, assembling, and testing key system subcomponents. The project delayed its scheduled launch from October 2026 to May 2027 and estimates that it will exceed its developmental cost baseline by over 12 percent.
- As of January 2024, Gateway – Power and Propulsion Element assessed that it had matured seven of its nine critical technologies to TRL 6. None of the technologies were mature at the project's preliminary design review in November 2021.

Agency Comments

We provided a draft of this report to NASA for its review and comment. In its written comments, reprinted in appendix VII, NASA generally agreed with the findings of the report. NASA also provided technical comments, which have been addressed in this report, as appropriate.

We are sending copies of the report to the NASA Administrator and interested congressional committees. In addition, the report will be available at no charge on GAO's website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or RussellW@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix VIII.

W. William Russell IV

W. William Russell
Director, Contracting and National Security Acquisitions

List of Committees

The Honorable Jeanne Shaheen
Chair
The Honorable Jerry Moran
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable Kyrsten Sinema
Chair
The Honorable Eric Schmitt
Ranking Member
Subcommittee on Space and Science
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Hal Rogers
Chairman
The Honorable Matt Cartwright
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Brian Babin
Chairman
The Honorable Eric Sorensen
Ranking Member
Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
House of Representatives

Appendix I: Individual Project Assessments

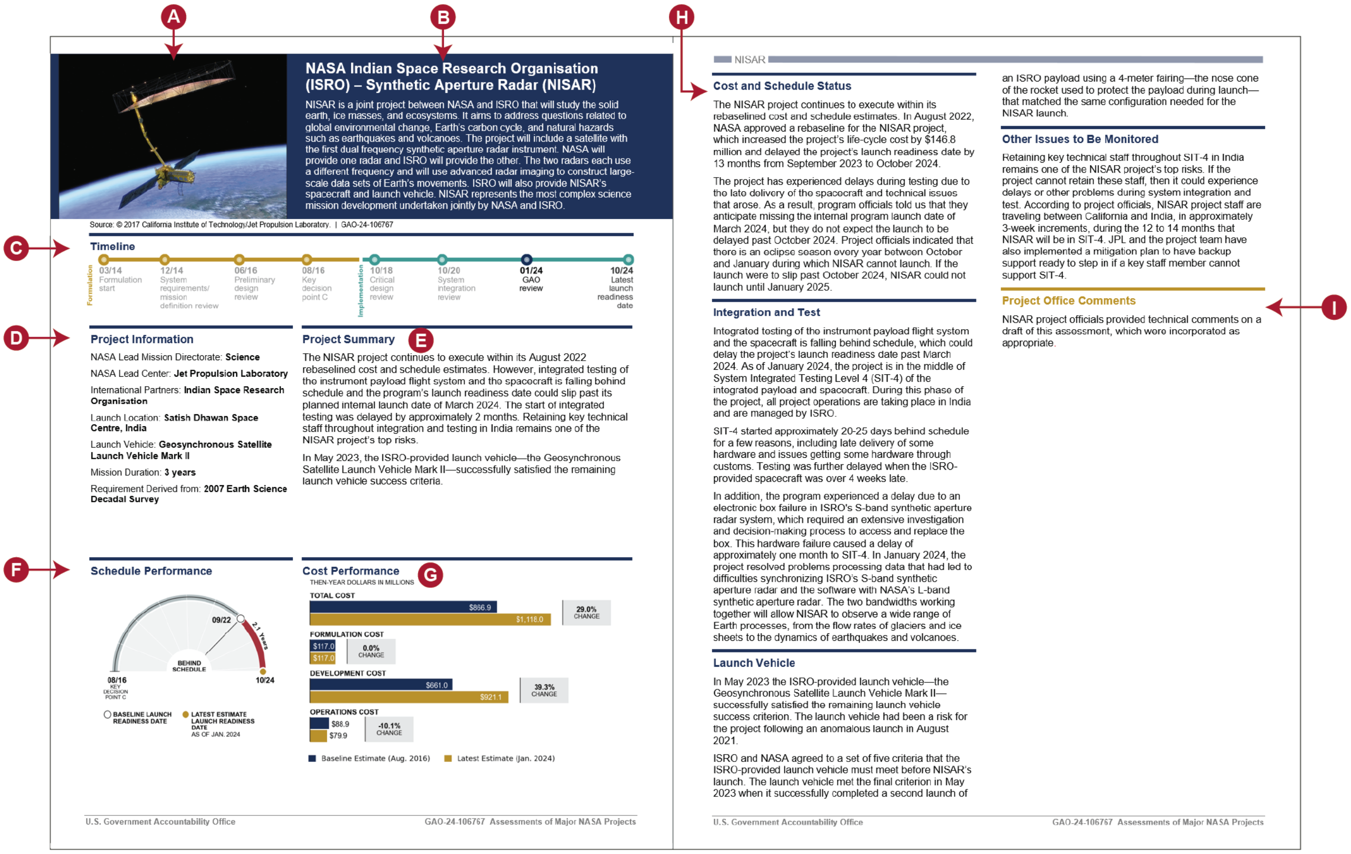
In the following section, we present 39 assessments:

- There are 24 individual assessments in a two-page or one-page profile format. Each of these assessments generally includes a description of the project or program's objectives; information about the NASA centers and international partners involved in the project; the project's cost and schedule performance; a timeline identifying key project dates; and a brief narrative describing the current status of the project. We provide assessments for projects and programs that have proceeded past their preliminary design review or that NASA has designated as category 1. These assessments also describe the challenges we identified and include an analysis of these challenges. In addition, we outline the extent to which each project faces cost, schedule, or performance risks because of these challenges, if applicable.
- There are 12 abbreviated assessments for projects that are early in formulation—or have not yet held preliminary design review—and that NASA has not designated as category 1. These assessments include a project description and preliminary cost and schedule estimates, if available.
- We also included three summaries. The first is a summary of NASA's Artemis missions, including the projects involved and timing of each mission, as well as a description of the mission. We also have summaries of the Gateway program and the Extravehicular Activity and Human Surface Mobility Program.

We provided NASA's project offices with an opportunity to review drafts of the assessments and summaries prior to their inclusion in this report. The project offices provided both technical corrections and general comments. We integrated the technical corrections, as appropriate, and summarized the general comments at the end of each project assessment and summary.

See figure 8 for an illustration of a sample assessment layout. Additional source information for images and figures can be found in appendix IX.

Figure 8: Illustration of a Sample Project Assessment



NASA Indian Space Research Organisation (ISRO) – Synthetic Aperture Radar (NISAR)

NISAR is a joint project between NASA and ISRO that will study the solid earth, ice masses, and ecosystems. It aims to address questions related to global environmental change, Earth's carbon cycle, and natural hazards such as earthquakes and volcanoes. The project will include a satellite with the first dual frequency synthetic aperture radar instrument. NASA will provide one radar and ISRO will provide the other. The two radars each use a different frequency and will use advanced radar imaging to construct large-scale data sets of Earth's movements. ISRO will also provide NISAR's spacecraft and launch vehicle. NISAR represents the most complex science mission development undertaken jointly by NASA and ISRO.

Source: © 2017 California Institute of Technology/Jet Propulsion Laboratory. | GAO-24-106767

Timeline

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **Indian Space Research Organisation**

Launch Location: **Satish Dhawan Space Centre, India**

Launch Vehicle: **Geosynchronous Satellite Launch Vehicle Mark II**

Mission Duration: **3 years**

Requirement Derived from: **2007 Earth Science Decadal Survey**

Project Summary

The NISAR project continues to execute within its August 2022 rebaselined cost and schedule estimates. However, integrated testing of the instrument payload flight system and the spacecraft is falling behind schedule and the program's launch readiness date could slip past its planned internal launch date of March 2024. The start of integrated testing was delayed by approximately 2 months. Retaining key technical staff throughout integration and testing in India remains one of the NISAR project's top risks.

In May 2023, the ISRO-provided launch vehicle—the Geosynchronous Satellite Launch Vehicle Mark II—successfully satisfied the remaining launch vehicle success criteria.

Schedule Performance

Cost Performance

U.S. Government Accountability Office GAO-24-106767 Assessments of Major NASA Projects

NISAR

Cost and Schedule Status

The NISAR project continues to execute within its rebaselined cost and schedule estimates. In August 2022, NASA approved a rebaseline for the NISAR project, which increased the project's life-cycle cost by $146.8 million and delayed the project's launch readiness date by 13 months from September 2023 to October 2024.

The project has experienced delays during testing due to the late delivery of the spacecraft and technical issues that arose. As a result, program officials told us that they anticipate missing the internal program launch date of March 2024, but they do not expect the launch to be delayed past October 2024. Project officials indicated that there is an eclipse season every year between October and January during which NISAR cannot launch. If the launch were to slip past October 2024, NISAR could not launch until January 2025.

Integration and Test

Integrated testing of the instrument payload flight system and the spacecraft is falling behind schedule, which could delay the project's launch readiness date past March 2024. As of January 2024, the project is in the middle of System Integrated Testing Level 4 (SIT-4) of the integrated payload and spacecraft. During this phase of the project, all project operations are taking place in India and are managed by ISRO.

SIT-4 started approximately 20-25 days behind schedule for a few reasons, including late delivery of some hardware and issues getting some hardware through customs. Testing was further delayed when the ISRO-provided spacecraft was over 4 weeks late.

In addition, the program experienced a delay due to an electronic box failure in ISRO's S-band synthetic aperture radar system, which required an extensive investigation and decision-making process to access and replace the box. This hardware failure caused a delay of approximately one month to SIT-4. In January 2024, the project resolved problems processing data that had led to difficulties synchronizing ISRO's S-band synthetic aperture radar and the software with NASA's L-band synthetic aperture radar. The two bandwidths working together will allow NISAR to observe a wide range of Earth processes, from the flow rates of glaciers and ice sheets to the dynamics of earthquakes and volcanoes.

Launch Vehicle

In May 2023 the ISRO-provided launch vehicle—the Geosynchronous Satellite Launch Vehicle Mark II—successfully satisfied the remaining launch vehicle success criterion. The launch vehicle had been a risk for the project following an anomalous launch in August 2021.

ISRO and NASA agreed to a set of five criteria that the ISRO-provided launch vehicle must meet before NISAR's launch. The launch vehicle met the final criterion in May 2023 when it successfully completed a second launch of an ISRO payload using a 4-meter fairing—the nose cone of the rocket used to protect the payload during launch—that matched the same configuration needed for the NISAR launch.

Other Issues to Be Monitored

Retaining key technical staff throughout SIT-4 in India remains one of the NISAR project's top risks. If the project cannot retain these staff, then it could experience delays or other problems during system integration and test. According to project officials, NISAR project staff are traveling between California and India, in approximately 3-week increments, during the 12 to 14 months that NISAR will be in SIT-4. JPL and the project team have also implemented a mitigation plan to have backup support ready to step in if a key staff member cannot support SIT-4.

Project Office Comments

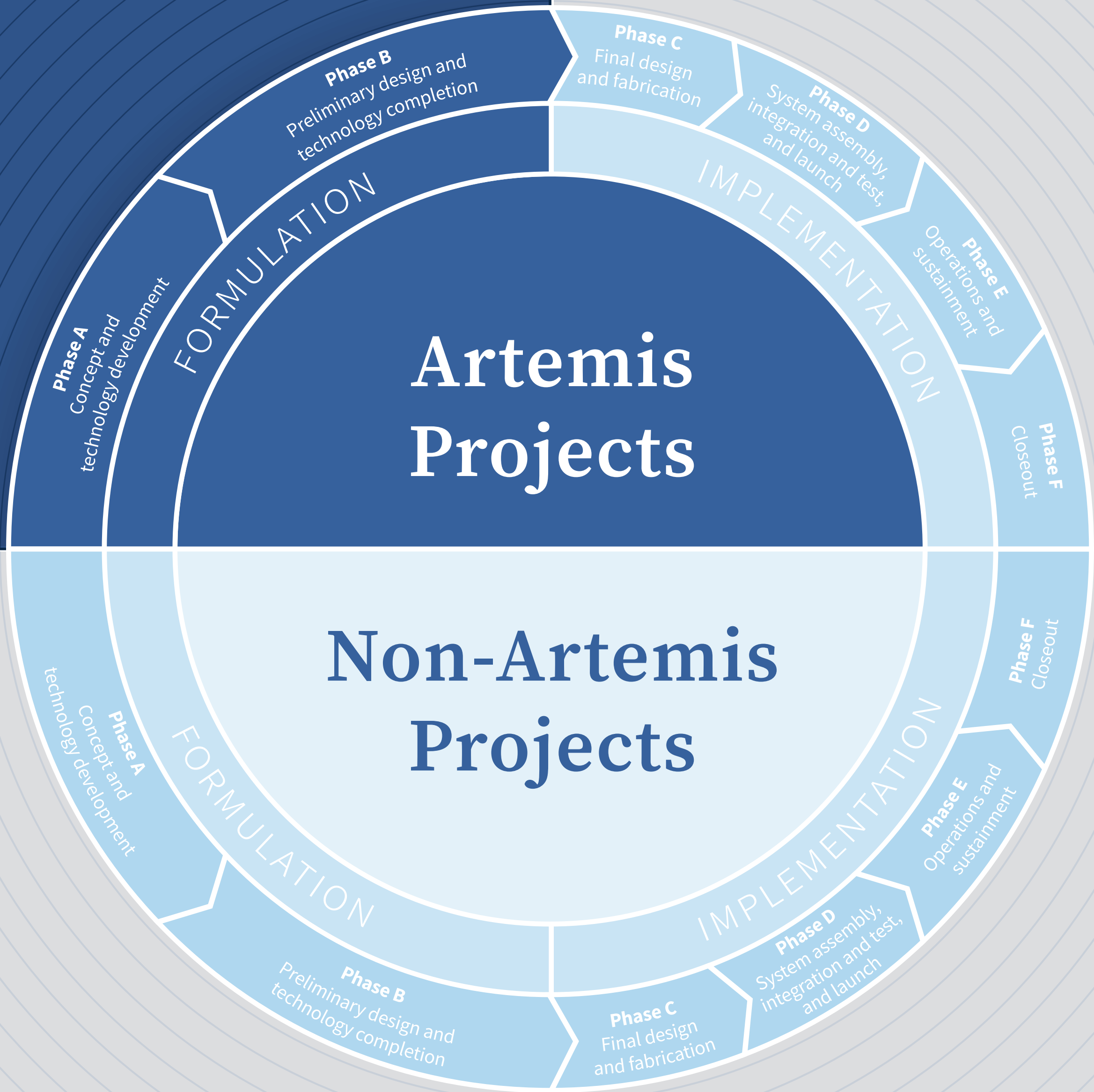
NISAR project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

U.S. Government Accountability Office GAO-24-106767 Assessments of Major NASA Projects

- A Illustration of the spacecraft, instrument, aircraft, launch vehicle, ground system, or space suit.
- B General description of the mission's objectives.
- C **Timeline** identifying key dates for the project including when the project began formulation, held major design reviews, began implementation after key decision point (KDP) C, and launched or fielded an operating capability.
- D **Project Information:** Information on the responsible NASA center and lead mission directorate, international partners, launch plans, mission duration, and the source of the mission's requirements.
- E **Project Summary:** Brief narrative describing the current status of the project.
- F **Schedule:** For projects in formulation, the preliminary launch readiness target date or range of dates. For projects in implementation, the approved schedule baseline and latest estimate.
- G **Cost:** For projects in formulation, the preliminary cost estimate. For projects in implementation, the approved cost baseline and latest estimate.
- H The second page of the assessment is an analysis of the project challenges and the extent to which each project faces cost, schedule, or performance risks because of these challenges.
- I **Project Office Comments:** General comments provided by the cognizant project office.

Source: GAO analysis. | GAO-24-106767

- Extravehicular Activity and Human Surface Mobility Program **(EHP)**
- EHP – Extravehicular Activity **(EVA)** Development (Artemis Space Suits)
- EHP - EVA Development (International Space Station Space Suits)
- EHP – Lunar Terrain Vehicle **(LTV)**
- Human Landing System **(HLS)** – Sustaining Lunar Development **(SLD)**
- Mobile Launcher 2 **(ML2)**



Source: GAO analysis of NASA data. | GAO-24-106767

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Artemis

MAJOR NASA PROJECTS AND PROGRAMS SUPPORTING ARTEMIS MISSIONS

NASA broadly refers to its series of missions to return astronauts into lunar orbit and onto the lunar surface as Artemis. These missions—illustrated in the timeline below and on the following page—require extensive coordination across NASA programs, contractors, and international partners. Initial missions will focus on establishing a long-term presence around the moon and later missions will focus on sending the first astronauts to Mars.

11/22

ARTEMIS I

PROGRAMS

SLS Block 1
Orion
EGS

NASA successfully launched an uncrewed Orion spacecraft on top of the SLS vehicle on November 16, 2022. During the Artemis I mission, the spacecraft traveled to a distant orbit some 70,000 kilometers beyond the moon before returning to Earth on December 11, 2022.

09/25

ARTEMIS II

PROGRAMS

SLS Block 1
Orion
EGS

The Artemis II mission will be a 10- to 14-day crewed flight with up to four astronauts. The crew will perform a lunar flyby and return to Earth to demonstrate the baseline Orion spacecraft capability ahead of a crewed lunar landing.

09/26

ARTEMIS III

PROGRAMS

SLS Block 1
Orion
EGS
HLS – Initial Capability
EHP - EVA Development
VIPER*

The Artemis III mission will be a crewed lunar landing mission. The Orion spacecraft will transport crew from Earth to a lunar orbit, where it will dock with the HLS. The HLS will take crew, who will wear new space suits, to the lunar surface to conduct operations. The HLS will then return crew back to the Orion spacecraft, which will transport them back to Earth.

**NASA plans to use the scientific data that VIPER collects to inform the first global water resources map of the moon and the Artemis III lunar landing site decisions.*

Legend:
Extravehicular Activity **(EVA)**
Exploration Ground Systems **(EGS)**
Extravehicular Activity and Human Surface Mobility Program **(EHP)**
Human Landing System **(HLS)**
Orion Multi-Purpose Crew Vehicle **(Orion)**
Space Launch System **(SLS)**
Volatiles Investigating Polar Exploration Rover **(VIPER)**

Source: GAO analysis of NASA documentation (data and images); manuelhuss/stock.adobe.com (moon image); NASA (Artemis logo). | GAO-24-106767


Human Landing System - Starship

09/28

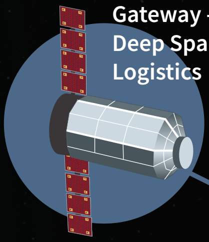
ARTEMIS IV

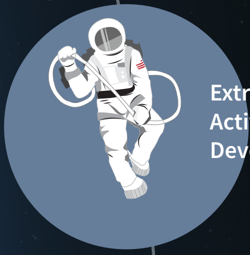
PROGRAMS

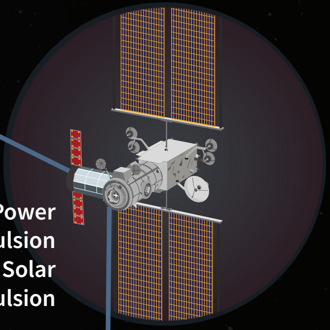
SLS Block 1B
Orion
EGS: ML2
HLS – SLD
EHP - EVA Development
Gateway: PPE, HALO, DSL, I-HAB
SEP

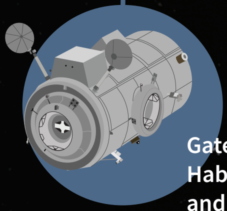
The Artemis IV mission will be a lunar orbiting and lunar landing mission. Prior to the mission, NASA plans to launch Gateway's PPE and HALO into a lunar orbit. The PPE will demonstrate the use of high-power solar electric propulsion thrusters that the SEP project is qualifying.

For the mission, NASA plans to launch the I-HAB component of the Gateway and the Orion spacecraft, which will contain the crew. This will be the first launch of the SLS Block 1B rocket using ML2. The crew will help integrate I-HAB with the HALO. The I-HAB is an international contribution that will provide additional living space to crew on the Gateway. NASA also plans to use a DSL flight to deliver cargo and other equipment to the Gateway. NASA will use a sustainable version of the human landing system to take the crew to the lunar surface.


Gateway - Deep Space Logistics


Extravehicular Activity Development


Gateway - Power and Propulsion Element with Solar Electric Propulsion


Gateway - Habitation and Logistics Outpost

03/30

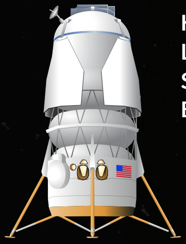
ARTEMIS V

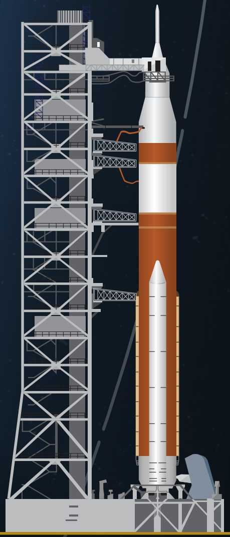
PROGRAMS

SLS Block 1B
Orion
EGS: ML2
HLS – SLD
EHP - EVA Development, LTV
Gateway: PPE, HALO, DSL, I-HAB, ESPRIT-RM, GERS
LTV

The Artemis V mission adds two internationally contributed modules to the Gateway—ESPRIT-RM and GERS—and is a lunar landing mission.

This mission will use a sustainable version of a human landing system from a second provider to take crew to the lunar surface. NASA plans to deliver the LTV to the lunar surface for crew use during lunar exploration activities.


Human Landing System - Blue Moon


Space Launch System Block 1B & Mobile Launcher 2

Legend:
Deep Space Logistics **(DSL)**
European System Providing Refueling, Infrastructure, and Telecommunications Refueler Module **(ESPRIT-RM)**
Extravehicular Activity **(EVA)**
Exploration Ground Systems **(EGS)**
Extravehicular Activity and Human Surface Mobility Program **(EHP)**
Gateway External Robotic System **(GERS)**
Habitation and Logistics Outpost **(HALO)**
Human Landing System **(HLS)**
International Habitat **(I-HAB)**
Lunar Terrain Vehicle **(LTV)**
Mobile Launcher 2 **(ML2)**
Orion Multi-Purpose Crew Vehicle **(Orion)**
Power and Propulsion Element **(PPE)**
Solar Electric Propulsion **(SEP)**
Space Launch System **(SLS)**
Sustaining Lunar Development **(SLD)**

Source: GAO analysis of NASA documentation (data and images); manuelhuss/stock.adobe.com (moon image) SpaceX (Starship image) and Blue Origin (Blue Moon image). | GAO-24-106767

Source: NASA. | GAO-24-106767

Extravehicular Activity and Human Surface Mobility Program (EHP)

EHP oversees the development of space suits and associated tools to support activities on the International Space Station (ISS), and modernized space suits and human surface mobility systems for lunar exploration activities during the Artemis missions. The program consists of two major projects: Extravehicular Activity (EVA) Development (space suits) and Lunar Terrain Vehicle (LTV). In 2022, NASA issued task orders to two contractors, Axiom Space and Collins Aerospace, to begin the demonstration and certification effort for the modernized space suits for the Artemis III mission and ISS, respectively. NASA selected three vendors for LTV system contract awards in March 2024.

Project Information

NASA-developed EHP projects:

- **EVA Development project**
- **LTV**

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

International Partners: **None**

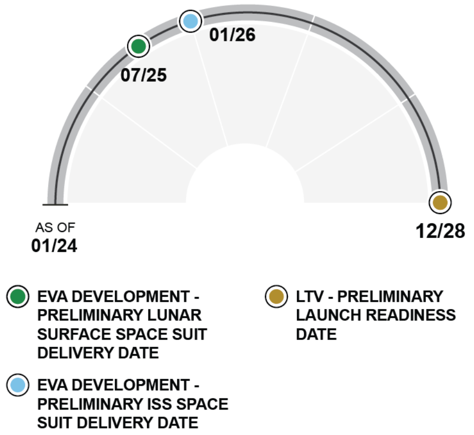
Current Status

NASA established EHP in December 2021 to oversee several related projects at one NASA center. In October 2023, EHP concluded its key decision point I milestone and entered the implementation phase for both projects. NASA is planning to acquire the space suits and associated tools and the LTV as services. NASA officials reported awarding additional task orders to Axiom and Collins in June 2023, for limited development on ISS and Artemis III suits, respectively, so each can act as a backup capability for the other to mitigate the risk of contractor performance issues. The EVA Development project plans to hold a preliminary design review-informed sync review in June 2024 to determine whether the project can meet its mission goals.

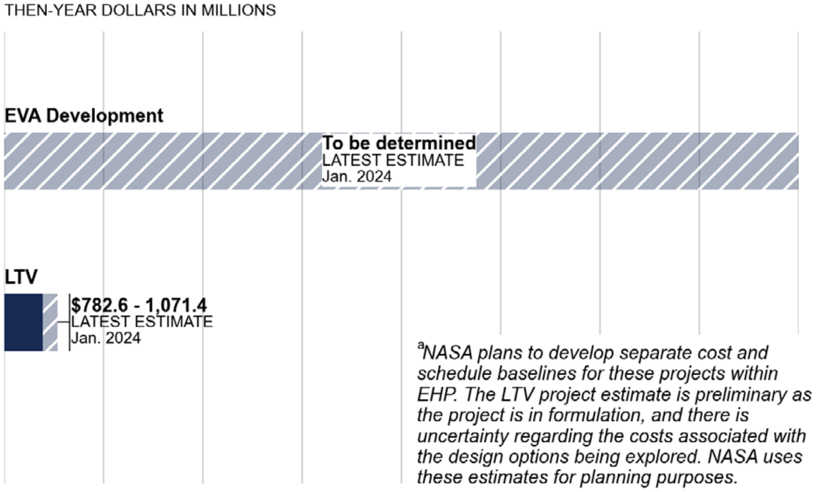
EHP was also responsible for overseeing development of a pressurized rover. In August 2023, NASA and the Japanese Aerospace Exploration Agency (JAXA) decided that JAXA will develop the rover and NASA will provide the lunar landing service. Accordingly, the rover is not included in our analysis.

The Artemis space suits are required for human exploration of the moon. The new ISS suit will replace an aging fleet of suits to provide extravehicular activity capability to maintain the ISS. NASA intends for the LTV to provide crewed and uncrewed transport on the lunar surface to enhance exploration for the Artemis V mission, currently planned for 2030.

Preliminary Schedule



Preliminary Cost[a]



[a] NASA plans to develop separate cost and schedule baselines for these projects within EHP. The LTV project estimate is preliminary as the project is in formulation, and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.

Project Office Comments

EHP officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

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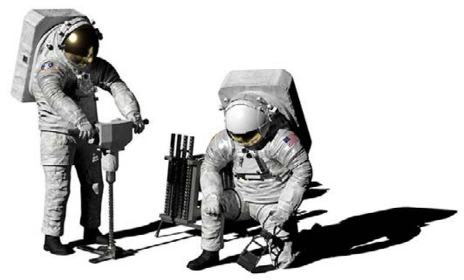
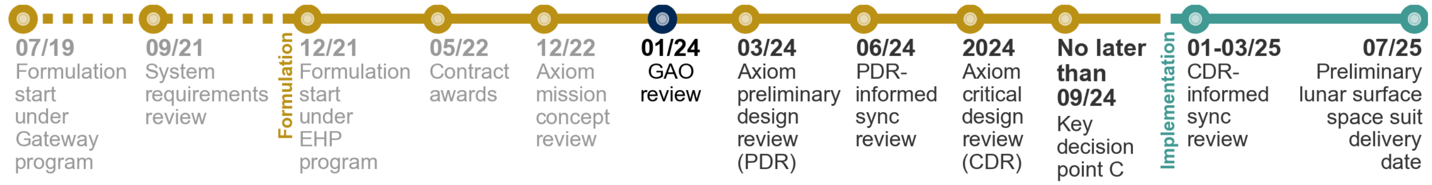


Source: NASA. | GAO-24-106767

Extravehicular Activity and Human Surface Mobility Program (EHP) – Extravehicular Activity (EVA) Development Project (Artemis Space Suits)

The EVA Development project is responsible for providing space suits and other hardware to support astronaut activities, referred to as EVAs, on the lunar surface for Artemis missions. The project office is overseeing contractors that will demonstrate, certify, and deliver: (1) tools the crew will use for lunar science and maintenance tasks; (2) interfaces the crew will use to connect to other systems, like the Human Landing System (HLS); and (3) space suits, including the portable life-support backpack and the pressurized garment that wraps around the astronauts. EHP manages the EVA Development project.

Timeline



07/19 Formulation start under Gateway program

09/21 System requirements review

12/21 Formulation start under EHP program

05/22 Contract awards

12/22 Axiom mission concept review

01/24 GAO review

03/24 Axiom preliminary design review (PDR)

06/24 PDR-informed sync review

2024 Axiom critical design review (CDR)

No later than 09/24 Key decision point C

01-03/25 CDR-informed sync review

07/25 Preliminary lunar surface space suit delivery date

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

International Partners: **None**

Launch Location: **N/A**

Launch Vehicle: **N/A**

Mission Duration: **5 years**

Requirement Derived from: **NASA Strategic Plan**

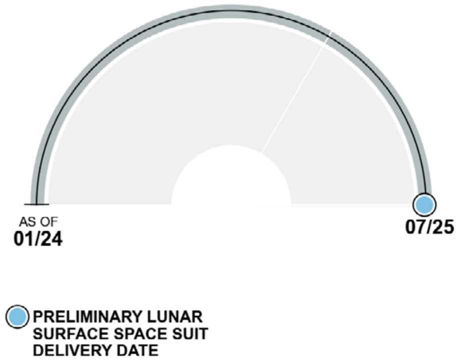
Project Summary

In 2022, NASA awarded indefinite-delivery, indefinite-quantity contracts to Axiom Space and Collins Aerospace, the scope of which includes the development and delivery of modernized space suits. The contracts set a minimum combined value of services to be ordered at nearly $1.3 billion and a maximum amount of $3.1 billion each. In September 2022, the project ordered the development and demonstration of a suit for lunar surface activities, from Axiom for $229 million. In June 2023, NASA issued an additional task order to Collins with a base value of $5 million to support a backup suit capability up to mission concept review to mitigate any risk of performance-related issues with Axiom.

Axiom successfully completed the crewed capability assessment in preparation for the preliminary design review. Project officials stated Axiom completed the preliminary design review in March 2024, 4 months later than originally planned.

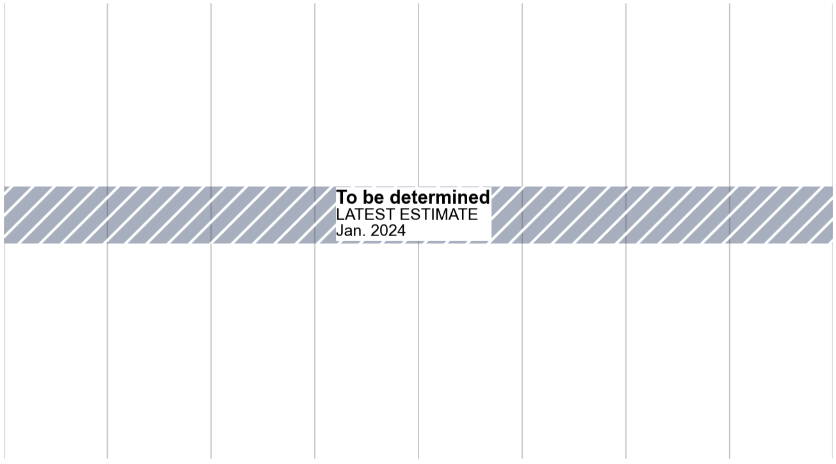
The project's top risks include changes to hardware, costs, and schedule as a result of undefined requirements for navigation and lighting, among other things, on the Artemis III mission. Additionally, Axiom is developing specialty hiring plans to address gaps in its workforce.

Preliminary Schedule



Preliminary Cost

THEN-YEAR DOLLARS IN MILLIONS



Cost and Schedule Status

In 2022, NASA awarded firm-fixed-price indefinite-delivery, indefinite-quantity contracts to Axiom and Collins Aerospace to provide safe and reliable commercial extravehicular activity services in a micro-gravity environment for the Artemis missions. The contracts set a minimum combined value of services to be ordered at nearly $1.3 billion and a maximum amount of $3.1 billion each. In September 2022, the project ordered the development and demonstration of a suit for lunar surface activities from Axiom for $229 million. Axiom is required to demonstrate a spacesuit that allows crew to successfully perform exploration and science missions on the lunar surface during the Artemis III mission, currently planned for September 2026.

To address the risk that Axiom might encounter performance issues, in June 2023, NASA issued an additional task order to Collins with a $5 million base value to initiate limited development of a backup lunar suit. Collins plans to conduct a mission concept review in April 2024.

Axiom and NASA began discussions to support preliminary design review in October 2023. Project officials stated that Axiom completed the preliminary design review in March 2024.

Axiom is currently assessing the planned critical design review date in 2024. The date is under review due to the delay in completing the preliminary design review and supply chain readiness to build a space suit assembly for a human-in-the-loop vacuum chamber test that simulates the space environment. This test is required to close the critical design review. As of January 2024, Axiom reported 11 months of schedule risk to completing this test, potentially pushing the critical design review into 2025. Axiom representatives said they have several mitigations to address this risk.

The EVA Development project plans to complete a preliminary design review-informed sync review in June 2024 before key decision point C, and then hold a critical design review-informed sync review in early 2025, or after completion of the contractors' critical design reviews. Project officials said the preliminary design review-informed sync review is when the agency will consider whether the project can meet its mission goals and determine if the project is effectively managed.

Technology and Design

Axiom completed a mission concept review for the Artemis space suits in December 2022. During this review, Axiom presented key management plans and tools needed for successfully developing the suit and its components. In October 2023, Axiom completed the crew capability assessment—which demonstrated the crew's ability to perform tasks in a high-fidelity prototype—using NASA's Partial Gravity Simulator and met all of the test objectives.

Additionally, NASA is addressing flammability concerns on the suit at the required pressure and oxygen saturation levels. To address material flammability concerns, NASA is conducting various atmospheric tests and ignition source mapping to better understand the risk.

Axiom is also addressing risks related to having sole-source suppliers for certain components. Some suit components have a limited number of suppliers globally; if those suppliers go out of business, Axiom will need to find other sources for the parts. This can take time or require design changes. For example, Axiom representatives told us that the company that provided the coating for the helmet went out of business, which required Axiom to find an alternative solution. To address this issue, Axiom representatives stated that they found another supplier of these coatings and in this case were able to avoid a schedule delay.

Collins is currently developing modernized suits for the International Space Station. Representatives said that they are designing their suit to be mostly dual use, with some minimal redesign needed for the Artemis suit based on the lunar environment.

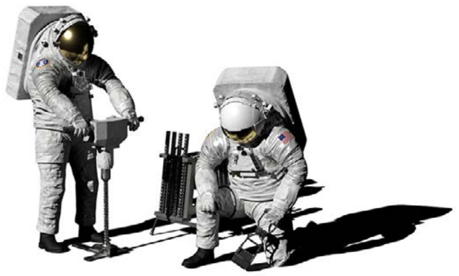
Other Issues to Be Monitored

The project stated that its top risks are related to Artemis III requirements that have not yet been determined, which could result in potential changes to hardware, costs, and schedule. For example, NASA documentation states that many of the navigation and lighting specifications have not yet been determined. To mitigate this risk, the program is reviewing requirements documentation and developing a process to assess and communicate the effects of adding any new requirements. The project stated that cost threats and reserves are managed at the EHP program level.

Additionally, Axiom is working to address workforce gaps in its specialized technical disciplines. NASA and Axiom established meetings between contractor and NASA subject matter experts to cover gaps in technical expertise. Axiom is still working to establish hiring plans for the additional personnel it needs.

Project Office Comments

EVA Development project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Source: NASA. | GAO-24-106767

Extravehicular Activity and Human Surface Mobility Program (EHP) – Extravehicular Activity (EVA) Development Project (International Space Station (ISS) Space Suits)

The EVA Development project is responsible for providing space suits and other hardware to support astronaut activities, referred to as EVAs, on the ISS. The project office is overseeing contractors that will demonstrate, certify, and deliver: (1) tools the crew will use for science and maintenance tasks; (2) interfaces the crew will use to connect to other systems, like the ISS; and (3) space suits, including the portable life-support backpack and the pressurized garment that wraps around the astronauts. EHP manages the EVA Development project.

Timeline

- **07/19** Formulation start under Gateway program
- **09/21** System requirements review
- Formulation
- **12/21** Formulation start under EHP program
- **05/22** Contract awards
- **04/23** Collins mission concept review
- **01/24** GAO review
- **04/24** Collins preliminary design review (PDR)
- **06/24** PDR-informed sync review
- **No later than 09/24** Key decision point C
- Implementation
- **2024** Collins critical design review (CDR)
- **01-03/25** CDR-informed sync review
- **01/26** Preliminary ISS space suit delivery date

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

International Partners: **None**

Launch Location: **N/A**

Launch Vehicle: **N/A**

Mission Duration: **5 years**

Requirement Derived from: **NASA Strategic Plan**

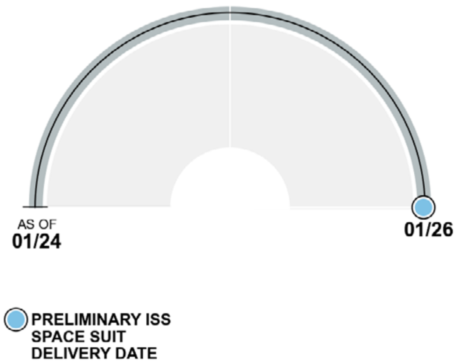
Project Summary

In December 2022, NASA issued a task order to Collins Aerospace to begin the demonstration and certification effort for ISS suits. The task order included two options. The first option covers post-critical design review through the ISS demonstration milestone. Collins completed its combined mission concept review and certification baseline review in April 2023 and plans to complete its preliminary design review in April 2024.

In June 2023, NASA issued Axiom a task order with a base value of $5 million to initiate ISS suit development through the certification baseline review, with options to complete activities through the final certification review. NASA took this step to address the risk that Collins might encounter performance issues.

The project's top risks for the ISS suit include awarding a service contract for producing the ISS suit before completing development and demonstrating the ISS suit, and the contractor's challenges with obtaining radiation-hardened components. Collins is working to mitigate supplier risks by acquiring commercial grade components and testing them for suitability.

Preliminary Schedule



Preliminary Cost

THEN-YEAR DOLLARS IN MILLIONS

Cost and Schedule Status

In May 2022, the project awarded firm-fixed-price indefinite-delivery, indefinite-quantity contracts to Axiom Space and Collins Aerospace.[34] In December 2022, the project issued a task order to Collins to begin the demonstration and certification effort for the ISS suit. The firm-fixed-price task order had a base value of $97.2 million for work through critical design review. The task order included two options. The first option covers post-critical design review through the ISS demonstration milestone. The second option covers post-ISS demonstration through the ISS certification review milestone.

Collins completed its combined mission concept review and certification baseline review in April 2023 and plans to complete its preliminary design review in April 2024. According to NASA officials, Collins delayed completion of its preliminary design review from June 2023 to April 2024 due to a notable amount of incomplete work. NASA officials said that Collins had to resubmit a number of documents because those items did not meet NASA's requirements for quality and completeness. A Collins representative said Collins had to rework these documents due to pushing to complete the work by the scheduled deadline. In December 2023, project officials also said that Collins would need to complete the crew capability assessment of the ISS suit, before it could conclude the preliminary design review. In January 2024, Collins completed the crew capability assessment in a manufactured zero-gravity environment onboard an aircraft. Collins also delayed completion of its critical design review in 2024 because it needs to acquire the hardware necessary to conduct a vacuum chamber test of the suit and due to delays in preliminary design review documents and approvals.

The EVA Development project plans to complete a preliminary design review-informed sync review in June 2024 before key decision point C and then hold a critical design review-informed sync review in early 2025. Project officials said the preliminary design review-informed sync review is when the agency will consider whether the project can meet its mission goals and determine if the project is effectively managed.

To address the risk that Collins might encounter performance issues, NASA issued a task order with a base value of $5 million to Axiom in June 2023 to initiate partial development of an ISS suit, with options to complete activities through the final certification review. According to NASA documentation, Axiom plans to conduct a combined mission concept and certification baseline review of its ISS suit in 2024.

Technology and Design

Prior to changing the project's acquisition strategy, NASA developed a government reference design of a modernized space suit, including building a test unit of the suit. The project took steps to complete most of the reference design and made the design publicly available for prospective contractors to use in their proposals. Project officials said Collins is not using the government reference design for its space suit. Those officials added that while Collins's design has similar basic architecture as NASA's, it is different at the component level and the logic of how the space suit works. Project officials said this is beneficial because if Collins was using NASA's reference design, it would be competing with Axiom for the same suppliers and parts, which may have resulted in additional schedule delays.

Axiom representatives said they will be modifying their Artemis lunar surface suit for the ISS. While the designs for the two suits are primarily the same, one difference is that the lunar boots will accommodate the need to operate in the lunar dust environment whereas the boots for the ISS suit do not need to meet that requirement.

Other Issues to Be Monitored

The project is tracking several risks related to ISS suit development. One of the project's top risks is that it will need to issue task orders for a contractor to produce suits for ISS missions prior to completing development and demonstrating the ISS suit. This could possibly result in spending funds on an unproven suit. NASA is planning to reduce this risk by including clauses in the task orders that are intended to protect the agency's resources if a successful demonstration is not achieved.

Additionally, project officials said that Collins is facing a risk related to obtaining long-lead radiation-hardened components. Officials said these components are difficult to source because they are expensive and require the contractor to purchase them far in advance. Collins is working to mitigate this supply risk by acquiring commercial grade components and testing them for suitability.

Project officials said that NASA is monitoring Collins's ability to complete the ISS demonstration by the planned date. According to these officials, it is important to meet this demonstration date because NASA transports crew to the ISS every 6 months—a delay to the demonstration date could affect which crew will be testing the space suits, which could affect crew training. Program officials said that NASA knew it would be challenging for Collins to meet the planned schedule because of issues with acquiring certain parts with long lead times and using different suppliers for some components.

Project Office Comments

EVA Development project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

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[34] An indefinite-delivery, indefinite-quantity contract provides for an indefinite quantity, within stated limits, of supplies or services during a fixed period. FAR 16.504(a). The government places orders for individual requirements. Id.

Source: Analytical Mechanics Associates. | GAO-24-106767

Extravehicular Activity and Human Surface Mobility Program (EHP) – Lunar Terrain Vehicle (LTV)

The LTV is a transportation system that will enable crew members to explore the lunar surface and allow NASA to conduct remote science operations. NASA intends for the LTV to be available for the Artemis V mission—planned for 2030—and future missions. In addition to serving as a mode of transportation, the LTV will: (1) transport and deploy small payloads; (2) conduct science operations with its robotic arm; (3) produce multimedia content of landings, points of interest, and crew activities; and (4) support science activities between crewed missions.

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

International Partners: **None**

Launch Location: **To be determined**

Launch Vehicle: **To be determined by LTV contractor(s)**

Mission Duration: **10 years**

Requirement Derived from: **Spacy Policy Directive 1, 2022 and NASA Strategic Plan**

Next Major Project Event: **Contract Award (March 2024)**

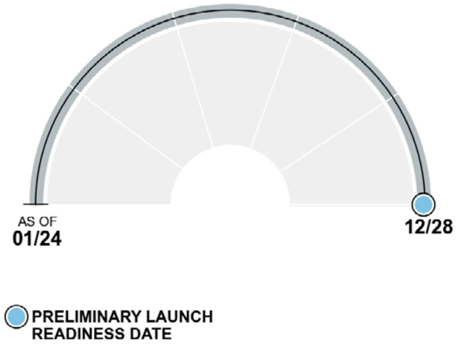
Current Status

In May 2023, NASA issued a solicitation for services to provide the LTV capability. The solicitation contemplated the award of one or more indefinite-delivery, indefinite-quantity contracts. The scope of the contract(s) would include the design, development, manufacture, testing, launch, and deployment of the LTV system. In March 2024, NASA selected three contractors for awards—Intuitive Machines, Lunar Outpost, and Astrolab.

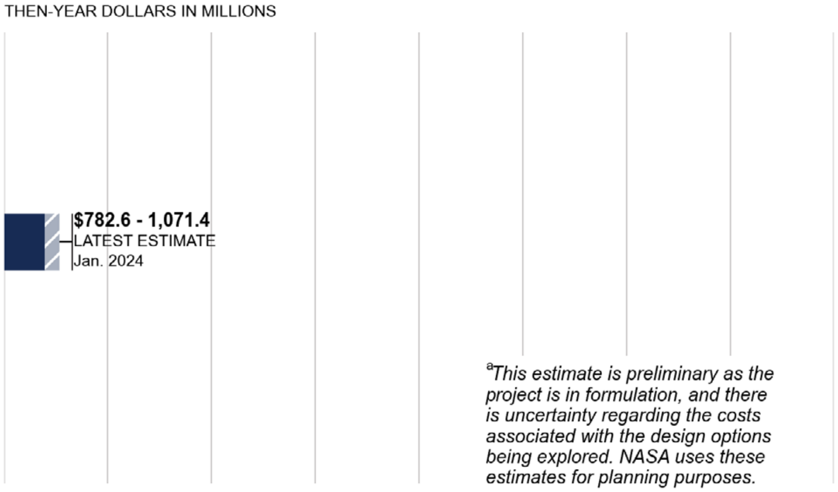
The project developed functional test hardware called the Ground Test Unit to serve as an adaptable proxy for contractor hardware, enabling NASA to develop testing protocols, evaluate operations, and understand risks and future training needs. The unit is drivable and being tested for crew use.

The project is tracking several risks. One risk reported by the project is related to insufficient funding for the LTV. To mitigate potential cost risks, project officials said there are cost reserves set aside at the EHP program level including for cybersecurity and additional subject matter experts. Additionally, the project is tracking the risk of an unsuccessful delivery of the LTV to the lunar surface because there may not be any prior lunar landing test flights with a lander of similar size, about 1-2 metric tons.

Preliminary Schedule



Preliminary Cost[a]



[a] *This estimate is preliminary as the project is in formulation, and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.*

Project Office Comments

LTV project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

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Source: SpaceX and Blue Origin. | GAO-24-106767

Human Landing System (HLS) – Sustaining Lunar Development (SLD)

The HLS program's SLD effort will demonstrate expanded capabilities beyond Artemis III to support a lasting crewed presence on the moon. These capabilities include transporting additional crew, docking with the Gateway—a sustainable outpost in lunar orbit—and operating near the lunar south pole for extended durations. SpaceX and Blue Origin will each develop lunar landers to deliver these expanded capabilities for the Artemis IV and V missions, respectively. NASA will certify that the providers' lunar lander designs meet NASA requirements and are safe for crew.

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Marshall Space Flight Center**

Launch Location: **Blue Origin – Cape Canaveral, FL; and SpaceX – Multiple Launch Locations**

Launch Vehicle: **Blue Origin – New Glenn; SpaceX – Super Heavy Booster**

Surface Mission Duration: **6-33 days**

Requirement Derived from: **Space Policy Directive 1**

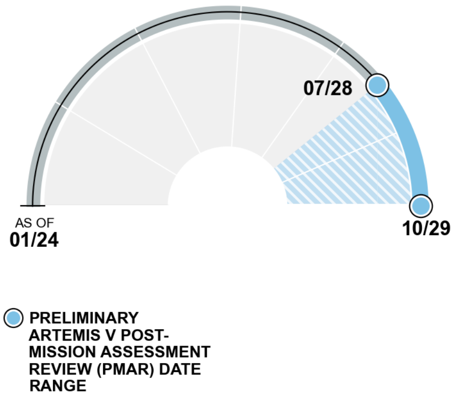
Next Major Project Event: **Preliminary Design Review**

Current Status

In November 2022, NASA awarded a modification valued at approximately $1.2 billion to its existing HLS contract with SpaceX to develop an SLD lander for the Artemis IV mission. In May 2023, NASA awarded a contract valued at approximately $3.4 billion, including options, to Blue Origin to develop an SLD lander for the Artemis V mission. SpaceX and Blue Origin held certification baseline reviews in May 2023 and November 2023, respectively. HLS officials said this review is the equivalent of a system requirements review, which ensures that the project's performance requirements and proposed system architecture or technical approach are aligned with the mission's performance requirements.

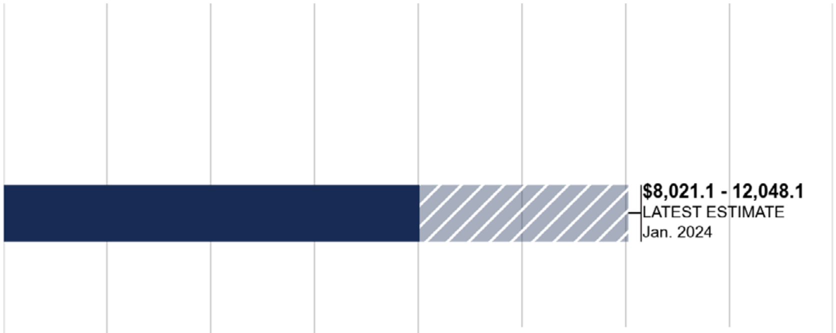
HLS officials said the program approved both reviews but identified additional work needed to address concerns. For example, the program found significant issues with SpaceX's supporting evidence that its mission can be achieved within schedule and acceptable risk. HLS officials noted that SpaceX's schedule lacked sufficient detail to assess progress, and, as a result, SpaceX agreed to provide more detailed schedule data for its SLD lander. The program also found that the Blue Origin lander needed additional work to align technical margins with schedule and known risks. Program officials said they expect Blue Origin to complete the additional work by the SLD preliminary design review.

Preliminary Schedule



Preliminary Cost[a]

THEN-YEAR DOLLARS IN MILLIONS



[a]This estimate is preliminary as the project is in formulation, and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.

Project Office Comments

HLS program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate. Officials noted that under the NASA contracts with SpaceX and Blue Origin, the Artemis IV and Artemis V post-mission assessment reviews will occur shortly after the completion of each crewed demonstration mission.

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Source: NASA. | GAO-24-106767

Mobile Launcher 2 (ML2)

ML2 is a project within the Exploration Ground Systems (EGS) program. It will provide a new launch platform and tower for the Space Launch System (SLS) Block 1B vehicle with the upgraded Exploration Upper Stage. The platform and tower support the SLS vehicle and Orion Multi-Purpose Crew Vehicle (Orion) spacecraft during vehicle stacking, transportation to the launch pad, and launch. In addition, ML2 provides all fuel, power, and environmental control connections to the vehicle up until launch.

Timeline

Formulation

- **Continued from EGS program** Formulation start
- **06/19** Contract signed
- **03/20** System requirements review
- **03/21 and 12/21** Preliminary design review steps 1 and 2
- **01/24** GAO review
- **01/24 and 04/24** Critical design review step 1 & 2
- **04/24** Key decision point C

Implementation

- **05-11/26** Bechtel delivery date range for ML2 hardware build

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Kennedy Space Center**

International Partners: **None**

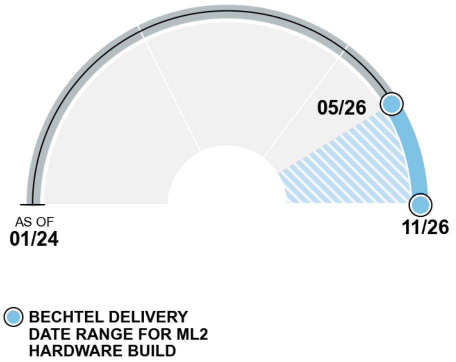
Requirement Derived from: **Consolidated Appropriations Act, 2018**

Project Summary

The ML2 project is still in the process of setting its cost and schedule baselines and NASA officials said they are negotiating contract changes with the prime contractor, Bechtel. NASA is targeting spring 2024 to set project cost and schedule baselines. In addition, NASA approved Bechtel to work to a November 2026 delivery date, which is 6 months later than the contract's delivery date. While Bechtel's current schedule is later than the preliminary estimated schedule for ML2, it supports a September 2028 Artemis IV launch readiness date.

NASA and Bechtel have made progress on ML2's design, steel fabrication, and construction. Bechtel held its contractor-level integrated critical design review (iCDR) in March 2023 and is working to address NASA's comments on the design. Bechtel started construction in August 2023, but as of January 2024, progress is slower than planned due to steel fabrication and delivery delays. According to NASA documentation, Bechtel has been mitigating these delays by resequencing construction activities and moving steel fabrication between subcontractors.

Preliminary Schedule



Preliminary Cost

THEN-YEAR DOLLARS IN MILLIONS

Cost and Schedule Status

The ML2 project is still in the process of setting its cost and schedule baselines and NASA officials said they are negotiating contract changes with Bechtel. NASA is targeting spring 2024 to set project cost and schedule baselines. According to NASA project officials, key decision point C has been delayed over 2½ years due to Bechtel's cost and schedule growth, changes in Bechtel management, weight concerns and associated redesigns, and most recently, steel fabrication delays. According to officials, as of December 2023, NASA's risk assessment for the ML2 contract exceeds Bechtel's risk-informed commitment. Officials said NASA and Bechtel are also negotiating a revision to the award fee plan to add milestone-based incentives in efforts to better motivate contractor performance improvement.

As of January 2024, Bechtel was working to a November 2026 delivery date, which is 6 months later than the contract's delivery date of May 2026. According to NASA officials, this date has been approved as an Over-Target Schedule delivery date. This delivery date supports the current Artemis IV launch date of September 2028. It also allows enough time for the 18 months NASA said that ML2 will need to support integrated testing with ground systems, as well as first-time processing and integration of the SLS Block 1B and ML2 before the planned launch.

Bechtel began steel construction for ML2 in August 2023, but as of January 2024, progress is slower than planned due to steel fabrication and delivery delays. NASA project officials stated that these delays are due to numerous factors, but the iterative nature of design is slowing things down relative to Bechtel's plan. Officials said that Bechtel provided initial drawings to fabricators to expedite long-lead steel development instead of waiting until designs were fully complete, but the original schedule did not reflect the resultant iteration. According to NASA documentation, Bechtel has been mitigating these delays by resequencing construction activities and moving steel fabrication between subcontractors. NASA officials said in December 2023 that momentum had picked up and once all required pieces are on site, construction can occur quickly.

Technology and Design

NASA is in the process of holding a two-step program-level CDR. NASA held Step 1 in January 2024, which was for hardware and programmatic content, and plans to hold Step 2 for software and verification and validation plans in April 2024.

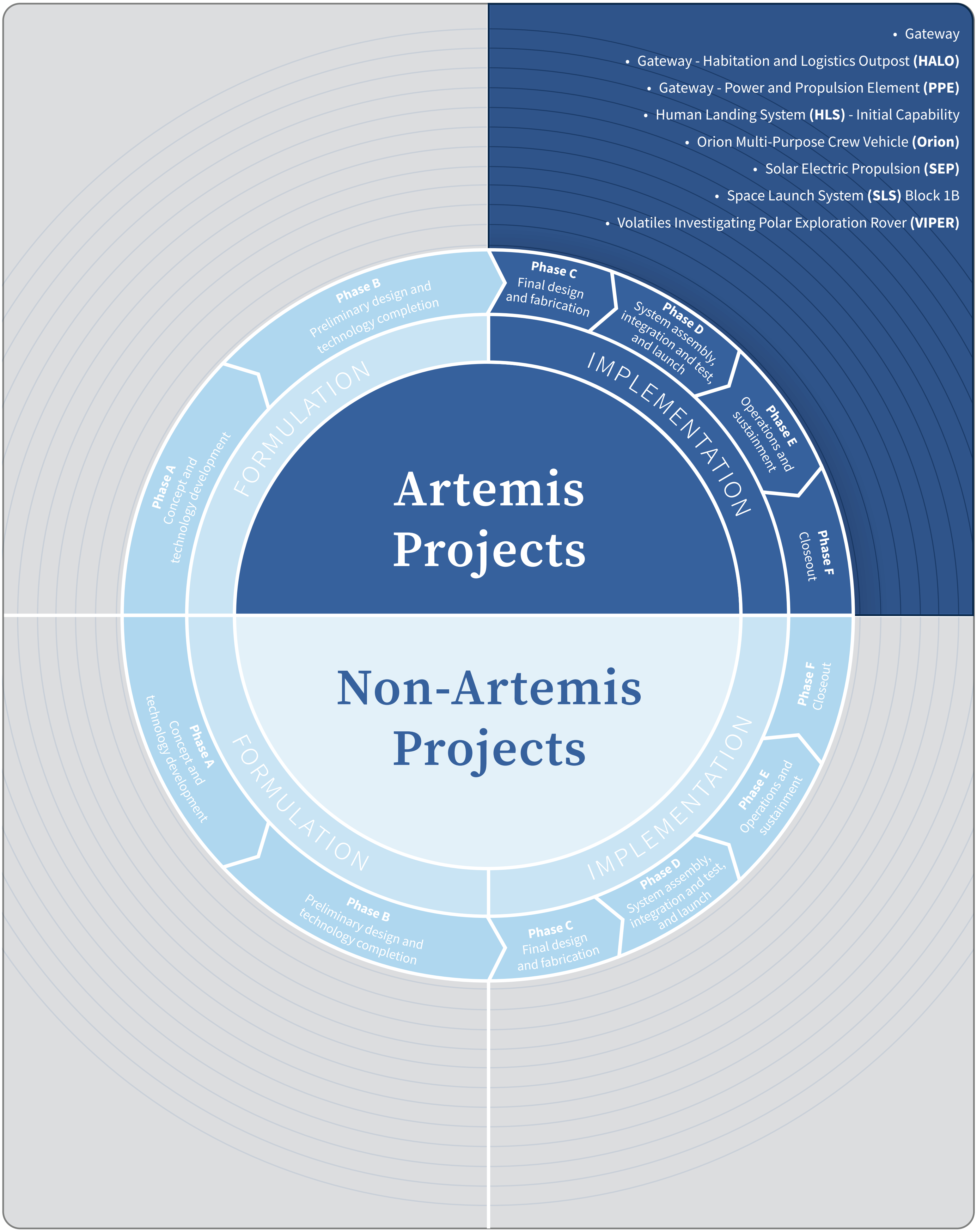
Bechtel successfully completed iCDR in March 2023. While NASA officials said the iCDR was successful, NASA had over 11,000 comments on Bechtel's design. NASA officials said that it is taking longer than expected for Bechtel to incorporate the comments into the design. As of January 2024, NASA anticipates that comments will be fully incorporated by April 2024. Further, Bechtel had not completed a key Mobile Launcher Structure design review before iCDR due to design analysis products taking longer than anticipated. NASA and Bechtel held this review in December 2023.

NASA is working with Bechtel to determine the extent to which new analysis may require modifications to the ML2 design. As a result of Artemis I launch post-flight data analysis, NASA officials determined that the SLS Block 1 vehicle created higher than anticipated launch induced loads, or forces, on the Mobile Launcher 1. An example of these higher than anticipated loads include the thermal environment experienced by the Mobile Launcher 1 as the SLS vehicle is launching. Officials said that since ML2's requirements are based on SLS Block 1B loads that are derived from Block 1, some requirements for the ML2 structure will need to change and additional steel reinforcements may be needed within the ML2 tower. This could add weight, but according to officials, it is too early to determine how much weight margin may be consumed. As of December 2023, the ML2 design is under its weight limit, with about 500,000 pounds of margin. NASA officials said conducting the analysis associated with the loads is a large effort and may result in government-driven cost growth.

NASA recently redesigned ML2's Vehicle Damper System (VDS), which is government-furnished equipment. The VDS is a stabilizing system that uses shock absorbers to keep the SLS launch vehicle from moving due to wind on the way to and at the launch pad. NASA originally planned to use ropes as the primary tension source, but officials said that the original design did not meet requirements during testing. The redesigned VDS uses a rigid arm that drops away for launch. Officials said the new design is simpler and does not add weight to the tower. According to officials, government costs for the VDS have remained the same and the redesign is not affecting the overall ML2 schedule.

Project Office Comments

In commenting on a draft of this assessment, ML2 project officials noted that since our review, the project has achieved some major milestones. For example, in May 2024, NASA and Bechtel completed Jack and Set, a major milestone where the primary base structure was moved to its permanent mount mechanisms. According to NASA, in order to complete this, the entire 2.6-million-pound skeleton of the base had to be fully torqued and welded. In addition, officials said the first three tower module structures have been erected. Officials also highlighted that completing the CDR Step 1 demonstrated NASA's confidence in the hardware design maturity and the program's cost and schedule. They noted that as of May 2024, ML2's CDR Step 2 had been delayed to June 2024; however, NASA officials said the milestone has no tangible effect on ML2 project progress. They also provided technical comments on a draft of this assessment, which were incorporated as appropriate.



- Gateway
- Gateway - Habitation and Logistics Outpost **(HALO)**
- Gateway - Power and Propulsion Element **(PPE)**
- Human Landing System **(HLS)** - Initial Capability
- Orion Multi-Purpose Crew Vehicle **(Orion)**
- Solar Electric Propulsion **(SEP)**
- Space Launch System **(SLS)** Block 1B
- Volatiles Investigating Polar Exploration Rover **(VIPER)**

Source: GAO analysis of NASA data. | GAO-24-106767

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Source: NASA. | GAO-24-106767

Gateway

The Gateway program aims to build a sustainable outpost in lunar orbit that will serve as a research platform, staging point for human and robotic exploration in deep space, and a technology test bed for future missions to Mars. It comprises multiple projects and is developing the outpost in two phases—initial and sustained. The initial capability includes the Power and Propulsion Element (PPE) and the Habitation and Logistics Outpost (HALO) to support the early Artemis missions using the Gateway. The sustained configuration adds additional NASA-led and international partner elements to support missions (see illustration on next page for the Gateway sustained configuration).

Project Information

NASA-developed Gateway elements

- **HALO**
- **PPE**
- **Deep Space Logistics (DSL)**

International partner contributions

- **International Habitat (I-HAB)**
- **European System Providing Refueling, Infrastructure, and Telecommunications Refueler Module (ESPRIT-RM)**
- **Gateway External Robotic System (GERS)**
- **H-II Transfer Vehicle-XG**
- **Crew and Science Airlock**

Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

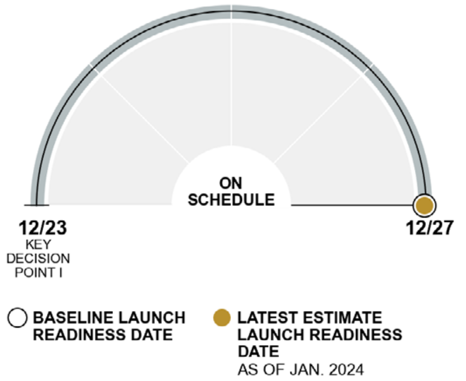
Current Status

In December 2023, NASA approved cost and schedule baselines for the Gateway's initial capability. The initial capability cost baseline is $5.3 billion. This includes the costs for the PPE, which will provide power and propulsion; the HALO, which will provide living space for crew; and the launch vehicle and program support for integration and launch. The schedule baseline for the comanifested vehicle launch—i.e., the PPE and HALO, which are launching on one vehicle—is December 2027. According to program officials, NASA will need to launch the Gateway initial capability at least a year before the Artemis IV mission date of September 2028. The program's baseline does not include the DSL project. NASA plans to establish separate cost and schedule baselines for this project.

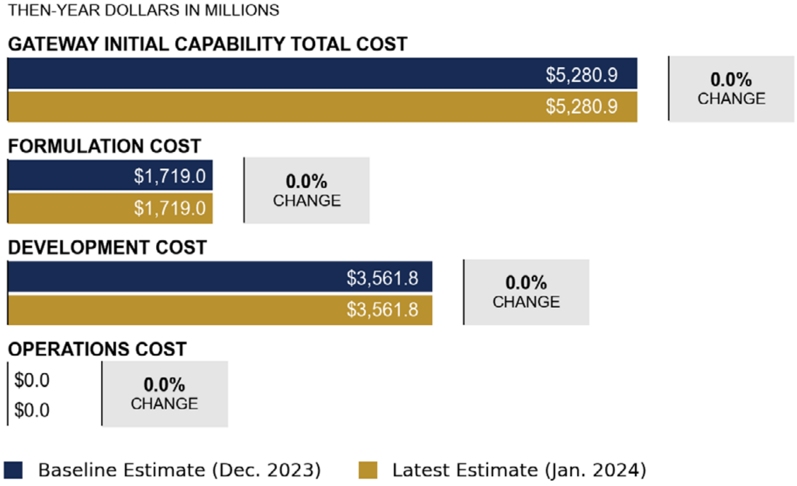
The DSL project is responsible for the execution of commercial services to deliver logistics vehicles that will provide the Gateway with cargo and supplies prior to crew arrival. In November 2023, NASA modified its contract with SpaceX to proceed with work to develop and build a logistics vehicle for the Artemis IV mission. The program plans to use the logistics delivery for Artemis IV to help address mass concerns for the PPE, HALO, and I-HAB, because the logistics vehicle can deliver cargo and equipment to the Gateway that previously needed to be launched on the HALO and I-HAB.

In January 2024, NASA and the Mohammed bin Rashid Space Centre of the United Arab Emirates finalized an agreement for the space centre to provide an airlock for Gateway.

Schedule Performance



Cost Performance

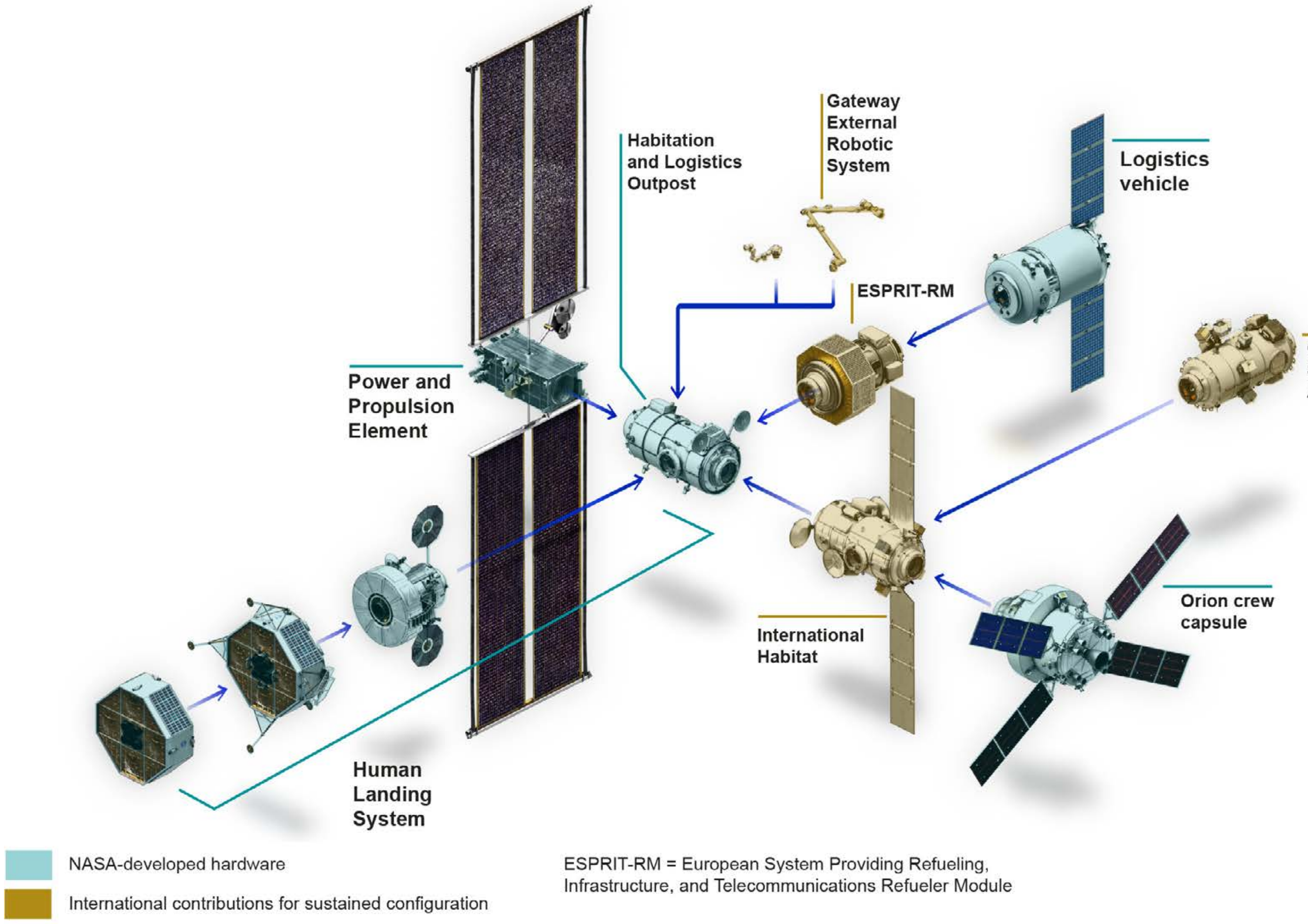


Gateway Initial and Sustained Configurations

The Gateway initial configuration includes the PPE and HALO elements. NASA plans to launch the PPE and the HALO in time to support the Artemis IV mission. During this mission, astronauts will arrive at the Gateway on the Orion Multi-Purpose Crew Vehicle (Orion), will help integrate the I-HAB with the HALO, and also conduct a lunar landing. The I-HAB will provide additional living space for crew on the Gateway.

The Gateway sustained configuration includes three U.S.-developed elements and four elements contributed by international partners. The illustration below shows the Orion crew capsule and a human landing system docked with the Gateway sustained configuration to support human lunar landing missions. The Orion crew capsule will transport crew from Earth to the Gateway, where they will transfer into a human landing system for transport to the lunar surface and back. After returning to the Gateway, the crew will return to Earth aboard the Orion crew capsule.

Illustration of the Orion Multi-Purpose Crew Vehicle and a Human Landing System Docked with the Gateway Sustained Configuration



ESPRIT-RM = European System Providing Refueling, Infrastructure, and Telecommunications Refueler Module

Source: GAO analysis of Gateway Program documentation (data); NASA (image). | GAO-24-106767

Note: The illustrations of the Human Landing System and Crew and Science Airlock are based on a government reference design.

Project Office Comments

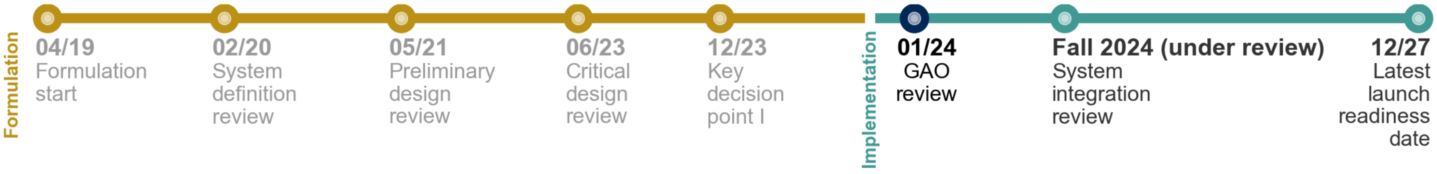
The Gateway program office was provided with a draft of this assessment and did not have any technical corrections or comments.

Source: NASA. | GAO-24-106767

Gateway – Habitation and Logistics Outpost (HALO)

The HALO will be the initial crew module for the Gateway. It will provide living quarters, as well as communication functions to the lunar surface and for visiting vehicles. It will also augment life support systems in conjunction with NASA's Orion Multi-Purpose Crew Vehicle. The HALO will also have docking ports to connect with other components. NASA plans to integrate the HALO and the Power and Propulsion Element (PPE) on the ground and launch them together, known as comanifesting. The HALO project is responsible for managing the integration, test, and launch of the comanifested PPE and HALO.

Timeline



Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

International Partners: **European Space Agency, Japan Aerospace Exploration Agency, Canadian Space Agency**

Launch Location: **Kennedy Space Center, FL**

Launch Vehicle: **Falcon Heavy**

Mission Duration: **15 years**

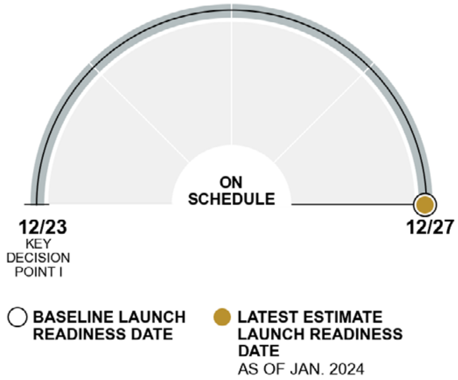
Requirement Derived from: **Space Policy Directive 1 and 2018 NASA Strategic Plan**

Project Summary

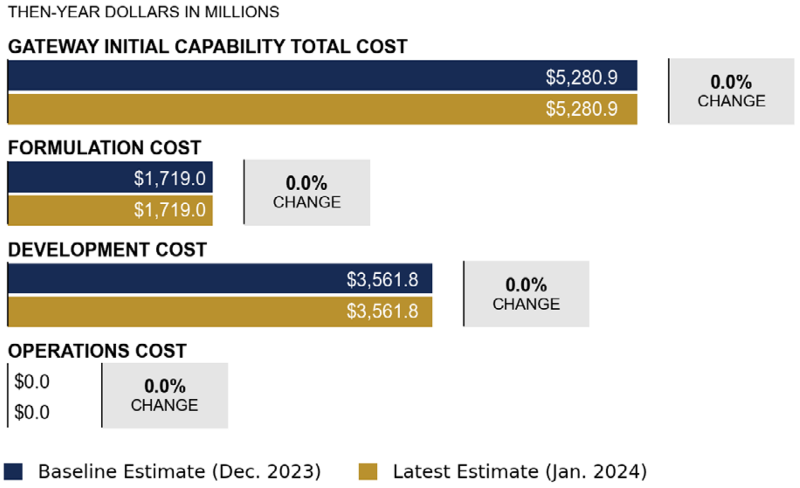
NASA established cost and schedule baselines for the Gateway initial capability—the HALO and the PPE together—in December 2023. The cost baseline of $5.3 billion includes the costs for the initial capability, the launch vehicle, and program support for integration and launch. The schedule baseline, set for December 2027, is the comanifested vehicle launch readiness date. Program officials said they plan to work to a more aggressive internal schedule than the baseline launch date but have not yet determined this date.

The project faces several technical challenges as it advances to a fall 2024 system integration review. For example, the comanifested vehicle's mass is significantly over its allocation, primarily due to the HALO's mass. To reduce the mass, the project may need to deliver some components on a logistics vehicle for crew to install on-orbit. The project may also need to reduce its capabilities or redesign components, which could result in cost growth or schedule delays. Project officials said they anticipate having a mass reduction plan and deciding which components and capabilities the HALO needs in spring 2024.

Schedule Performance



Cost Performance[a]



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[a] *This estimate includes the costs of the PPE and the HALO, which will launch together, the launch vehicle, and portions of program mission execution essential for the launch.*

Cost and Schedule Status

NASA established cost and schedule baselines for the Gateway initial capability—the HALO and the PPE together—in December 2023. The cost baseline of $5.3 billion includes the costs for the initial capability, the launch vehicle, and program support for integration and launch. The HALO project makes up a little more than one-third of the overall cost. The schedule baseline is the comanifested vehicle launch readiness date of December 2027. The baselines are about $1.6 billion more than the preliminary cost estimate and 22 months later than the preliminary schedule. NASA largely attributes the increases to worse-than-predicted schedule performance and requirements changes, primarily for the PPE.

The HALO project is working with its contractor, the PPE project, NASA, and its international partners to update its internal project schedule. Program officials stated the comanifested vehicle needs to launch at least a year before the September 2028 Artemis IV mission to allow time for the vehicle to transit from Earth to the moon and prepare for docking. Therefore, NASA would need to integrate the HALO and the PPE and launch them by September 2027 to support the mission. Program officials said they plan to work to a more aggressive internal launch date than the baseline launch date but have not yet determined this new date.

As the project updates its internal schedule, officials said they would incorporate delays to testing the primary structure. The project finished welding the structure in October 2023 but had to delay testing it to make several repairs. These repairs could compromise the structure's integrity. The project plans to test in spring 2024 whether the HALO primary structure can withstand the force required to be launched into and operate in space. Project officials said they also plan to incorporate into their updated internal schedule delays to the delivery of the electrical power system, which will distribute power generated by the PPE to the HALO and other Gateway modules. Project officials said the delays are due to changes to hardware design and development of an engineering model.

The project expects to modify its contract for software and design updates and is evaluating proposals for three contract modifications. Officials stated that the project is considering the use of a cost-type task order to address software integration challenges. They said it was too early to determine the modifications' effects on cost and schedule.

Technology and Design

The project completed its critical design review in June 2023. At the review, the project released 41 percent of its design drawings. This is lower than our design best practice, which recommends releasing 90 percent of drawings by critical design review to reduce the risk of design changes that may cause cost growth and schedule delays. Project officials attributed the low drawing counts primarily to the HALO's environmental control and life support system, which is at a lower level of maturity. They said they plan to release additional drawings by the end of 2024, which would get them closer to 90 percent released.

Due to the primary structure testing delays, project officials said they plan to delay their system integration review from March to fall 2024 and split the single review into two. Project officials said the first review would occur in summer 2024, prior to installing flight harnesses—groupings of wires or cables that transmit signals and electrical power—and other components onto the HALO primary structure. Officials said the second review would occur in fall 2024, around the time a subcontractor delivers the completed HALO module to the contractor facility for environmental testing.

At the program's baseline review, the Gateway standing review board identified two concerns related to the HALO. The first concern was about the integrated active thermal control system and environmental control and life support system's ability to keep the HALO cool. The project plans to add heat management capabilities that will lower the HALO's heat and humidity. If the systems cannot sufficiently regulate the HALO's temperature, then this could impair the HALO's performance.

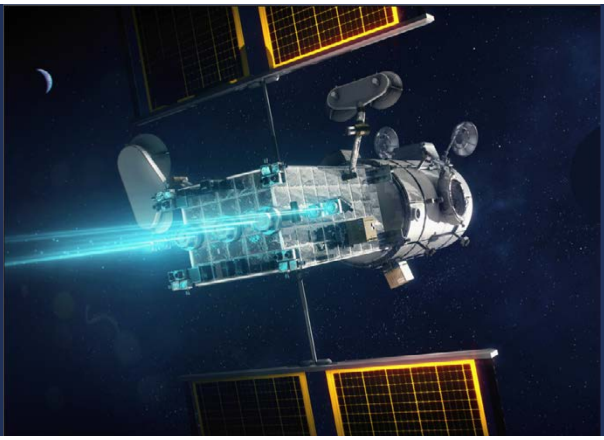
The second concern is related to the comanifested vehicle exceeding its mass allocation. The HALO's mass is the primary driver of the overage. As of February 2024, it is 539 kilograms over its allocation. The mass increased last year as the project matured its internal structures design and started receiving weights on hardware. Project officials stated the HALO is also facing a potential 602-kilogram mass increase because the contractor miscalculated the wire harness mass. If the comanifested vehicle's combined mass exceeds its mission design limits, then the vehicle could struggle to reach the correct lunar orbit.

To address this concern, the project is exploring ways to reduce mass. For example, the project identified 329 kilograms of components to potentially deliver via a logistics vehicle to the Gateway for the crew to install on-orbit. However, the project may need to reduce the HALO's capabilities or redesign components to further reduce mass, which could impede performance or cause cost increases and schedule delays.

HALO project officials said they are working with the PPE project and their contractors to assess how their mass affects their power needs and the amount of time the comanifested vehicle needs to transit to lunar orbit. HALO project officials said they anticipate having a mass reduction and power plan—and deciding which components and capabilities the project needs—in spring 2024.

Project Office Comments

HALO project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Source: NASA. | GAO-24-106767

Gateway – Power and Propulsion Element (PPE)

The PPE will be a spacecraft that provides power, communication, and the ability to change orbits, among other things, to the Gateway—a sustainable outpost planned for lunar orbit. The Gateway's PPE also aims to demonstrate advanced solar electric propulsion (SEP) technology to support future human space exploration. NASA is managing the development of SEP as a separate project. NASA plans to integrate the PPE and the Gateway's Habitation and Logistics Outpost (HALO) on the ground and launch them together. After NASA integrates the HALO and PPE together, it creates one vehicle for launch known as a comanifested vehicle.

Timeline

Formulation

- **09/17** Formulation start
- **09/19** System requirements review
- **11/21** Preliminary design review
- **12/23** Key decision point I

Implementation

- **01/24** GAO review
- **03/24** Critical design review
- **Under review** PPE delivery for integration with HALO
- **12/27** Latest launch readiness date

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Glenn Research Center**

International Partners: **Canadian Space Agency and European Space Agency**

Launch Location: **Kennedy Space Center, FL**

Launch Vehicle: **Falcon Heavy**

Mission Duration: **15 years**

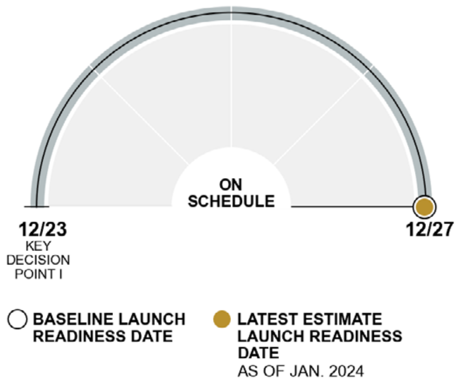
Requirement Derived from: **Space Policy Directive 1 and 2018 NASA Strategic Plan**

Project Summary

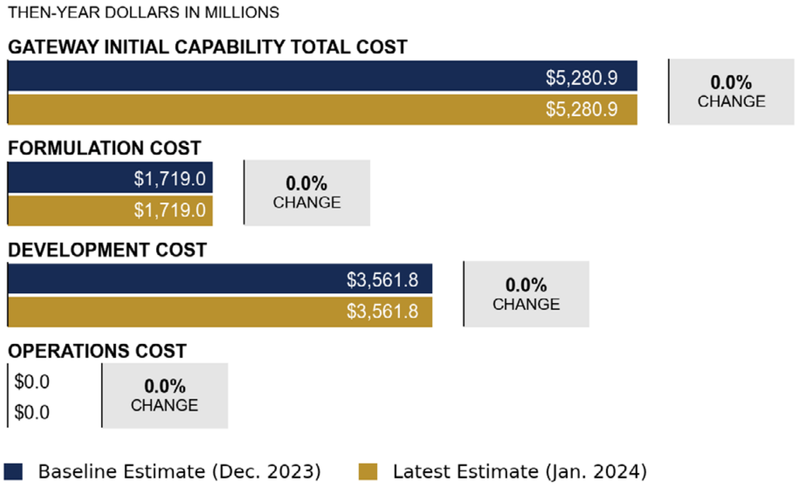
NASA established cost and schedule baselines for the Gateway Initial Capability—which comprises the PPE and HALO elements—in December 2023. The cost baseline of $5.3 billion includes costs for the initial capability, the launch vehicle, and program support for integration and launch. The schedule baseline is the comanifested vehicle launch readiness date of December 2027. These baselines are about $1.6 billion more than the preliminary cost estimate and 22 months later than the preliminary schedule estimate. NASA attributes the later schedule to worse-than-predicted schedule performance and the increased cost to a later schedule and requirements changes, primarily for the PPE. The PPE project's contract has experienced 172 percent growth overall, with more expected due to pending modifications.

The project worked to mitigate numerous technical and schedule risks as it proceeded toward its March 2024 critical design review. For example, the project is working to address technical challenges with network hardware. Officials said that they are attempting to address the challenges using the existing design, but that they may have to replace components to mitigate the issue, which could affect cost and schedule.

Schedule Performance



Cost Performance[a]



[a] *This estimate includes the costs of the PPE and the HALO, which will launch together, the launch vehicle, and portions of program mission execution essential for the launch.*

Cost and Schedule Status

NASA established cost and schedule baselines for the Gateway initial capability, which refers to the HALO and PPE together, in December 2023. The cost baseline of $5.3 billion includes costs for the initial capability, the launch vehicle, and program support for integration and launch. The PPE project makes up a little less than one-third of the overall cost. The schedule baseline is the comanifested vehicle launch readiness date of December 2027. These baselines are about $1.6 billion more than the preliminary cost estimate and 22 months later than the preliminary schedule estimate. NASA attributes the later schedule to worse-than-predicted schedule performance and the increased cost to the later planned launch readiness date and requirements changes, primarily for the PPE.

The PPE project is working with its contractor, the HALO and SEP projects, NASA, and its international partners to update its internal project schedule. According to program officials, NASA will need to launch the comanifested vehicle at least a year before the September 2028 Artemis IV mission to allow time for the vehicle to transit from Earth to the moon and prepare for docking. Therefore, NASA would need integrate the HALO and the PPE and launch them by September 2027 to support the mission. Program officials said that when they finalize their internal schedule, it will be to an earlier date than the baseline launch date of December 2027.

The PPE project continues to experience contract cost growth due to requirements changes. NASA completed a $289 million modification to its contract with Maxar in July 2023. According to project officials, this modification was the third major requirements update and furthered the alignment of the Gateway program’s needs with the capabilities to be provided by the PPE including changes because of NASA’s decision to comanifest the PPE and the HALO. The modification increased the contract value to over $1 billion and the contract now exceeds its total value at the time of award by 172 percent. As of February 2024, the project plans to complete three additional contract modifications, which project officials said they expect will further increase the contract costs. Officials said these modifications will add cybersecurity, mission design and guidance, navigation, and control content deferred from the prior modification, and new requirements.

Technology and Design

At the baseline review, the Gateway standing review board identified two concerns related specifically to PPE. The board noted that the PPE project’s cybersecurity plan was incomplete, and that software and avionics content was not mature. The Gateway program and PPE project addressed the cybersecurity concern via a task order and plan to hold additional reviews to address the avionics and software concern.

In January 2024, the project reported that seven of its nine critical technologies are mature. Our best practice for technology maturity states that critical technologies should achieve technology readiness level 6 by preliminary design review to minimize risks for further product development. When the PPE project held its preliminary design review in November 2021, none of its critical technologies were mature. According to project officials, the remaining two technologies will not be mature until after the critical design review. Project officials said that the prime contractor has a different view on the timing of maturing technologies, and they do not view either technology as a major risk.

According to project officials, the PPE project delayed its critical design review from October 2023 to March 2024 to allow its contractor additional time to complete subsystem reviews due to requirements changes stemming from the July 2023 contract modification. The project continues to mitigate several technical issues and risks as it prepares for the critical design review. For example, as of February 2024, the project estimated the PPE’s mass to be about 170 kilograms over its allocation on the comanifested vehicle, assuming the propellant tanks are completely filled. Project officials said they can reduce mass by carrying less propellant depending on mission needs. If the project does not achieve the target mass, it could result in a reduction of spacecraft capabilities.

The Gateway program is tracking a risk regarding the PPE’s ability to sufficiently control the Gateway’s positioning on orbit when larger and heavier visiting vehicles—including the Human Landing System—are docked with it. According to project officials, losing precise control of the Gateway could result in degradation of performance. The Gateway program is investigating ways to have the visiting vehicles assume some control when docked with the Gateway.

The project is concerned that the PPE network hardware, which allows the PPE to communicate with other Gateway components, might not meet performance requirements due to technical challenges. Officials reported they are working to address the challenges using the existing design, but they may need to replace components to mitigate the issue, which could affect cost and schedule.

The project is tracking a risk that critical hardware components, including its propellant tanks, could fail during launch or wear out over the life of the PPE. The project and its contractor completed evaluations of the tanks to certify that they are ready for final manufacturing and installation onto the spacecraft. The tanks are on the project’s critical path—the part of the schedule with the least amount of schedule reserve available. Thus, further delays would delay the overall project schedule.

Project Office Comments

PPE project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Source: SpaceX. | GAO-24-106767

Human Landing System (HLS) – Initial Capability

The HLS will provide crew access to the lunar surface and demonstrate initial capabilities required for deep space missions. NASA plans to use the HLS initial capability for the Artemis III mission to the moon. The HLS will deliver a crew from lunar orbit to the lunar surface, provide capabilities for lunar surface extravehicular activities, and then return the crew and materials to lunar orbit to enable their return to Earth. For Artemis III, the HLS will dock with the Orion Multi-Purpose Crew Vehicle (Orion) in lunar orbit. Contractors will lead the design, development, testing, and evaluation of the HLS; NASA will certify its design and flight readiness.

Timeline

Formulation

- **05/19** Formulation start
- **05/20** Base period contractor selections
- **12/20** Continuation review
- **07/21** Exercise of Option A
- **12/23** Key decision point C

Implementation

- **01/24** GAO review
- **2025** Critical design review
- **2025** Uncrewed lunar landing flight test
- **2026** Design certification review
- **2026** Planned launch of HLS lander Starship
- **02/28** Lunar orbit checkout review

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Marshall Space Flight Center**

Launch Location: **Multiple launch locations including Kennedy Space Center, FL, and Boca Chica, TX**

Launch Vehicle: **SpaceX Super Heavy Booster**

Mission Duration: **6.5 days**

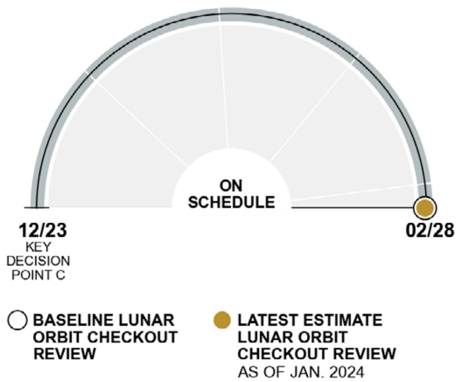
Requirement Derived from: **National Space Policy Directive 1 and NASA Strategic Plan**

Project Summary

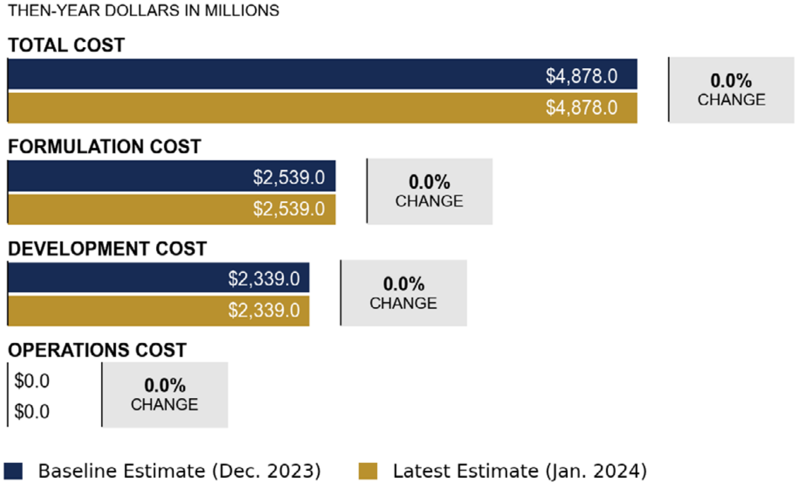
In December 2023, NASA established cost and schedule baselines for the HLS Initial Capability at the 70 percent joint cost and schedule confidence level, as required by NASA policy. The cost baseline is $4.9 billion, and the schedule baseline is February 2028 for the lunar orbit checkout review. This review will examine whether the HLS Starship is ready to perform the Artemis III mission and receive crew from the Orion spacecraft. Though NASA set the program's schedule baseline to February 2028, the agency is working toward the planned Artemis III mission date of September 2026.

SpaceX conducted a second integrated flight test of its Starship lander on November 18, 2023. HLS program officials said that, while the integrated Starship was terminated earlier than planned, the test produced sufficient data to conduct an orbital launch architecture assessment data review. SpaceX conducted a third integrated flight test of the integrated Starship on March 14, 2024. NASA reported that the Starship reached its expected orbit and completed propellant transfer demonstration operations.

Schedule Performance



Cost Performance



Cost and Schedule Status

In December 2023, NASA established cost and schedule baselines for the HLS program's initial capability, which will support the Artemis III mission. NASA tied the HLS initial capability schedule baseline to a lunar orbit checkout review in February 2028, based on a 70 percent joint cost and schedule confidence level, as required by NASA policy. The joint cost and schedule confidence level is an integrated analysis of a project's cost, schedule, risk, and uncertainty, which indicates a project's likelihood of meeting a given set of cost and schedule targets. The lunar orbit checkout review will examine the readiness of the HLS Starship to perform the Artemis III mission and receive crew from the Orion spacecraft. Additionally, the joint cost and schedule confidence level used to set the HLS program's baseline did not include detailed schedule activities for other NASA programs or projects that will be needed for the Artemis III mission (i.e., Orion). Though NASA set the program's schedule baseline to February 2028, NASA's current plan for the Artemis III mission is September 2026.

NASA set the HLS Initial Capability baseline life-cycle cost at about $4.9 billion, which covers the effort through the post-mission assessment review. This review will examine the success of the mission and take place no later than 30 days after mission completion. In addition to the $2.9 billion option that NASA exercised in July 2021 to develop and demonstrate the HLS for Artemis III, the cost baseline includes NASA program office costs, and contract costs for work done by SpaceX, Blue Origin, and Dynetics before NASA selected SpaceX to develop the Artemis III HLS.

Technology and Design

SpaceX conducted a second integrated flight test of its Starship lander on top of its super heavy booster—also called an orbital flight test—on November 18, 2023. HLS program officials said that, while the integrated Starship was terminated earlier than planned, the test produced sufficient data to conduct an orbital launch architecture assessment data review. Program officials said that SpaceX could choose whether to conduct an additional orbital flight test before attempting the propellant transfer test. SpaceX conducted a third integrated flight test of the integrated Starship on March 14, 2024. NASA reported that the Starship reached its expected orbit and completed propellant transfer demonstration operations.

SpaceX's progress in developing its propellant storage and transfer technologies is a top risk for the program. SpaceX's plan for landing astronauts on the moon requires on-orbit propellant transfer between multiple Starship vehicles in low-earth orbit before the HLS Starship can be sent to and dock with the Orion spacecraft in lunar orbit.

The HLS program and SpaceX have taken steps to further develop the propellant storage and transfer technologies. In December 2023, the program reported that SpaceX used significant NASA technical expertise to support its technology development. SpaceX's second integrated flight test incorporated NASA technology for accurately estimating propellant mass in space, according to HLS program officials. Further, the HLS program tested large propellant valves at Marshall Space Flight Center, and generated independent models to assess propellant aggregation, usage, and storage. At the program's key decision point C meeting, the standing review board recommended that SpaceX's in-space propellant transfer tests inform the program's critical design review, currently planned for 2025.

Project Office Comments

HLS program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Source: NASA. | GAO-24-106767

Orion Multi-Purpose Crew Vehicle (Orion)

Orion is being developed to transport and support astronauts beyond low earth orbit and will launch atop NASA's Space Launch System (SLS). The current design includes a crew module, service module, launch abort system, and rendezvous proximity operations and docking capability (RPOD). The program successfully completed one uncrewed mission (Artemis I) in 2022 and is planning for the first crewed mission (Artemis II) in 2025. NASA also plans to produce additional Orion capsules to transport crew for a planned 2026 lunar landing mission (Artemis III) and later missions. The Orion program is continuing to advance the development of the vehicle started under the canceled Constellation program.

Timeline

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Johnson Space Center**

International Partners: **European Space Agency (ESA)**

Launch Location: **Kennedy Space Center, FL**

Launch Vehicle: **Space Launch System**

Mission Duration: **Up to 21 days active mission duration capability with four crew**

Requirement Derived from: **NASA Authorization Act of 2010**

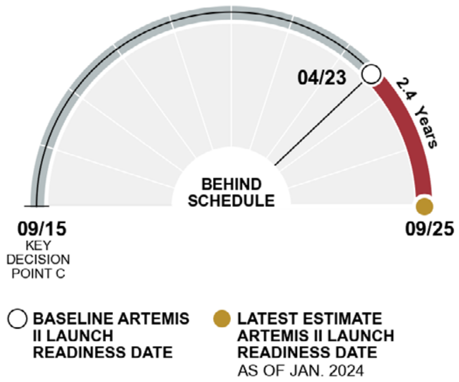
Project Summary

The Orion program increased its life-cycle costs by $321 million, which officials said was due to delays to the Artemis II launch, and officials anticipate additional cost growth after the recent announcement of a September 2025 Artemis II launch readiness date. Orion's costs are now 25.2 percent above its original baseline. Furthermore, the new launch date is 9 months later than the program's most recent plan, and almost 2½ years past the program's baselined schedule. NASA officials said ensuring crew safety is the primary driver for the Artemis II schedule change. Artemis II will be the first test of critical environmental control and life support systems, as well as displays and controls.

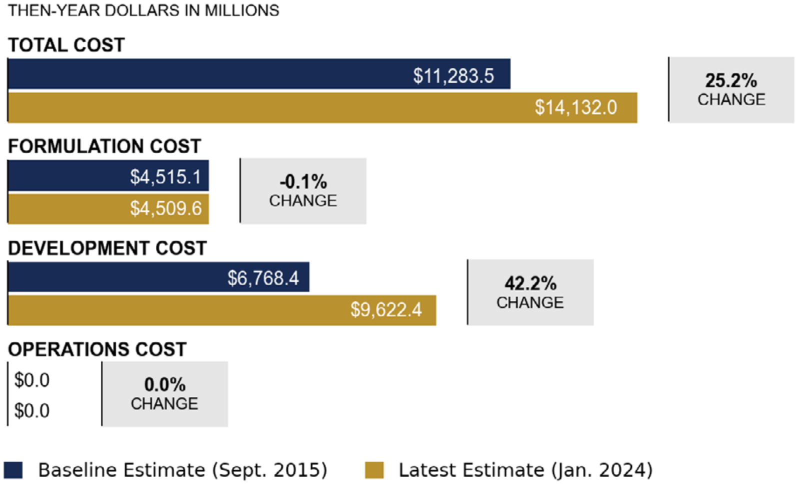
Integration and testing for the Orion Artemis II capsule is ongoing. NASA is conducting investigations to determine next steps to mitigate issues with the digital motor controller circuitry of a few life support components and crew module batteries. According to officials, the heat shield investigation team is still determining root cause, and the team is expected to report its findings to NASA leadership in June 2024.

The program is also making progress toward Artemis III, with officials stating that ESA's service module is anticipated for delivery in July 2024.

Schedule Performance



Cost Performance – Under Review



Cost and Schedule Status

The Orion program increased its life-cycle cost estimate by an additional $321 million. The program's costs are now 25.2 percent above the program's original baseline and 2.3 percent above the program's 2021 rebaseline. For the 2021 rebaseline, some cost increases reflected additional requirements for the RPOD capability, as well as costs due to COVID-19, among other factors. According to program officials, the $321 million increase was to support delaying Artemis II's launch date by 7 months to December 2024. Officials said costs continue to be under review as they anticipate additional cost growth after NASA announced in January 2024 that Artemis II would occur in September 2025. The new launch date is 9 months later than the program's most recent plan, and almost 2½ years past the program's baselined schedule. NASA officials said that ensuring crew safety is the primary driver for the Artemis II schedule change.

Integration and Test

Integration and testing for the Orion Artemis II capsule is ongoing. In October 2023, NASA integrated the Orion crew module and service module. Functional testing of the integrated module is complete. As of January 2024, officials said the program had paused installation of the final backshell panels that enclose the capsule. They said they are waiting for the completion of the crew module battery investigation because they do not want to risk having to install and remove the backshell panels more than necessary. Once the panels are installed, Orion will undergo environmental testing before being delivered to Exploration Ground Systems at Kennedy Space Center for final processing and integration with the SLS.

Orion is actively working to mitigate issues with its life support system circuitry, crew module batteries, and the heat shield ahead of the launch.

Challenges with the digital motor controller circuitry for life support components have stalled Orion testing. Artemis II is the first test of critical environmental control and life support systems, but the circuitry for selected digital motor controllers in one of these systems failed Artemis III acceptance testing. These controllers operate motorized valves in the crew module cabin and crew module adapter. For example, two affected controllers operate a valve that is part of the cabin ventilation system that controls the cabin and suit air temperatures. Officials said they modified the circuit's design to fix the issue for Artemis III hardware. For Artemis II, NASA is examining the affected controllers to determine if there are operational workarounds to use the controllers as-is. Officials said that, though testing is stalled, they do not anticipate needing to separate the crew and service modules. As of January 2024, officials said they hope to know the path forward in spring 2024.

Orion is also working to resolve issues with the crew module's batteries. Officials said there are four batteries in the crew module to provide power when the service module is not there, such as in an abort situation or during reentry to Earth. During qualification testing, the battery qualification unit lost capacity, which officials said meant the battery was not providing the maximum amount of power. Officials believe that the qualification battery was initially damaged during an earlier test that mimicked the shock environment experienced by the batteries when the crew and service module separate, such as during a launch abort scenario. NASA is working to identify the root cause so it can determine how to proceed. Officials said options could include replacing the batteries or leaving as-is, and they anticipate next steps will be finalized in spring 2024.

The Orion program is also investigating the heat shield, which experienced more damage than anticipated during Artemis I. During reentry to Earth's atmosphere, the heat shield experienced unexpected material loss. According to officials, analysis indicated that the permeability of the material was lower than their models had indicated. For Artemis II, officials said the current investigation is evaluating flight trajectories with new heat shield modeling to determine if this will be sufficient to address this issue. Officials said an option for Artemis III and beyond may be to modify their manufacturing process to increase and optimize the permeability in heat shield materials. However, the investigation is ongoing. Officials said they plan to report their findings to NASA leadership in June 2024.

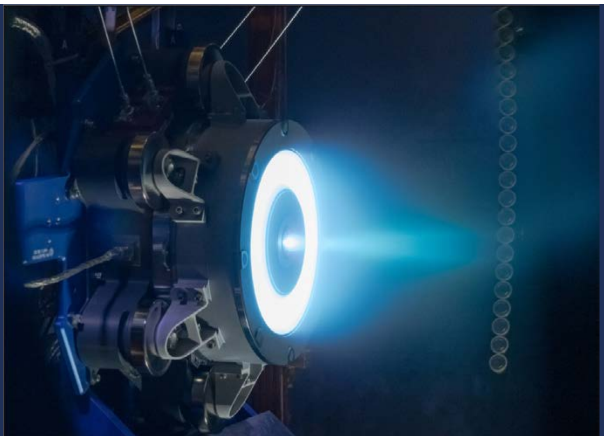
Other Issues to Be Monitored

The Orion program is making progress toward Artemis III readiness, with a primary schedule driver being ESA's delivery of the service module. ESA's planned delivery was delayed from October 2023 to April 2024 because ESA had to redesign some hardware and NASA officials said ESA had to replace other hardware. In May 2024, officials said the delivery had been further delayed to July 2024. NASA is also making progress with RPOD, which will be demonstrated in part during Artemis II before being used in full for Artemis III.

NASA's Moon to Mars office is tracking potential issues with the Artemis IV mission's planned mass. The Artemis IV mission will include Orion comanifested with an International Habitat (I-HAB) on the SLS Block 1B launch vehicle. As of November 2023, both I-HAB and Orion had exceeded their masses. Orion officials said they are not pursuing design changes to reduce mass at the program level. However, NASA established a team to mitigate the issue. The team is determining actions to reduce I-HAB mass, add additional Orion propellant, and obtain additional SLS performance information.

Project Office Comments

Orion program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate. Program officials stated that they added scope and work to the program when it rebaselined in 2021. The costs associated with that scope and work were not included in the program's original cost baseline.



Source: Jef Janis, Alcyon Technical Services. | GAO-24-106767

Solar Electric Propulsion (SEP)

The SEP project is a technology demonstration that aims to develop high power electric propulsion technologies for NASA exploration and to empower the U.S. space industry. Solar electric propulsion uses energy from the sun to ionize and accelerate gas, resulting in higher fuel efficiency. This reduces the mass of propellant needed for spaceflight missions beyond low-Earth orbit compared to conventional chemical propulsion systems. The SEP project is developing an Advanced Electric Propulsion System (AEPS) that will fly on the Gateway's Power and Propulsion Element (PPE). Specifically, the project is building and testing two qualification thrusters and managing the assembly of three flight thrusters for the PPE.

Timeline

Formulation
- 03/15 Formulation start
- 05/16 AEPS system requirements review
- 08/17 AEPS preliminary design review
- 02/20 Key decision point C

Implementation
- 03/22 AEPS critical design review
- **01/24** GAO review
- 07/25 Complete delivery of three AEPS flight thrusters to the PPE
- 01/29 AEPS life qualification test report complete

Project Information

NASA Lead Mission Directorate: **Space Technology**

NASA Lead Center: **Glenn Research Center**

International Partners: **None**

Launch Location: **Kennedy Space Center, FL (with PPE)**

Launch Vehicle: **Falcon Heavy (with PPE)**

Mission Duration: **15 years (with PPE)**

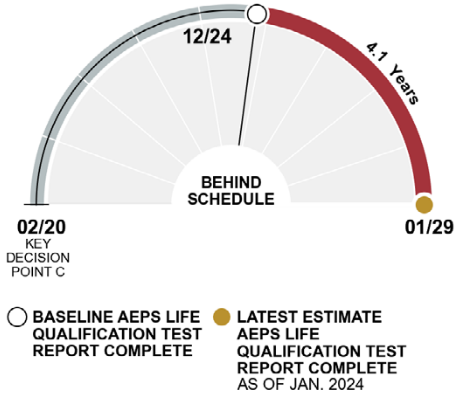
Requirement Derived from: **2018 Strategic Objectives 2.2, 3.1, 4.2**

Project Summary

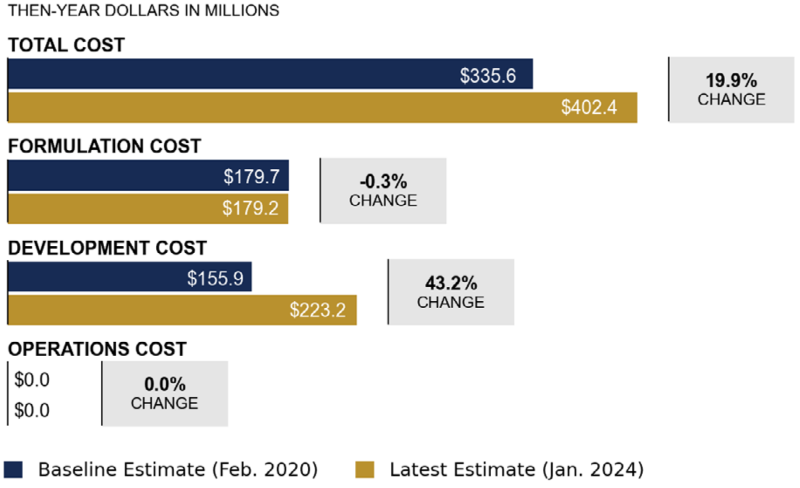
As of January 2024, the SEP project exceeded its previously rebaselined costs by $20 million and schedule by 3 months due to redesigning the thruster harnesses. The project previously rebaselined its cost and schedule in March 2022 after exceeding its cost baseline by $46.8 million and delaying its completion date by 46 months. NASA modified the SEP contract for the thruster harness design changes and plans to modify it again in summer 2024 to accommodate final changes to the harness. The project is working with the contractor to ensure that thruster delivery dates meet the PPE project's schedule.

According to SEP officials, the biggest technical challenge to completing the delivery of the thrusters is completing manufacturing and installation of the redesigned harness. In addition, the project resolved several issues related to the thruster's cathode assembly but is tracking fabrication of the remaining flight and qualification cathode units to ensure they meet their assembly need dates. In July 2023, the SEP project successfully demonstrated that the thruster technologies were mature after completing acceptance testing on the first of two qualification models.

Schedule Performance



Cost Performance



Cost and Schedule Status

As of January 2024, the project exceeded its previously rebaselined costs by $20 million and its schedule by 3 months due to redesigning its thruster harnesses—the groupings of wire or cable that transmit signals and electrical power. The project had to redesign the harnesses to address a hardware incompatibility with the PPE spacecraft. The Exploration Systems Development Mission Directorate is responsible for the cost increase because the harnessing requirements changes stemmed from the PPE project. The SEP project previously rebaselined its cost and schedule in March 2022, after exceeding its cost baseline by $46.8 million and delaying its completion date by 46 months.

NASA modified the SEP project's contract with Aerojet Rocketdyne in November 2023 to incorporate the thruster harness requirements changes. Officials told us the project plans to modify it again in summer 2024 to accommodate final changes to the harness.

As of January 2024, the project estimated up to 12 months in delays to delivering the flight thrusters to the PPE project. According to project officials, they are working with the contractor to streamline their schedule and meet the PPE project's need date for delivery of the flight thrusters.

Technology and Design

According to the SEP project, the biggest technical challenge to completing the delivery of the thrusters is completing manufacturing and installation of the redesigned harness. The original harness design, which Aerojet Rocketdyne installed on the first of two qualification models, met initial PPE requirements. However, after fabrication, PPE and SEP determined that the harnesses needed to be redesigned due to an incompatibility between the harness wiring and the heritage hardware on the PPE spacecraft. In March 2023, the PPE and SEP projects determined that replacing the wire was the best option. They chose a wire that met three of four critical factors and was readily available from the PPE contractor. According to project documentation, the wire was not rated by the manufacturer to the necessary temperature; however, reviews indicated the wire should be capable of higher temperatures. According to project officials, at that time, the SEP project also considered a smaller gauge wire that met temperature requirements but would have required up to an estimated 12 months to obtain. Officials report that the project ordered a supply of the smaller gauge wire as a risk mitigation while it proceeded with additional analysis and testing on the readily available wire to verify the temperature rating.

As of January 2024, Aerojet Rocketdyne fabricated two of three redesigned harnesses for the first flight thruster. However, the project reports that Aerojet Rocketdyne did not fabricate the third harness because the wire it received from the PPE contractor was discolored, implying possible corrosion, due to a manufacturing or storage issue with the supplier. In addition, project officials report that initial testing on the wire indicated that the project may not be able to use the wire at the higher temperatures. As a result, the project conducted testing in parallel on the alternate smaller gauge wire. In March 2024, the SEP and PPE projects completed their evaluation and decided to use the alternate wire.

The SEP project will not fully test the new harness design on its second qualification thruster until after the contractor builds all three flight thrusters. The joint PPE and SEP project control board decided to proceed with the original harness design installed on the first qualification model and maintain the planned production flow with the three flight models to protect the delivery schedule to the PPE project. Safety and Mission Assurance representatives on the control board raised concerns with this approach given the potential effect on schedule if issues are discovered on the second qualification model that require changes to the three flight models. The board agreed to implement additional environmental testing on the second qualification model to help address these concerns.

The project also continues to address risks related to the cathode, which produces electrons for the thrusters. During this process, the temperature changes from hot to cold and can cause stress to the cathode's joints. Prior to the harness redesign, the cathode was the project's biggest technical and schedule risk. The project resolved several cathode design issues over the past 3 years and completed assembly of the first qualification and flight cathodes. According to project officials, the first qualification cathode has begun testing and the first flight cathode is ready for installation onto the thruster. The project is tracking the fabrication of the cathodes to ensure the remaining flight and qualification units meet their assembly need dates.

The first of two qualification model thrusters completed acceptance testing—including limited vibration, thermal-cycling, and performance testing—in July 2023. According to NASA documentation, the acceptance test matured the thruster to technology readiness level 6. By demonstrating a representative prototype of the technology in a relevant environment that simulates the harsh conditions of space, the testing helped to minimize risks during further development for the PPE project. Officials report that the SEP project and its contractor have begun conducting environmental tests on the first qualification model, which simulate conditions that the spacecraft will experience during launch.

Project Office Comments

SEP project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Source: NASA. | GAO-24-106767

Space Launch System (SLS) Block 1B

The SLS Block 1B is a planned evolution of the SLS Block 1. The SLS Block 1 is NASA's first human-rated, heavy-lift vehicle since the Saturn V and is intended to enable deep-space Artemis and Mars missions. The SLS Block 1B will retain the core stage, RS-25 engines, and solid rocket boosters from Block 1, but replace the interim cryogenic propulsion stage with the more powerful Exploration Upper Stage (EUS) and adapters for payloads. The EUS will have four RL-10 engines with a total of 97,000 pounds of thrust, which will increase the amount of mass the SLS Block 1B can deliver to the moon and other destinations.

Timeline

Formulation
- **2014** Formulation funding start
- **11/16** Preliminary design review
- **05/23** Integrated vehicle critical design review
- **12/23** Key decision point C

Implementation
- **01/24** GAO review
- **07/24** Software critical design review
- **No earlier than 04/27** System integration review
- **01/28** Design certification review date
- **09/28** Artemis IV mission date

Project Information

NASA Lead Mission Directorate: **Exploration Systems Development**

NASA Lead Center: **Marshall Space Flight Center**

International Partners: **None**

Launch Location: **Kennedy Space Center, FL**

Launch Vehicle: **N/A**

Mission Duration: **Varied based on destination**

Requirement Derived from: **NASA Authorization Act of 2010**

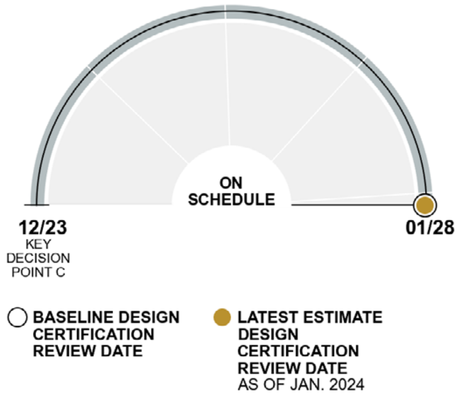
Project Summary

In December 2023, NASA confirmed the SLS Block 1B capability upgrade. It also established cost and schedule baselines with a committed design certification review date of January 2028 and a life-cycle cost of approximately $4.9 billion.

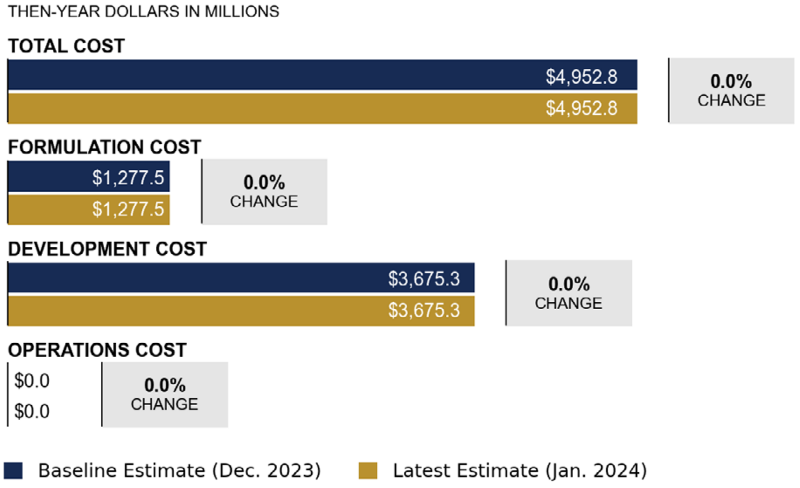
NASA completed the SLS Block 1B integrated vehicle critical design review (CDR) in May 2023, began the flight software CDR in September 2023, and expects to complete the review in July 2024. Transitioning to SLS Block 1B, the program will move all SLS Block 1 flight computers and software from the core stage to the EUS. The new configuration will affect computer performance due to radiation, which is a key technical concern.

According to program officials, there is a requirement for a new autonomous flight safety system on SLS Block 1B. Officials stated that under the requirement, the program must develop software and hardware that will autonomously abort flights if needed to protect the public.

Schedule Performance



Cost Performance



Cost and Schedule Status

In December 2023, NASA approved cost and schedule baselines for the SLS Block 1B capability upgrade. In doing so, it established a committed design certification review date of January 2028 and a life-cycle cost of approximately $4.9 billion. The design certification review is a final review to demonstrate that a system fulfills all functional, performance, physical, and safety requirements.

As of November 2023, NASA had already spent nearly $3 billion developing the SLS Block 1B. NASA set the new SLS Block 1B baselines at the 70 percent joint cost and schedule confidence level (JCL). A JCL is an integrated analysis of a project’s cost, schedule, risk, and uncertainty, the results of which indicate a project’s likelihood of meeting a given set of cost and schedule targets.

The SLS Block 1B baseline does not include the cost of system elements common with SLS Block 1, such as the core stage and solid rocket boosters. The cost for these elements will be included in the 5-year production and operations estimate for the SLS program. It also does not include the cost of infrastructure improvements needed at Kennedy Space Center to launch the vehicle. These improvements include Mobile Launcher 2, which the Exploration Ground Systems program is developing to support the SLS vehicle during stacking, transportation to the launch pad, and launch.

Technology and Design

NASA split the SLS Block 1B CDR into two parts—an integrated vehicle CDR and flight software CDR. These reviews are only for the Block 1B-specific elements as most of the SLS design remains the same as the Block 1 configuration flown on Artemis I. NASA completed the SLS Block 1B integrated vehicle CDR in May 2023. NASA does not expect to release 90 percent of manufacturing drawings for the EUS until August 2024. Program officials consider the EUS design to be mature because the project completed the EUS design layouts in July 2023. According to program officials, they used design layouts instead of drawings to design the EUS and the layouts allow them to create and release drawings to manufacturers as needed.

NASA began the SLS Block 1B flight software CDR in September 2023 after completing the integrated vehicle CDR and expects to complete the software CDR in July 2024. Officials indicated that this type of strategy is not uncommon, because it makes sense to establish the hardware baseline and then develop requirements for flight software to support that design. NASA plans to use the results from the Block 1B flight software CDR to continue the remaining flight software development approach, with four post-CDR flight software versions planned prior to the Artemis IV mission.

Transitioning to SLS Block 1B, the program will move all SLS Block 1 flight computers and software from the core stage to the EUS, which poses a technical concern related to radiation. On SLS Block 1, the flight computers were on the core stage and the interim upper stage that the EUS is replacing. With Block 1B, no flight computers will remain on the core stage. According to agency officials, NASA determined that in the long term it would be more efficient to consolidate avionics in one set of flight computers on the EUS instead of having them on EUS and the core stage. In this new configuration, however, the flight computers are exposed to ionizing radiation longer than they are in the Block 1 configuration. The radiation will affect the performance of the computers over time. According to officials, NASA is currently conducting assessments and analyses to identify approaches to minimize the radiation impact. Officials stated that this is a key technical concern going into and coming out of the flight software CDR.

Other Issues to Be Monitored

According to program officials, the Block 1B will be the first SLS flight using an Autonomous Flight Safety System under the Space Force's range modernization initiative. Implementing this system will require development of software and hardware that will autonomously terminate flight based on preestablished mission parameters to protect the public. The current flight safety system on SLS Block 1 vehicles is commanded by a human on the ground. Program officials indicated that the program is currently ensuring the new system has the right fault tolerance and notification capabilities to maximize crew safety while protecting the public.

Project Office Comments

SLS Block 1B program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Volatiles Investigating Polar Exploration Rover (VIPER)

VIPER will be a lunar rover that aims to understand how much water is on the moon and where the water is located, among other things. The VIPER project plans to use the rover's three spectrometers and a 1-meter drill with temperature sensors to accomplish these goals. NASA plans for the scientific data that VIPER collects to inform the first global water resources map of the moon and the Artemis III lunar landing site decisions. The VIPER project is continuing to develop the rover started under the canceled Resource Prospector project.

Source: NASA. | GAO-24-106767

Timeline

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Ames Research Center**

International Partners: **none**

Launch Location: **To be determined**

Launch Vehicle: **Commercial Lunar Payload Services (CLPS) contractor-provided SpaceX Falcon Heavy**

Mission Duration: **3 Earth months (~100 days)**

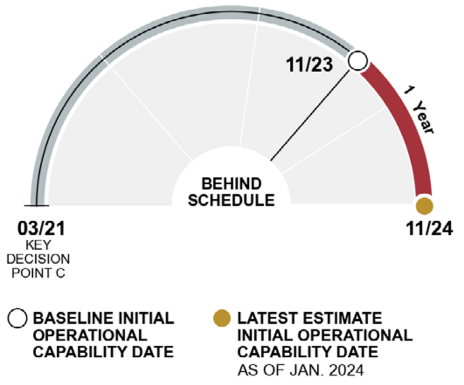
Requirement Derived from: **2011 Planetary Science Decadal Survey**

Project Summary

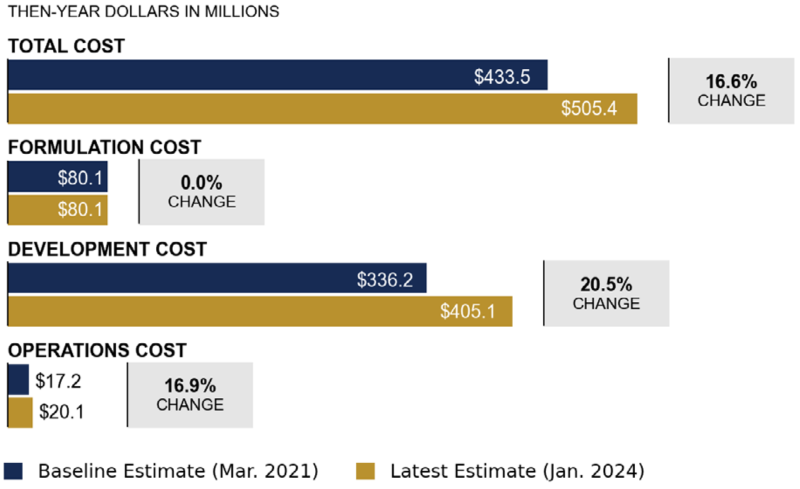
In August 2023, VIPER was approved to begin system assembly and integration and test, and to prepare for launch. At the same time, NASA approved a project replan with an increased expected life-cycle cost of $505 million. One of the factors for the increase was to accommodate the program's launch readiness date delay from November 2023 to November 2024. As of April 2024, the VIPER project estimated that all fiscal year 2024 funding will be used up by July 2024 unless additional funding is provided. Although VIPER system integration has been ongoing, project officials report that issues arising from vendor delivery delays due to supply chain issues have required the use of all project-funded schedule reserves.

The VIPER project continued to face mass issues, but this has now been mitigated with a plan to purchase additional mass from Astrobotic. With this purchase, the project's mass margin will now meet project requirements and the project does not expect to use mass reduction options such as removal of a solar panel.

Schedule Performance – Under Review



Cost Performance – Under Review



Cost and Schedule Status

In August 2023, the NASA Science Mission Directorate approved VIPER to begin system assembly and integration and testing, and to prepare for launch. This decision included approving the project's replan with updated costs to accommodate the 1-year delay to VIPER's lunar delivery from November 2023 to November 2024. As a result, VIPER life-cycle costs increased to $505 million. VIPER's cost baseline does not include funding for CLPS task order costs or for prior development work under the Resource Prospector project.

Although NASA approved the new project life-cycle cost of $505 million, final costs will likely exceed that amount. At the time of that decision, the VIPER Review Team requested that additional headquarters cost reserves of up to $21 million be held as the review team believed the funds may be needed to meet key schedule milestones. NASA did not approve that request. NASA officials explained they had confidence in the VIPER cost estimate and, if additional cost reserves were required, that would be addressed through the request process.

As of April 2024, the VIPER project reported that all project fiscal year 2024 funding would be exhausted by July 2024. The project is currently negotiating with NASA for additional funding to solve these cost issues and a potential shift in launch date.

Project officials report that vendor delivery issues and supply chain concerns posed cost and schedule challenges for the project. While the project received all critical hardware from its vendors as of November 2023, officials stated that key hardware deliverables were up to 18 months late. They also reported that some vendor delivered hardware required remediations that used project schedule reserves. For example, solder issues in fall 2023 on some hardware used up all project schedule reserves in remediation efforts.

The VIPER lunar delivery date was moved to November 2024 because NASA wanted Astrobotic—the CLPS contractor providing end-to-end commercial payload services between Earth and the moon—to conduct additional testing on the company's Griffin lander propulsion system. Project officials said that NASA wanted to lower the mission risk because of the importance of VIPER and the resources invested in the project. In January 2024, the first mission using the Astrobotic Peregrine lander failed due to propulsion system issues after launch. Astrobotic planned to use information from the Peregrine lander to help inform development of the Griffin lander. The project is continuing to assess the effect of this issue on its schedule, including being directed by NASA to explore the next available science window that would meet VIPER mission requirements for the lighting conditions on the moon, which would be in fall 2025.

Integration and Test

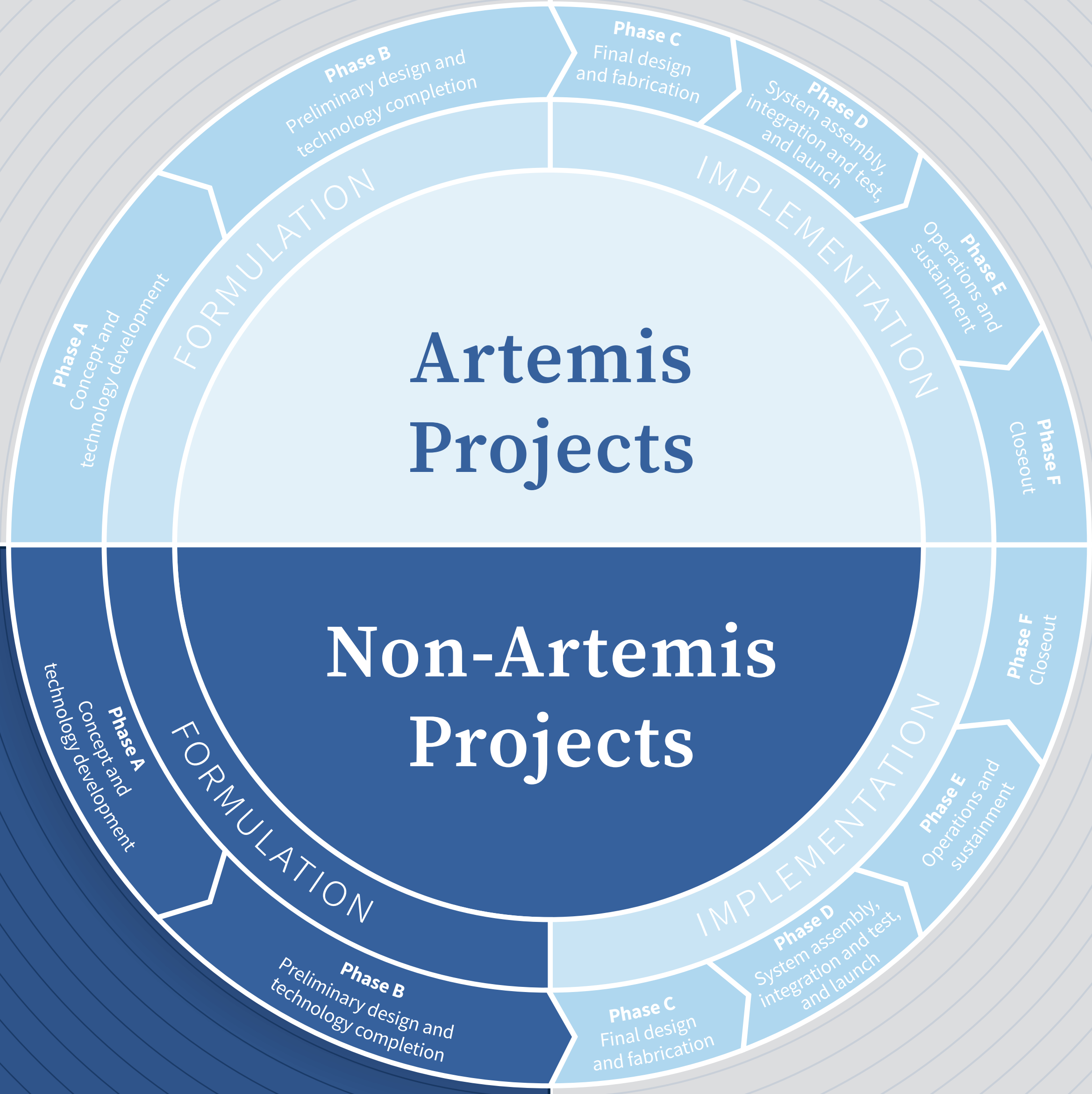
As of December 2023, the VIPER rover is 50 percent built and has all system-level testing remaining. To preserve the project's schedule from late vendor deliveries, the project reduced some subsystem tests. As a result, some detectable issues have been discovered during rover integration and consumed schedule reserves.

Design

The project is tracking and closely monitoring a risk related to the rover's mass. While the program had previously been evaluating mass reduction options, such as the removal of a solar panel, project officials stated that the project has maintained its mass margins. The CLPS office has committed to purchasing an additional 10 kilograms from Astrobotic if needed, as of February 2024, but has not yet made the purchase. Project officials explained that the purchase of additional mass involves compensating Astrobotic to trade Griffin lander mass margin to VIPER, after Astrobotic verifies the lander would need no redesign for the mass margin decrease. This purchase would ensure that VIPER will remain in the desired mass margin, if needed. The project previously appointed a systems engineer to find ways to reduce mass, but project officials stated the project does not currently expect to use mass reduction options.

Project Office Comments

VIPER project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.



- Dragonfly
- Electrified Powertrain Flight Demonstration **(EPFD)**
- Mars Sample Return **(MSR)**

Source: GAO analysis of NASA data. | GAO-24-106767

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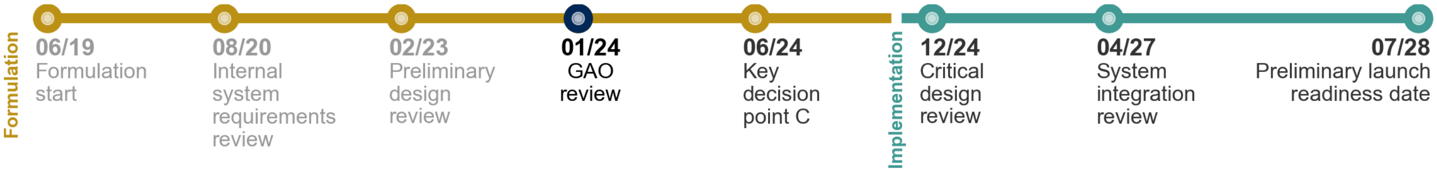
Dragonfly

Dragonfly is an eight-bladed rotorcraft that will visit Titan—Saturn's largest moon—and fly like a drone to sample and examine dozens of sites and search for the building blocks of life. It will explore organic dunes and the deposits of an impact crater where liquid water and complex organic materials key to life once existed together for possibly tens of thousands of years. It will also investigate how far prebiotic chemistry has progressed. This mission is the first time that NASA will fly an eight-bladed rotorcraft and take advantage of Titan's dense atmosphere to gather science on another planetary body. It will fly its entire science payload to new places for repeated and targeted access to surface materials.

Source: Johns Hopkins University Applied Physics Laboratory. | GAO-24-106767

Timeline



Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Marshall Space Flight Center**

International Partners: **Centre National d'Etudes Spatiales (France), Japan Aerospace Exploration Agency, German Aerospace Center**

Launch Location: **Kennedy Space Center, FL**

Launch Vehicle: **To be determined (Heavy Class)**

Mission Duration: **10 years**

Requirement Derived from: **2011 Planetary Science Decadal**

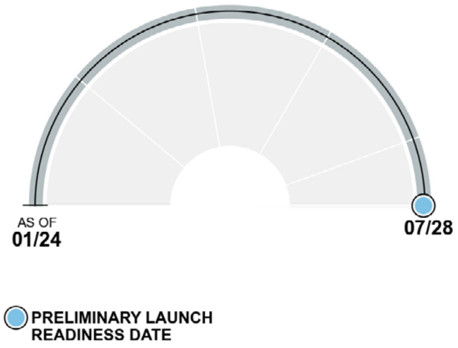
Project Summary

NASA postponed establishing Dragonfly's cost and schedule baselines until mid-2024. Following the release of the fiscal year 2025 President's Budget Request, NASA will hold another review to establish its cost and schedule baselines, including the mission's launch readiness date.

Previously, in March 2023, the Dragonfly project passed its preliminary design review (PDR). At the time, NASA directed the project to conduct a replan due to funding constraints. As part of that replan, Dragonfly estimated a new launch readiness date of July 2028 and reassessed costs to fit within the funding constraints. According to project officials, the funding reserves for fiscal years 2024 and 2025 are inadequate, but the project has sufficient reserves for the following years.

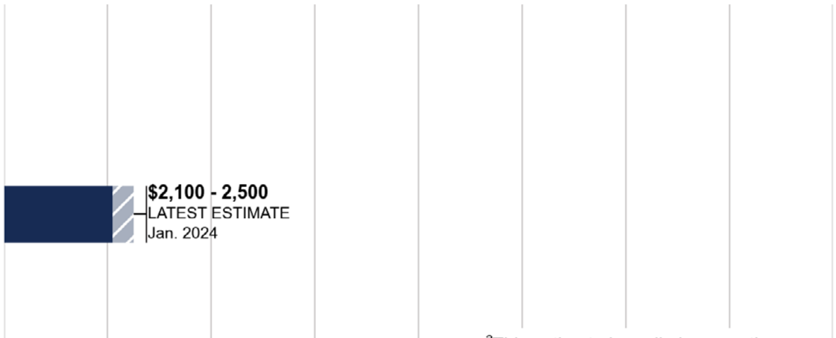
The project continues to make progress on the rotorcraft lander and its instruments. Dragonfly is continuing to mature its design as it works toward its critical design review.

Preliminary Schedule



Preliminary Cost[a]

THEN-YEAR DOLLARS IN MILLIONS



[a] *This estimate is preliminary as the project is in formulation, and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.*

Cost and Schedule Status

The Dragonfly project did not receive agency approval to formally proceed into the implementation phase in December 2023. However, the project was directed to proceed with implementation phase development work in fiscal year 2024. NASA plans to hold another review to set its cost and schedule baselines in mid-2024 following the release of the fiscal year 2025 President's Budget Request, including the mission's launch readiness date.

Following the PDR meeting, in March 2023, NASA directed Dragonfly to initiate a replan because the project's planned costs did not align with NASA's funding constraints. As part of the replan, NASA provided Dragonfly with funding targets for the remainder of the project's development. Project officials said that they completed the replan in July 2023, which included new cost, staffing, and schedule plans. Under the replan, officials said that cost reserves for fiscal years 2024 and 2025 are inadequate for all project-identified cost threats if they are materialized but should be adequate for fiscal years 2026 to 2028. Project officials said that supply chain issues have increased costs. As a result of that replan, the project also estimated a new launch readiness date of July 2028, which is 13 months later than the previous schedule estimate that was set in January 2022.

Technology and Design

The project passed the technical objectives of the PDR in March 2023, and all three critical technologies were matured to technology readiness level 6. This aligns with our best practice for technology maturity, which states that critical technologies should achieve a technology readiness level 6 by PDR to minimize risks for further product development. Dragonfly is continuing to mature its design as it works toward its critical design review.

The project continues to make progress on the designs of its flight system but is tracking several risks. Project officials said that they have thermal structural concerns with the material that Dragonfly uses in its spacecraft thermal protection system to protect the heatshield from intense heat as it enters Titan's thick atmosphere. The project is concerned with the performance of the material and the issue could affect the schedule. Dragonfly is working with the Mars Sample Return project to test the material, which remains a significant technical issue.

The project is also concerned with the lander's ability to transition to powered flight after it separates from the backshell, which is part of the protective barrier used during entry, descent, and landing to Titan. It is working on the activities prior to lander release to ensure that the conditions are favorable to facilitate the lander's transition to powered flight and fly down to land on Titan's surface. Project officials said that they are working to understand all the aerodynamics associated with the release of the lander and how to ensure it lands correctly.

The lander's insulation has never been used before and the project is concerned that lander testing may show that it has heat leaks greater than anticipated. This may require changes to the lander that could increase its weight. In addition, the lander is sensitive to temperature, so if it has a small hole, the resulting leak could cause it to get too cold and be unable to function. The project plans to mitigate this risk by sealing the inside of the lander and conducting testing.

The lander design is also closely linked to the design of the instruments. For example, the Drill for Acquisition of Complex Organics (DrACO) was moved from the lander leg to the body to reduce risk, which required major changes to DrACO's design. The Dragonfly Camera Suite (DragonCam) design also faces risks due to its integration with the lander. DragonCam hardware is protected from the Titan environment even though it is outside the lander body. The environment that DragonCam hardware experiences is reliant on how the instrument is accommodated by the lander.

The project continues to make progress on the designs of its instruments, but faces technical, cost, or schedule challenges that the project is working to resolve within its current resources. For example, the project added a second navigation camera to the Dragonfly Camera Suite and descoped the second Micro-Imager camera. The Dragonfly Mass Spectrometer faces technical challenges related to its valves and power supply that threaten the project's cost and schedule. Additionally, the Dragonfly Geophysics and Meteorology Package may have to apply cost reserves due to the cost of its electronics parts.

Project Office Comments

Dragonfly project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

After the Dragonfly project reviewed a draft of this assessment, the project announced that NASA confirmed the project and stated that it entered the implementation phase in April 2024.

Electrified Powertrain Flight Demonstration (EPFD)

EPFD is a technology demonstration project overseeing the commercial development of hybrid electric-powered aircraft. The program is working with two industry partners—GE Aviation (GE) and magniX—to mature Electrified Aircraft Propulsion (EAP) technologies for commercial aircraft through ground and flight demonstrations. The use of EAP technologies can lead to lower operating costs and benefits, such as higher fuel efficiency and reduced noise emissions. GE is developing a megawatt-class powertrain system for single-aisle aircraft carrying approximately 150 passengers. magniX is developing a hybrid commuter aircraft for transporting approximately 45 passengers.

Source: GE Aerospace and magniX livery images. | GAO-24-106767

Timeline

Formulation

06/20	Formulation start
09/21	Contract awards
2022	GE system requirements review
2022	GE preliminary design review
2023	magniX system requirements review
01/24	GAO review
2024	magniX preliminary design review
2024	GE critical design review
2024	Key decision point C

Implementation

2025	magniX critical design review
2026-2027	First flight for concept 1 and 2

Project Information

NASA Lead Mission Directorate: **Aeronautics Research**

NASA Lead Center: **Virtual Project Office**

International Partners: **None**

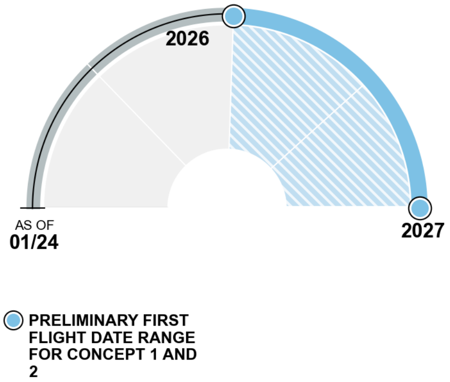
Requirement Derived from: **Aeronautics Research Mission Directorate Strategic Implementation Plan**

Project Summary

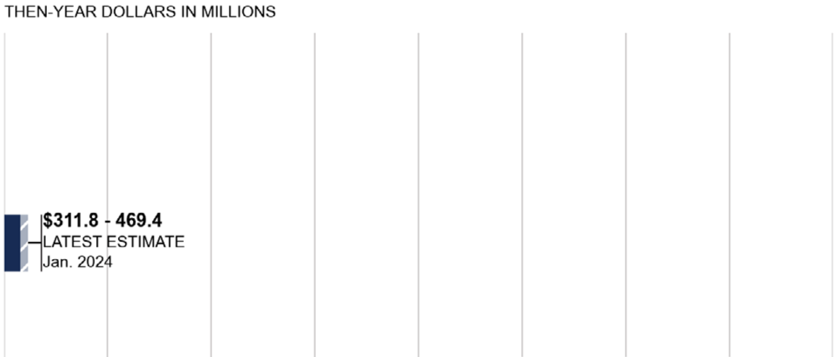
The EPFD project expects to establish cost and schedule baselines that are beyond the project's preliminary ranges at key decision point (KDP) C in spring 2024. Project officials said that NASA chose to extend the project's schedule and increase the budget profile in preparation for KDP C. According to project officials, the firm-fixed-price nature of the contracts with industry partners has helped mitigate cost growth. However, NASA's costs are increasing because the agency workforce is remaining on the project longer than originally planned. The EPFD project and its two industry partners are tracking risks that a constrained supply base for critical components could further affect the project's schedule.

Both industry partners are making progress developing their systems. The project reports that both have a credible path to demonstrating technological maturity at the end of their planned flight demonstrations.

Preliminary Schedule – Under Review



Preliminary Cost[a] – Under Review



[a]*This estimate is preliminary as the project is in formulation, and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.*

Cost and Schedule Status

The EPFD project expects to establish cost and schedule baselines that are beyond the project's preliminary ranges at KDP C in spring 2024. Project officials said that NASA chose to extend the project's life cycle and increase the budget profile in preparation for KDP C. Officials indicated that this will ensure that the program schedule is not too aggressive and that funding margin is available in the years after the program is baselined. The project's KDP B decision memorandum presented a life-cycle cost estimate target range of $311.84 million to $469.41 million with a KDP C date of March 2022. The project's latest estimates are $562.4 million and first flight in the 2026-2027 time frame. These estimates are being refined ahead of the planned KDP C.

The project has experienced delays that are due, in part, to supply chain and workforce availability issues caused by COVID-19. Additionally, the project and its two industry partners are tracking risks that a constrained supply base for critical components could further affect the project's schedule. The constrained supply base is due to the technical complexity of these unique parts and raw material shortages, among other reasons.

NASA awarded two hybrid firm-fixed-price, cost-share contracts to GE and magniX in 2021. These contracts are firm-fixed-price until the critical design reviews, at which point NASA and the industry partners will each fund 50 percent of the total contract costs through contract closeout, which includes flight demonstration. According to project officials, despite ongoing delays, the firm-fixed-price nature of the contracts helped mitigate cost growth. However, NASA's costs are increasing because the agency workforce is remaining on the project longer than originally planned.

GE Aerospace. GE completed its integrated baseline review of anticipated costs and schedule in November 2023. GE's next milestone is its critical design review, which it delayed. Project officials said that GE flew baseline flights in fiscal year 2023 to assess the performance and operational procedures. Project officials stated that knowledge from these tests reduces the likelihood of changes to the aircraft performance and safety after the critical design review.

magniX. magniX completed its system requirements review in February 2023, but shifted its preliminary design review from November 2023 to January 2024. Project officials indicated that magniX plans to hold an integrated baseline review of its cost and schedule in February 2024 ahead of KDP C. Project officials stated that magniX experienced a $20 million cost increase when its original airframe integrator backed out after contract award. However, the new aircraft integrator, AeroTEC, is the leading aircraft integrator of electrified aircraft propulsion technology.

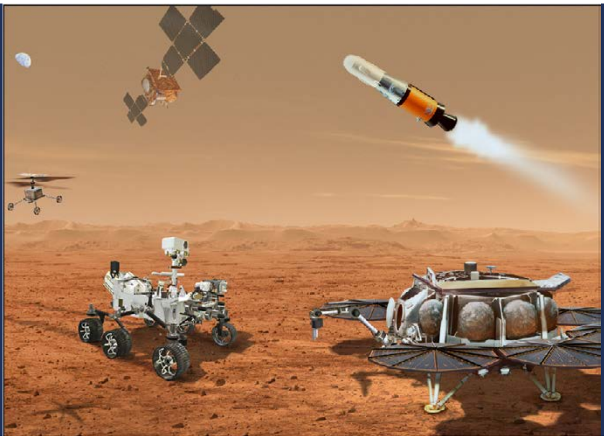
Technology and Design

The EPFD project is categorized as a technology demonstration project. As such, the project uses technology readiness data to assess the maturity of its critical technologies at various points in their life cycles but has flexibility to determine when it will mature technologies. One of the project's objectives is for both industry partners to demonstrate a technology readiness level 6 through ground and flight demonstrations for their individual integrated powertrain systems at the conclusion of the project. The project reported that both GE and magniX have a clear and credible path to demonstrate this technology readiness level at the end of their first flight demonstrations.

However, the project still has technical concerns for both GE and magniX. According to project officials, their top technical concern for GE is aircraft integration and that GE's test schedule may not include sufficient time to implement lessons learned between tests. For magniX, project officials indicated their top technical concern is the energy storage system because magniX is close to the desired performance at the individual battery cell level, but needs to achieve some technical advances to meet its desired performance at the system level.

Project Office Comments

EPFD project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Mars Sample Return (MSR)

The MSR program is a joint endeavor between NASA and the European Space Agency (ESA). It plans to collect Martian samples gathered by the Mars Perseverance Rover and bring them safely back to Earth for study and analysis. NASA's planned contributions include the Sample Return Lander (SRL), the Mars Ascent Vehicle, and the sample Capture, Containment and Return System (CCRS). ESA's planned contributions include the Earth Return Orbiter and Sample Transfer Arm. This mission is planning the first launch from the surface of another planet and the first international, interplanetary relay effort.

Source: Cal Tech / NASA Jet Propulsion Laboratory. | GAO-24-106767

Timeline

Formulation

- **09/20** Formulation start
- **07/22** System requirements/ mission definition review
- **09/23** Independent review board report
- **01/24** GAO review
- **2025 (under review)** Preliminary design review
- **Under review** Key decision point C

Implementation

- **Under review** Critical design review
- **Under review** System integration review
- **Under review** CCRS preliminary delivery readiness date
- **06-07/28 (under review)** SRL preliminary launch readiness date

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **European Space Agency**

Launch Location: **Eastern Range, FL (Sample Return Lander) and French Guiana (Earth Return Orbiter)**

Launch Vehicle: **TBD**

Mission Duration: **5 years**

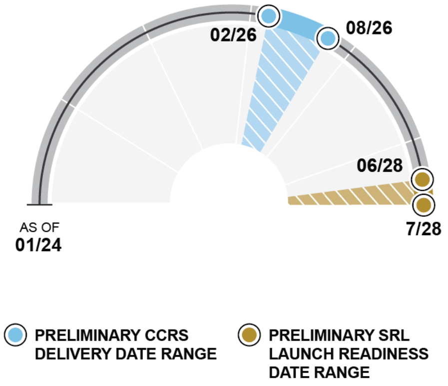
Requirement Derived from: **2011 Planetary Science Decadal and 2022 Planetary Science and Astrobiology Decadal Survey**

Project Summary

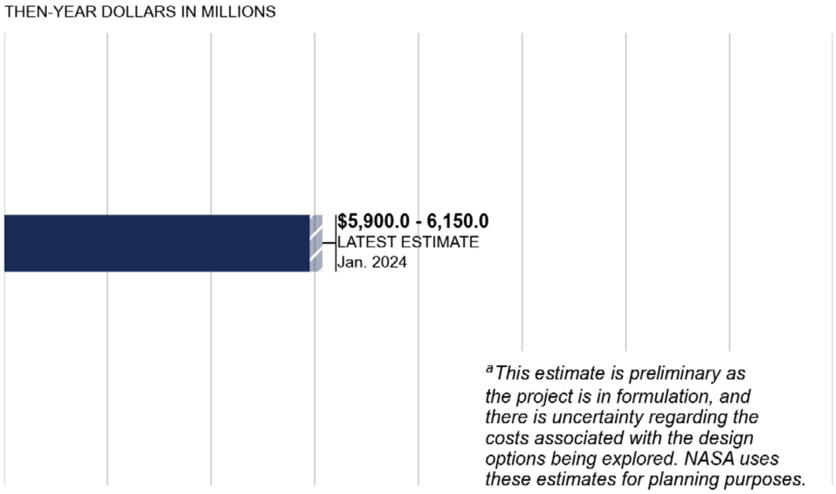
In spring 2023, the MSR program halted its preliminary design review and confirmation while an independent review board conducted an assessment due to the program's ongoing funding, schedule, technical, and architectural challenges. In September 2023, the independent review board issued a broad range of findings and recommendations. In response, NASA created the MSR Independent Review Board Response Team, which plans to make a recommendation regarding the program's path forward by the second quarter of fiscal year 2024. In early 2024, the Jet Propulsion Laboratory cut staff by about 8 percent—more than 500 employees—in response to MSR funding constraints.

As of January 2024, the MSR program had matured all seven of its critical technologies to technology readiness level 6 or higher. In response to the independent review board, NASA has paused work on one critical technology and is considering descoping two other technologies as part of potential changes to the mission architecture.

Schedule Performance – Under Review



Cost Performance[a] – Under Review



[a] This estimate is preliminary as the project is in formulation, and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.

Cost and Schedule Status

The MSR program had been working toward the mission's preliminary design review scheduled for September 2023 and its project confirmation in October 2023. However, in spring 2023, the program temporarily halted its preliminary design review and confirmation while an independent review board assessed the program. The independent review board conducted this assessment due to the program's ongoing funding, schedule, technical, and architectural challenges. In September 2023, the independent review board reported that the MSR program's cost, schedule, and technical baselines were not credible within likely funding profiles.

According to the independent review board's report, technical issues and programmatic risks, as well as the MSR program's performance-to-date, indicated a near-zero probability of the program meeting its 2028 launch readiness date. The report noted a potential launch window in 2030, but the launch opportunity would require significantly increased funding and timely resolution of issues facing the program. Additionally, the report stated that decoupling the launch readiness dates of the Sample Return Lander and the Earth Return Orbiter, in addition to potential alternate mission architectures, may allow the program to fit within likely annual funding constraints.

In response to these findings, NASA created the MSR Independent Review Board Response Team. The response team plans to make a recommendation to agency leadership on the program's path forward by the second quarter of fiscal year 2024. In addition, NASA officials told us the program paused work on Capture, Containment, and Return System—a component of the Earth Return Orbiter—indefinitely.

In addition to responding to the independent review board's report, the program is also responding to funding constraints. In February 2024, in response to MSR funding constraints, the Jet Propulsion Laboratory announced a workforce reduction. The Jet Propulsion Laboratory stated that the decision followed exhaustive measures to align with reduced funding allocations from NASA. Approximately 530 employees, constituting about 8 percent of the laboratory's workforce, alongside an additional 40 contractor staff, were affected across various technical and support sectors. Laboratory officials report that this reduction is part of strategic adjustments to maintain operational capabilities at the laboratory within the allocated funding, ensuring the continuation of critical missions and projects.

Technology and Design

Under the current program architecture, NASA plans to use Perseverance—a rover currently collecting samples on Mars—to deliver the samples it acquires to NASA's Sample Return Lander. Then, the ESA-contributed Sample Transfer Arm on the lander will transfer the samples to the Mars Ascent Vehicle, which will launch the samples into Martian orbit to rendezvous with the Earth Return Orbiter.[35]

As of January 2024, the MSR program had matured all seven of its critical technologies to technology readiness level 6 or higher. However, the program indefinitely paused additional development work on the critical technology related to the Capture, Containment, and Return System. Furthermore, the program is considering descoping two other technologies—the sample recovery helicopters and the pinpoint landing system—as part of potential changes to the mission architecture. These potential descopes are in response to the independent review board's findings.

Another critical technology—the Mars Ascent Vehicle's Thrust Vector Control system—reached technology maturity in January 2024 and will be required for returning the samples to Earth. The Thrust Vector Control system is responsible for the supersonic thrust control of the small rocket that will transport Martian samples into orbit to rendezvous with the Earth Return Orbiter. The system was one of the MSR program's primary technology development efforts.

Project Office Comments

MSR program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

After the MSR program reviewed a draft of this assessment in April 2024, NASA announced that it plans to solicit proposals for rapid industry studies to investigate alternate MSR mission designs or elements. The MSR program will focus on continuing work on elements that are likely to remain in future mission designs and assessing the findings of these studies through fiscal year 2025.

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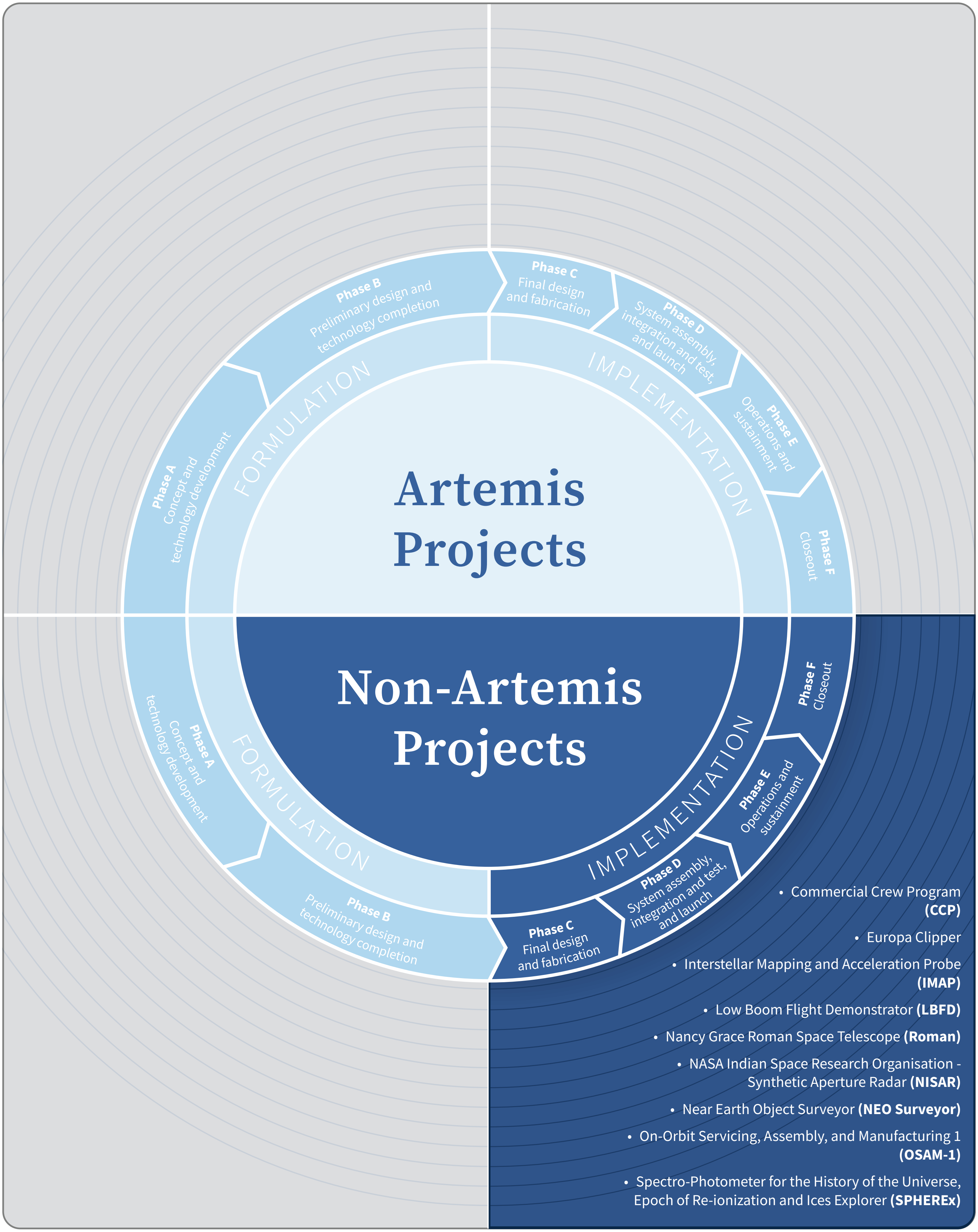
[35] For a depiction of the existing architecture under review by the response team, see GAO, *NASA: Assessments of Major Projects*, GAO-23-106021 (Washington, D.C.: May 31, 2023).



- Commercial Crew Program **(CCP)**
- Europa Clipper
- Interstellar Mapping and Acceleration Probe **(IMAP)**
- Low Boom Flight Demonstrator **(LBFD)**
- Nancy Grace Roman Space Telescope **(Roman)**
- NASA Indian Space Research Organisation - Synthetic Aperture Radar **(NISAR)**
- Near Earth Object Surveyor **(NEO Surveyor)**
- On-Orbit Servicing, Assembly, and Manufacturing 1 **(OSAM-1)**
- Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer **(SPHEREx)**

Source: GAO analysis of NASA data. | GAO-24-106767

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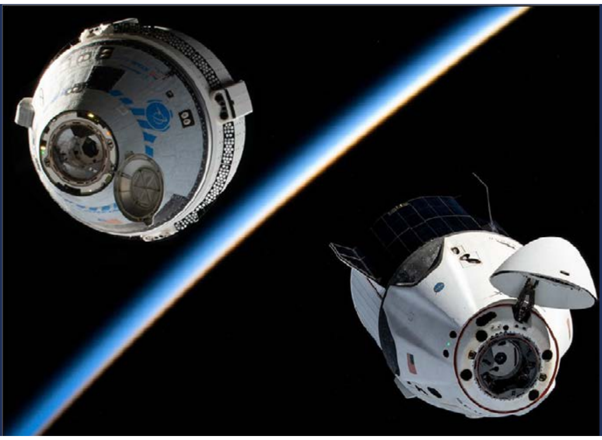
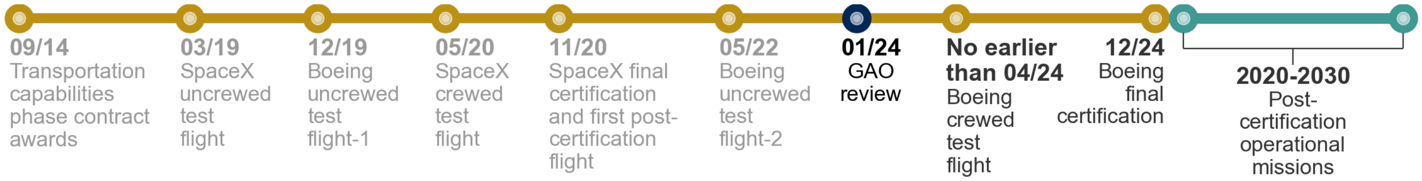


Source: NASA. | GAO-24-106767

Commercial Crew Program (CCP)

CCP oversees the development of crew transportation systems by commercial companies to carry NASA astronauts to and from the International Space Station (ISS). The program is working with Boeing and SpaceX to design, develop, test, and operate crew transportation systems. NASA must certify that these crew transportation systems meet its standards for human spaceflight before the companies can fly crewed missions to and from the ISS. NASA certified SpaceX in November 2020.

Timeline



Project Information

NASA Lead Mission Directorate: **Space Operations**

NASA Lead Center: **Kennedy Space Center**

Commercial Partners: **Boeing and SpaceX**

Launch Location: **Boeing – Cape Canaveral Space Force Station, FL; SpaceX – Kennedy Space Center, FL**

Launch Vehicle: **Boeing – Atlas V; SpaceX – Falcon 9**

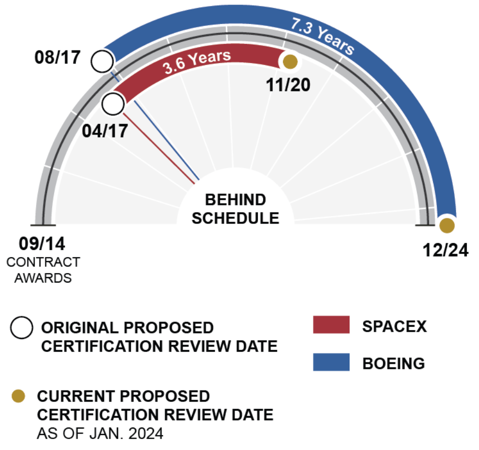
Requirement Derived from: **NASA Strategic Plan**

Project Summary

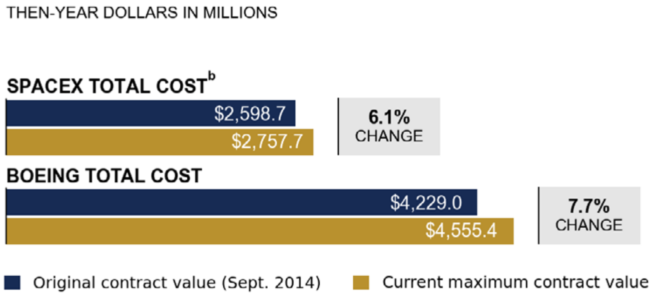
CCP and Boeing continue to make progress toward certifying Boeing's crew transportation system to transport crew to and from the ISS. Boeing's certification review—which has been delayed at least 7 years—is planned for December 2024.

As of January 2024, Boeing was working toward a crewed flight test in April 2024. Boeing previously decided not to move forward with a crewed flight test attempt in July 2023 due to two late issues that were discovered by CCP's verification processes in the lead up to the flight. The Boeing and CCP program managers said that they each sought an independent review of their programs to determine whether the two issues were outliers or symptoms of a larger problem. Boeing's independent review is complete and, according to Boeing's program manager, no major issues or unacceptable risks were identified. As of January 2024, CCP's independent review is ongoing.

Schedule Performance



Cost Performance[a]



[a] *As reported by NASA as of January 2024 and includes contract costs for development, operations, and special studies*

[b] *SpaceX completed development and completed all 6 post-certification missions in its original contract by September 2023. We consider the cost of subsequent SpaceX post-certification missions to be an increase in scope and not cost growth on the original contract. Therefore, SpaceX's costs will not change after September 2023.*

Cost and Schedule Status

CCP and Boeing continue to progress toward certifying Boeing's crew transportation system to transport crew to and from the ISS. As of January 2024, Boeing was working toward a crewed flight test in April 2024. Boeing's certification review—which has been delayed at least 7 years—is planned for December 2024, and the first service mission is currently planned for February 2025.

CCP officials said the timing of the first service mission will be partially driven by the outcome of the crewed flight test. Boeing's first service mission is currently planned to take place the same month as a SpaceX service mission, even though CCP officials said there will only be one mission to the ISS in that time period. This means NASA will have to decide which provider—Boeing or SpaceX—flies in that time slot. The CCP program manager said NASA will decide in spring 2024, or around the time Boeing attempts its crewed flight test.

Integration and Test

In July 2023, Boeing decided not to move forward with a crewed flight test attempt after Boeing and NASA identified two issues as part of a joint verification process. The two issues were a parachute joint that failed to meet NASA's required level of safety, and a wiring tape meant to protect chafing that was found to be flammable in the configuration used on Boeing's capsule. NASA briefed the Aerospace Safety Advisory Panel on these issues and the panel recommended an independent review, according to NASA officials.

The Boeing and CCP program managers said that they each sought an independent review of their programs to determine whether the two issues were outliers or symptoms that compounding risks were incrementally accepted into the system. Boeing's program manager said the company conducted an independent review of seven areas, including software problem reports, configuration changes from previous flights, and risks to loss of mission. The program manager said this review was completed by December 2023. The program manager also said the results of this review were shared with NASA, and no major issues or unacceptable risks were identified.

As of December 2023, CCP's independent review is ongoing. CCP engineering managers are evaluating previous reviews and approvals to determine if the program missed any issues. NASA's Engineering and Safety Center, which conducts independent assessments of high-risk projects to ensure safety and mission success, is also assessing key technical issues for the crewed flight test. For example, in addition to the parachutes and the wiring tape, it is also assessing the active thermal control system valves as part of the flight readiness process for Boeing's crewed flight test. CCP officials stated that, as of January 2024, Boeing modified these valves and completed its remediation of the wiring tape for the crewed flight test.

CCP's program manager said Boeing's schedule for a crewed flight test in April 2024 is driven by remaining work to certify the parachute system. Boeing implemented design and hardware changes to address the two issues described above, such as redesigning the parachute joint and removing the wiring tape. In January 2024, NASA conducted a drop test of the modified parachute system to confirm the functioning of the redesigned and strengthened parachute joint, among other things. Remaining work includes the submission and review of the certification work for the parachute system. As of December 2023, Boeing has approximately 5 weeks of schedule margin for the crewed flight test.

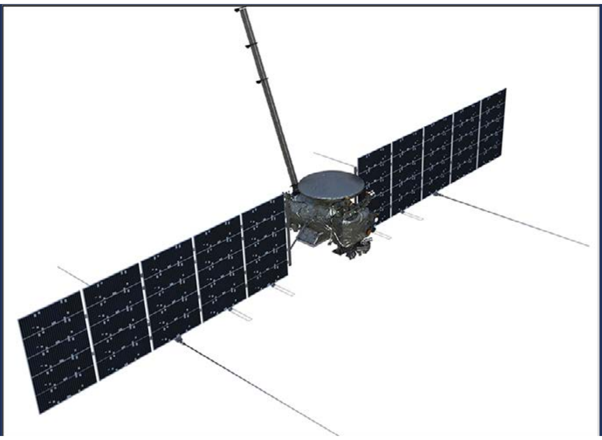
Other Issues to Be Monitored

In September 2023, CCP decided to pursue certification of a second SpaceX launch pad (launch pad 40) at Kennedy Space Center as a back-up capability for CCP missions. SpaceX will continue to launch CCP missions from its current launch pad (launch pad 39A), unless there is a schedule conflict with a higher priority mission or damage to the pad.

Project Office Comments

In commenting on a draft of this assessment, CCP officials concurred with the technical content in the draft. They stated that NASA and Boeing continue work to certify Boeing's crew transportation system. Once certified, officials said NASA plans to conduct crew transportation missions to the ISS by alternating missions between the providers. Officials stated that CCP has demonstrated the benefits of crew rotation missions, innovation, and cost effectiveness through its partnerships with industry and use of competition.

After the CCP program reviewed a draft of this assessment, NASA announced that Boeing's crewed flight test was planned for early May 2024 to accommodate ISS activities in late April.



Europa Clipper

The Europa Clipper mission aims to investigate whether Europa—a Jupiter moon—could harbor conditions suitable for life. The project plans to place a spacecraft in orbit around Jupiter and conduct a series of investigatory flybys of Europa. The mission will use its nine instruments to characterize Europa's ice shell and any subsurface water; analyze the composition and chemistry of its surface and atmosphere; and gain an understanding of the formation of its surface features.

Source: NASA/Jet Propulsion Laboratory-California Institute of Technology. | GAO-24-106767

Timeline

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **None**

Launch Location: **Kennedy Space Center, FL**

Launch Vehicle: **Falcon Heavy**

Mission Duration: **4-year science mission**

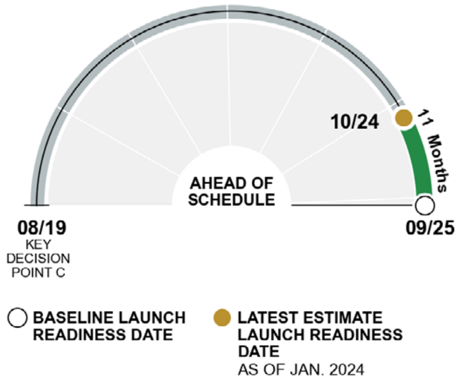
Requirement Derived from: **2011 Planetary Science Decadal Survey**

Project Summary

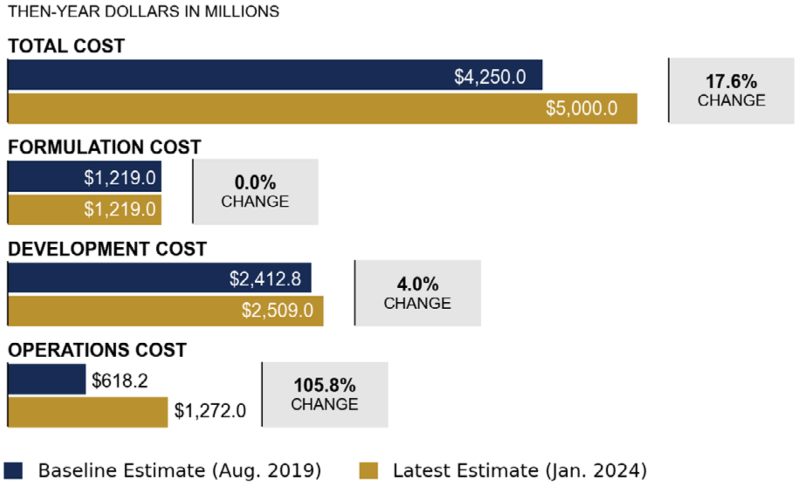
The Europa Clipper project continues to operate within its updated cost and schedule estimates, which NASA finalized in April 2022. However, cost and schedule remain a concern for the project due to late hardware deliveries and the scope of the remaining work. In February 2023, the Europa Clipper standing review board conducted an updated assessment of the project and determined that the project's October 2024 launch date remains viable, but the project's schedule is under significant stress. The project faces cost risks due to the lack of reserves.

Completing assembly, test, and launch operations (ATLO) is the project's critical path for its schedule, as well as its top risk. Late deliveries of scientific instruments and spacecraft hardware have affected the ATLO schedule and led to cost growth. The Jet Propulsion Laboratory granted the project priority for staffing to address staffing shortages and implement schedule recovery options such as adding Sundays and third shifts to the work week.

Schedule Performance



Cost Performance



Cost and Schedule Status

The Europa Clipper project continues to operate within its updated cost and schedule estimates, which NASA finalized in April 2022. However, cost and schedule remain a concern for the project due to late hardware deliveries and the scope of the remaining work.

In February 2023, the Europa Clipper standing review board conducted an updated assessment of the project and determined that the project's October 2024 launch date remains viable, but the project's schedule is under significant stress. The board also concluded that the project could require as much as $108 million from Science Mission Directorate reserves to complete the remaining work. The directorate released $40 million of reserves to the project in June 2023.

The project completed a new estimate at completion for the system assembly, integration and test, and launch phase—phase D—in August 2023. By December 2023, it determined that, even with the $40 million released in June 2023, the project needs an additional $65 million from headquarters' reserves to cover currently anticipated project costs. As of December 2023, the project needs an additional $5.4 million beyond the $60 million that the Science Mission Directorate is currently holding in reserves for use in fiscal year 2024. The project is working to finish phase D within the available reserves and is tracking opportunities to reduce demands on project reserves, such as by descoping activities.

If the project misses its October 2024 launch date, its next launch opportunity is in November 2025, which is about 2 months after the committed launch date.

Integration and Test

Completing ATLO is the project's critical path—the portion of the program with the least amount of schedule reserve available—as well as its top risk. According to project officials, early in 2023, late deliveries of instruments and avionics to ATLO were driving cost growth. Project officials indicated that, while all the science instruments had been delivered, almost all of them were delivered late. In addition, the project had to rework some spacecraft avionics. As of December 2023, however, delivery of all major items that are planned to be installed at the Jet Propulsion Laboratory was complete.

The late deliveries to ATLO consumed much of the margin in the ATLO schedule, which has 52 days of margin as of January 2024. The project added staff to the ATLO teams to provide more resiliency and to enable use of schedule recovery options such as adding Sundays and third shifts to the work week. Staff availability at the Jet Propulsion Laboratory has threatened the project's cost and schedule performance in the past, but project officials indicated that staffing issues improved in calendar year 2023 since the laboratory gave the project priority for staffing after the Psyche mission launched. According to project officials, delays within the Psyche project had previously prevented some Jet Propulsion Laboratory staff from transitioning to the Europa Clipper project.

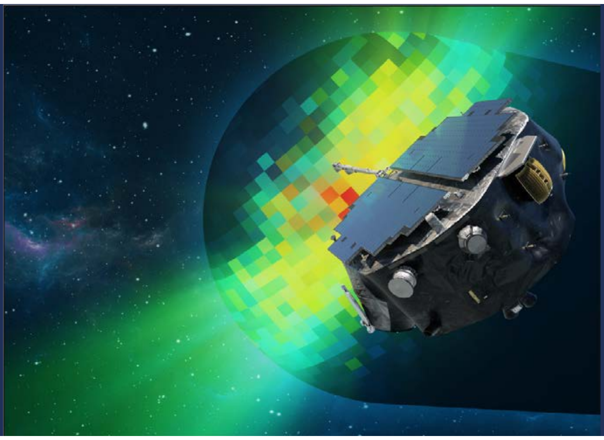
The project is concerned that it will be difficult to complete software verification and validation to determine whether the software meets requirements and performs all required functions within the available schedule and budget. The project's high fidelity test venue is unable to meet all the testing demands despite working three shifts 7 days a week. To mitigate the problem, the project is acquiring a second high-fidelity test venue that will provide more space for testing. Officials indicated that the project is also shifting testing as appropriate to other lower fidelity testing systems, including some avionics test beds that are largely automated and can run around the clock for lower-level testing.

Other Issues to Be Monitored

The project deferred some phase D activity to post-launch in phase E. Specifically, the project deferred mission planning software development activities into phase E. According to project officials, the software that will be completed in phase E is not needed until after the spacecraft reaches Europa in 2030. But, the software will allow the project to use the MERLIN system—a new multi-mission next generation ground system that incorporates different capabilities into one toolset. Officials expect that when the MERLIN system is fully integrated with Europa Clipper, it will simplify mission execution and spacecraft control. Project officials indicated that delaying this development does not hinder the project's capability to launch and control the spacecraft during cruise or to support early operations, but they do expect it to affect costs.

Project Office Comments

In commenting on a draft of this assessment, Europa Clipper project officials stated that the project continues to actively track cost performance and projects the cost at completion of Phase D, based on project officials' insight into team performance and progress. Officials said the verification and validation program is making good progress and is on track to be completed within the remaining schedule. The officials also provided technical comments, which were incorporated as appropriate.



Interstellar Mapping and Acceleration Probe (IMAP)

IMAP is a spinning spacecraft that will help researchers better understand the boundary where the heliosphere collides with interstellar medium, or material from the rest of the galaxy. The heliosphere is the bubble created by the solar wind—a constant flow of particles from our sun—and the boundary limits the amount of harmful cosmic radiation entering the solar system. IMAP includes 10 instruments and will reside in an orbit almost 1 million miles from Earth, where it will collect and analyze particles that make it through the boundary.

Source: NASA/Princeton/Johns Hopkins APL/Josh Diaz. | GAO-24-106767

Timeline

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Goddard Space Flight Center**

International Partners: **Polish Academy of Sciences (Poland), University of Bern (Switzerland), Imperial College of London (UK)**

Launch Location: **Cape Canaveral Space Force Station, FL**

Launch Vehicle: **Falcon 9**

Mission Duration: **2 years**

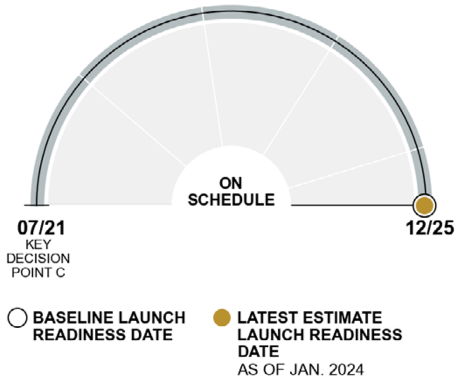
Requirement Derived from: **2013 Heliophysics Decadal Survey**

Project Summary

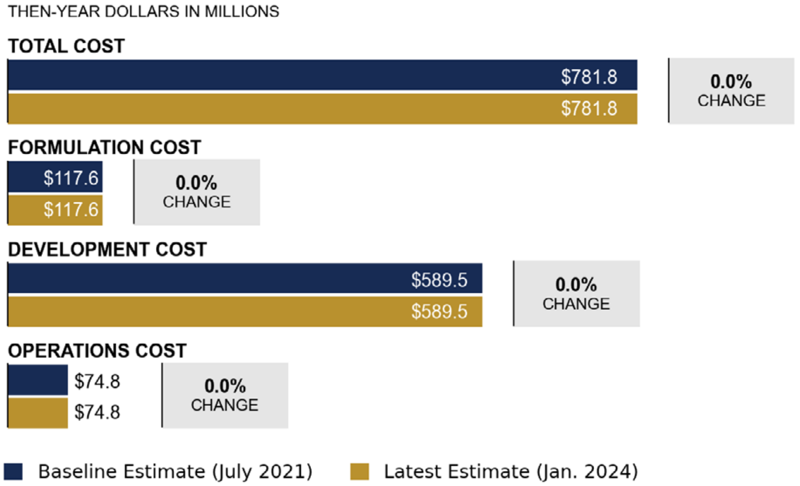
The IMAP project is operating within the cost and schedule baselines that NASA established in July 2021. The IMAP project entered the system assembly, integration and test, and launch phase—phase D—in December 2023. It also moved the internal launch date from February 2025 to May 2025 due to delays in instrument development.

The project held a successful system integration review in September 2023 with two stated issues: instrument readiness for integration and test, and launch vehicle requirements. As of January 2024, the Compact Dual Ion Composition Experiment (CoDICE) and IMAP-Lo instruments remained the project's primary and secondary critical paths, but the project is applying resources to reduce schedule delays. Officials report that the project is working with NASA and the launch vehicle contractor to address delays getting data from the contractor and to ensure that the launch vehicle estimates for loads and environments do not exceed IMAP's requirements. For example, the vibrations experienced during launch cannot exceed certain parameters.

Schedule Performance



Cost Performance



Cost and Schedule Status

The IMAP project is operating within the cost and schedule baselines that NASA established in July 2021. An IMAP official said the project is using funds to apply resources such as staff and facilities to save schedule. For example, the project shifted some testing to alternate sites to avoid schedule conflicts at test facilities.

The IMAP project entered the system assembly, integration and test, and launch phase—Phase D—in December 2023. It also decided to move the internal launch date from February 2025 to May 2025 due to delays in instrument development. The new date still falls within the project's schedule baseline. The project is also using $2.5 million of reserves to account for the increase in launch-related costs.

The project held a successful system integration review in September 2023. At that time, its standing review board stated that the project is ready to proceed to integration and test. Following the review, the project and board conducted a schedule analysis that determined the previous launch date was not feasible, leading to the change. In addition to recognizing the project's many strengths, the board noted issues related to instrument readiness for integration and meeting launch vehicle requirements.

Instruments

IMAP's instruments have had several fabrication, delivery, and testing delays. As a result of these delays, several of the project's 10 instruments were behind schedule prior to the internal launch date shift. For example, the project has had potential quality or testing difficulties with parts such as micro channel plates. These parts are necessary for multiple instruments, including IMAP-Lo—which will measure the energy and position of certain interstellar atoms—to detect particles in space.

The CoDICE instrument—which will measure the distribution and composition of particles that make it into the heliosphere—has also fallen behind schedule due to staffing shortages and fabrication delays, among other issues. According to a project official, various parts on CoDICE and other IMAP instruments require specialized coatings that only a limited number of vendors can apply. As noted above, the project is addressing the schedule impacts of these issues through additional resources, and the instruments are progressing into assembly and test.

Launch Vehicle

NASA selected the SpaceX Falcon 9 as the launch vehicle for IMAP. At the system integration review, the standing review board also noted issues with launch vehicle requirements. As IMAP approaches integration, the project has concerns regarding the launch vehicle requirements in three areas:

1. **Coupled loads analysis.** The coupled loads analysis is necessary to understand the environment that the spacecraft and instruments experience during launch. A project official stated that they received the initial analysis data approximately 10 months later than scheduled. In addition, the data provided did not include the complete launch configuration, meaning that the current estimate will require additional data and refinement. The next data delivery is not until June 2024, but the project is working with NASA and SpaceX to obtain interim data sooner.
2. **Fairing access.** The project initially planned to be able to access the fairing, which is the top of the rocket that houses its payload, very close to launch to remove covers meant to prevent contamination to IMAP's sensitive instruments. Access to the fairing so late in the launch campaign presented challenges to SpaceX's process. The IMAP team reassessed the need for access to the fairing and late removal of instrument covers and determined that they will only need access for contingencies. The project is coordinating additional mitigations to ensure proper cleaning of the fairing with SpaceX and the payload processing facility.
3. **Nutation.** The project was concerned about SpaceX's ability to meet the project's requirements to limit nutation, which refers to a small disturbance of the wobble caused by the spacecraft spinning on its axis. If the launch vehicle exceeds the nutation requirement, the spacecraft may need to perform additional maneuvers. While SpaceX's current projections indicate an amount of nutation above what the project required, an IMAP official told us the project can accept those projections if they are accurate. The project may be able to close the nutation issue once NASA Launch Services Program Independent Verification and Validation confirms SpaceX's nutation analysis.

Project Office Comments

IMAP project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Low Boom Flight Demonstrator (LBFD)

LBFD is a flight demonstration project that is developing the X-59 aircraft for the Quesst mission to show that noise from supersonic flight—sonic boom—can be reduced to levels acceptable to the public for eventual commercial use in overland flight paths. After the aircraft transfer review, the project plans to transfer the flight demonstration aircraft to the other Quesst projects. NASA's Flight Demonstrations and Capabilities project will support community testing by the Commercial Supersonic Technology project and will gather community responses to the flights and create a database to support the development of international noise standards, which are needed to open the market for supersonic flight.

Source: NASA. | GAO-24-106767

Timeline

Formulation	03/13	Start of concept formulation studies
	03/14	Mission definition review
	09/16	LBFD formulation start
	08/18	Preliminary design review
	11/18	Key decision point C
Implementation	09/19	Critical design review
	01/24	GAO review
	10/24	Latest first flight date
	09/25	Systems acceptance review
	10/26	Aircraft transfer review

Project Information

NASA Lead Mission Directorate: **Aeronautics Research**

NASA Lead Center: **Virtual project office**

International Partners: **None**

Requirement Derived from: **Aeronautics Research Mission Directorate Strategic Implementation Plan**

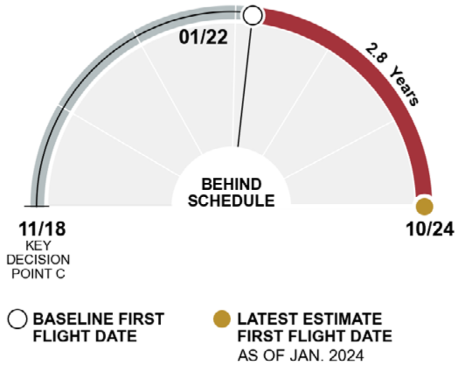
Project Summary

In January 2024, the LBFD project rebaselined its cost and schedule. The project has exceeded its cost baseline by 44 percent and delayed the first flight by over 2½ years. The project was previously at risk of rebaselining, but the use of contractor funds to complete some of the work since 2022 helped defer this outcome. The new project cost estimates assume that the contractor will continue to offset some of its costs with its own funds.

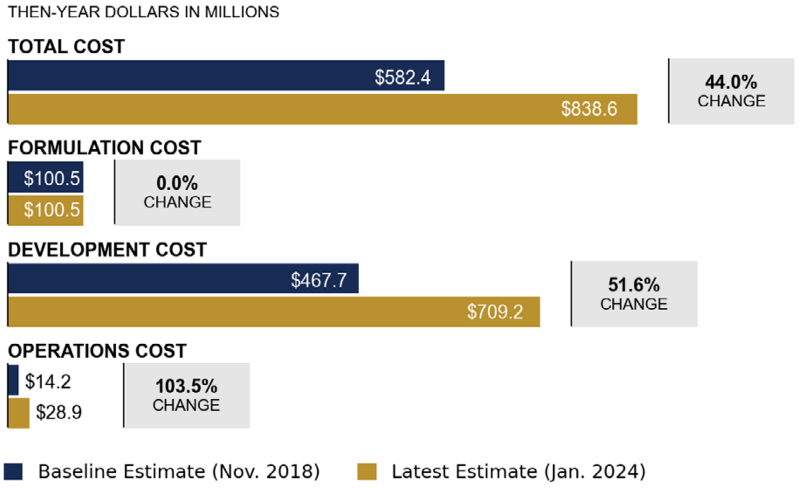
Project officials said the rebaseline was unavoidable because the first flight was delayed beyond January 2024. They also said recent schedule delays were caused by discoveries during testing that required investigation and rework. According to NASA documentation, almost every planned activity required some level of rework during the integration and test phase.

In January 2024, NASA publicly revealed the LBFD aircraft during its rollout ceremony—a major milestone before its first flight. The aircraft rollout preceded the start of integrated ground testing, such as engine runs and taxi tests.

Schedule Performance



Cost Performance



Cost and Schedule Status

The LBFD project rebaselined in January 2024, which NASA documentation states was primarily due to continued challenges with contractor performance. The project has exceeded its cost baseline by 44 percent and delayed the first flight by over 2½ years. Since 2022, the contractor's use of its investment funds to complete some work helped defer this outcome. The new baseline assumes that the contractor will continue to offset its costs with its own investment funds.

The project's development cost grew by over $100 million since last year and the project delayed the baseline first flight date by 17 months. According to project officials, the rebaseline was unavoidable if the first flight date was delayed beyond January 2024.

According to NASA documentation, multiple issues caused the recent schedule delays. These issues included overly optimistic planning, continued lack of contractor performance, discoveries during testing that required investigation and rework, and electrical system challenges. For example, NASA documentation indicates that the contractor has consistently underestimated the time needed to reach schedule milestones.

In addition, according to officials, NASA had previously modified the contract with Lockheed Martin to require additional testing because some aircraft simulations were not included as part of the contractor's testing plan. These tests are now included in the project's schedule, contributing 3 weeks to the recent schedule delay.

Integration and Test

According to NASA documentation, almost every planned activity required some level of rework during integration and testing. For example, the contractor continues to conduct a lot of rework on the wiring. In one case, the project had to correct wiring for part of the flight control system after the plane behaved unexpectedly. Project officials said they found the wiring was implemented correctly according to design drawings, but the design drawings were incorrect. In addition, the project's schedule slipped by 4 months to investigate and resolve issues with the aircraft's vehicle management system.

In addition, staffing concerns continue to be a risk as the project progresses toward first flight. According to NASA, the contractor's workforce challenges, such as inexperienced staff, have already contributed to the discoveries of issues that resulted in rework during integration and testing. Moving forward, the experience and expertise of staff supporting the remaining tests continues to be a concern. Project officials said they worked with the contractor to ensure that staffing levels during testing were realistic within the project's refined test schedule.

In January 2024, NASA publicly revealed the LBFD aircraft during its rollout ceremony—a major milestone before its first flight. The aircraft rollout revealed the assembled and painted aircraft and preceded the start of integrated ground testing, such as engine runs and taxi tests. Integrated ground testing is a high-risk activity because of the likelihood that the project will discover issues during this testing.

Other Issues to Be Monitored

The LBFD project is one of three projects in the Quesst mission. The mission has two goals: (1) develop an aircraft with technology to reduce the loudness of a sonic boom, and (2) fly the aircraft over up to five communities and gather data on public response to the noise. The LBFD project is responsible for the aircraft development and supports the acoustic validation phase along with the other two projects, which will conduct the work on community responses.

The results from this mission will support the Committee on Aviation Environmental Protection, an international group that meets every 3 years. As a result of the recent delays to the first flight date, the Quesst mission can no longer support the committee's 2028 meeting as originally planned. The Quesst mission data will be used to support the committee's meeting in 2031 instead.

The other two projects in the Quesst mission have previously adjusted their schedules to try to accommodate previously realized LBFD schedule delays. The most recent 17-month delay to the LBFD first flight will also affect the costs for the other two projects. NASA has not yet identified the extent of this cost growth.

Project Office Comments

In commenting on a draft of this assessment, LBFD project officials stated that despite the challenges, there was significant progress made on the project in 2023, including the completion of the installation of command and control and flight test instrumentation wire; completion of unpowered system checkouts; progress on powered system testing; and completion of the Ground Vibration Test as well as the initiation of the Surface Freeplay Test and Structural Coupling Test. Officials also stated that, while the activities are taking longer than planned, there was a significant amount of work accomplished in 2023. They also provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Nancy Grace Roman Space Telescope (Roman)

Roman, formerly known as the Wide-Field Infrared Survey Telescope, is an observatory designed to perform wide-field imaging and survey of the near-infrared sky. The Roman project plans to answer questions about the structure and evolution of the universe and expand our knowledge of planets beyond our solar system. The telescope has a primary mirror that is 2.4 meters in diameter, and its primary instrument will have a field of view that is 100 times larger than the Hubble Space Telescope's infrared instrument. The project plans to launch Roman to an orbit about 1 million miles from Earth. The project is also planning a guest observer program that may provide observation time to academic and other institutions.

Source: NASA/Goddard Space Flight Center. | GAO-24-106767

Timeline

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Goddard Space Flight Center**

International Partners: **European Space Agency, Centre National d'Etudes Spatiales (France), Japan Aerospace Exploration Agency, Max Planck Institute (Germany)**

Launch Location: **Kennedy Space Center /Eastern Range, FL**

Launch Vehicle: **Falcon Heavy**

Mission Duration: **5 years (does not include on-orbit commissioning)**

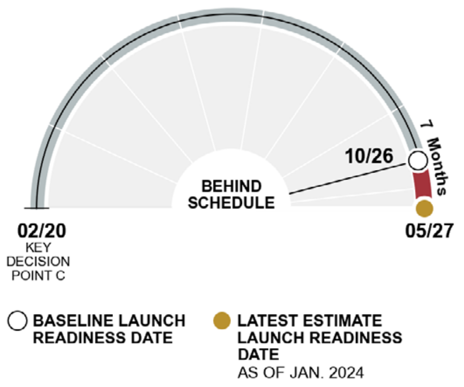
Requirement Derived from: **2010 Astrophysics Decadal Survey**

Project Summary

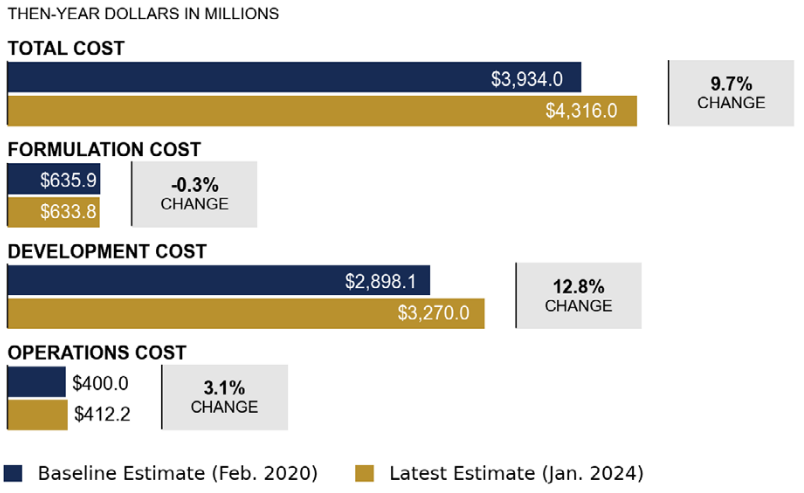
The Roman project continues to operate within its replanned life-cycle cost of $4.3 billion and launch readiness date of May 2027 despite its reduced cost reserve availability. The project is working to an earlier launch readiness date of October 2026 and continues to execute according to its revised integration and test schedule. Roman made progress fabricating and testing key system subcomponents. The project completed integration of the Wide Field Instrument and completed some initial testing, which found two performance issues that can be fixed but will delay delivery by approximately 6 weeks. Roman is tracking several technical risks. For example, a risk related to the high gain antenna system could result in a failure of the antenna to deploy. Another risk involves the deployment failure of the Deployable Aperture Cover sunshade.

The project completed assembly of the Roman Coronagraph Instrument (CGI) flight system and is still on schedule to deliver the instrument to the Goddard Space Flight Center in May 2024. In November 2023, the CGI project completed its full functional test, which identified some issues that the project is working to resolve.

Schedule Performance



Cost Performance



Cost and Schedule Status

The Roman project continues to operate within its replanned cost and schedule baselines, which were updated in June 2021. The replan set a life-cycle cost of $4.3 billion and a launch readiness date of May 2027. The project is still working to an earlier launch readiness date of October 2026, which was the original baseline date prior to the replan.

In January 2024, NASA released $65.9 million of cost reserves to the Roman project but will not increase its total cost. These cost reserves restore project-held cost reserves to about 26 percent for fiscal year 2024. However, these reserves bring the overall Roman cost reserves to about 20 percent. The Goddard Space Flight Center procedural requirements for Roman are for the project to hold cost reserves equal to at least 25 percent of the estimated cost remaining during the final design and fabrication phase.[36] In late 2024, NASA will assess whether additional cost reserves are needed for fiscal years 2025 and 2026 as part the key decision point process.

In 2022, the project replanned its integration and test schedule to mitigate limited schedule reserves. The project continues to execute according to its revised schedule. For example, project officials said that the project has worked with the Optical Telescope Assembly contractor to resolve technical and resource issues and are confident in its ability to meet the revised August 2024 delivery. The contractor continues to take appropriate steps to mitigate possible schedule impacts from ongoing technical challenges, according to the project.

Integration and Test

The project continues to make progress building, assembling, and testing key system subcomponents. For example, the project completed integration of the Wide Field Instrument, which is intended to measure light from a billion galaxies and perform a survey of the inner Milky Way. In November 2023, the project completed some initial testing of the Wide Field Instrument and found two performance issues that can be fixed but will delay delivery by approximately 6 weeks. Vibration, acoustics, and electromagnetic interference and compatibility testing of the Wide Field Instrument is on schedule, and several subassemblies of the Optical Telescope Assembly were completed. However, the project continues to track a schedule risk that it attributes to contractor delays due to technical issues with the Optical Telescope Assembly, which could result in a late delivery and impact the project's schedule.

The project is making progress on the assembly of the spacecraft's structural verification unit in preparation for environmental testing. Deployment of the spacecraft's high gain antenna system's deployable hinge showed degradation after use, resulting in a risk that any undetected damage to the hinge could result in a failure to deploy. A failure would hamper the spacecraft's ability to communicate with ground stations. Roman is conducting additional analysis and tests to mitigate the risk.

The project completed a manufacturing readiness review for the flight unit of the Launch Loads Vibration Isolation System, but the project is tracking a performance risk. The Launch Loads Vibration Isolation System protects the telescope from launch vibrations and spacecraft-generated disturbances while on-orbit. This system's flight isolators are currently a critical path item in the integration and test schedule. If they do not perform as expected, it could result in a schedule delay and increased costs due design changes.

The project is tracking a risk that the Deployable Aperture Cover sunshade will fail to deploy fully due to the extremely cold environment. The sunshade will prevent sunlight from reaching the telescope lens while in transit and provide shade after deployment. In 2024, once the flight shade is integrated, the project will begin performing the final risk mitigation steps, which include performance checks and environmental testing.

Coronagraph Instrument

The project continues to make progress on the CGI, but challenges include its aggressive integration and test schedule and remaining system level risks. The CGI is a technology demonstration designed to perform high contrast imaging and spectroscopy of nearby exoplanets. It is managed separately from the Roman observatory and places no science requirements on Roman. The project completed assembly of the CGI flight system in 2023 and is still on schedule to deliver it to the Goddard Space Flight Center in May 2024.

In November 2023, the project completed its full functional test of the CGI, during which it experienced several software issues. Some of these issues were resolved during the test, but the project is still working to resolve others. The CGI had no significant hardware issues during the test other than a known risk related to camera performance degradation in new test venues. If the cameras do not perform as expected, the schedule and cost would grow to address these issues. The project is proceeding with its CGI test program, which includes thermal and other types of testing.

Project Office Comments

Roman and CGI project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

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[36] NASA, Goddard Space Flight Center, *Funded Schedule Margin and Budget Margin for Flight Projects*, Goddard Procedural Requirements 7120.7B (Sept. 17, 2018).

NASA Indian Space Research Organisation (ISRO) – Synthetic Aperture Radar (NISAR)

NISAR is a joint project between NASA and ISRO that will study the solid earth, ice masses, and ecosystems. It aims to address questions related to global environmental change, Earth's carbon cycle, and natural hazards such as earthquakes and volcanoes. The project will include a satellite with the first dual frequency synthetic aperture radar instrument. NASA will provide one radar and ISRO will provide the other. The two radars each use a different frequency and will use advanced radar imaging to construct large-scale data sets of Earth's movements. ISRO will also provide NISAR's spacecraft and launch vehicle. NISAR represents the most complex science mission development undertaken jointly by NASA and ISRO.

Source: © 2017 California Institute of Technology/Jet Propulsion Laboratory. | GAO-24-106767

Timeline

Formulation

- 03/14 Formulation start
- 12/14 System requirements/ mission definition review
- 06/16 Preliminary design review
- 08/16 Key decision point C

Implementation

- 10/18 Critical design review
- 10/20 System integration review
- **01/24 GAO review**
- **10/24 Latest launch readiness date**

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **Indian Space Research Organisation**

Launch Location: **Satish Dhawan Space Centre, India**

Launch Vehicle: **Geosynchronous Satellite Launch Vehicle Mark II**

Mission Duration: **3 years**

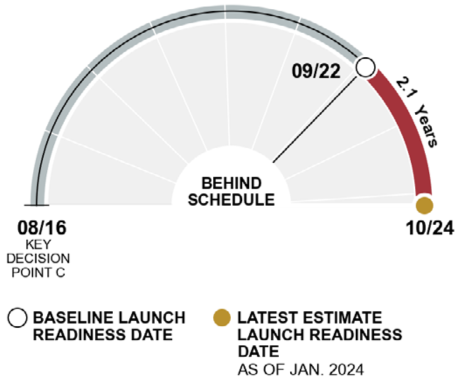
Requirement Derived from: **2007 Earth Science Decadal Survey**

Project Summary

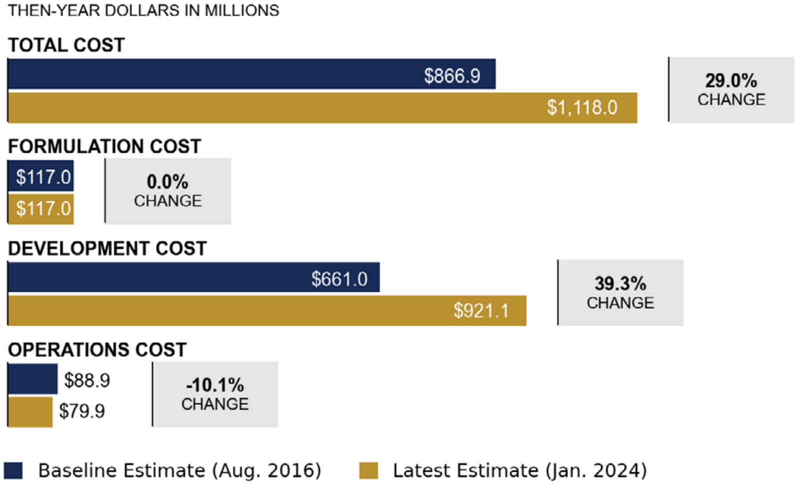
The NISAR project continues to execute within its August 2022 rebaselined cost and schedule estimates. However, integrated testing of the instrument payload flight system and the spacecraft is falling behind schedule and the program's launch readiness date could slip past its planned internal launch date of March 2024. The start of integrated testing was delayed by approximately 2 months. Retaining key technical staff throughout integration and testing in India remains one of the NISAR project's top risks.

In May 2023, the ISRO-provided launch vehicle—the Geosynchronous Satellite Launch Vehicle Mark II—successfully satisfied the remaining launch vehicle success criteria.

Schedule Performance



Cost Performance



Cost and Schedule Status

The NISAR project continues to execute within its rebaselined cost and schedule estimates. In August 2022, NASA approved a rebaseline for the NISAR project, which increased the project's life-cycle cost by $146.8 million and delayed the project's launch readiness date by 13 months from September 2023 to October 2024.

The project has experienced delays during testing due to the late delivery of the spacecraft and technical issues that arose. As a result, program officials told us that they anticipate missing the internal program launch date of March 2024, but they do not expect the launch to be delayed past October 2024. Project officials indicated that there is an eclipse season every year between October and January during which NISAR cannot launch. If the launch were to slip past October 2024, NISAR could not launch until January 2025.

Integration and Test

Integrated testing of the instrument payload flight system and the spacecraft is falling behind schedule, which could delay the project's launch readiness date past March 2024. As of January 2024, the project is in the middle of System Integrated Testing Level 4 (SIT-4) of the integrated payload and spacecraft. During this phase of the project, all project operations are taking place in India and are managed by ISRO.

SIT-4 started approximately 20-25 days behind schedule for a few reasons, including late delivery of some hardware and issues getting some hardware through customs. Testing was further delayed when the ISRO-provided spacecraft was over 4 weeks late.

In addition, the program experienced a delay due to an electronic box failure in ISRO's S-band synthetic aperture radar system, which required an extensive investigation and decision-making process to access and replace the box. This hardware failure caused a delay of approximately 1 month to SIT-4. In January 2024, the project resolved problems processing data that had led to difficulties synchronizing ISRO's S-band synthetic aperture radar and the software with NASA's L-band synthetic aperture radar. The two bandwidths working together will allow NISAR to observe a wide range of Earth processes, from the flow rates of glaciers and ice sheets to the dynamics of earthquakes and volcanoes.

Launch Vehicle

In May 2023 the ISRO-provided launch vehicle—the Geosynchronous Satellite Launch Vehicle Mark II—satisfied the remaining launch vehicle success criteria. The launch vehicle had been a risk for the project following an anomalous launch in August 2021.

ISRO and NASA agreed to five criteria that the ISRO-provided launch vehicle must meet before NISAR's launch. The launch vehicle met the final criterion in May 2023 when it successfully completed a second launch of an ISRO payload using a 4-meter fairing—the nose cone of the rocket used to protect the payload during launch—that matched the same configuration needed for the NISAR launch.

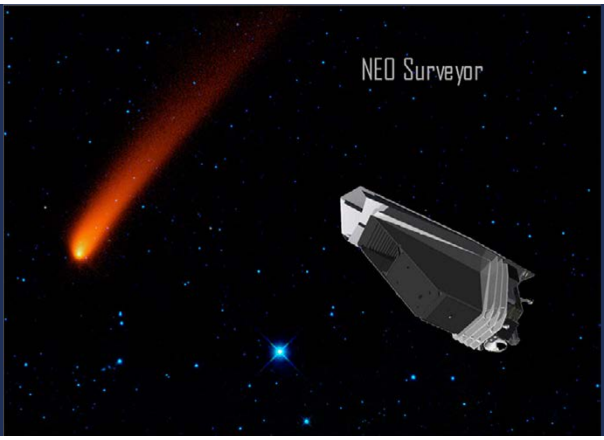
Other Issues to Be Monitored

Retaining key technical staff throughout SIT-4 in India remains one of the NISAR project's top risks. If the project cannot retain these staff, then it could experience delays or other problems during system integration and test. According to project officials, NISAR project staff are traveling between California and India, in approximately 3-week increments, during the 12 to 14 months that NISAR will be in SIT-4. The Jet Propulsion Laboratory and the project team have also implemented a mitigation plan to have backup support ready to step in if a key staff member cannot support SIT-4.

Project Office Comments

NISAR project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

After the NISAR project reviewed a draft of this assessment, NASA announced that it plans to establish a new launch readiness date in April 2024. Remaining work before launch includes shipping the radar antenna reflector to California to apply a special thermal coating and returning the reflector to India for integration with the spacecraft.



Near Earth Object (NEO) Surveyor

NEO Surveyor is a space-based telescope designed to search for NEOs such as asteroids and comets that are 140 meters or larger in diameter. By accomplishing this survey, the telescope will detect, track, catalog, and characterize NEOs to identify objects that could be potentially hazardous. The project aims to obtain detailed physical characterization data for individual objects that are likely to pose an impact hazard, and to characterize the entire population of potentially hazardous NEOs to inform mitigation strategies. The NEO Surveyor continues work previously done under the NEO Camera project.

Source: University of Arizona. | GAO-24-106767

Timeline

Formulation	06/20	Formulation start
Formulation	09/20	System requirements/ mission definition review
Formulation	09/22	Preliminary design review
Formulation	11/22	Key decision point C
Implementation	01/24	GAO review
Implementation	02/25	Critical design review
Implementation	07/26	System integration review
Implementation	06/28	Latest launch readiness date

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **None**

Launch Location: **To be determined**

Launch Vehicle: **To be determined**

Mission Duration: **5 years**

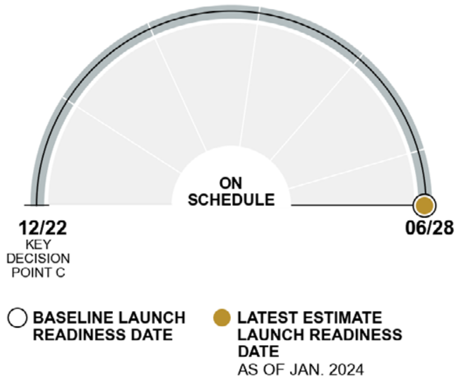
Requirement Derived from: **The George E. Brown, Jr. Near-Earth Object Survey Act, Pub. L. No. 109-155, § 321 (2005)**

Project Summary

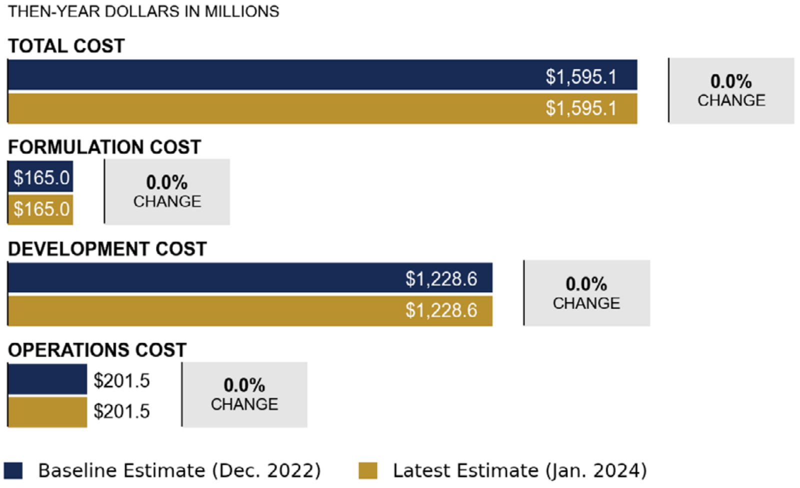
The NEO Surveyor project continues to operate within its cost and schedule baselines set in December 2022, with limited project reserves for fiscal years 2023 and 2024. To conserve the remaining reserves, the project continued to focus on higher-risk instrument work. In fiscal year 2024, the project began reconstituting the spacecraft team in order to resume development work that had been put on hold to focus the project's limited resources to instrument development.

The project has made a few design changes leading up to its critical design review in February 2025. For example, it redesigned the propulsion system and the instrument enclosure, the latter of which keeps light out of the telescope. The project also continues to face manufacturing delays and test chamber issues that threaten its schedule margin and delivery dates. It plans to hold biweekly meetings with the chamber subcontractors to mitigate any further issues.

Schedule Performance



Cost Performance



Cost and Schedule Status

The NEO Surveyor project continues to operate within its cost and schedule baselines set in December 2022. Officials stated that because of NASA funding constraints in fiscal years 2023 and 2024, NASA is not holding any cost reserves for the project until fiscal year 2025. In addition, as of October 2023, the project's cost reserves stood at 19 percent, which is below the Jet Propulsion Laboratory's recommended 25 percent level for project-held reserves.

The project has taken several actions to mitigate the lack of headquarters-held reserves and the low project-held reserves in fiscal year 2024. For example, in fiscal year 2023, the project continued to focus on higher-risk instrument work and defer work on the spacecraft. The project also released some of its fiscal year 2024 reserves to get an early start on risk reduction activities. Officials said these activities included approving long lead procurements, starting design work for the spacecraft, and adding margin to the critical paths.

The project directed the contractor to begin reconstituting the spacecraft team in fiscal year 2024 in order to resume development work, such as procurements, that had been put on hold to focus the limited resources to instrument development.

The project executed a replan before setting its cost and schedule baselines in 2022. Officials detailed how the replan affected the acquisition process, including the need for further negotiations with contractors. Based on the timing of the negotiations, officials reported the project shifted the sequence of the integrated baseline review (IBR) by holding a project-level IBR in August 2023 and planning to hold a second one in spring 2024. The IBR process is used to verify technical content and the realism of related performance budgets, resources, and schedules. The first IBR resulted in 46 actions and findings, which have all been addressed.

The project continues to track cost and schedule risks related to industrial base issues, such as supply chains and inflation. The project has reported longer lead times for parts and higher costs while resoliciting contracts.

Technology and Design

The project has made design changes as it conducts subsystem and instrument critical design reviews leading up to the project critical design review in February 2025. The project removed the re-pressurization system that was added to the propulsion system in the previous redesign in 2022. Officials said the project descoped the design to reduce complexity, increase performance, and reduce cost.

The project also changed the design of the instrument enclosure, which keeps light out of the telescope. Officials said the project's sun exposure technical requirements covered too extreme of contingency scenarios, such as surviving 10 minutes in the sun. The project could not design to those high technical requirements without potentially delaying schedule. As a result, the project relaxed the sun exposure technical requirements to allow for instrument enclosure design changes that decreased the complexity and improved performance. Officials said the project conducted additional analyses to ensure the new technical requirements would cover potential scenarios. Officials said this analysis and design change added approximately 7 weeks to the schedule. Following the changes, the project conducted a successful instrument enclosure critical design review.

Other Issues to Be Monitored

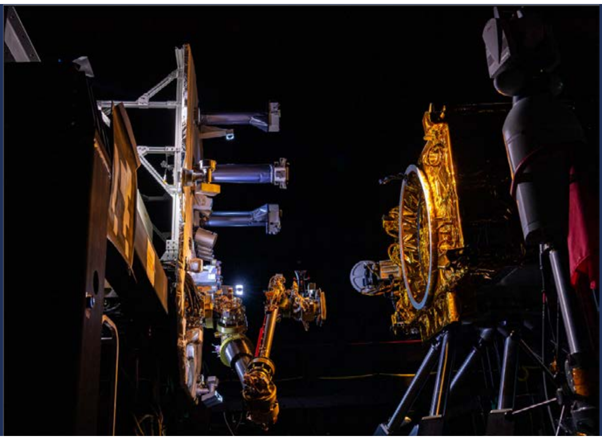
One of the project's top risks is to the instrument enclosure manufacturing schedule. Quality issues during panel fabrication and testing could delay the manufacturing schedule. To mitigate this risk, the project is restructuring integration and testing, descoping tests, and starting tooling early. Officials noted that the schedule has margin for one major delay during manufacturing or integration and testing, but any additional issues could delay the project schedule.

The complexity of thermal testing poses a risk to both cost and schedule if test replans are necessary. For example, officials said it was difficult to find a chamber that met the temperature and size requirements for their test. The project is working with Johnson Space Center to hold the external thermal balance test in late 2024. The test, which is the first of three tests needed to complete thermal verification, is planned to assess the performance of the radiators and shields to keep the instrument cool.

The project is also tracking the risk of unexpected delays constructing a thermal vacuum chamber, including supply chain issues. The chamber needs to be completed by the start of instrument integration and testing and drives the delivery of the instrument for flight system integration and launch. If the chamber is not ready in time, it could delay instrument delivery. The project plans to hold biweekly meetings with chamber subcontractors for the duration of the contract to mitigate any further issues.

Project Office Comments

NEO Surveyor project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Source: NASA/Mike Guinto. | GAO-24-106767

On-Orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1)

The OSAM-1 project plans to demonstrate a capability to autonomously refuel and extend the life of on-orbit satellites. Specifically, OSAM-1 plans to autonomously rendezvous with, inspect, capture, refuel, adjust the orbit of, safely release, and depart from the U.S. Geological Survey's Landsat 7 satellite. The satellite's operations can be extended if the refueling is successful. The project also plans to use the SPace Infrastructure DExtrous Robot (SPIDER) payload to demonstrate on-orbit assembly and installation of an antenna. NASA plans to transfer OSAM-1 technologies to commercial entities.

Timeline

Formulation
- **05/16** Formulation start
- **10/16** System requirements/ mission definition review
- **11/17** Preliminary design review
- **06/20** Key decision point C

Implementation
- **02/22** Critical design review
- **11/23** System integration review
- **01/24** GAO review
- **03/24** NASA announces project cancellation
- **12/26 (under review)** Latest launch readiness date

Project Information

NASA Lead Mission Directorate: **Space Technology**

NASA Lead Center: **Goddard Space Flight Center**

International Partners: **None**

Launch Location: **To be determined**

Launch Vehicle: **To be determined**

Mission Duration: **12 months**

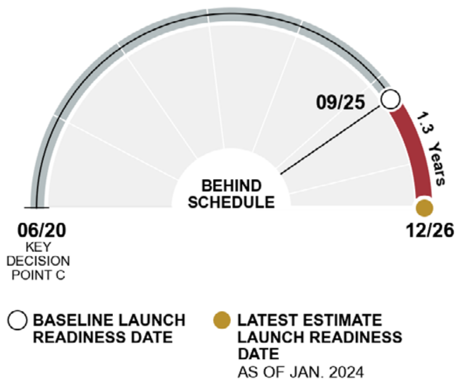
Requirement Derived from: **Consolidated Appropriations Act, 2016**

Project Summary

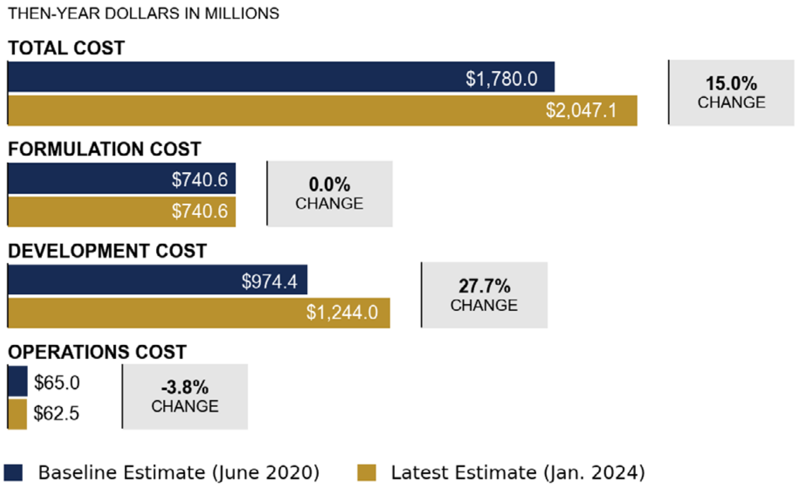
In March 2024, NASA announced its plans to discontinue the OSAM-1 project. In connection with this decision, NASA cited spacecraft bus delivery delays, supply chain issues, significant cost growth, persistent technical performance challenges, and a broader community evolution away from refueling unprepared spacecraft. The independent review board commissioned by NASA conducted surveys of industry members that showed no dependence on OSAM-1 technologies or technology gaps that OSAM-1 uniquely fills. Officials reported that, in February 2024, NASA completed a continuation review where the independent review board recommended cancelation of the project.

Before announcing the cancelation of the project, the OSAM-1 project was reviewing its rebaselined cost and schedule estimates because it had exhausted its cost and schedule reserves. The project rebaselined its cost and schedule in May 2022, but ongoing development issues for the spacecraft bus and the two robot systems—the servicing and SPIDER payloads—have led to further schedule delays and subsequent cost growth.

Schedule Performance – Under Review



Cost Performance – Under Review



Cost and Schedule Status

In March 2024, NASA announced its plans to discontinue the OSAM-1 project. In connection with the discontinuation decision, NASA cited spacecraft bus delivery delays, supply chain issues, significant cost growth, persistent technical performance challenges, and a broader community evolution away from refueling unprepared spacecraft. The independent review board commissioned by NASA conducted surveys of industry members that showed no dependence on OSAM-1 technologies or technology gaps that OSAM-1 uniquely fills. Officials reported that in February 2024, NASA completed a continuation review where the independent review board recommended cancelation of the project. Closeout activities, including storage of hardware for an indeterminate period to identify another potential use, will conclude in fiscal year 2025. Throughout its life cycle, the OSAM-1 project experienced recurring cost growth and schedule delays due to scope changes, the COVID-19 pandemic, and issues with developing new technologies and supplier quality.

Before announcing the cancelation of the project, the OSAM-1 project was reviewing its May 2022 rebaselined cost and schedule estimates because it had exhausted its cost and schedule reserves. In September 2023, the project proposed updated life-cycle cost and launch readiness date estimates ($2.2 billion and July 2027, respectively) to NASA. These estimates were based on the project's past performance data and exceeded current baselines by approximately $187 million and 7 months.

Following the project's cost and schedule rebaseline in May 2022, continued development issues for the spacecraft bus and the two robot systems—the servicing and SPIDER payloads—have led to further schedule delays and subsequent cost growth. For example, the project experienced delays due to additional time needed to correct quality issues with the hardware used to build and test actuators, which help move the robot arm. Officials reported that quality and skilled labor issues affected the project's ability to execute to its cost and schedule baselines. The project was able to accommodate some schedule delays caused by late deliveries by adjusting the integration process, as officials said there was some flexibility to adjust the order in which instruments and subsystems are integrated onto the spacecraft.

The project held its system integration review in November 2023. At that time, the project reported that it met its technical criteria and was ready to proceed with integration. The review board found that the project should continue to work on the revised plan and gain headquarters' approval of the project's proposed cost and schedule estimates.

Technology and Design

The OSAM-1 project descoped portions of the project to save costs and reduce the burden on the schedule. For example, it descoped the SPIDER Makersat payload and a corresponding requirement for manufacturing a structurally and thermally stable beam in space due to persistent delivery delays. Officials said this descope would not affect the project's ability to meet its mission requirements.

As of January 2024, the project's primary critical path was the delivery delay of the SPIDER robot arm system due to technical and scheduling issues with the Dexterous End Effector motors, which are used to move the hand at the end of the robot arm. Officials said that oversight on schedule management has been difficult because they had to work through several layers of contractors and subcontractors.

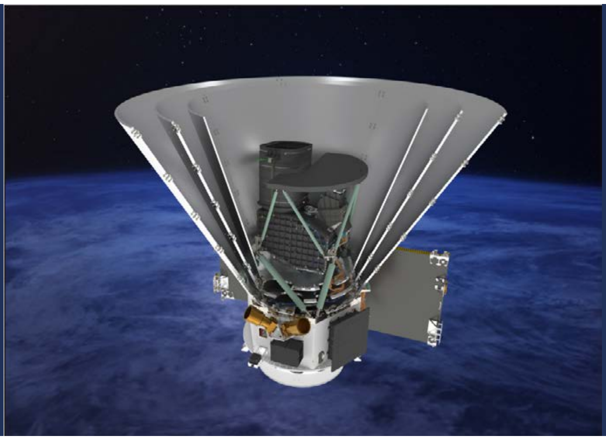
The project faced challenges with the development of the servicing payload's light detection and ranging (LiDAR) system. Officials noted that the LiDAR acquisition process changed several times, and after a NASA LiDAR system failed during an environmental unit test, the project decided to procure a commercial LiDAR unit as a backup.

Additionally, the project faced schedule risks related to flight hardware deliveries for robot components in the servicing payload, including robot electronics units (REU) and robot arms. Like the LiDAR, the acquisition process for the REU changed several times. Officials said commercial solutions were not able to meet requirements, so development of the REU was brought in-house to Goddard Space Flight Center. While the Goddard Space Flight Center did not have a history of building robot arms or the computers to control them, officials stated they used their workforce expertise in designing and fabricating motor control electronics. The project faced challenges in accessing a workforce with the right skills, which contributed to REU development delays.

The servicing payload robot arms, however, were designed and built by Maxar Robotics and officials said Maxar Robotics experienced numerous delays due to COVID shutdowns, supply chain issues, and substantial quality control issues at subcontractors.

Project Office Comments

OSAM-1 project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer (SPHEREx)

The SPHEREx mission will use a telescope to probe the origin and destiny of the universe, explore whether planets around the other stars could harbor life, and explore the origin and evolution of galaxies. The mission will create a map of the entire sky and survey the sky every 6 months to gather data on more than 450 million galaxies and 100 million stars in the Milky Way.

Source: NASA/Jet Propulsion Laboratory-California Institute of Technology. | GAO-24-106767

Timeline

Project Information

NASA Lead Mission Directorate: **Science**

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **Korea Astronomy and Space Science Institute**

Launch Location: **Vandenberg Space Force Base, CA**

Launch Vehicle: **Falcon 9**

Mission Duration: **27 months**

Requirement Derived from: **2010 Astrophysics Decadal Survey**

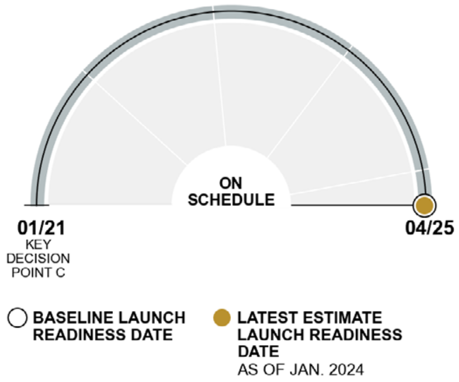
Project Summary

NASA increased the SPHEREx project’s life-cycle costs by $36.7 million above its baseline costs as part of its key decision point D in January 2024. According to NASA documentation, the recent cost increase was due to technical challenges, issues with vendor performance, and increased support the project provided to its university partner. The SPHEREx project continues to work toward a launch date of February 2025, which is 2 months before its baseline launch readiness date.

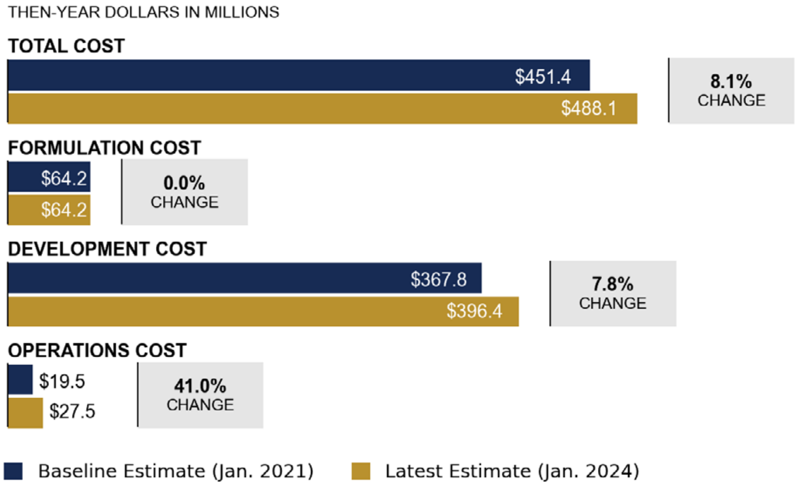
In November 2023, the project successfully held its system integration review, which evaluates the readiness of a project to begin system assembly, integration, and test activities. The project plans to begin its observatory level integration and test in early 2024.

As part of the recent cost increase, NASA also increased the funding for the science portion of the mission, which addressed a risk that a shortfall in funding would result in significant losses to the project’s science efforts and returns.

Schedule Performance



Cost Performance



Cost and Schedule Status

In January 2024, NASA increased the SPHEREx project's life-cycle costs by $36.7 million above its baseline costs as part of its key decision point D. These funds are to rebuild the project's cost reserves to the level projects are to plan for under Jet Propulsion Laboratory guidance and increase science funding. In 2022, NASA had released $38.1 million in headquarters-held reserves to the project to cover costs for issues related to the COVID-19 pandemic, lack of skilled staffing at vendors, supply chain issues, inflation, and resource shortages resulting from the war in Ukraine. As a result, the project was left with only $12.7 million in headquarters-held reserves, which was not enough to cover the project's cost shortfall issues without also increasing the project's baseline life-cycle costs.

According to NASA documentation, the main factors contributing to the recent cost growth were technical challenges and issues with the timeliness and quality of deliveries from vendors. In addition, the project had to provide more support to its university partner than expected. For example, the project moved work into the Jet Propulsion Laboratory due to vendor quality issues and limited infrastructure available at its university partner. Project officials said it costs more to complete work at Jet Propulsion Laboratory compared to universities and other suppliers.

The project continues to work toward a targeted launch date of February 2025, which is 2 months before its baseline launch readiness date of April 2025. Project officials said the objective is to finish as quickly as possible because it would cost more money to run the project for a longer duration. According to officials, the project has already used available schedule mitigations, such as reductions in testing. Officials said that any additional reductions in testing would not be prudent because the project is currently planning for the bare minimum of verification that must be performed.

Integration and Test

The project successfully held its system integration review in November 2023. This review evaluates the readiness of a project to begin the system assembly, integration, and test activities. The project plans to begin observatory level integration and test in early 2024.

As part of the system integration review, the standing review board identified an issue related to the Near Space Network that the project needs to use to downlink data during operations. To test the communication between the spacecraft and the ground network, the project needs to reconfigure testing equipment that was previously used for the NASA – ISRO Synthetic Aperture Radar project. The project is working to reconfigure this equipment by February 2024 to meet timelines for the compatibility test. A delay in testing could have significant cost and schedule effects. In addition, a ground station in Antarctica needs to be upgraded and there is a limited window to complete this work.

Another technical challenge the project faced was that the flight computer used on the spacecraft bus, called the integrated avionics unit, needed to be reworked. The vendor was providing the same unit to the Space Weather Follow-On project and, according to project documentation, NASA prioritized the rework for this project over SPHEREx. This resulted in months of delays in delivering the integrated avionics unit to SPHEREx, which also contributed to the project's recent cost growth.

Operations

The project was previously tracking a risk that more resources would be needed to process science data during the operations phase. This risk was the result of earlier underestimations of the science analysis efforts needed to fulfill the science objectives. Project officials said the nature of conducting science missions and planning something that has never been done before makes cost estimation difficult.

The project decided to carry this shortfall as a risk until its system integration review. At this review, the project requested additional science funding, which was approved as part of the key decision point D cost increase. According to NASA documentation, if the science funding shortfall was not addressed, there would have been significant losses to the project's science objectives. These losses may have included descopes to science tools and insufficient infrastructure to support public use of data products generated by the project. The overall science return from the project would have been lower if the science community's use of the data decreased as a result of descopes.

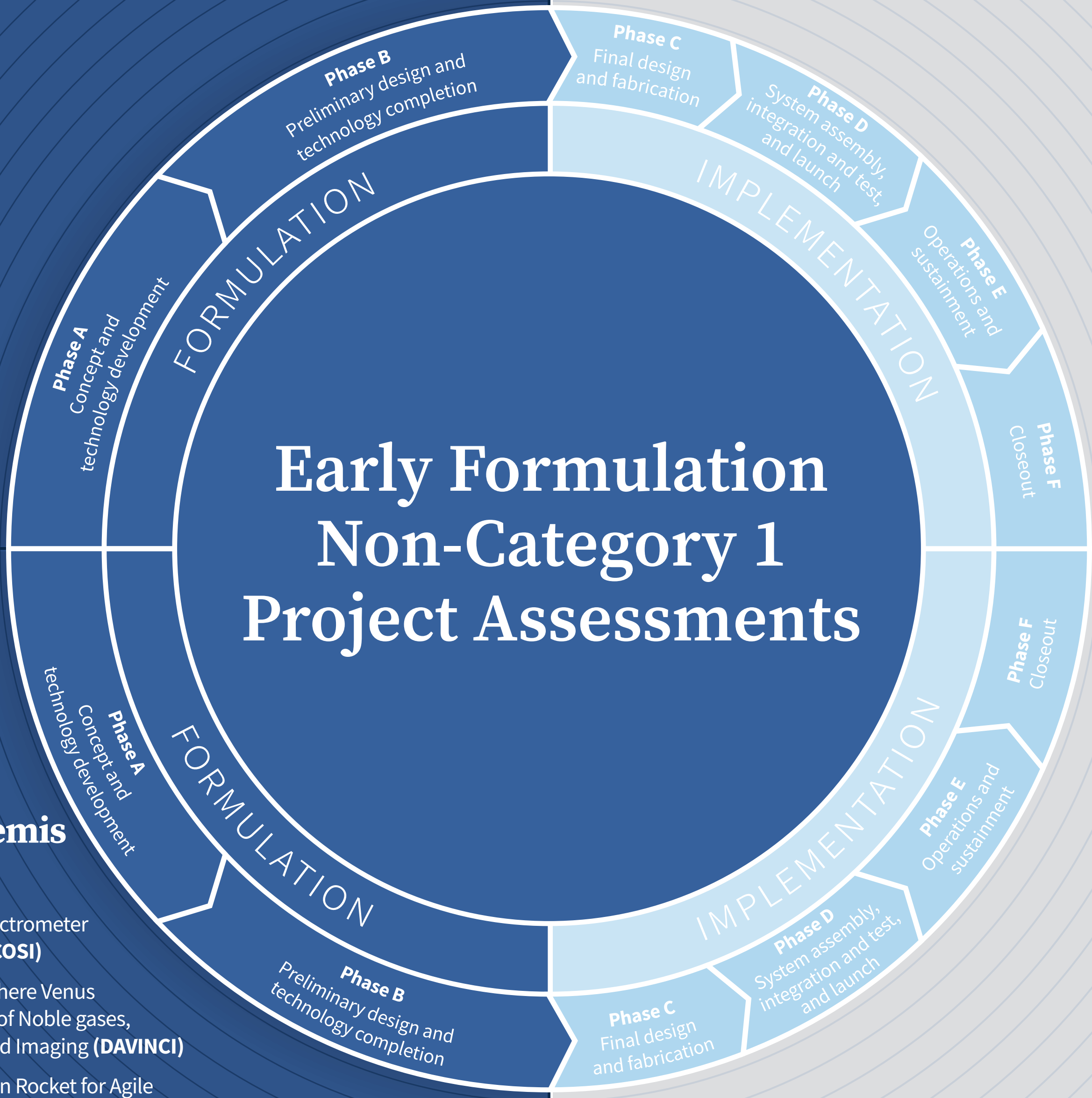
Project Office Comments

SPHEREx project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Artemis Projects

- Gateway – Deep Space Logistics **(DSL)**

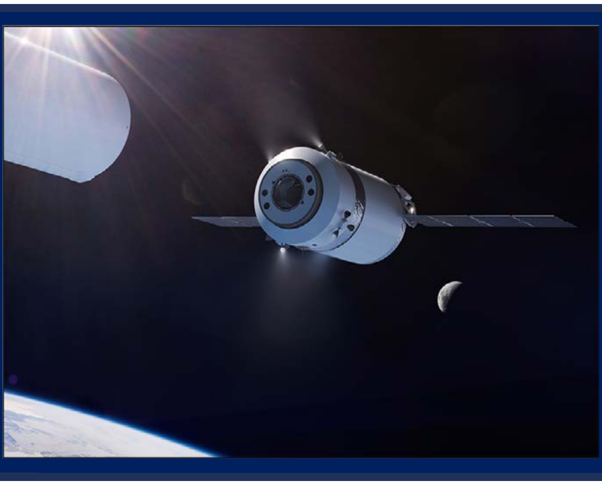
Early Formulation Non-Category 1 Project Assessments



Non-Artemis Projects

- Compton Spectrometer and Imager **(COSI)**
- Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging **(DAVINCI)**
- Demonstration Rocket for Agile Cislunar Operations **(DRACO)**
- Earth Systems Observatory **(ESO)** – Atmosphere Observing System **(AOS)**
- ESO – Gravity Recovery and Climate Experiment – Continuity **(GRACE-C)**
- ESO – Surface Biology and Geology **(SBG)**
- HelioSwarm
- Landsat Next
- MUlti-slit Solar Explorer **(MUSE)**
- Sustainable Flight Demonstrator **(SFD)**
- Venus Synthetic Aperture Radar **(VenSAR)**

Source: GAO analysis of NASA data. | GAO-24-106767



Source: SpaceX. | GAO-24-106767

Gateway – Deep Space Logistics (DSL)

Project that will execute commercial end-to-end services to provide the Gateway with cargo deliveries, supplies, stowage, and trash disposal prior to crew arrival to maximize the length of crew stays on the Gateway.

Next Milestone

System Requirements Review (to be determined)

Preliminary Estimates as of January 2024

Cost	Launch Date
To be determined	To be determined

Source: University of California, Berkeley. | GAO-24-106767

Compton Spectrometer and Imager (COSI)

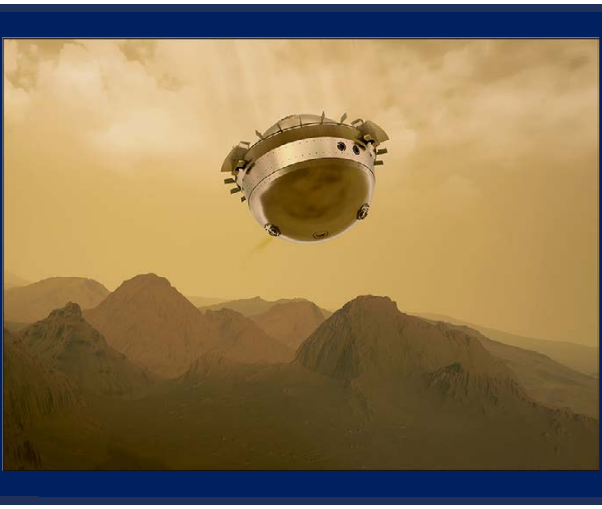
Gamma-ray telescope to study the recent history of stars and formation of chemical elements in the galaxy.

Next Milestone

Key Decision Point C (April 2024)

Preliminary Estimates as of January 2024

Cost	Launch Date
$266.8 million to $293.9 million	June 2027 – December 2027



Source: NASA/Goddard Space Flight Center. | GAO-24-106767

Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI)

Spacecraft and deep atmosphere probe to measure the composition and environmental properties of Venus's atmosphere and surface, to understand how its evolution diverged from Earth's and determine whether it ever had oceans of liquid water.

Next Milestone (Under Review)

Preliminary Design Review (June 2025)

Preliminary Estimates as of January 2024 (Under Review)

Cost	Launch Date
$1.2 billion to $1.6 billion	June 2029

Demonstration Rocket for Agile Cislunar Operations (DRACO)

A technology demonstration of nuclear thermal propulsion managed jointly between NASA and the Defense Advanced Research Projects Agency (DARPA). NASA will fund and manage the overall development and fabrication of the nuclear thermal rocket engine through completion of reactor and engine integration and will support launch and mission operations.

Next Milestone

Project Approval and Implementation (September 2024)

Preliminary Estimates as of January 2024

Cost	Reactor to Engine Integration Completion Date
$293.2 million to $360 million	First quarter of 2027 to third quarter of 2028

Source: DARPA. | GAO-24-106767

EARTH SYSTEM OBSERVATORY
AOS
ATMOSPHERE OBSERVING SYSTEM

Earth System Observatory (ESO) – Atmosphere Observing System (AOS)

Comprises four spacecraft—two each in polar (AOS-Sky) and inclined (AOS-Storm) orbits—that will investigate cloud, precipitation, and aerosol processes to improve weather, air quality, and climate predictions.

Next Milestone

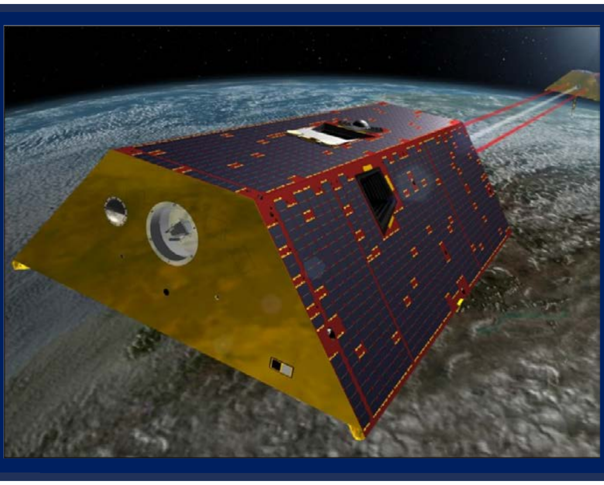
System Requirements/Mission Definition Review
AOS-Storm (June 2024)
AOS-Sky (to be determined)

Preliminary Estimates as of January 2024[a]

Cost	Launch Date
$1.8 billion to $2 billion	July 2028 – June 2030, AOS-Storm December 2030 – June 2032, AOS-Sky

Source: NASA/Goddard Space Flight Center. | GAO-24-106767

[a] NASA plans to restructure the ESO-AOS mission in fiscal year 2025.



Earth System Observatory (ESO) – Gravity Recovery and Climate Experiment – Continuity (GRACE-C)

Two satellites that will continue more than 20 years of large-scale mass change observations used to assess drought and to understand sea level rise, Earth’s energy imbalance, and ice mass loss.

Next Milestone

Preliminary Design Review (March 2024)

Preliminary Estimates as of January 2024

Cost	Launch Date
$587.8 million to $617.8 million	May 2028 – December 2028

Source: NASA. | GAO-24-106767

Earth System Observatory (ESO) – Surface Biology and Geology (SBG)

Two instruments—the Thermal Infrared instrument (SBG-TIR) to be built by the Jet Propulsion Laboratory (JPL) and flown in partnership with the Italian Space Agency; and the Visible Short Wave Infrared instrument (SBG-VSWIR) to be built by commercial partners. These instruments will answer climate, ecosystems, hydrology, solid Earth, and weather-related questions.

Next Milestone

Key Decision Point B
TIR and VSWIR (March 2024)

Preliminary Estimates as of January 2024[a]

Cost	Launch Date
$786 million to $877 million	April 2028 – April 2029

Source: NASA. | GAO-24-106767

[a] NASA plans to restructure the ESO-SBG mission in fiscal year 2025.

HelioSwarm

Constellation of nine spacecraft—one hub spacecraft and eight co-orbiting small satellites—that will investigate solar wind turbulence and its evolution by measuring solar plasma from different points in space simultaneously.

Next Milestone

System Requirements Review (October 2024)

Preliminary Estimates as of January 2024

Cost	Launch Date
To be determined	Second quarter of fiscal year 2029

Source: NASA. | GAO-24-106767

Landsat Next

Constellation of three Earth-observing satellites, run by NASA and U.S. Geological Survey, to provide enhanced land imaging capabilities and continue the 50-year data record of the Landsat program.

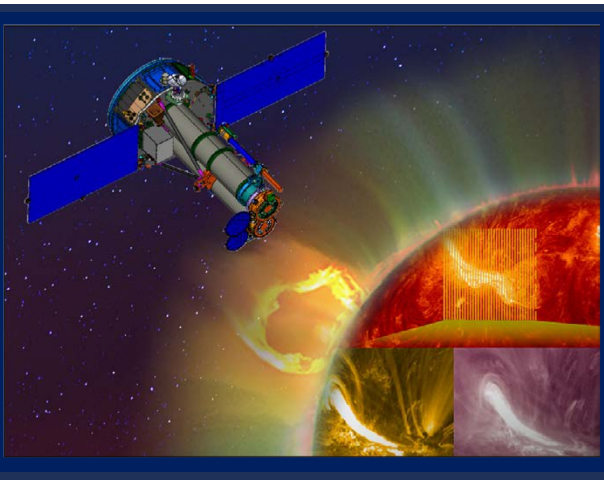
Next Milestone

System Requirements/Mission Definition Review (November 2024)

Preliminary Estimates as of January 2024

Cost	Launch Date
$1.5 billion to $1.7 billion	November 2030 – September 2031

Source: NASA. | GAO-24-106767



MUlti-slit Solar Explorer (MUSE)

Spacecraft that will observe the sun's ultraviolet radiation, including the processes that drive solar flares, and will capture high-resolution images of the sun.

Next Milestone

Key Decision Point C (May 2024)

Preliminary Estimates as of January 2024

Cost	Launch Date
To be determined	To be determined

Source: NASA/Lockheed Martin Advanced Technology Center. | GAO-24-106767

Sustainable Flight Demonstrator (SFD)

Flight demonstration project that plans to develop and flight test environmentally sustainable airframe technology to inform industry decisions associated with the next generation of single aisle aircraft.

Next Milestone

Preliminary Design Review (March 2025)

Preliminary Estimates as of March 2024

Cost	First Flight Date
$668 million to $766 million	September 2028 – September 2030

Source: Boeing. | GAO-24-106767

Venus Synthetic Aperture Radar (VenSAR)

An instrument that collects synthetic aperture radar imaging and polarimetry, altimetry, and microwave radiation measurements of Venus’s surface as part of the European Space Agency’s EnVision Mission to Venus.

Next Milestone

Key Decision Point B (April 2024)

Preliminary Estimates as of January 2024

Cost	Launch Date
To be determined	To be determined

Source: NASA. | GAO-24-106767

Appendix II: Objectives, Scope, and Methodology

This is our 16th annual report assessing selected large-scale NASA programs and projects. When NASA determines that a project has an estimated life-cycle cost of over $250 million, we include that project in our annual review through its launch date or the project's end of development.[1] We did not include projects that held key decision point (KDP) A or its equivalent after December 1, 2023.

The objectives of our review were to assess (1) the cost and schedule performance of NASA's portfolio of major projects; (2) the maturity of NASA's technologies; and (3) the current status of major NASA projects, as reflected in individual project assessments. In appendix I, we include 24 individual assessments for major NASA projects and programs that have proceeded past their preliminary design or that NASA has designated as category 1, which are NASA's most expensive projects and have total project life-cycle cost estimates that exceed $2 billion. We also include 12 abbreviated assessments for those projects that are early in their life cycle and have not been designated as category 1. We did not complete individual assessments for two projects—the Psyche project and Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)—because they launched during our review.

To conduct our review, we developed several standard data questionnaires. NASA's Office of the Chief Financial Officer completed the questionnaires on project cost and schedule data. We used another questionnaire that was completed by project offices to gather general data on the projects, such as their category (i.e., category 1, 2, or 3), as well as information on the projects' technology and design maturity, key schedule events, and development partners.[2] The information available on an individual project depends on where it is in its life cycle. For

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[1] NASA's spaceflight program and project management policy describes a program as a strategic investment by a mission directorate or mission support offices with a defined architecture and/or technical approach, requirements, funding, and a management structure that initiates and directs one or more projects. The policy further describes a project as a specific investment identified in a program plan having defined requirements, a life-cycle cost, a beginning, and an end. We refer to the projects and programs in our cost and schedule and technology maturity analyses as major projects throughout this report.

[2] According to NASA's key project management policy, NASA designates a project as category 1 if the total life-cycle cost of the project is over $2 billion, the project includes significant radioactive material, or the project has a human spaceflight component. Projects with lower life-cycle cost estimates are category 2 or 3, depending on their cost and priority level. NASA, *NASA Space Flight Program and Project Management Requirements*, Procedural Requirements 7120.5F (Aug. 3, 2021).

example, for projects in an early stage of development—called formulation—there are still unknowns about technology and design. We compared the current questionnaire data to questionnaire data from our prior reviews in order to analyze long-term trends. To determine the categories (i.e., category 1 or non-category 1) of major NASA projects included in our reviews from 2014 to 2024, we used data collected from the project-provided questionnaires.

To assess the cumulative cost and schedule performance of major NASA projects, we compared the current development cost and schedule data that we received from NASA for the 16 projects in the implementation phase during our review to the projects' original baselines established at key decision point C.[3] The Commercial Crew Program has a tailored project life cycle and project management requirements, so it was excluded from these analyses. All of the latest estimates for cost and schedule data were provided by NASA in response to our questionnaires and were as of January 2024. We took additional steps to assess the quality and reliability of the data, such as ensuring the data summed to the totals provided and reviewing any changes since our last data collection. The team followed up with the agency on any perceived errors or unexplained cost changes.

To examine longer-term trends for NASA's portfolio of major projects in development, we compared the original baseline development costs as well as the total cumulative cost overruns for the portfolio for each year between 2014 and 2024. We grouped these costs according to the category of each project reported to us in project questionnaires. The cost and schedule performance data for each project in the portfolio are in each of our annual reports since we began reporting in 2009.

To assess annual cost and schedule performance, we compared the cumulative cost and schedule performance data received from NASA during this review to the performance data presented in the prior year's report for projects in the implementation phase during our review. This analysis identifies whether a project's latest development cost or

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[3] All cost and schedule original baseline data are from estimates documented at each project's key decision point C. At least five other projects—Orion Multi-Purpose Crew Vehicle (Orion); Solar Electric Propulsion (SEP); On-Orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1); NASA Indian Space Research Organisation – Synthetic Aperture Radar (NISAR); and Low Boom Flight Demonstrator (LBFD)—have rebaselined. We use the original baseline data when calculating cumulative overruns for the purposes of our analyses.

schedule estimate is overrunning the estimates from our prior year report. Prior year report cost and schedule estimates were generally based on data collected early in the calendar year that we issued our report. All cost information in this report is presented in nominal then-year dollars for consistency with budget data. We did not assess the cost and schedule performance of projects in formulation because they have not yet established baselines.

To understand how projects that recently entered development would affect the composition of the portfolio of major projects moving forward, we used the cost data described above to calculate the total development cost for the new projects and compared those costs to the total development costs for all projects in the portfolio. We also analyzed NASA's fiscal year 2025 budget request to review how the request was allocated to Artemis major projects, non-Artemis major projects, and the rest of the agency.

To understand what steps NASA is taking to improve project performance for its major projects, we reviewed our May 2023 report on the status of major NASA projects, NASA's Space Flight Program and Project Management Requirements, and NASA's fiscal year 2024 and 2025 Budget Requests.[4] We also met with the NASA Associate Administrator, the NASA Chief Program Management Officer, and other NASA senior leaders.

To assess technology maturity, we used questionnaire data that provided the technology readiness levels (TRL) of each of the project's critical technologies at various stages of project development, including at the preliminary design review (PDR). We took steps to assess the reliability of the project office-supplied data on a number of critical technologies and associated technology readiness levels. For example, we reviewed any changes since our last report. Since TRLs at PDR represent a snapshot in time, previously reported data do not change. For projects that held PDR since our last report, we compared any changes since our last data collection. Originally developed by NASA, TRLs are measured on a scale of one to nine, beginning with paper studies of a technology's feasibility

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[4] GAO, *NASA: Assessment of Major Projects*, GAO-23-106021 (Washington, D.C.: May 31, 2023). NASA, *Space Flight Program and Project Management Requirements*, Procedural Requirements 7120.5F (Aug. 3, 2021); *FY 2024 President's Budget Request Summary* (Mar. 22, 2023); and *FY 2025 President's Budget Request Summary* (Mar. 11, 2024).

and culminating with a technology fully integrated into a completed product. See appendix VI for the definitions of TRLs.

For the 11 projects that identified critical technologies and held their PDRs, we compared the TRLs of those projects' reported critical technologies against our technology maturity best practice to determine the extent to which these projects met the best practice. Our best practices work has shown that reaching a TRL 6 by PDR is the level of maturity needed to minimize risks for space systems entering product development.[5] TRL 6 indicates that a representative prototype of the technology has been demonstrated in a relevant environment. We did not assess technology maturity for those projects that had not reached PDR before December 31, 2023, or for projects that reported no critical technologies. Due to changes in our methodology in 2020 about how projects report critical technologies, we compared this year's results with data after that change, therefore including data from 2021, 2022, and 2023.

Of the projects past PDR that we reviewed for technology maturity, we excluded four projects from our analysis because they did not report any critical technologies. We also excluded the Human Landing System (HLS) – Initial Capability because the project does not receive information about critical technologies from its contractor. HLS officials told us that they have a variety of ways to gain insight on the contractor's performance, such as through an interim design review that officials said functioned as a checkpoint between PDR and critical design review. Additionally, we excluded the Commercial Crew Program because it has a tailored life cycle and project management requirements outside of the normal NASA life-cycle process.

We also excluded four flight and technology demonstration projects from our technology maturity best practice analysis: Electrified Powertrain Flight Demonstration (EPFD), Low Boom Flight Demonstrator (LBFD), On-orbit Servicing, Assembly, and Manufacturing-1 (OSAM-1), and Solar Electric Propulsion (SEP). We excluded these, in part, because NASA does not apply a best practice of TRL 6 by PDR to these projects.

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[5] GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects [Reissued with revisions on Feb. 11, 2020.]*, GAO-20-48G (Washington, D.C.: Jan. 7, 2020).

Instead, we previously reviewed how NASA assesses technology maturity for these projects.[6]

Project Profile Information on Each Individual Project Assessment

This year, we developed individual project assessments for projects with estimated life-cycle costs greater than $250 million. We did not complete individual assessments for projects that launched during our review (i.e., Psyche and PACE). For each assessment, we included a description of the project's objectives; information concerning the lead NASA mission directorate, the NASA center and international partners involved in the project, if applicable; the project's cost and schedule performance, when available; key project dates; and a brief narrative describing the current status of the project. We also provided a detailed discussion of project challenges for selected projects, as applicable.

We included 12 abbreviated assessments for projects that are early in formulation—or have not yet held preliminary design review as of December 31, 2023—and that NASA did not designate as category 1. The abbreviated assessments include a project description and preliminary cost and schedule estimates, if available. We also developed summaries of NASA's Artemis efforts, including a description of the first five missions, and of the Gateway program and the Extravehicular Activity and Human Surface Mobility Program. These summaries describe how the projects included in our review relate to these programs or missions.

To assess the cost and schedule changes of each project, we either obtained data directly from NASA's Office of the Chief Financial Officer through our questionnaire or used preliminary estimates provided in project documentation. For the Commercial Crew Program, we obtained current cost and schedule data directly from the program. When applicable, we compared the level of cost and schedule reserves held by the project to the level required by the policy. We also had NASA confirm that the preliminary estimates for the 19 projects in formulation remained accurate, as of January 2024. NASA provided preliminary estimates of life-cycle cost ranges and associated schedules—which are generally established at KDP A or B—for 14 projects that had not yet entered implementation. Two other projects have preliminary schedule estimates, but associated preliminary cost estimates are yet to be determined. For three other projects in formulation, NASA has not yet established preliminary cost or schedule estimates. According to NASA's key project management policy, projects establish preliminary cost and schedule

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[6] GAO-23-106021.

range estimates at KDP A.[7] At KDP B, these estimates are updated to be risk-informed range estimates with a joint cost and schedule confidence level. Estimates established at KDP A or B are preliminary and are not considered a formal commitment by the agency on cost and schedule for the mission deliverables.

To assess project schedules, we determined when NASA initiated the project, which is generally referred to as formulation start. Projects can be initiated in two basic ways: a direct assignment of a project or a competitive process, typically through a broad agency announcement such as an announcement of opportunity. NASA refers to a project's start as KDP A or the beginning of the formulation phase. Projects selected as a result of a one-step announcement of opportunity enter formulation at KDP A. Projects selected as a result of a two-step announcement of opportunity process perform a concept development study and go through evaluation for down-selection, which serves as KDP B. The end of development is determined at KDP C and could be the projected or actual launch date, first flight date, or review date. The implementation phase includes the operations of the mission and concludes with project disposal.

Project Challenges Discussion on Each Individual Project Assessment

To assess the status, risk, and challenges for each project, we submitted a questionnaire to each project office. In the questionnaire, we requested information on the maturity of critical technologies, the number of releasable design drawings or other design stability data at project milestones, and international partnerships.[8] When applicable, we compared the level of maturity of critical technologies at PDR and the percentage of design drawings released at critical design review against our best practices.[9] We also interviewed representatives from projects across multiple NASA centers to discuss the information on the questionnaires and the projects' statuses. We did not interview representatives for most of the projects that are early in formulation—or have not yet held preliminary design review—and that NASA designated

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[7] NASA, *NASA Space Flight Program and Project Management Requirements*, Procedural Requirements 7120.5F (Aug. 3, 2021).

[8] We did not collect this information for the Commercial Crew Program because it is excluded from the related portfolio analyses.

[9] GAO-20-48G; and *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002).

as category 2 or 3, or from the two projects that launched or completed development during our audit.

We then reviewed project documentation—including monthly status reports, schedules, risk assessments, and major project review documentation—to corroborate any testimonial evidence we received in the interviews. These reviews allowed us to identify further challenges faced by NASA projects. The second page of each project assessment highlights key challenges that affected that project or could affect that project's performance. For this year's report, we identified challenges across the projects that we reviewed in the categories of cost and schedule, design, integration and test, launch vehicle, contractor performance, operations, and technology. These challenges do not represent an exhaustive or exclusive list and are based on our definitions and assessments, not those of NASA.

We conducted this performance audit from April 2023 to June 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 that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: Estimated Costs and Launch Dates for Major NASA Projects and Programs Assessed in GAO's 2024 Report

In this report, we reviewed the cost and schedule for 36 major NASA projects. Five of these are Artemis-related projects in the formulation phase, which takes the project from concept to preliminary design. The estimates in table 3 and table 4 are preliminary as the projects are in formulation, and there is uncertainty regarding the costs and schedules associated with the design options being explored. NASA uses these estimates for planning purposes. Table 3 shows the preliminary key schedule milestone event date, such as launch readiness, suit delivery, or first flight. The table also includes associated cost estimates for the five projects where available.

Table 3: Preliminary Cost and Schedule Estimates of Artemis-Related Major NASA Projects in Formulation

Project name	Preliminary cost estimate (dollars in millions)	Preliminary key schedule milestone date
EHP – LTV	782.6 – 1,071.4	Dec. 2028
EHP – EVA Development	TBD	July 2025 Lunar suit delivery Jan. 2026 ISS suit delivery
Gateway – DSL	TBD	TBD
HLS – SLD	8,021.1 – 12,048.1	July 2028 – Oct. 2029
ML2	TBD	May 2026 – Nov. 2026

Legend: EHP – LTV: Extravehicular Activity and Human Surface Mobility Program – Lunar Terrain Vehicle; EVA: Extra Vehicular Activity; DSL: Deep Space Logistics; HLS SLD: Human Landing System – Sustaining Lunar Development; ML2: Mobile Launcher 2; TBD: To Be Determined.

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data for GAO's current assessment were collected as of January 2024.

Table 4 shows the preliminary key schedule milestone event date and associated cost estimates for 14 non-Artemis major NASA projects in the formulation phase.

Table 4: Preliminary Cost and Schedule Estimates of Non-Artemis Major NASA Projects in Formulation

Project name	Preliminary cost estimate (dollars in millions)	Preliminary key schedule milestone date
COSI	266.8 – 293.9	June 2027 – Dec. 2027
DAVINCI[a]	1,200 – 1,600	June 2029
DRACO	293.2 – 360.0	Q1 2027 – Q3 2028
Dragonfly	2,100 – 2,500	July 2028

Project name	Preliminary cost estimate (dollars in millions)	Preliminary key schedule milestone date
EPFD[a]	311.8 – 469.4	2026 - 2027
ESO – AOS[b]	1,808.5 – 1,988.5	July 2028 – June 2030 AOS-Storm Dec. 2030 – June 2032 AOS-Sky
ESO – GRACE-C	587.8 – 617.8	May 2028 – Dec. 2028
ESO – SBG[c]	786 – 877	Apr. 2028 – Apr. 2029
HelioSwarm	TBD	Q2 fiscal year 2029
Landsat Next	1,524.0 – 1,731.0	Nov. 2030 – Sept. 2031
MSR[a]	5,900.0 – 6,150.0	Feb. 2026 – Aug. 2026 CCRS delivery readiness date June 2028 – July 2028 SRL LRD
MUSE	TBD	TBD
SFD	667.9 – 765.8	Sept. 2028 – Sept. 2030
VenSAR	TBD	TBD

Legend: CCRS: Capture, Containment, and Return System; COSI: Compton Spectrometer and Imager; DAVINCI: Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging; DRACO: Demonstration Rocket for Agile Cislunar Operations; EPFD: Electrified Powertrain Flight Demonstration; ESO – AOS: Earth System Observatory – Atmosphere Observing System; ESO – GRACE-C: Earth System Observatory – Gravity Recovery and Climate Experiment-Continuity; ESO – SBG: Earth System Observatory – Surface Biology and Geology; LRD: Launch Readiness Date; MSR: Mars Sample Return; MUSE: MUlti-slit Solar Explorer; Q: Quarter; SFD: Sustainable Flight Demonstrator; SRL: Sample Retrieval Lander; TBD: To Be Determined; VenSAR: Venus Synthetic Aperture Radar.

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data for GAO's current assessment were collected as of January 2024 with the exception of SFD data, which were collected in March 2024.

[a] The preliminary cost or schedule estimates for the DAVINCI, EPFD, and MSR projects are under review. Until those reviews are complete, information presented above is based on the latest estimates GAO received from NASA.

[b] NASA officials told GAO that they have several ongoing studies examining the ESO-AOS mission as part of Phase A formulation. The scope of findings could lead to changes in the mission architecture, costs, and schedule.

[c] The SBG estimate includes the SBG-thermal infrared (SBG-TIR) platform, an instrument contribution to an Italian-led mission, and SBG-visible and short-wave infrared (SBG-VSWIR) hyperspectral platform, a NASA mission.

Table 5 shows the original cost and key schedule milestone baselines for six Artemis-related projects in implementation. Implementation includes building, launching, and operating the system, among other activities, and baselines are set at a project's confirmation review. The table also shows current key schedule milestone dates and life-cycle cost estimates. These key schedule milestone dates include launch readiness, design certification, or first flight, among other activities.

Table 5: Life-Cycle Cost and Schedule Estimates of Artemis-Related Major NASA Projects and Programs in Development

Project name	Original baseline key schedule milestone date	Current key schedule milestone date	Original baseline life-cycle cost estimate (dollars in millions)[a]	Current life-cycle cost estimate (dollars in millions)
Gateway Initial Capability[b]	Dec. 2027	Dec. 2027	5,280.9	5,280.9
HLS – Initial Capability	Feb. 2028	Feb. 2028	4,878.0	4,878.0
Orion[c]	Apr. 2023	Sept. 2025	11,283.5	14,132.0
SEP	Dec. 2024	Jan. 2029	335.6	402.4
SLS Block 1B	Jan. 2028	Jan. 2028	4,952.8	4,952.8
VIPER[c]	Nov. 2023	Nov. 2024	433.5	505.4

Legend: HLS: Human Landing System; Orion: Orion Multi-Purpose Crew Vehicle; SEP: Solar Electric Propulsion; SLS: Space Launch System; VIPER: Volatiles Investigating Polar Exploration Rover.

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data for GAO's current assessment were collected as of January 2024.

[a] All original baselines in the table are from the project's confirmation review.

[b] The Gateway Initial Capability estimates include the cost and schedule of the Power and Propulsion Element and Habitation and Logistics Outpost projects (which will launch together), the launch vehicle, and portions of program mission execution essential for the launch.

[c] The cost estimates for Orion and VIPER are under review. The VIPER schedule estimate is also under review. The Orion estimate does not reflect cost growth associated with the current Artemis II launch date of September 2025. Until those reviews are complete, information presented above is based on the latest estimates that GAO received from NASA.

Table 6 shows the original cost and key schedule milestone baselines as well as the current key schedule milestone dates and life-cycle cost estimates for 11 non-Artemis major NASA projects in implementation.

Table 6: Life-Cycle Cost and Schedule Estimates of Non-Artemis Major NASA Projects and Programs in Development

Project name	Original baseline key schedule milestone date	Current key schedule milestone date	Original baseline life-cycle cost estimate (dollars in millions)[a]	Current life-cycle cost estimate (dollars in millions)
CCP-Boeing[b]	Aug. 2017	Dec. 2024	4,229.0	4,555.4
CCP-SpaceX[b]	Apr. 2017	Nov. 2020	2,598.7	2,757.7
Europa Clipper	Sept. 2025	Oct. 2024	4,250.0	5,000.0
IMAP	Dec. 2025	Dec. 2025	781.8	781.8
LBFD	Jan. 2022	Oct. 2024	582.4	838.6
NISAR	Sept. 2022	Oct. 2024	866.9	1,118.0

Project name	Original baseline key schedule milestone date	Current key schedule milestone date	Original baseline life-cycle cost estimate (dollars in millions)[a]	Current life-cycle cost estimate (dollars in millions)
NEO Surveyor	June 2028	June 2028	1,595.1	1,595.1
OSAM-1[c]	Sept. 2025	Dec. 2026	1,780.0	2,047.1
Psyche	Aug. 2022	Oct. 2023	996.4	1,242.4
PACE	Jan. 2024	Feb. 2024	889.7	948.1
Roman[d]	Oct. 2026	May 2027	3,934.0	4,316.0
SPHEREx	Apr. 2025	Apr. 2025	451.4	488.1

Legend: CCP: Commercial Crew Program; IMAP: Interstellar Mapping and Acceleration Probe; LBFD: Low Boom Flight Demonstrator; NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; NEO: Near Earth Object; OSAM-1: On-Orbit Servicing, Assembly and Manufacturing 1; PACE: Plankton, Aerosol, Cloud, ocean Ecosystem; Roman: Nancy Grace Roman Space Telescope; SPHEREx: Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer.

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data for GAO's current assessment were collected as of January 2024.

[a] All original baselines in the table are from the project's confirmation review.

[b] The Commercial Crew Program has a tailored project life cycle and project management requirements and did not establish a baseline. The cost values represent the original contract values and latest maximum contract values as reported by NASA.

[c] In March 2024, NASA announced that it was canceling the OSAM-1 project. As such, NASA is reviewing the final cost and schedule of this project.

[d] The cost and schedule estimates for Roman include the related technology demo mission, the Roman Coronagraph Instrument (CGI).

NASA approved rebaselines for five major projects since it set their original cost and key schedule milestone baselines at their commitment reviews. Table 7 shows the latest approved rebaselined estimates for cost and key schedule milestone dates (such as first flight or launch readiness), as well as the current estimates for cost and key schedule milestone dates for these projects.

Table 7: Approved Rebaseline and Current Life-Cycle Cost and Schedule Estimates for Major NASA Projects and Programs

Project name	Date of latest approved rebaseline	Latest approved rebaseline key schedule milestone date	Current key schedule milestone date	Latest approved rebaseline life-cycle cost estimate (dollars in millions)	Current life-cycle cost estimate (dollars in millions)
LBFD	Jan. 2024	Oct. 2024	Oct. 2024	838.6	838.6
NISAR	Aug. 2022	Oct. 2024	Oct. 2024	1,118.0	1,118.0
Orion[a]	Aug. 2021	May 2024	Sept. 2025	13,811.0	14,132.0
OSAM-1[a]	May 2022	Dec. 2026	Dec. 2026	2,047.1	2,047.1
SEP	Mar. 2022	Oct. 2028	Jan. 2029	382.4	402.4

Legend: LBFD: Low Boom Flight Demonstrator; NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; Orion: Orion Multi-Purpose Crew Vehicle; OSAM-1: On-Orbit Servicing, Assembly and Manufacturing 1; SEP: Solar Electric Propulsion.

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Data for GAO's current assessment were collected as of January 2024.

[a] The Orion project's cost is under review. The Orion estimate does not reflect cost growth associated with the current Artemis II launch date of September 2025. In March 2024, NASA announced that it was canceling the OSAM-1 project. As a result, information presented above is based on the latest estimates that GAO received from NASA.

Appendix IV: List of Major NASA Projects and Programs Included in GAO's Annual Assessments from 2009 to 2023

We reviewed 84 major NASA projects or programs since our initial assessment in 2009. Fifty projects were included in our assessments from 2009 to 2023 but were not included in the 2024 individual project assessments because their development culminated in an event such as a launch, an achievement of minimum success criteria, or cancelation. See table 8 for a list of these 50 projects.

Table 8: Major NASA Projects and Programs Reviewed in GAO's Annual Assessments from 2009 to 2023

Major project name	Year first reported	Date of development end	Result of development
Aquarius	2009	2012	Launched
Ares I	2009	2011	Canceled
Asteroid Redirect Robotic Mission	2016	2017	Canceled
Dawn	2009	2009	Launched
Double Asteroid Redirection Test	2018	2021	Launched
ExoMars Trace Gas Orbiter	2012	2013	Canceled
Exploration Ground Systems	2016	2022	Achieved launch readiness
Gamma-ray Large Area Space Telescope	2009	2009	Launched
Geospace Dynamics Constellation	2022	2024	Canceled
Glory	2009	2011	Launched but did not reach orbit
Global Precipitation Measurement Mission	2009	2014	Launched
Gravity Recovery and Climate Experiment Follow-On	2014	2018	Launched
Gravity Recovery and Interior Laboratory	2010	2012	Launched
Herschel	2009	2010	Launched
Ice, Cloud, and Land Elevation Satellite-2	2011	2018	Launched
Ionospheric Connection Explorer	2010	2012	Launched
Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport	2014	2018	Launched
James Webb Space Telescope	2009	2021	Launched
Juno	2010	2012	Launched
Kepler	2009	2010	Launched
Landsat Data Continuity Mission	2009	2013	Launched
Landsat 9	2017	2021	Launched
Laser Communications Relay Demonstration	2018	2021	Launched
Lucy	2018	2021	Launched
Lunar Atmosphere and Dust Environment Explorer	2011	2014	Launched
Lunar Reconnaissance Orbiter	2009	2010	Launched
Magnetospheric Multiscale	2010	2015	Launched
Mars 2020	2015	2020	Launched

Appendix IV: List of Major NASA Projects and Programs Included in GAO's Annual Assessments from 2009 to 2023

Major project name	Year first reported	Date of development end	Result of development
Mars Atmosphere and Volatile EvolutioN	2011	2014	Launched
Mars Science Laboratory	2009	2012	Launched
National Polar-orbiting Operational Environmental Satellite System Preparatory Project	2009	2012	Launched
Orbiting Carbon Observatory	2009	2009	Launched but did not reach orbit
Orbiting Carbon Observatory-2	2011	2015	Launched
Orion[a]	2009	2011	Canceled
Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer	2013	2017	Launched
Parker Solar Probe	2011	2018	Launched
Plankton, Aerosol, Cloud, ocean Ecosystem	2017	2024	Launched
Psyche	2018	2023	Launched
Radiation Belt Storm Probes	2010	2013	Launched
Radiation Budget Instrument	2017	2018	Canceled
Solar Dynamics Observatory	2009	2010	Launched
Soil Moisture Active Passive	2011	2015	Launched
Space Launch System	2012	2022	Launched
Space Network Ground Segment Sustainment	2013	2021	Achieved minimum success
Stratospheric Observatory for Infrared Astronomy	2009	2014	Full operational capability
Surface Water and Ocean Topography	2014	2022	Launched
Tracking and Data Relay Satellite Replenishment K	2011	2013	Launched
Tracking and Data Relay Satellite Replenishment L	2011	2014	Launched
Transiting Exoplanet Survey Satellite	2015	2018	Launched
Wide-field Infrared Survey Explorer	2009	2010	Launched

Source: GAO analysis of NASA data. | GAO-24-106767

[a] The original Orion project was canceled in June 2011 when the Constellation program was canceled after facing significant technical and funding issues. During the closeout process for the Constellation program, NASA identified elements of the Ares I and Orion projects that would be transitioned for use on the new Space Launch System and Orion Multi-Purpose Crew Vehicle programs. In 2014, NASA adopted Orion as the common name for Orion Multi-Purpose Crew Vehicle, which stems from the canceled project.

Appendix V: Cumulative and Annual Development Cost and Schedule Performance for NASA's Current Portfolio of Major Projects

Table 9 shows the cumulative cost and schedule changes for major NASA projects as measured from their original development cost and schedule baseline approved at key decision point C.

Table 9: Cumulative Development Cost and Schedule Overruns for NASA's Current Portfolio of Major Projects and Programs

			Changes from original baseline to current assessment		
Current performance status	**Project**	**Original baseline development cost estimate (then-year dollars in millions)**	**Development schedule delay (years)**	**Development cost overrun (then-year dollars in millions)**	**Development cost growth percentage**
First year estimate reported	Gateway Initial Capability[a]	3,561.8	0	0.0	0.0
	HLS – Initial Capability	2,339.0	0	0.0	0.0
	SLS Block 1B	3,675.3	0	0.0	0.0
No variance expected from cost or schedule baselines	IMAP	589.5	0	0.0	0.0
	NEO Surveyor	1,228.6	0	0.0	0.0
Mixed cost or schedule performance	Europa Clipper	2,412.8	(0.9)	96.2	4.0
Overrunning original estimate	LBFD	467.7	2.8	241.5	51.6
	NISAR	661.0	2.1	260.1	39.3
	OSAM-1[b]	974.4	1.3	269.6	27.7
	Orion[b]	6,768.4	2.4	2,854.0	42.2
	PACE	558.0	0.1	43.2	7.7
	Psyche	681.9	1.2	116.3	17.1
	Roman[c]	2,898.1	0.6	371.9	12.8
	SEP	155.9	4.1	67.3	43.2
	SPHEREx	367.8	0	28.6	7.8
	VIPER[b]	336.2	1.0	68.9	20.5
Totals		**27,676.4**	**14.5**	**4,417.6**	

Legend: HLS: Human Landing System; SLS: Space Launch System; IMAP: Interstellar Mapping and Acceleration Probe; NEO: Near Earth Object; LBFD: Low Boom Flight Demonstrator; NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; OSAM-1: On-orbit Servicing, Assembly, and Manufacturing 1; Orion: Orion Multi-Purpose Crew Vehicle; PACE: Plankton, Aerosol, Cloud, ocean Ecosystem; Roman: Nancy Grace Roman Space Telescope; SEP: Solar Electric Propulsion; SPHEREx: Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer; VIPER: Volatiles Investigating Polar Exploration Rover.

Source: GAO analysis of NASA data. | GAO-24-106767

Note: Positive values indicate cost growth or launch delays. Values in parentheses indicate cost decreases or earlier than planned launch dates. Data were collected as of January 2024. Note that the values do not sum due to rounding.

[a] The Gateway Initial Capability's estimates include the cost and schedule of the PPE and HALO projects (which will launch together), the launch vehicle, and portions of program mission execution essential for the launch.

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[b] The cost estimates for Orion and VIPER are under review. The VIPER schedule estimate is also under review. The Orion estimate does not reflect cost growth associated with the current Artemis II launch date of September 2025. In March 2024, NASA announced that it was canceling the OSAM-1 project. As a result, the information presented above is based on the latest estimates GAO received from NASA.

[c] The cost and schedule estimates for Roman include the related technology demo mission, the Roman Coronagraph Instrument (CGI).

Table 10 shows the annual development cost overruns and schedule delays since our 2023 report.

Table 10: Annual Development Cost Overruns and Schedule Delays for Major NASA Projects and Programs in Development since GAO's 2023 Assessment

		Changes between last GAO assessment and current assessment	
Annual performance status	**Project(s)**	**Schedule delay (years)**	**Cost growth (dollars in millions)**
First year estimate reported[a]	Gateway Initial Capability[b]	N/A	N/A
	HLS – Initial Capability	N/A	N/A
	SLS Block 1B	N/A	N/A
No change from prior year	Europa Clipper, Roman[c], OSAM-1[d], IMAP, NEO Surveyor, NISAR	0	0
Underrunning prior estimate	Psyche	0	(15.6)
	PACE	(0.3)	(31.1)
Overrunning prior estimate	Orion[d]	0.8	321.2
	LBFD	1.4	101.8
	SPHEREx	0	28.6
	SEP	0.3	20.0
	VIPER[d]	0	5.0
Totals		**2.3**	429.9

Legend: HLS: Human Landing System; SLS: Space Launch System 1B; Roman: Nancy Grace Roman Space Telescope; OSAM-1: On-orbit Servicing, Assembly, and Manufacturing 1; IMAP: Interstellar Mapping and Acceleration Probe; NEO: Near Earth Object; NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; PACE: Plankton, Aerosol, Cloud, ocean Ecosystem; Orion: Orion Multi-Purpose Crew Vehicle; LBFD: Low Boom Flight Demonstrator; SPHEREx: Spectro-Photometer for the History of the Universe, Epoch of Re-ionization and Ices Explorer; SEP: Solar Electric Propulsion; VIPER: Volatiles Investigating Polar Exploration Rover.

Source: GAO analysis of NASA data. | GAO-24-106767

Notes: Data for GAO's current assessment are as of January 2024. Positive values indicate cost growth or launch delays. Values in parentheses indicate cost decreases or earlier than planned launch dates.

[a] These projects moved from formulation to implementation during GAO's review period; therefore, they did not report cost or schedule performance against a baseline in GAO's prior report against which to assess a change.

[b] The Gateway Initial Capability's estimates include the cost and schedule of the PPE and HALO projects (which will launch together), the launch vehicle, and portions of program mission execution essential for the launch.

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[c] The cost and schedule estimates for Roman include the related technology demo mission, the Roman Coronagraph Instrument (CGI).

[d] The cost estimates for Orion and VIPER are under review. The VIPER schedule estimate is also under review. In March 2024, NASA announced that it was canceling the OSAM-1 project. As a result, information presented above is based on the latest estimates that GAO received from NASA.

Appendix VI: Technology Readiness Levels

Table 11: NASA Hardware Technology Readiness Levels (TRL)

TRL	Definition	Hardware description
1	Basic principles observed and reported.	Scientific knowledge is generated underpinning hardware technology concepts or applications.
2	Technology concept or application formulated.	Invention begins. Practical application is identified but speculative, and no experimental proof or detailed analysis is available to support the conjecture.
3	Analytical and experimental proof-of-concept of critical function or characteristics.	Research and development are initiated, including analytical and laboratory studies to validate predictions regarding the technology.
4	Component or breadboard validation in a laboratory environment.	A low fidelity system/component breadboard is built and operated to demonstrate basic functionality in a laboratory environment.
5	Component or brassboard validated in a relevant environment.	A medium-fidelity component or brassboard, with realistic support elements, is built and operated for validation in a relevant environment to demonstrate overall performance in critical areas. Performance predictions are made for subsequent development phases.
6	System/sub-system model or prototype demonstration in a relevant environment.	A high-fidelity prototype of the system/subsystems that adequately addresses all critical scaling issues is built and tested in a relevant environment to demonstrate performance under critical environmental conditions.
7	System prototype demonstration in an operational environment.	A high-fidelity prototype or engineering unit that adequately addresses all critical scaling issues is built and functions in the actual operational environment and platform (ground, airborne, or space).
8	Actual system completed and “flight qualified” through test and demonstration.	The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment and platform (ground, airborne, or space). If necessary, life testing has been completed.
9	Actual system flight proven through successful mission operations.	The final product is successfully operated in an actual mission.

Source: GAO analysis and representation of NASA TRLs from NASA Procedural Requirements 7123.1C, Appendix E. | GAO-24-106767

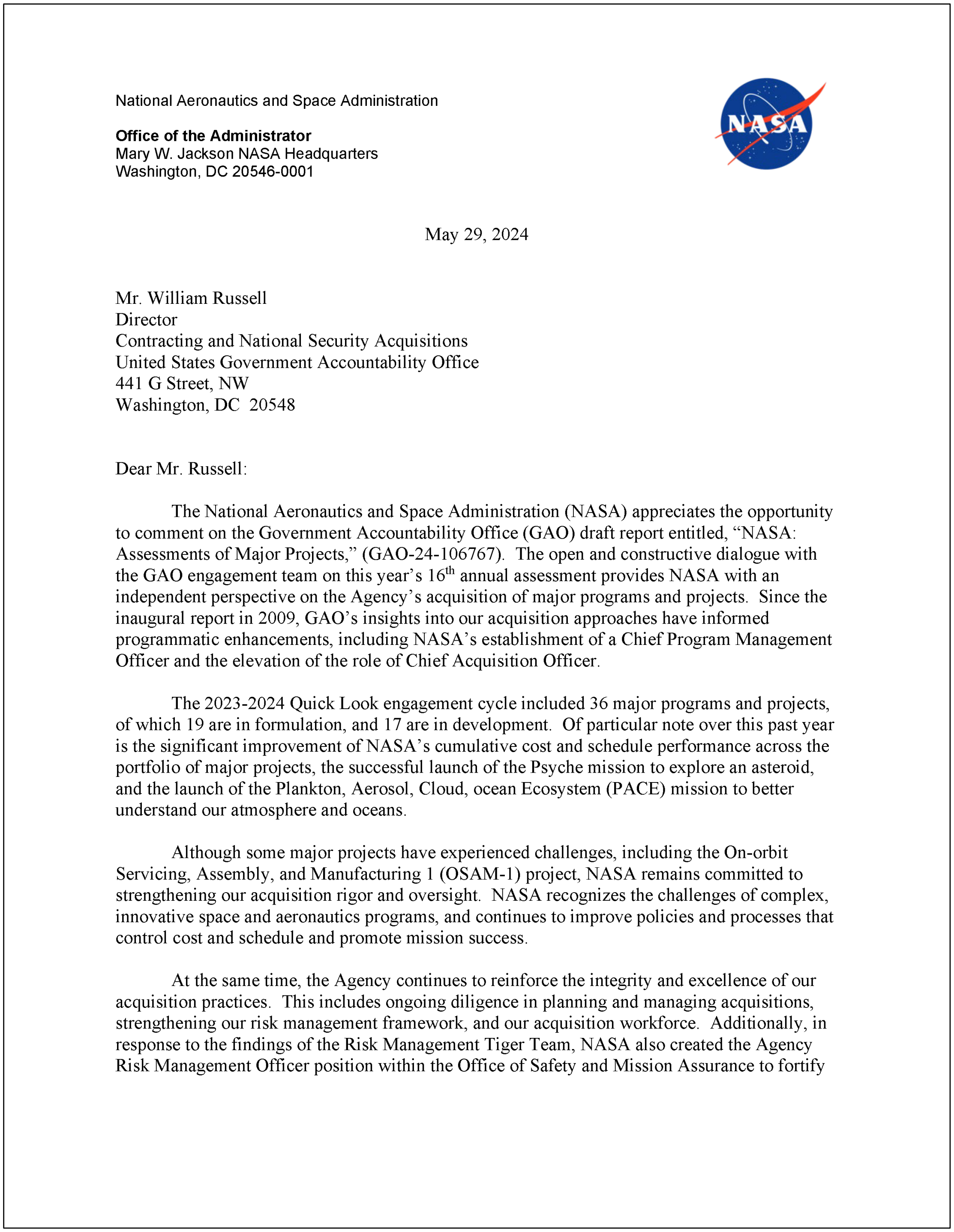
Table 12: NASA Software Technology Readiness Levels (TRL)

TRL	Definition	Software description
1	Basic principles observed and reported.	Scientific knowledge is generated underpinning basic properties of software architecture and mathematical formulation.
2	Technology concept or application formulated.	Practical application is identified but speculative, and no experimental proof or detailed analysis is available to support the conjecture. Basic properties of algorithms, representations, and concepts defined. Basic principles are coded, and experiments are performed with synthetic data.
3	Analytical and experimental proof-of-concept of critical function or characteristics.	Development of limited functionality to validate critical properties and predictions using non-integrated software components occurs.
4	Component or breadboard validation in a laboratory environment.	Key, functionality critical software components are integrated and functionally validated to establish interoperability and begin architecture development. Relevant environments are defined and performance in the environment predicted.

TRL	Definition	Software description
5	Component or brassboard validated in a relevant environment.	End-to-end software elements implemented and interfaced with existing systems/simulations conforming to target environment. End-to-end software system tested in relevant environment, meeting predicted performance. Operational environment performance predicted.
6	System/sub-system model or prototype demonstration in a relevant environment.	Prototype implementations of the software demonstrated on full-scale, realistic problems. Partially integrated with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.
7	System prototype demonstration in an operational environment.	Prototype software exists having all key functionality available for demonstration and test. Well integrated with operational hardware/software systems demonstrating operational feasibility. Most software bugs removed. Limited documentation available.
8	Actual system completed and “flight qualified” through test and demonstration.	All software has been thoroughly debugged and fully integrated with all operational hardware and software systems. All user documentation, training documentation, and maintenance documentation completed. All functionality successfully demonstrated in simulated operational scenarios. Verification and validation are completed.
9	Actual system flight proven through successful mission operations.	All software has been thoroughly debugged and fully integrated with all operational hardware and software systems. All documentation has been completed. Sustaining software support is in place. System has been successfully operated in the operational environment.

Source: GAO analysis and representation of NASA TRLs from NASA Procedural Requirements 7123.1C, Appendix E. | GAO-24-106767

Appendix VII: Comments from NASA



National Aeronautics and Space Administration

Office of the Administrator
Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001

May 29, 2024

Mr. William Russell
Director
Contracting and National Security Acquisitions
United States Government Accountability Office
441 G Street, NW
Washington, DC 20548

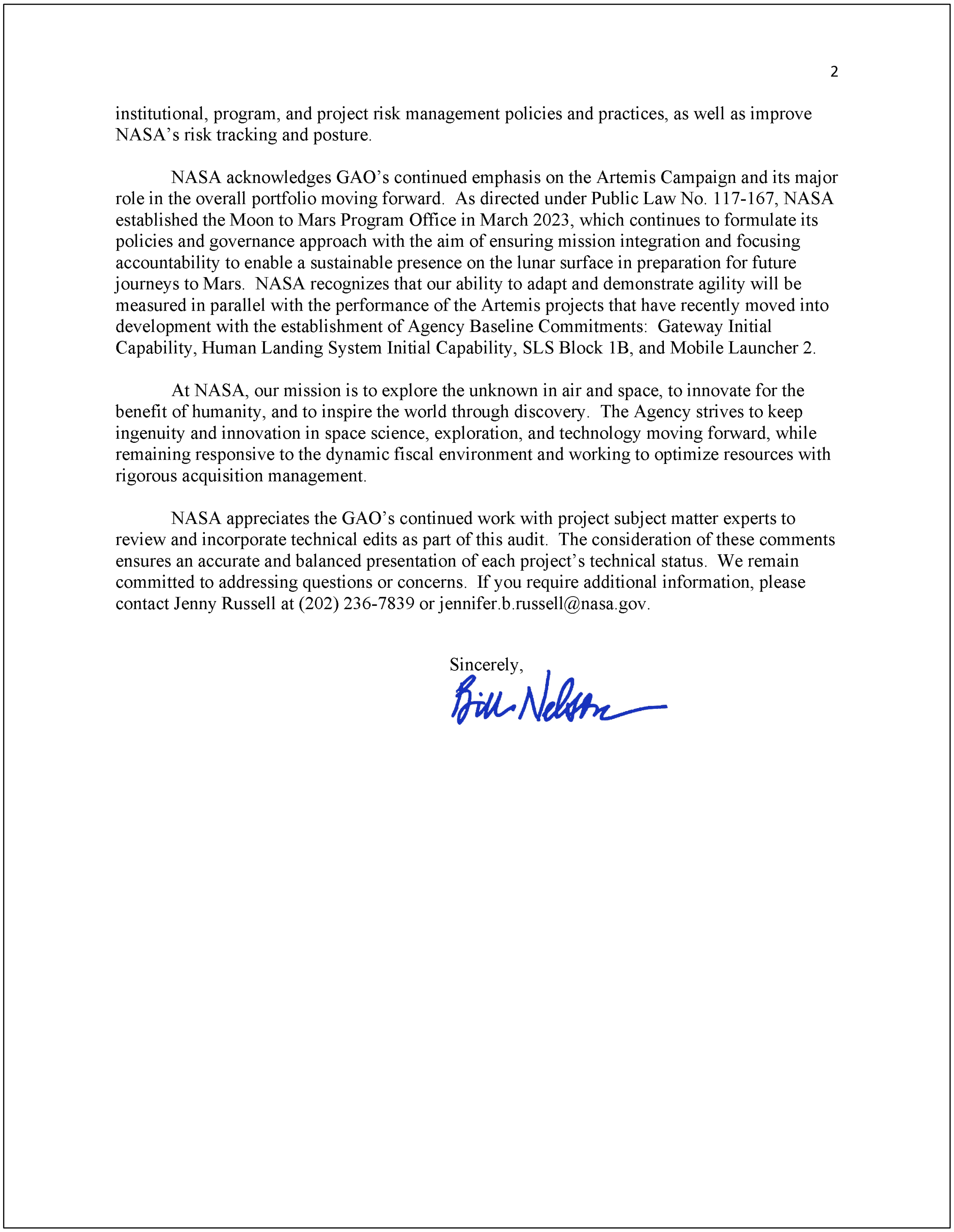
Dear Mr. Russell:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to comment on the Government Accountability Office (GAO) draft report entitled, "NASA: Assessments of Major Projects," (GAO-24-106767). The open and constructive dialogue with the GAO engagement team on this year's 16th annual assessment provides NASA with an independent perspective on the Agency's acquisition of major programs and projects. Since the inaugural report in 2009, GAO's insights into our acquisition approaches have informed programmatic enhancements, including NASA's establishment of a Chief Program Management Officer and the elevation of the role of Chief Acquisition Officer.

The 2023-2024 Quick Look engagement cycle included 36 major programs and projects, of which 19 are in formulation, and 17 are in development. Of particular note over this past year is the significant improvement of NASA's cumulative cost and schedule performance across the portfolio of major projects, the successful launch of the Psyche mission to explore an asteroid, and the launch of the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission to better understand our atmosphere and oceans.

Although some major projects have experienced challenges, including the On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1) project, NASA remains committed to strengthening our acquisition rigor and oversight. NASA recognizes the challenges of complex, innovative space and aeronautics programs, and continues to improve policies and processes that control cost and schedule and promote mission success.

At the same time, the Agency continues to reinforce the integrity and excellence of our acquisition practices. This includes ongoing diligence in planning and managing acquisitions, strengthening our risk management framework, and our acquisition workforce. Additionally, in response to the findings of the Risk Management Tiger Team, NASA also created the Agency Risk Management Officer position within the Office of Safety and Mission Assurance to fortify



institutional, program, and project risk management policies and practices, as well as improve NASA's risk tracking and posture.

NASA acknowledges GAO's continued emphasis on the Artemis Campaign and its major role in the overall portfolio moving forward. As directed under Public Law No. 117-167, NASA established the Moon to Mars Program Office in March 2023, which continues to formulate its policies and governance approach with the aim of ensuring mission integration and focusing accountability to enable a sustainable presence on the lunar surface in preparation for future journeys to Mars. NASA recognizes that our ability to adapt and demonstrate agility will be measured in parallel with the performance of the Artemis projects that have recently moved into development with the establishment of Agency Baseline Commitments: Gateway Initial Capability, Human Landing System Initial Capability, SLS Block 1B, and Mobile Launcher 2.

At NASA, our mission is to explore the unknown in air and space, to innovate for the benefit of humanity, and to inspire the world through discovery. The Agency strives to keep ingenuity and innovation in space science, exploration, and technology moving forward, while remaining responsive to the dynamic fiscal environment and working to optimize resources with rigorous acquisition management.

NASA appreciates the GAO's continued work with project subject matter experts to review and incorporate technical edits as part of this audit. The consideration of these comments ensures an accurate and balanced presentation of each project's technical status. We remain committed to addressing questions or concerns. If you require additional information, please contact Jenny Russell at (202) 236-7839 or jennifer.b.russell@nasa.gov.

Sincerely,

Bill Nelson

Appendix VIII: GAO Contact and Staff Acknowledgments

GAO Contact

W. William Russell, (202) 512-4841 or RussellW@gao.gov

Staff Acknowledgments

In addition to the contact named above, Kristin Van Wychen (Assistant Director); Tonya Woodbury (Analyst-in-Charge); John Armstrong; Paul Bauer; Ryan Braun; Lena Burleson; Tina Cota-Robles; Matthew T. Crosby; Lorraine Ettaro; Edward Harmon; Erin Kennedy; Joy Kim; Meredith Allen Kimmett; Adie Lewis; Joseph Mancina; John Ortiz; Jose A. Ramos; Sarahi Robles; Carrie Rogers; Erin E. Roosa; Kimberly Schuster; Daniel Singleton; Juli Steinhouse; Ryan Stott; John Warren; Alyssa Weir; and Adam Wolfe made significant contributions to this report.

Appendix IX: Additional Source Information for Images and Figures

This appendix contains credit, copyright, and other source information for images, tables, or figures in this product when that information was not listed adjacent to the image, table, or figure.

Front cover banner graphic: NASA (Gateway), Johns Hopkins University Applied Physics Laboratory (Dragonfly), Lockheed Martin (Low Boom Flight Demonstrator).

Front cover: NASA (Mobile Launcher 2).

GAO analysis of NASA data (all cost performance figures),

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Related GAO Products

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