United States Government Accountability Office

Report to Congressional Addressees

September 2022

NASA LUNAR PROGRAMS

Improved Mission Guidance Needed as Artemis Complexity Grows

Accessible Version

GAO-22-105323

GAO Highlights

Highlights of GAO-22-105323, a report to congressional addressees

September 2022

NASA LUNAR PROGRAMS

Improved Mission Guidance Needed as Artemis Complexity Grows

Why GAO Did This Study

In May 2021, GAO found that NASA faced many challenges to its ambitious goal of returning astronauts to the moon by 2024. Subsequently, NASA delayed the planned lunar landing, known as Artemis III, to no earlier than 2025. Artemis III is one in a planned series of missions to eventually establish a sustainable lunar presence and a path to Mars over the next decade-plus. Successfully executing these missions requires extensive coordination across several NASA programs and with a wide range of contractors to ensure systems operate together seamlessly and safely.

A House report to an appropriations bill included a provision for GAO to review NASA's proposed lunar-focused programs. This report assesses the extent to which NASA (1) is managing mission integration risks; (2) developed Artemis mission-level schedules; and (3) assessed the ability of the Artemis workforce to manage and oversee lunar landing missions.

GAO reviewed relevant NASA documents, schedules, and plans and interviewed NASA headquarters and center officials.

What GAO Recommends

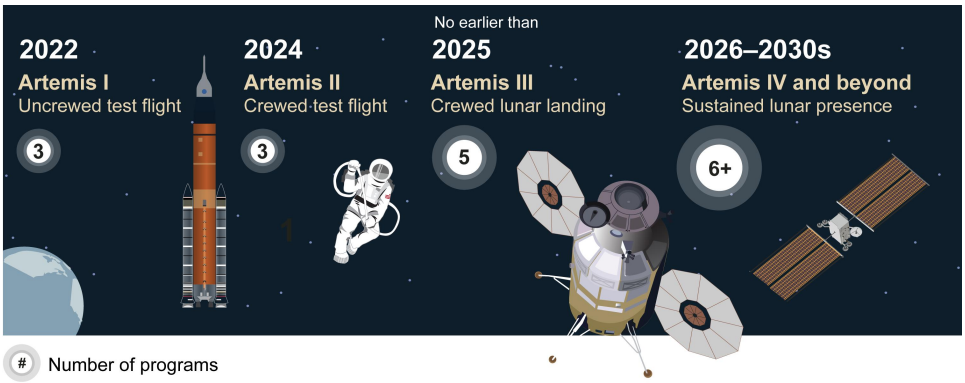
GAO is making four recommendations, including that NASA develop Artemis mission-level schedule management guidance and develop guidance on conducting Artemis workforce scenario planning. NASA concurred with all four of the recommendations.

View GAO-22-105323. For more information, contact William Russell at (202) 512-4841 or RussellW@gao.gov.

What GAO Found

The National Aeronautics and Space Administration (NASA) plans to conduct Artemis missions—a series of missions that will return astronauts to the moon, build a sustainable lunar presence, and ultimately bring humans to Mars—into the 2030s.

Artemis Missions and the Number of Programs Needed for Each Mission



Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

To do this, NASA will need to develop, acquire, and integrate a number of new systems. NASA has made progress on integration and risk management for the first lunar landing mission, Artemis III. For example, NASA established integration processes, roles, and responsibilities, and recently took additional steps to manage risks for the series of missions.

NASA, however, does not yet have guidance for creating or managing Artemis mission schedules that will help integrate the individual programs required for launch. NASA is using existing schedule management guidance developed for individual programs, not multi-program missions. Without guidance specifically for multi-program missions, NASA lacks reasonable assurance it has consistent schedule management practices in place for the Artemis schedules. Schedule management guidance would also assist coordination, which will be increasingly necessary as the Artemis missions will involve more programs over time and therefore become more complex.

NASA conducts workforce planning through the programs that comprise the Artemis missions across the next 5 budget years. NASA faces uncertainties beyond that horizon that have hindered longer-term planning. However, NASA is committing billions of dollars in development and production contracts for future Artemis missions that extend into the 2030s. This will require an extensive workforce to execute. Prior GAO work found that other agencies facing uncertainty assessed a range of future options, known as scenario planning, which provided flexibility to determine future workforce needs. In May 2022, NASA officials said they were examining the use of scenario planning to help future workforce planning efforts. But they have not yet completed or implemented guidance to do so. As NASA begins to execute the first of many Artemis missions, it has the opportunity to use scenario planning to inform future workforce environments it may face and address broader workforce challenges.

Contents

Abbreviations

AES	Advanced Exploration Systems
ASAP	Aerospace Safety Advisory Panel
ESD	Exploration Systems Development
EGS	Exploration Ground Systems
HALO	Habitation and Logistics Outpost
HEOMD	Human Exploration and Operations Mission Directorate
HLS	Human Landing System
IMS	integrated master schedule
NASA	National Aeronautics and Space Administration
OCHCO	Office of the Chief Human Capital Officer
OCFO	Office of the Chief Financial Officer
OPM	U.S. Office of Personnel Management
Orion	Orion Multi-Purpose Crew Vehicle
PPBE	Planning, Programming, Budgeting, and Execution
PPE	Power and Propulsion Element
SLS	Space Launch System
SpaceX	Space Exploration Technologies Corporation
SRA	schedule risk analysis
VIPER	Volatiles Investigating Polar Exploration Rover

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September 8, 2022

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 Eddie Bernice Johnson
Chairwoman
Committee on Science, Space, and Technology
House of Representatives

The Honorable Matt Cartwright
Chairman
The Honorable Robert B. Aderholt
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The National Aeronautics and Space Administration (NASA) plans to return astronauts to the moon, build a sustainable lunar presence over the next decade, and ultimately travel to Mars. To accomplish these goals, NASA plans to partner with industry to execute a series of missions known collectively as Artemis. Each Artemis mission is comprised of multiple, integrated programs. The first and second Artemis missions will serve as demonstrations of the Space Launch System (SLS) launch vehicle, Orion Multi-Purpose Crew Vehicle (Orion), and associated ground systems known as Exploration Ground Systems (EGS).

Artemis III—which NASA estimates will occur no earlier than 2025—and later missions will rely on new programs to develop systems needed to land astronauts on the moon, including a Human Landing System (HLS) to transport crew to and from the lunar surface and space suits for lunar surface operations. For the Artemis IV mission and beyond, NASA is also developing a lunar orbiting outpost known as Gateway to act as a habitat and safe work environment for astronauts and as a communications relay between the lunar surface and the Earth. Gateway will help support

NASA's longer-term lunar exploration goals to create a sustained presence on the moon.

In the fiscal year 2023 President's budget request, NASA requested almost $35 billion over the next 5 years to support Artemis missions. Successfully executing these missions requires extensive coordination across several NASA programs and with a wide range of contractors to address the risks inherent in integrating multiple systems to ensure they operate together seamlessly and safely. In addition, NASA will need to ensure that the lunar programs, once in operation, will be safe for the crew and can operate in a challenging deep space environment.

The House Report accompanying H.R. 4505, Commerce, Science, Justice, and Related Agencies Appropriations Bill, 2022 included a provision for GAO to review NASA's lunar-focused programs. This report assesses the extent to which NASA has (1) managed integration risks for the Artemis III mission; (2) developed mission-level schedules to inform planning for Artemis; and (3) assessed the ability of the Artemis workforce to manage and oversee missions. This is our third report on NASA's Artemis enterprise.[1]

To assess the extent to which NASA managed integration risks for the Artemis III mission, we reviewed the risk management plan, concept of operations document, Systems Engineering Management plan, and charter documents for the various control boards that oversee Artemis missions.[2] We also reviewed Artemis risk review briefing documents to determine the extent to which officials identified mission level risks and how they are coordinated and managed. We interviewed NASA officials to determine the status of establishing key roles and responsibilities and developing internal processes and products to manage cross-program and mission-level risks.

[1]GAO, *NASA Lunar Programs: Significant Work Remains, Underscoring Challenges to Achieving Moon Landing in 2024*, GAO-21-330 (Washington, D.C.: May 26, 2021); and *NASA Lunar Programs: Opportunities Exist to Strengthen Analyses and Plans for Moon Landing*, GAO-20-68 (Washington, D.C.: Dec. 19, 2019).

[2]NASA defines risk as an uncertain future event that could threaten the achievement of explicitly established and stated performance objectives/requirements related to safety, mission success, cost and schedule. NASA, *Advanced Exploration Systems Risk Management Plan (Oct. 19, 2021).*

To assess the extent to which NASA has developed Artemis mission-level schedules and used them to inform planning, we reviewed Artemis II mission and Orion program schedule data and schedule management plans. Specifically, we assessed how NASA integrated program and mission-level schedules. We analyzed the Artemis II mission-level schedule to determine the extent to which NASA followed applicable GAO scheduling best practices.[3] To assess the extent to which NASA developed an Artemis III schedule, we interviewed officials about progress made and reviewed a draft schedule management plan. We also interviewed NASA officials to determine how they develop and use mission-level schedules.

To assess the ability of the Artemis workforce to manage and oversee lunar landing missions, we reviewed NASA center workforce plans, and interviewed human capital, Artemis management, and center officials. We also determined the extent to which NASA has assessed its Artemis workforce, including the extent to which skills gaps exist, by comparing NASA's process and documentation against NASA policy and guidance and relevant principles for strategic workforce planning that we previously identified.[4]

We conducted this performance audit from June 2021 to September 2022 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.

Background

[3]GAO, *GAO Schedule Assessment Guide: Best Practices for Project Schedules,* GAO-16-89G (Washington D.C.: Dec. 22, 2015).

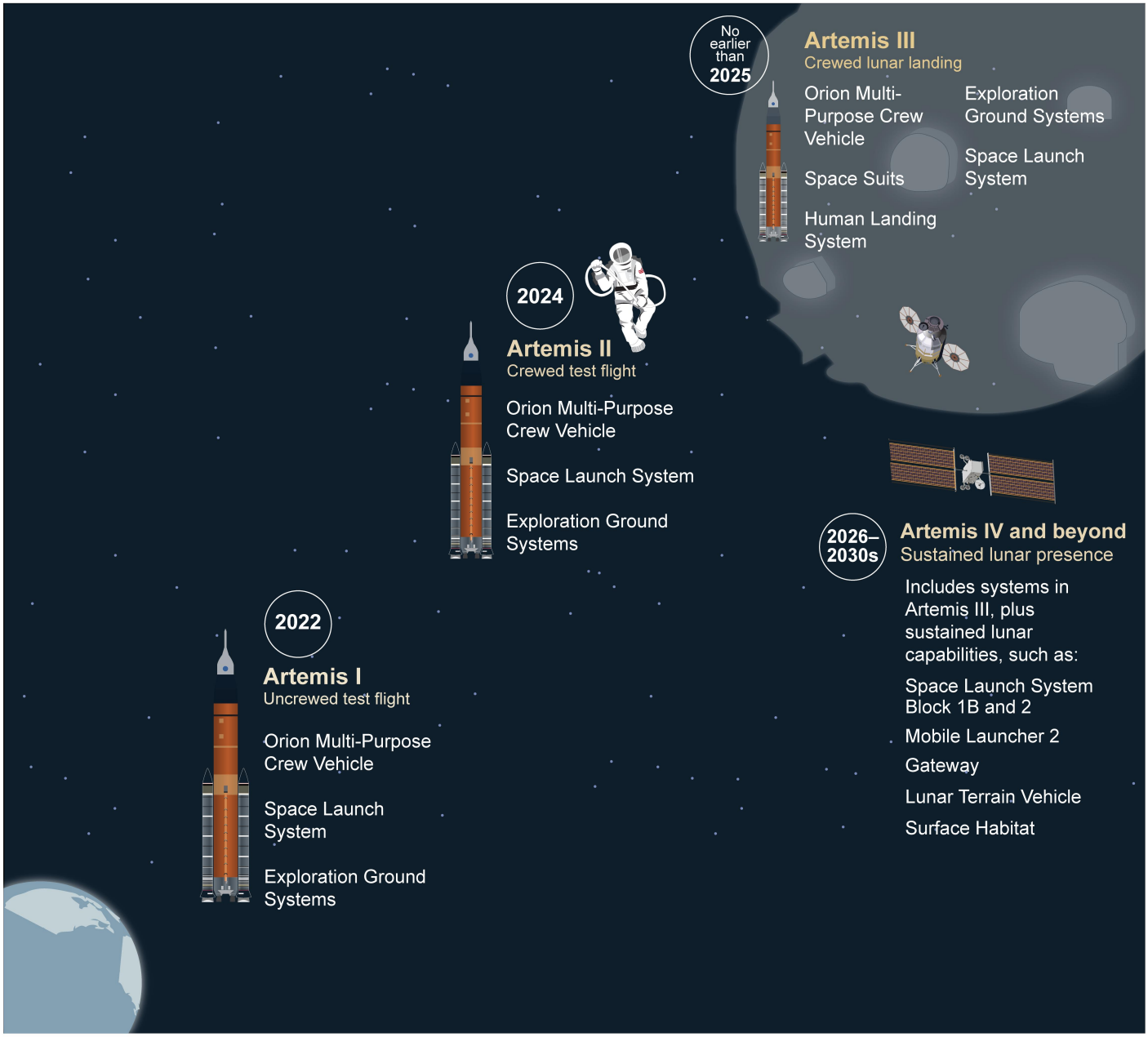
[4]GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning*, GAO-04-39 (Washington, D.C.: Dec. 11, 2003).

Key Elements of NASA's Planned Return to the Moon

The goal of NASA's Artemis enterprise is to return U.S. astronauts to the surface of the moon, including a sustained lunar presence and ultimately human exploration of Mars. To do so, NASA programs are developing multiple highly complex and interdependent systems that will need to be integrated to support individual Artemis missions.[5] The Artemis I and II missions are the first planned uncrewed and crewed demonstration missions, respectively, of the SLS, Orion, and EGS programs. In addition to SLS, Orion, and EGS, NASA's Artemis III mission incorporates new programs, which are developing space suits and a landing system to put humans on the surface of the moon. See figure 1 for programs needed to accomplish the Artemis missions.

[5]NASA distinguishes between programs and projects in its policies and guidance. A NASA program has a dedicated funding profile and defined management structure, and may include several projects. Projects are specific investments under a program that have defined requirements, life-cycle costs, schedules, and their own management structure. For the purposes of this report, we refer to both programs and projects as programs.

Figure 1: Artemis Missions and the Programs Needed to Accomplish Each Mission



Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

In March 2022, we found that the success of this complex series of missions depends on NASA successfully managing and integrating the individual programs.[6] See appendix I for more information on the programs that comprise the Artemis missions and the contractors and international partners that support them.

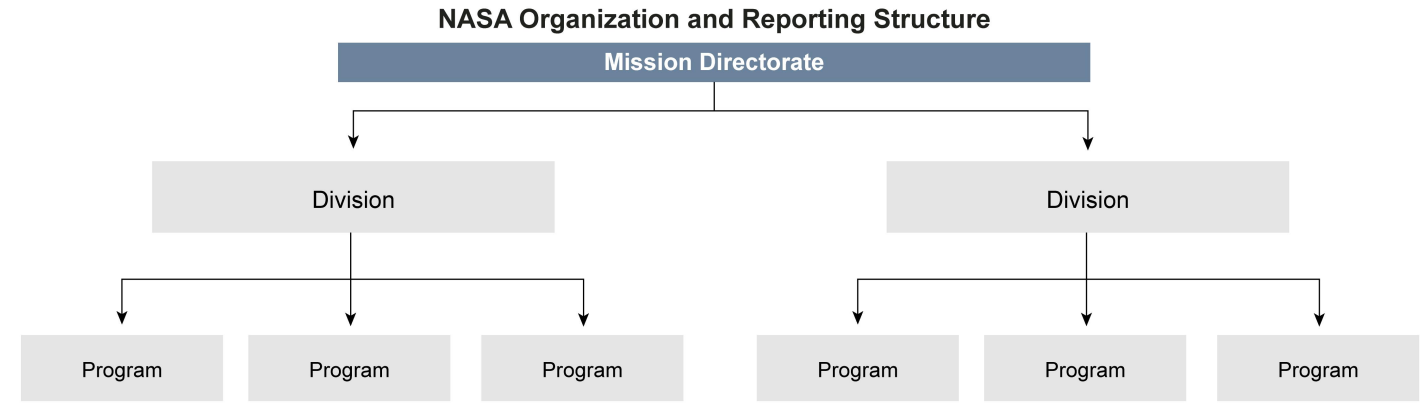
NASA's Artemis Mission Management Organization

In September 2021, NASA announced plans to reorganize its Human Exploration and Operations Mission Directorate (HEOMD). HEOMD was previously responsible for managing programs to enable human exploration of the solar system, including to the moon and eventually Mars. Within HEOMD, two divisions were primarily responsible for overseeing the programs necessary for Artemis missions—Exploration Systems Development (ESD) and Advanced Exploration Systems (AES). ESD was responsible for managing the Artemis I and II missions and the individual SLS, Orion, and EGS programs. AES was responsible for managing Artemis III and beyond. The reorganization split HEOMD into two new directorates, with one focused on existing space operations and the other focused on exploration systems for the Artemis missions. The newly formed Exploration Systems Development Mission Directorate oversees the Common Exploration Systems Development Division (formerly ESD) as well as the Artemis Campaign Development Division (formerly AES). Since the majority of our audit work was conducted prior to the reorganization, we will refer to groups by their previous names.

In April 2022, NASA finalized the plans for the reorganization. Officials explained that NASA's reorganization of its human spaceflight mission directorate is intended to result in lunar programs sharing people and resources across the agency. Under the reorganization, the general mission directorate management structure remains the same (see fig. 2).

[6]GAO, *NASA Lunar Programs: Moon Landing Plans are Advancing but Challenges Remain*, GAO-22-105533 (Washington, D.C.: Mar. 1, 2022).

Figure 2: Generic NASA Mission Directorate Organization and Reporting Structure



Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

In addition to the mission directorate and division management, the programs supporting Artemis missions are spread across various NASA centers. Center directors are responsible for providing and obtaining resources, overseeing the assignment of workforce and facilities, and managing center operations to facilitate program execution. According to NASA policy, the key role of the center director is to determine how best to execute the various programs at the center while balancing resources across mission directorate needs in accordance with agency priorities.[7]

Prior GAO Reports on Artemis Missions and Programs

Over the past 8 years, we issued two reports assessing the progress of NASA's Artemis efforts, as well as several other reports on the programs that support the Artemis missions.[8] For example, in December 2019, we found that NASA had refocused its acquisition plans to support an

[7]NASA, *The NASA Organization with Change 85*, NASA Policy Directive 1000.3E (Apr. 15, 2015).

[8]GAO-21-330; *NASA Human Space Exploration: Significant Investments in Future Capabilities Require Strengthened Management Oversight*, GAO-21-105 (Washington, D.C.: Dec. 15, 2020); GAO-20-68; *NASA Human Space Exploration: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs*, GAO-19-377 (Washington, D.C.: June 19, 2019); *NASA Human Space Exploration: Integration Approach Presents Challenges to Oversight and Independence,* GAO-18-28 (Washington, D.C.: Oct.19, 2017); and *GAO, Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability*, GAO-14-631 (Washington, D.C.: July 23, 2014).

accelerated plan to land astronauts on the moon by 2024, 4 years earlier than planned.[9] In that same report, we found that NASA had begun making decisions related to requirements, cost, and schedule for programs but was behind in taking these steps for the whole lunar mission. We found that NASA risked discovering integration challenges late in the development process because it established some requirements for individual lunar programs before finalizing requirements for the overall lunar mission. At the time of that report, we found that NASA planned to take steps to mitigate this risk by holding reviews to ensure that requirements aligned across programs. We made six recommendations to NASA, including to (1) create a cost estimate for the Artemis III mission and commit to a completion date, and (2) finalize a cohesive document outlining the rationale for selecting its lunar plans. NASA concurred with all six of the recommendations, and to date has implemented the recommendation to define and schedule reviews that align requirements across lunar programs.

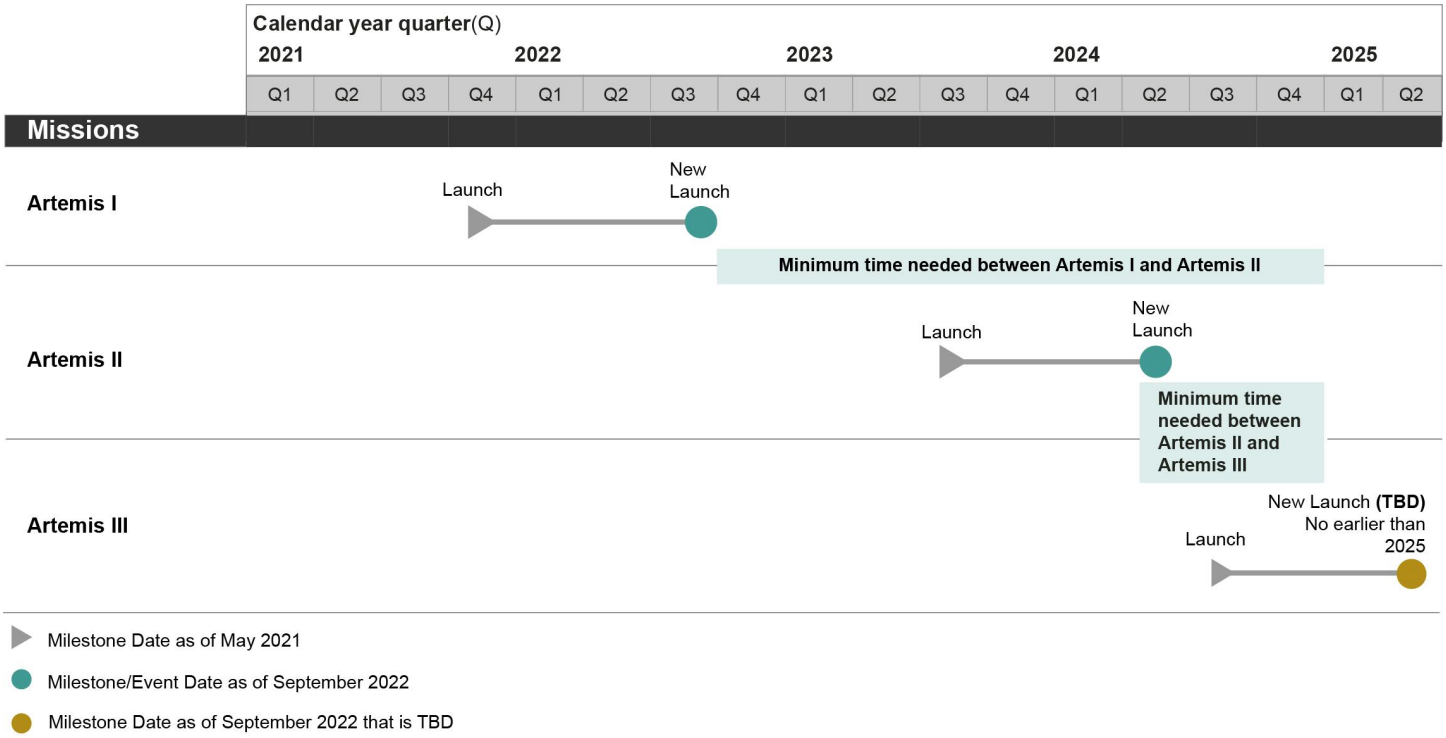
In May 2021, we found that NASA had made progress in achieving its goal of returning humans to the moon but the ambitious schedule decreased the likelihood of NASA achieving its goal.[10] We made four recommendations in the 2021 report, including that NASA should document the process for determining key programmatic and technical tools for the Artemis missions. NASA concurred with three of the recommendations, but did not concur with the fourth, which related to the costs included in a lunar rover's cost estimate.

Since our May 2021 report, NASA delayed Artemis mission time frames and key program milestones several times. For example, most recently, NASA experienced technical challenges in attempting to fuel the Artemis I launch vehicle during the final test prior to launch. Addressing these challenges will further delay the launch until at least September 2022, almost 4 years past the original November 2018 launch date. Delays to the Artemis I launch have a cascading effect on the Artemis II and III mission schedules because there is a minimum time needed between those missions. NASA also delayed the Artemis II mission to May 2024, 13 months past the original April 2023 launch date, as a result of revising the Orion program's schedule. Figure 3 illustrates recent Artemis mission delays.

[9]GAO-20-68.

[10]GAO-21-330.

Figure 3: Artemis Missions I through III Delays since GAO's May 2021 Lunar Programs Report



Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

Note: Due to delays with Artemis I, the minimum time between missions now exceeds the planned Artemis II launch date.

In November 2021, NASA announced that it was no longer working to its goal of an Artemis III lunar landing in 2024 and that the new date would be no earlier than 2025. NASA officials attributed this change to a 7-month delay in working on the lunar lander, subsequent to a bid protest and federal court complaint regarding the award of the lander's contract. In announcing the delay, senior NASA officials acknowledged that the prior 2024 goal was unrealistic. Although NASA has made progress on the Artemis III mission, in March 2022, we found NASA faced a number of challenges to its schedule.[11]

[11]GAO-22-105533.

NASA Efforts on Strategic Workforce Planning

NASA established a strategic workforce planning policy and issues guidance to its centers annually to assist in planning its workforce.[12] In January 2016, NASA assessed its strategic workforce planning efforts and found that its strategic workforce planning capability was not effective and posed a high risk to the agency.[13] Specifically, centers were independently trying to assess future needs with minimal guidance from the mission directorate, and there was minimal to no integration across other centers.

As a result, in June 2016, NASA developed a plan to address and implement actions to help strategic workforce planning efforts. The plan outlined an approach for centers to each create a workforce master plan covering a 5- to 20-year future horizon reflecting a top-down look at key changes necessary to maintain the health and alignment of the workforce. NASA intended for these actions to reflect the work demand for near-term as well as long-term needs. In 2018 and 2019, NASA took steps to implement some of the items it identified in its 2016 plan. For example, NASA piloted Center Workforce Master Plans and subsequently worked with all centers to develop them.

In December 2019, NASA issued a memo titled *NASA's Strategic Workforce Planning Guidance for Mission Workforce*.[14] The memo established guiding principles for NASA workforce planning such as developing a demand-driven, agile, and strategically shaped workforce. NASA also established workforce requirements to reduce the permanent

[12]NASA, *Strategic Workforce Planning*, NASA Policy Directive (NPD) 3010.1B (Feb. 11, 2022).

[13]NASA, Mission Support Council Decision Package, Business Services Assessment Human Capital Recommendations, MSC-2015-01-001b (January 22, 2016). NASA defines a strategic workforce plan as an integrated, agency-wide multi-year workforce transformation plan that integrates both horizontally across centers, mission directorates, and capability managers, and vertically from the agency level down to the individual employee, all in strategic alignment with current and future mission priorities.

[14]NASA, NASA Strategic Workforce Planning Guidance for Mission Workforce (Dec. 16, 2019). The memo called for detailed guidance to be included in NASA's Office of the Chief Human Capital Office's Planning, Programming, Budgeting, and Execution (PPBE) strategic workforce planning guidance for fiscal year 2022.

civil service workforce between fiscal years 2021 and 2025 and leverage more term-limited employees.

In May 2022, NASA issued a memo on improving the workforce forecasting and the strategic planning process for the mission workforce.[15] Among other things, the memo established goals for process and planning improvements for forecasting workforce demand and strategic workforce planning. The memo directed mission directorates to issue workforce planning guidance for the near term—the next 1 to 5 years—and the long term—5 years and beyond. Included in this requirement, the memo directed mission directorates to draft and share this guidance by fall 2022 with the intent for annual updates.

Artemis Mission Integration and Risk Management Plans Have Progressed

NASA continues to make progress on its integration and risk management plans for the first crewed lunar landing mission, Artemis III. For example, the AES division held the first in a series of planned reviews to align requirements for Artemis III and later missions and issued several key requirements and governance documents. NASA also established integration processes, roles, and responsibilities for Artemis III, and matured its processes for managing risks for the overall series of Artemis missions. Previously, AES primarily used a bottom-up approach to risk management; however, it has recently taken steps to increase focused and defined management attention to help ensure that mission risks are captured in a timely manner.

NASA Has Made Progress Establishing Artemis III Integration Processes, Products, and Roles and Responsibilities

Since we last reported in May 2021, the AES division—responsible for the Artemis III mission and beyond—held its first synchronization review in September 2021, which accomplished several important objectives related to integration and ensuring requirements are aligned across

[15]NASA, *Improving PPBE/Workforce Forecasting and the Strategic Planning Process for Mission Workforce* (Washington, D.C.: May 26, 2022).

program and mission levels.[16] For example, the review confirmed that Artemis mission products, processes, and organizational responsibilities were defined; systems were properly integrated as part of the overall architecture; and integrated technical and programmatic risks, mitigation plans, and resources were identified. The review focused primarily on the Artemis III mission, but also supported mission planning for later Artemis missions.

During the synchronization review, NASA officials also reviewed whether the technical baseline was sufficiently mature and requirements were aligned across the human exploration and operations mission directorate, AES division, and individual Artemis programs. For example, the division compared its communications requirements, among other identified priority areas, against mission directorate-level requirements to ensure they aligned. The division identified additional analysis in several areas that was needed to ensure that all requirements are easily understandable and verifiable. For example, the review identified that additional requirements related to extravehicular activities and mass limitations need to be verified, among others. This is significant because, as we reported in December 2019, NASA faced a potential for requirements gaps due to having to reconcile requirements among multiple organizational levels.[17] Further, we reported in May 2021 that late discovery of such gaps could contribute to cost or schedule growth.[18] As we reported, NASA officials acknowledged this risk, and planned to hold periodic synchronization reviews to help mitigate it. According to an agency official, the AES division plans to hold these reviews approximately annually.

As part of the synchronization review process, the AES division additionally issued several documents that together define the division's governance structure, integration processes, and risk management strategy for Artemis missions. Other relevant documents are currently in draft form, and according to officials, nearing completion (see table 1).

[16]GAO-21-330.

[17]GAO-20-68.

[18]GAO-21-330.

Table 1: Status of Selected Advanced Exploration Systems (AES) Governance, Mission Integration, and Risk Management Documents for Artemis III and Beyond

Document	Description	Date Issued
AES Lunar Exploration Requirements	Establishes the requirements baseline for the systems that AES manages, such as the Human Landing System and the Gateway.	July 2021
AES Integrated Concept of Operations	Specifies a framework for requirements, to provide operational context to the programs and supporting organizations that will enable Artemis III and subsequent missions. With the Division Requirements Document, this concept of operations provides programs with the information required to identify system requirements and interfaces with other programs and support organizations, and perform systems analyses to create integrated program requirements.	September 2021
Systems Engineering Management Plan	Describes systems engineering and integration roles and responsibilities, describes framework for integration of AES programs, and addresses integration with Exploration Systems Development programs.	September 2021
AES Risk Management Plan	Provides a systematic process for identifying, analyzing, and handling risks, while considering cost, schedule, performance, and safety concerns; describes horizontal and vertical risk communication processes; provides roles and responsibilities of personnel involved in risk management; and establishes the risk database tool used to document and communicate risks	October 2021
AES Control Board Charter / Joint AES / Exploration Systems Development Control Board Charter	Establishes the AES Control Board and defines the board's responsibility, authority, functions, and membership. This charter also establishes the Joint AES Control Board / Exploration Systems Development Control Board.	January 2022
Verification and Validation Plan	Expected to identify the activities that will establish compliance with the requirements (verification) and that the system will meet the customers' expectations (validation).	Draft - TBD
Implementation Plan	Expected to describe (1) division roles and responsibilities, (2) responsibility for systems integration activities required to integrate elements for Artemis III from agency components and external stakeholders, (3) tailoring of entrance and success criteria for technical reviews, and (4) the governance structure for approving and overseeing programmatic and technical baselines, among other information	Draft - TBD

Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

AES has generally established risk management roles and responsibilities for Artemis III and later missions, including how AES leadership will collaborate with its counterparts in ESD on risks that affect programs in both divisions. According to AES officials, their Artemis roles and responsibilities are similar to those established previously for the ESD division, and officials from the two divisions frequently collaborate with each other. For example, the divisions each have risk manager positions that work in parallel with each other. The division risk managers each chair Integrated Risk Working Groups that examine risks from respective Artemis programs, and they attend each other's group meetings.

In addition, AES finalized a written charter for its AES Joint Integration Control Board in December 2021. This board manages cross-program integration for the AES division and serves as an additional forum to discuss, integrate, and elevate risks to higher levels of agency management, as it deems appropriate. ESD also has a control board that performs similar functions. In addition, the AES/ESD Joint Integration Control Board is used when decision-making affects programs in more than one division. The divisions elevate decisions and risks to the mission directorate level as needed, where ultimate decision authority resides.

NASA Is Maturing its Processes for Identifying and Managing Artemis III Mission Risks

NASA established several mechanisms for identifying and tracking Artemis III risks and has begun implementing them. For example:

- **Risk Database:** AES and ESD division leadership each use the same risk management database, which serves as a repository for risk information across the divisions. According to officials, the individual programs that the divisions each manage input risk information into this database. In addition, risks from external parties, such as international partners and contractors, are manually added and updated. Officials stated that these external parties typically have their own risk management systems. However, if an external party risk becomes significant enough to escalate or if it has multiple programs as stakeholders, the respective program will add it to the database so that it is accessible to all the relevant parties.
- **Risk Scorecard:** AES officials said that the division recently developed a similar risk scorecard to that previously in use by ESD to score the likelihood and potential consequences of risks. An AES official noted that they made some conscious decisions to deviate slightly from ESD's scorecard. For example, ESD's scorecard is broken out in more detail for risks with lower–rated consequences to certain requirements, whereas AES's scorecard is more detailed for risks that have higher-rated consequences. Officials also said that individual programs within the divisions are generally expected to use the scorecard for their respective division. Organizations that had already developed risk criteria before the division scorecard was in use are allowed to continue using their own scorecard for internal risks, but are required to rescore risks according to the AES scorecard when they become significant enough to escalate or if they have multiple programs as stakeholders.

- **Risk Reviews:** AES holds Cross-Program Risk Reviews informed by the integrated risk working groups discussed above. These reviews examine cross-program risks, or those risks that have implications for more than one Artemis program. These could include risks to Artemis III that are owned by ESD or an external party. A cross-program risk could highlight similar issues in multiple programs, which may indicate important trends or the need for a system-wide risk mitigation solution instead of a program-owned solution. Additionally, the AES division holds an AES Top Risk Review to discuss the status of top program and division risks, proposals to escalate a risk from program-level to division-level, and proposals to de-escalate a top division risk to a lower level, as well as other risk-related topics, as needed. The AES division began using formal risk reviews to review top risks in February 2020. In December 2021, the risk review was renamed to Artemis Top Risk Review and is used to review Artemis III and later mission risks. For example, the review documentation includes several program-level risks specifically related to the Human Landing System, which will first be used on Artemis III. Such risks include the integration of hardware and software and potential mass concerns, among others.

NASA's approach for Artemis III risk management has primarily been bottom-up, meaning that individual programs are responsible for elevating risks to the divisions and, in turn, divisions are responsible for elevating risks to the mission directorate level. Officials said risk identification often occurs at the program level because that is where it usually becomes apparent that a requirement or objective may not be met. From there, the risk is communicated horizontally and vertically to affected stakeholders.

During the course of our review, in January 2022, we found that NASA's risk management plans did not have a formal top–down process to identify risk. Without focused and defined management attention, NASA could have missed identifying potential aggregated risks that could affect the success of a particular mission. NASA's risk management policy notes the importance of ensuring that risks are coordinated both horizontally and vertically, as well as across and within programs and institutions.[19] It states that a risk management plan should include establishing risk communication protocols between management levels, including the frequency and content of reporting. The policy also notes

[19]NASA, *Agency Risk Management Procedural Requirements,* NASA Procedural Requirements (NPR) 8000.4B (Dec. 6, 2017).

that for some purposes, it is not adequate to consider a list of risks, but rather it is necessary to consider risks in the aggregate.

Officials told us that it had been their practice at risk reviews and other forums to purposefully ask management to give concerted thought to aggregation of risks and consider what risks might be missing. However, this process was not a formal part of the agenda at such sessions. In response to our discussions, in June 2022, officials reported that they added a top-down review of risks to the recurring agenda for the AES Top Program Risk Review to ensure a level of focused management attention. According to NASA officials, this action was intended to ensure regular discussions as to whether the top identified risks adequately convey risk posture, what additional risks need to be created in order to encompass the most significant challenges, and whether certain risks should be consolidated or if parent risks should be created. Formally establishing a process for management review and consideration of potential new risks is a positive step because it will help ensure regular, focused management attention to the identification of risks that could affect mission success.

Lack of Mission-Level Guidance Affects Artemis Schedules and Hampers Planning

NASA does not yet have agency-wide, mission-level schedule management guidance to inform realistic integration schedules and launch dates for Artemis missions, which NASA plans to conduct into the 2030s. Currently, NASA is using parts of its existing program-level schedule management guidance to develop schedules for these Artemis missions. Further, while the agency developed an Artemis II mission-level schedule, it has not yet conducted an Artemis II schedule risk analysis (SRA). An SRA is an important tool that could help NASA to identify a realistic risk-informed launch date. NASA also has not yet developed a mission-level schedule for the Artemis III mission, but plans to develop one by the end of 2022, approximately 2 years from the mission's earliest planned launch.

NASA Does Not Have Agency-wide Guidance for Developing and Managing Mission-level Schedules

NASA does not have agency-wide schedule management guidance specific to creating or managing multi-program mission-level schedules,

such as those needed for Artemis missions. Existing schedule management guidance, such as the Office of the Chief Financial Officer's (OCFO) NASA Schedule Management Handbook, applies to programs and does not specify its applicability to mission-level schedules. OCFO officials noted that examples in the handbook may have some applicability for mission-level schedules, which are composed of multiple program schedules. However, without documenting mission-level schedule expectations in guidance, NASA lacks reasonable assurance it has consistent schedule management practices in place for the Artemis schedules.

Further, without mission-level schedule management guidance, there may not be the same level of schedule development oversight and management for missions as there is for programs. For example, a program's independent assessment team typically evaluates schedule best practices at key decision point reviews. However, because NASA does not manage Artemis as a program, Artemis missions do not have key decision point reviews or the same dedicated independent review process for schedules. Similarly, NASA's Schedule Management Handbook ties best practices to program life cycles and key decision points to guide when and where to apply best practices, but Artemis missions do not follow the same life cycle process as programs. As a result, the process of creating a mission-level schedule that follows similar best practices to program schedules is not consistent.

We found differences between the divisions' approaches to create and maintain mission-level schedules due to a lack of mission-level schedule management guidance. For example, schedulers from each program in the ESD division update the Artemis II mission-level schedule, whereas AES division officials collect each program's schedule and extract key information to make the Artemis III and beyond mission-level schedules. Mission-level guidance could help standardize schedule management across divisions, which will be increasingly important as the Artemis missions involve more programs and become more complex over time.

Standards for Internal Control in the Federal Government states that management should design control activities—such as policies and procedures—to achieve objectives and respond to risks.[20] Further, these standards state that management should implement control activities

[20]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: September 2014).

through policies. NASA's Schedule Management Handbook for programs also states that consistent schedule guidance supports an efficient and effective decision-making process and can help ensure NASA meets internal and external stakeholder expectations. Mission-level schedule management guidance could help set expectations and produce consistent schedules for future Artemis missions, which NASA plans to execute at least through 2030.

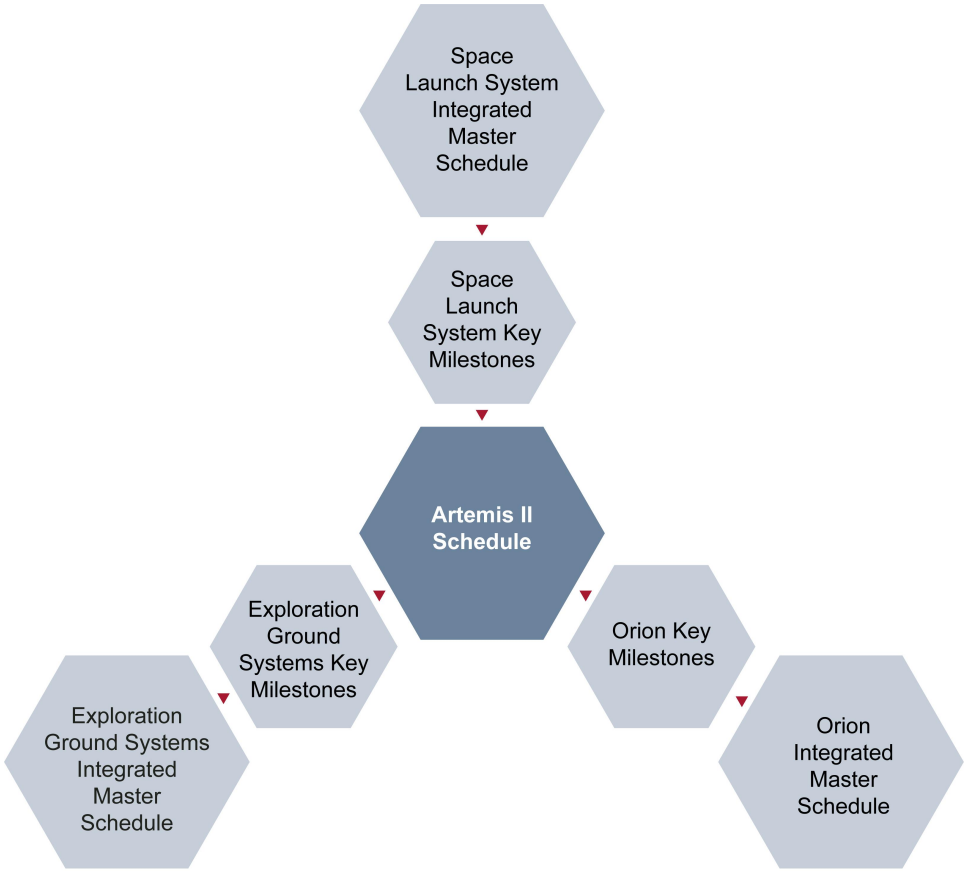
NASA Has Not Performed Key Schedule Risk Analysis for Artemis II to Inform Realistic Launch Date

Without mission-level schedule management guidance, in July 2018, the ESD division created its own Schedule Management Plan, which outlined a mission-level schedule creation process for Artemis II. According to NASA's Schedule Management Handbook, developing a schedule management plan is not required but it is a best practice. Officials explained that the division's Schedule Management Plan draws on existing NASA schedule guidance for programs. The Artemis II schedule is a high-level summary schedule composed of key program milestones and integration activities leading up to launch. A summary schedule rolls up lower-level schedule information to provide a strategic view of activities and milestones necessary to complete the mission. Each of the three programs needed for the Artemis II mission has scheduling personnel who update the mission-level schedule each month with key activities from their integrated master schedules (IMS) (see fig. 4).[21] ESD requires that, at a minimum, programs report their top three critical paths in the mission-level schedule.[22] OCFO officials also told us there is no agency policy on what should be included in summary schedules, such as the Artemis II mission schedule.

[21]An integrated master schedule is a schedule document that combines all planned work in a logical sequence of activities.

[22]The critical path is the longest continuous sequence of activities in a schedule and defines the earliest completion date.

Figure 4: Exploration Systems Development Division's Artemis II Schedule Creation Process



Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

After evaluating the quality of the Artemis II schedule, we found that it generally followed the best practices for scheduling that we assessed it against.[23] When we initially assessed vertical traceability—which ensures data are consistent between different levels of a schedule—we were unable to trace information between the Orion IMS and the Artemis II schedule. Without vertical traceability between the two schedules, different decision makers may be working toward different schedule expectations. In response to our analysis of vertical traceability, NASA added additional information to the Artemis II schedule. This improved the ability to trace Orion key milestones to the Artemis II schedule, though dates did not align. NASA officials explained that this is because

[23]GAO-16-89G.

program-level schedule data may have a lag, but are input into the Artemis II schedule to try to reflect the most current information. Appendix II provides more information on our assessment of NASA's schedule against scheduling best practices.

Although NASA has an Artemis II schedule, the ESD division has not conducted an SRA. An SRA is an analysis that uses statistical techniques to predict the likelihood of a project's completion date, or in this case, a launch date. Using the Artemis II schedule, ESD officials said they plan to conduct an initial SRA sometime in 2022 after Artemis I launches, but they do not have a planned completion date. Conducting a high quality SRA as close as possible after the Artemis I mission would give NASA a more informed launch date for Artemis II—currently scheduled for May 2024—as it begins key integration activities.

The NASA Schedule Management Handbook states that programs should conduct an SRA sometime between the program's concept and preliminary design and then update it as needed. Because there is no mission-level schedule management guidance, missions are not bound to the same timelines as programs for conducting an SRA. However, all three programs required for Artemis II are past preliminary design. Additionally, a lesson learned that NASA identified from the Artemis I SRA was to build an SRA model early, even if it requires high-level assumptions. The GAO Schedule Guide also states that in addition to conducting an SRA, agencies should update it to incorporate new risks and schedule updates.[24] Therefore, with less than 2 years until launch, ESD should have already completed an initial SRA and be updating it as changes arise.

Comparatively, NASA completed an initial mission-level SRA for Artemis I by 2018. Shortly after completing the SRA, NASA announced that the December 2019 to June 2020 planned launch window was unlikely. According to officials, ESD updated the Artemis I SRA multiple times to incorporate major schedule changes such as programs rebaselining. After conducting an SRA for Artemis I, NASA reported that the analysis focused management attention on key areas, served as a catalyst for more robust schedule analysis, and provided additional data and insight into the way risks may affect multiple programs, among other things.

[24]GAO-16-89G.

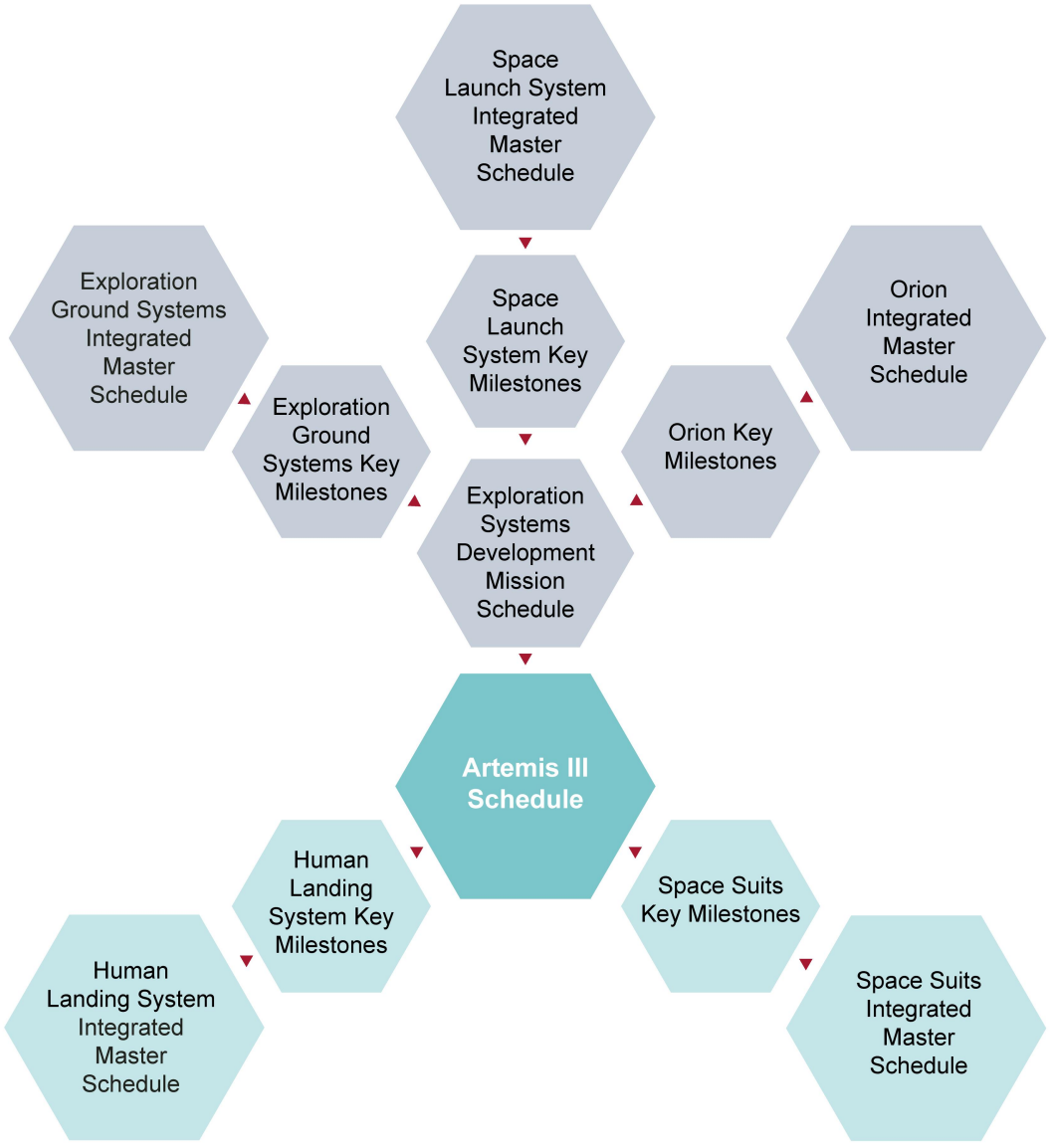
NASA is already underestimating risks to achieving the current Artemis II launch date. Specifically, NASA estimates it will require about 27 months between Artemis I and Artemis II due to Orion integration activities and reuse of avionics from the Artemis I crew capsule on the Artemis II crew capsule. Officials noted that the time between missions depends on the amount of risk assumed. Since Artemis I is scheduled to launch in September 2022, Artemis II cannot logistically happen before December 2024, 7 months beyond the planned May 2024 date. If NASA does not conduct an Artemis II SRA based on a high-quality mission schedule, NASA decision makers may not be able to identify the schedule risks most likely to further delay the launch.

NASA Has Not Yet Completed a Schedule for Artemis III Mission, but Plans to Do So

The AES division—which is responsible for managing the Artemis III and later missions—does not yet have a completed Artemis III mission-level schedule. In lieu of mission-level guidance, the division is creating its own Schedule Management Plan that it expects to finalize by June 2022. Officials said the schedule management plan will incorporate scheduling processes from NASA's Schedule Management Handbook since most of its best practices apply to the Artemis schedule, and will outline the division's process for developing mission-level schedules and SRAs.

AES plans to extract key activities and critical path information from individual program IMSs to develop a mission-level schedule for Artemis III and beyond. This includes gathering schedule information from programs managed by the ESD division as well (see fig. 5). The AES and ESD divisions plan to collaborate on mission-level schedules and SRAs for Artemis III and later missions.

Figure 5: Advanced Exploration Systems Division's Artemis III Schedule Creation Process



Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

In November 2021, AES officials indicated they have not yet developed an Artemis III schedule because they were waiting on schedule information for two programs: (1) HLS, which experienced delays after the resolution of a contract award bid protest and U.S. Federal Court complaint, and (2) Space Suits, which recently changed its acquisition strategy and was evaluating contractor proposals.[25] Officials reported they have since received the HLS schedule and Artemis III schedule development is underway. AES officials said the division plans to complete the schedule by September 2022 and update it monthly. This means NASA would create its Artemis III schedule a little over 2 years from its earliest planned launch date.

After completing the Artemis III schedule, AES officials said the division plans to conduct an SRA and update it twice a year, or as needed. Officials said the SRA results will inform the likelihood and reasonableness of the Artemis III mission date planned for no earlier than 2025 as well as inform management decisions. Although AES and ESD reported working together closely and frequently, there is no division-level data sharing policy across the divisions for the Artemis III mission. AES officials said the division's Schedule Management Plan—currently in draft—will provide guidance on data sharing. Additionally, while NASA typically requires programs, as part of the independent review process, to document internal partnerships, Artemis is not a program.[26] Our prior work found that articulating coordination agreements in formal documents can strengthen the commitment to work collaboratively.[27] Documenting schedule data sharing policies could also help bolster the quality of information for decision makers by assigning roles and responsibilities and establishing compatible policies for division-level data sharing. Conversely, a lack of guidance on how to coordinate data sharing, as groups at NASA become more interdependent, could affect the agency's

[25]On June 1, 2022, NASA announced that it selected two contractors to design, develop, and deliver space suits for Artemis missions and the International Space Station. Space suits, also known as the Exploration Extravehicular Activity program, is part of NASA's Extravehicular Activity and Human Surface Mobility Program.

[26]NASA, Standard Operating Procedure Instruction, SOPI 6.0, SRB Programmatic Assessment Process (May 23, 2017). Specifically, NASA's standard operating procedure requires internal partners—partners between a project and other NASA Centers, research institutions, international partners, or other business arrangements not involving contracts or procurements—to document schedule reporting requirements in specified documents, such as a letter of agreement.

[27]GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms,* GAO-12-1022 (Washington, D.C.: September 2012).

ability to effectively make decisions, communicate quality information, and leverage previous investments.

NASA's Workforce Planning Does Not Assess Long-term Artemis Needs

NASA conducts workforce planning for the programs that comprise the Artemis missions across the next 5 budget years. NASA, however, does not conduct workforce planning past the 5 year budget horizon because, according to officials we spoke with, it faces uncertainty that makes long-term workforce planning challenging. At the same time, NASA is committing billions of dollars in development and production contracts for future Artemis missions that extend into the 2030s. This will require a skilled, agile, and effective workforce to execute. The agency is also undergoing broader changes, such as a large segment of its workforce approaching retirement, which will affect Artemis missions. NASA has identified long-term workforce planning as a goal since 2016 but has not yet completed guidance.

NASA Workforce Planning Processes Broadly Include Artemis Needs in the Near-term

NASA centers capture Artemis mission workforce needs through the annual budget request process and through annual center-developed workforce plans. NASA's Office of the Chief Human Capital Officer (OCHCO) leads the workforce planning activities and analysis and develops guidance with input from agency and mission directorate leadership. During this process, mission directorates determine civil service and contractor workforce demand, including the skills needed for each center for a 5-year budget-planning horizon. This process supports the proposed budget request to Congress.

Artemis missions are comprised of programs located across various NASA centers (see fig. 6). Those centers conduct the workforce planning that includes their respective Artemis programs.

Figure 6: National Aeronautics and Space Administration Centers and the Artemis Programs They Manage

Source: GAO analysis of National Aeronautics and Space Administration documentation. | GAO-22-105323

It is NASA policy to conduct workforce planning activities annually for a 5-year budget horizon to ensure it has a workforce that is sufficiently agile in size and mix and strategically shaped to provide the mix of skills to meet the agency missions.[28] The mission directorates are responsible for defining current and future work requirements for their respective areas and anticipating the duration of those requirements. In turn, NASA center directors are responsible for assigning workforce resources, including personnel with the needed skills, to programs within the center to meet the requirements set by the mission directorates.

[28]NASA, *Strategic Workforce Planning,* NASA Procedural Directive (NPD) 3010.B (Feb. 11, 2022).

In 2019, NASA issued a memo on strategic workforce planning efforts to guide the agency's efforts to manage its workforce strategically to be demand-driven, agile, and strategically shaped. According to the memo, strategically planning its workforce will help NASA keep pace with technological advances and a thriving aerospace industry as well as manage increased reliance on commercial and academic partners.[29] Additionally, the centers recently began producing annual center workforce plans, which are aligned with the budget request process. These plans are intended to identify the current workforce makeup, project future workforce requirements, and identify skills critical to continued mission success. NASA's February 2022 strategic workforce planning policy further directs the centers to develop center workforce plans to describe workforce planning activities over the next 5 fiscal years and include an analysis of any workforce gaps the centers identify.[30] These center workforce plans broadly capture Artemis mission workforce issues because they assess the programs that comprise the Artemis missions.

NASA Does Not Conduct Workforce Planning Beyond 5 Years into the Future, which Limits Insight into Long-Term Artemis Workforce Needs

Officials we spoke to at the headquarters and center levels told us that they do not conduct workforce planning beyond a 5-year budget-planning horizon. They identified several reasons for not doing so, including the following:

- **Undefined mission requirements.** Officials from two centers told us that the centers do not know mission directorate goals relative to Artemis missions past the 5-year budget horizon, which hinders their ability to conduct formal workforce planning. NASA's fiscal year 2022 executive summary of center workforce plans found that a lack of long-term demand data makes long-term workforce planning difficult. One center director indicated that the agency's tendency to focus on the current year of budget execution plus 1 or 2 years restricts the center's ability to make hiring plans that align with mission requirements that stretch across a longer time horizon. According to

[29]NASA, *NASA Strategic Workforce Planning Guidance for Mission Workforce* (Dec. 16, 2019).

[30]NASA, *Strategic Workforce Planning*, NASA Procedural Directive (NPD) 3010.1B (Feb. 11, 2022).

officials, the specifics of the Artemis missions are needed to determine the number and skillset of the required workforce. Center officials from one center said that without insight into the specific goals of a given Artemis mission and how programs plan to acquire systems, it is difficult to determine whether they have the right workforce longer term.

- **Uncertainty in funding availability.** Center officials from each of the centers we met with said that delays to the budget allocation process require them to work in an environment of budget uncertainty, making it difficult to plan specifics past the next fiscal year. Officials from one center said it is not a good use of time to conduct formal workforce planning beyond the 5-year budget time horizon because they cannot match resources to requirements.
- **Uncertainty in congressional and administration priorities**. Officials from each of the centers we met with told us that changes in agency direction as a result of congressional and presidential administration priority changes are an obstacle to long-term planning. The 2021 Aerospace Safety Advisory Panel Annual Report also noted that changing priorities over nearly 20 years have created workforce planning challenges. The report stated that changes in priorities created a ripple of uncertainty and the loss of a strong mission focus in the workforce that persists today. However, the last two presidential administrations have remained steady in their focus on returning to the moon.

At the same time, however, NASA is committing billions of dollars in development and production contracts for future Artemis missions that extend into the 2030s, well past the 5-year budget horizon. For example, in December 2020 we reported that NASA was planning eight Artemis missions between 2021 and 2030, with more to follow.[31] We found that NASA is awarding contracts for major systems across the Orion, SLS, and EGS programs to support up to 14 Artemis missions that are valued at approximately $30 billion. These missions are expected to launch into the 2030s.

NASA identified long-term workforce planning as a priority nearly 7 years ago and recently began developing guidance for mission directorates and centers. However, NASA has not completed or implemented this guidance. In 2016, NASA's Mission Support Council identified a lack of long-term planning over 5-, 10-, and 20-year time horizons as a shortfall in the agency's strategic workforce planning. In the resulting 2016

[31]GAO-21-105.

implementation plan, NASA identified steps to develop guidance to help centers assess their workforce over 5, 10, and 20 years. However, as of June 2022, these guidelines were not complete.

Additionally, in fall 2021, NASA initiated an effort to establish and improve long-term workforce planning and provide guidance to the centers. As a result of this effort, in May 2022, NASA issued a memo on planned improvements to the agency's current workforce planning process as well as efforts to forecast and conduct strategic planning in the near and long-term.[32] The memo directs mission directorates to issue written and verbal guidance to centers for forecasting workforce needs during a near- and mid-term planning horizon of 1 to 5 years and long-term planning, which it considers to be beyond 5 years. The memo directs mission directorates to provide a draft of the guidance to centers by fall 2022 with the intention to update it annually.

NASA has an opportunity to implement the initiatives identified in its May 2022 memo to maintain the momentum gained from recent workforce efforts and improve long-term workforce planning in light of broader agency and Artemis workforce challenges. These challenges include:

- **Changing workforce demographics.** NASA documents on strategic workforce planning identified risk in the current workforce demographics. For example, the fiscal year 2022 annual workforce plan executive summary notes that 24 percent of NASA's workforce was eligible to retire at the beginning of fiscal year 2022. Centers indicated that potential retirements create a risk to their workforce due to concerns over the loss of technical expertise without adequately transferring knowledge to newer employees. For example, one center official we spoke with said that they expect a wave of retirements after the Artemis I mission launches, resulting in a loss of personnel with important technical skills, experience, and institutional knowledge. An Aerospace Safety Advisory Panel (ASAP) report reiterated concerns over maintaining technical expertise as NASA undertakes the Artemis missions, which are more complex than previous human space flight programs.[33] On the other hand, officials from NASA's OCHCO said that newer employees have different skill sets—such as data

[32]NASA, *Improving PPBE/Workforce Forecasting and the Strategic Planning Process for Mission Workforce* (May 26, 2022).

[33]NASA Aerospace Safety Advisory Panel Annual Report, *Annual Report for 2020* (Washington, D.C.: Jan. 1, 2021); and *Annual Report for 2021* (Washington, D.C.: Jan. 1, 2022).

sciences, machine learning, and experience with artificial intelligence—that will be helpful as NASA aligns its workforce with emerging technical trends. These officials said that balancing the continuity needed for effective approaches to executing programs with new ways of thinking is an important aspect of strategic workforce planning as the agency seeks to be more agile and demand-driven.

- **Competition with the private sector.** According to the fiscal year 2022 annual workforce plan executive summary, due to the rapid expansion of the commercial space industry, NASA must compete for many of the employees that traditionally would have sought out NASA for employment. The executive summary states that in some geographic areas and for some skill types, NASA has difficulty offering the salary and benefits that the private sector is providing. Agency officials we spoke with said this is a concern although applicants are still drawn to NASA due to its reputation as being a good place to work and its significance to U.S. achievements. Officials from NASA's OCHCO told us that while they are competing with the private sector for skilled workers, NASA is increasingly partnering with the private sector as well and may see some workers rotate in and out of NASA throughout their careers.

NASA is also changing the way it procures its systems, which requires an experienced, skilled, agile, and effective workforce to oversee and execute these efforts. As we have reported, NASA has expanded its efforts to award contracts with commercial companies, especially for its human spaceflight efforts.[34] NASA sought to leverage commercial companies and encourage the growth of the private spaceflight sector in 2005 when it established the Commercial Crew and Cargo Program. According to the September 2020 Artemis plan, NASA stated that it plans to continue to build on its experience with commercial companies for the Artemis missions, including the HLS, Gateway, and Extravehicular Activity and Human Surface Mobility programs. According to NASA, it is moving in this direction because the agency believes that using a commercial services or products-type approach versus in-house development or traditional acquisition approaches can expand commercial participants as well as increases competition, innovation, flexibility, speed, and affordability. The ASAP 2020 and 2021 reports found that the overall strategy that NASA plans to use for its programs—whether to make, manage, or buy a given system—has major

[34]GAO, *NASA: Lessons from Ongoing Major Projects Could Improve Future Outcomes*, GAO-22-105709 (Washington, D.C.: Feb. 9, 2022).

implications for the kind of expertise and experience the agency's workforce will need.[35] While NASA has historically relied on a workforce with specialized technical expertise and systems engineering skills to build space systems and manage programs, changes to acquisition approaches mean that NASA will need a workforce with the skills to oversee commercial contracts while retaining technical expertise. NASA's fiscal year 2022 annual workforce plan executive summary recommended that the agency seek to better understand how a mix of a contractor and civil servant workforce can meet mission requirements in the near, mid, and long term.

As NASA executes the programs comprising Artemis, the agency has the opportunity to use the acquisition plans and commercial contracting approaches it is pursuing now to inform potential future workforce scenarios, even as NASA faces workforce uncertainties and challenges. In our prior work, we identified some approaches used by other agencies to help assess future workforce needs when faced with uncertainties.[36] One approach involves scenario planning, in which an agency that operates in a changing environment uses a range of scenarios, each of which represents different future environments that the agency may face, to help predict how the scope and volume of its activities might change in each scenario. According to the U.S. Office of Personnel Management's (OPM) Scenario-Based Workforce Planning tool, the purpose of scenario-based planning is to help develop information to plan for unforeseen and foreseeable events.[37] The tool states that an organization can use scenarios to help officials envision possible and plausible future conditions, shift their thinking about the external environment, and consider how future conditions will affect their organization, among other uses. OPM's scenario planning tool lays out several steps to help organizations effectively use scenario planning to assist with their workforce planning. These steps include preparing the scenario planning project; exploring, developing, and applying the scenarios; and finally, evaluating the scenario planning project effort. The OPM scenario planning tool states that organizations can consider what the future, and

[35]NASA Aerospace Safety Advisory Panel Annual Report, *Annual Report for 2020* (Washington, D.C.: Jan. 1, 2021); and *Annual Report for 2021* (Washington, D.C.: Jan. 1, 2022).

[36]GAO-04-39.

[37]Office of Personnel Management, *Scenario-Based Workforce Planning Tool.*

the organization, will look like in 10 years as they examine possible and plausible future scenarios.

Key principles for effective strategic workforce planning that we identified state that it is essential that agencies determine the skills and competencies that are critical to successfully achieving their future missions and goals.[38] Our prior work found that the most important consideration is that the skills and competencies identified are clearly linked to the agency's mission and long-term goals. Agencies can use various approaches for making fact-based determinations of the critical human capital skills and competences needed for the future. Our work found that agencies using scenario planning gained flexibility to determine future workforce requirements.

Officials from NASA's OCHCO told us that they were examining the use of scenario planning to help future workforce planning efforts. Officials said that they were working with NASA's Chief Financial Officer as well as mission directorates to understand which aspects of scenario planning could work at NASA and whether adjustments or additional tools may be necessary for it to be helpful. These officials told us they are assessing potential time frames for implementing scenario planning to effectively align with the budget planning process. Officials said they hope to roll out scenario planning in the near future but did not have a planned date.

NASA's May 2022 memo lays out several considerations for mission directorates to develop written and verbal guidance, which are good steps in addressing the shortfalls in its long-term workforce planning that NASA identified in 2016. For example, the memo includes direction for mission directorates to consider and suggest scenarios they may face during the next 1 to 5 years, among other things. As mission directorates work to issue draft guidance to centers for long-term workforce planning beyond 5 years, NASA has the opportunity to consider and suggest scenarios specific to the Artemis mission workforce, since those missions are planned into the 2030s. Completing and implementing long-term workforce planning guidance will be important as NASA embarks on its goals to return humans to the moon and Mars—goals that will require a workforce to execute this set of complex, multi-program missions worth billions of dollars into the next decade.

[38]GAO-04-39.

Conclusions

NASA is pursuing an ambitious goal of returning humans to the lunar surface, which NASA estimates will occur no earlier than 2025. This will require an increasing number of complex programs to be seamlessly integrated. The agency has made progress to better identify and provide senior leadership visibility into mission-level risks. NASA is also beginning to take initial steps to create Artemis mission-level schedules, but additional steps are needed to ensure that senior NASA leaders have quality, risk-informed information for decision-making. This includes developing mission-level schedule management guidance and ensuring that SRAs are conducted early, updated frequently, and based on high-quality schedules. As the complexity of future missions increases with the addition of more programs, effective collaboration on schedule data across divisions will be also be important to ensure an integrated approach to mission planning. To oversee these efforts into the 2030s as planned, NASA will need a workforce that is sufficiently agile in size and mix and strategically shaped to provide a mix of skills to accomplish its missions. NASA faces some workforce planning challenges and has recently taken promising steps to address shortfalls in the near-term. NASA has a further opportunity to better address longer-term workforce challenges that could affect Artemis mission success through the use of workforce scenario planning.

Recommendations for Executive Action

We are making the following four recommendations to NASA:

The NASA Administrator should ensure that the Chief Financial Officer, in coordination with the mission directorates, develops Artemis mission-level schedule management guidance. (Recommendation 1)

The NASA Administrator, in coordination with the relevant mission directorates, should ensure that NASA conducts a schedule risk analysis for the Artemis II mission as close as possible to completion of the Artemis I mission and update it as needed to incorporate schedule updates and new risks. (Recommendation 2)

The NASA Administrator, in coordination with the relevant mission directorates for Artemis III and later missions, should ensure that NASA develops guidance for division-level schedule collaboration including

setting expectations for data sharing and the type(s) of data required. (Recommendation 3)

The NASA Administrator should ensure that the Office of the Chief Human Capital Officer develops guidance that identifies a regular and recurring process for long-term Artemis workforce scenario planning to address future uncertainties, at least 5 years beyond the existing 5-year workforce plans. (Recommendation 4)

Agency Comments and Our Evaluation

We provided a copy of this report to NASA for review and comment. NASA provided written comments that are reprinted in appendix III. In its response, NASA concurred with all four recommendations and estimated that actions to close these recommendations would occur between October 2022 and September 2023. NASA also provided technical comments that we incorporated as appropriate.

We are sending copies of this report to the NASA Administrator and interested congressional committees. In addition, the report is available at no charge on the GAO website at https://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 key contributions to this report are listed in appendix IV.

W. William Russell
Director, Contracting and National Security Acquisitions

Appendix I: Programs, Projects, and Key Partners Supporting Artemis Missions

Table 2: Programs and Key Partners Supporting Artemis Missions

Program or project	Description	NASA partner information
Orion Multi-Purpose Crew Vehicle (Orion)	Orion is being developed to transport and support astronauts beyond low-Earth orbit and will launch atop the Space Launch System. The current design includes a crew module, service module, launch abort system, and rendezvous proximity and docking capability.	NASA reported that it awarded Lockheed Martin a cost-plus-award-fee development contract to design, build, and test Orion spacecraft to support Artemis I and II and an indefinite-delivery/indefinite-quantity production contract that includes a commitment to order a minimum of six and a maximum of 12 Orion spacecraft. Additionally, the European Space Agency is contributing the European Service Module.
Space Launch System (SLS)	The SLS is intended to be NASA's first human-rated heavy lift launch vehicle designed for deep space operations. The program is intended to enable deep-space Artemis and Mars missions. SLS comprises hardware from the Shuttle and Constellation programs, and new developments.	NASA reported that it awarded contracts to three commercial companies—The Boeing Company, Aerojet-Rocketdyne, and Northrop Grumman—to develop the major elements of the SLS for the first two Artemis missions. NASA reported that Boeing is to provide the launch system's Core Stage and Upper Stage, Aerojet the RS-25 Engines, and Northrop Grumman the Solid Rocket Boosters that help power the SLS.
Exploration Ground Systems (EGS)	The EGS program is modernizing and upgrading infrastructure at the Kennedy Space Center and developing software to integrate, process, and launch SLS and Orion. Additionally, the program will recover the Orion vehicle after its mission. The EGS program comprises the Mobile Launcher, Crawler Transporter, Vehicle Assembly Building, and Launch Pad 39-B.	NASA reported that its prime contractor for EGS, Jacobs, supports the program through the Test and Operations Support Contract at Kennedy Space Center. NASA reported that the contract was initially awarded in 2012 with options to extend it through September 2022. NASA stated that EGS is currently working to extend the contract through January 2023 with a two month option period. According to contractor information, Jacobs is responsible for receiving all SLS and Orion flight hardware, assembling and integrating all the components, conducting final test and checkout, transporting the vehicle to the pad, and helping to launch it.

Program or project	Description	NASA partner information
Gateway	The Gateway program aims to develop and build a sustainable outpost in lunar orbit. The outpost will serve as a research platform for NASA and its commercial and international partners, a staging point for human and robotic exploration in deep space, and a technology test bed for future Mars missions. NASA is planning for the Gateway to maneuver to different orbits around the moon, which will allow access to a variety of locations on the lunar surface.	The program is composed of multiple projects that are responsible for executing portions of the Gateway mission.[a] Individual teams manage the projects, with funding and key milestones controlled at the program level. Gateway program management is responsible for ensuring the overall integration of all the individual projects.
Gateway: Power and Propulsion Element (PPE)	PPE is being designed to provide the Gateway with power, communications, and the ability to change orbits, among other things.	In May 2019, NASA awarded a firm-fixed price contract to Maxar Technologies Inc. to develop and demonstrate power, propulsion, and communications capabilities. Project officials expect contract modifications for a range of requirements changes related to the comanifest and to align project requirements with Gateway program requirements, among other things.
Gateway: Habitation and Logistics Outpost (HALO)	HALO is being designed to provide docking ports for visiting vehicles, space for habitation and storage, and the systems to support crew on board the Gateway.	In June 2020, NASA definitized a firm fixed price and cost-plus-incentive-fee contract for HALO to Northrop Grumman Space to develop HALO's preliminary design. In July 2021, NASA reported definitizing a firm-fixed-price modification valued at over $930 million to the project's contract to add work for the HALO's production and integration with PPE, among other things.
Gateway: Deep Space Logistics	The Deep Space Logistics project manages the Gateway Logistics Services contract, which will be used to buy services to transport cargo, science experiments, and supplies to support Artemis missions.	In March 2020, NASA awarded an initial firm fixed-price, indefinite delivery/indefinite quantity contract to Space Exploration Technologies Corporation (SpaceX), which guarantees the company a minimum of two logistics missions. SpaceX is responsible for building, integrating, and operating the logistics vehicle. Under the contract, NASA may award further task orders to additional logistics service providers, allowing them to compete for future missions.
Space suits	NASA plans to update the design of its space suits, which supply life support, including oxygen and water, among other things, to astronauts for lunar surface operations. The updates include additional protection from extreme temperatures and hazards in the lunar environment, such as dust; increased mobility; and extended service life for lunar surface operations.	In July 2021, NASA approved a new acquisition strategy that includes competition among commercial vendors to, among other things, demonstrate and produce the space suits and associated systems. In June 2022, NASA announced that it selected Axiom Space and Collins Aerospace to design, develop, and deliver space suits for Artemis missions and the International Space Station.

Program or project	Description	NASA partner information
Human Landing System	The Human Landing System is to provide crew transportation from the Gateway or from Orion to the lunar surface and back and demonstrate capabilities required for deep space missions.	In April 2021, NASA announced the selection of SpaceX to develop the Artemis III lunar lander. After the award, Blue Origin and Dynetics filed bid protests with GAO, which GAO denied in July 2021.[b] Subsequently, in August 2021, Blue Origin filed a complaint with the U.S. Court of Federal Claims, which the court dismissed in November 2021. On March 31, 2022, NASA reported that it released a new draft solicitation for companies interested in developing and demonstrating additional astronaut moon landers.
Commercial Lunar Payload Services	Commercial Lunar Payload Services companies are to provide NASA with end-to-end commercial payload delivery services to the surface of the moon. The services include integrating payloads onto a robotic lander, launching the lander, and operating the lander and payloads. The payloads include science instruments and technology demonstrations that will characterize the lunar environment and inform the development of future landers and other exploration systems needed for human lunar surface exploration.	NASA reported awarding firm fixed-price, multiple-award, indefinite delivery/indefinite quantity contracts to a total of 14 companies to deliver science and technology payloads to the lunar surface.
Volatiles Investigating Polar Exploration Rover (VIPER)	VIPER is being designed to investigate volatiles—including water, carbon dioxide, and other chemicals that boil at low temperatures—at the lunar South Pole. NASA could potentially use these volatiles to support sustained human presence on the lunar surface.	NASA is developing VIPER in house. In June 2020, NASA issued a task order to Astrobotic, a Commercial Lunar Payload Services company, to deliver the rover to the lunar surface in late 2023 or early 2024.

Source: GAO review of National Aeronautics and Space Administration documentation and contracts. | GAO-22-105323

[a]NASA calls the individual projects within the Gateway program elements. For the purpose of this report, we refer to them as projects.

[b]A bid protest is a challenge to the terms of a solicitation or the award of a federal contract. GAO's Procurement Law Division adjudicates bid protests filed at GAO and provides an objective, independent, and impartial forum for the resolution of disputes concerning the awards of federal contracts.

Appendix II: Results of GAO's Assessment of Artemis II Schedule against Key Scheduling Best Practices

We assessed NASA's Artemis II schedule against tailored criteria from the GAO Schedule Assessment Guide.[1] Due to the Artemis II schedule creation process, we did not conduct a standard GAO schedule reliability assessment that evaluates qualitative and quantitative information. However, select quantitative criteria from the Schedule Guide are suitable for the purpose. Those criteria and measures can be found under Best Practice 2 (Sequencing all activities), Best Practice 4 (Establishing the duration for all activities); Best Practice 5 (Verifying the schedule is traceable vertically and horizontally); and Best Practice 6 (Confirming that the critical path is valid).

[1]GAO, *GAO Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

Table 3: Results of GAO's Assessment of Artemis II Schedule against Key Scheduling Best Practices

GAO best practice	Results
Sequencing All Activities:  Schedule activities must be logically sequenced and linked. Doing so ensures activities can collectively lead to completing milestones, guiding work, and measuring progress.	**Substantially met.** Our analysis found the Artemis II schedule to be a generally well-sequenced network with few logic anomalies. The Artemis II schedule also contains 10 leads of varying duration, but up to 32 months long. As negative lags, leads imply the unusual measurement of negative time and require exact foresight about future events. In response to our findings, NASA officials addressed some issues we identified but stated that other logic anomalies were necessary artifacts of the summary level nature of the Artemis II schedule. *Key Questions Assessed:* *1. Are the majority of the relationships within the detailed schedules finish-to-start?* *2. Are predecessor links (with the exception of the start milestone) or successor links (with the exception of the finish milestone) missing?* *3. Are any predecessors or successors dangling?* *3a. Does each activity (except the start milestone) have an F-S or S-S predecessor that drives its start date?* *3b. Does each activity (except the finish milestone and deliverables that leave the project without subsequent effect on the project) have an F-S or F-F successor that it drives?* *4. Do summary activities have predecessor or successor links?* *5. Do activities have start-to-finish links?* *6. How much convergence (that is, several parallel activities converging at one major event) is there in the schedule? For activities that have many converging predecessors, do those predecessors have adequate float?* *7. Does the schedule contain date constraints other than "as soon as possible"? Is each one justified in the schedule documentation?* *8. Are lags or leads specified between the activities? Can these be more accurately characterized by improving logic or adding activity detail?*
Durations for All Activities:  Schedules should realistically reflect how long each activity should take. Durations should be reasonably short to better measure progress. If activities are too long, the schedule may not have enough detail for effective progress measurement and reporting.	**Substantially met.** As a summary-level schedule, the Artemis II schedule is expected to be comprised of long-duration summary activities. However, the Artemis II schedule does include a significant number of long-duration activities, with some durations greater than 1,000 days, though none of these very long activities appear as critical. The average duration of activities on the critical path is 32 days and the median is 16, offering more insight into detailed effort for those activities that will cause a day-for-day slip in the mission. *Key Questions Assessed:* *1. For a detailed schedule, are durations short enough to be consistent with the needs of effective planning and program execution?* *2. Are activities long in duration because of level-of-effort activity or rolling wave planning?*

GAO best practice	Results
Traceability in Schedule: Traceability in Schedule  Source: GAO. | GAO-22-105323 A schedule should be vertically traceable—that is, data are consistent between different levels of a schedule. A schedule should also be horizontally traceable, which demonstrates the overall schedule is rational and planned in a logical sequence.	**Partially met.** Our analysis found that the Artemis II schedule is horizontally traceable. However, we found a lack of mapping information between the Artemis II schedule and the Orion integrated master schedule (IMS) which makes it difficult for anyone unfamiliar with the details of the Orion IMS to vertically trace activities between the two files. The Artemis II schedule we initially received for the assessment did not include any information that would allow tracing activities and milestones to the Orion IMS. NASA subsequently provided two updated Artemis II schedule files with additional tracing information. We used the additional information to trace to the Orion IMS, but dates did not align perfectly in the five examples we traced, with some weeks apart. *Key Questions Assessed:* *1. Are the key dates consistent between lower-level detailed working schedules and higher-level summary schedules? Do all lower-level activities roll up into higher work breakdown structure levels?* *2. Has horizontal traceability been demonstrated by observing the effects of delaying an activity by many days within the schedule or a similar shock to the network?*
The Critical Path Is Valid: The Critical Path is Valid  Source: GAO. | GAO-22-105323 The critical path is the longest continuous sequence of activities in a schedule and defines the earliest completion date. A valid critical path is necessary for examining the effects of any activities slipping along this path.	**Substantially met.** We found the critical path to be straightforward, continuous, and with no major logic anomalies once we removed a date constraint from a key milestone. *Key Questions Assessed:* *1. Is the critical path, or longest path (in the presence of date constraints), calculated by the scheduling software valid?* *1a. Are any activities in the schedule missing logic or constrained without justification? Are these issues resulting in an unreliable critical path?* *1b. Is the critical path a continuous path from the status date to the major completion milestones?* *1c. Does the critical path start with a constraint so that other activities are unimportant in driving the milestone date? If so, is there justification for that constraint?* *1d. Does the critical path include level-of-effort activities? Is the critical path driven by activities of unusually long duration that are not considered planning packages?* *1e. Is the critical path driven in any way by lags or leads?*

Source: GAO. I GAO-22-105323

Appendix III: National Aeronautics and Space Administration Comments

National Aeronautics and Space Administration

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

August 16, 2022

Reply to Attn of: Exploration Systems Development Mission Directorate

Mr. W. William Russell
Director
Contracting and National Security Acquisitions
United States Government Accountability Office
Washington, DC 20548

Dear Mr. Russell:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Government Accountability Office (GAO) draft report entitled, "NASA Lunar Programs: Improved Mission Guidance Needed as Artemis Complexity Grows" (GAO-22-105323), dated July 1, 2022.

GAO found that NASA does not yet have guidance for creating or managing Artemis mission schedules that will help integrate the individual programs required for launch. Without guidance specifically for multi-program missions, NASA lacks reasonable assurance it has consistent schedule management practices in place for the Artemis schedules. Schedule management guidance would also assist coordination, which will be increasingly necessary as the Artemis missions will involve more programs over time and therefore become more complex.

In the draft memorandum, GAO makes four recommendations addressed to the NASA Administrator.

Specifically, GAO recommends the following:

Recommendation 1: The NASA Administrator should ensure that the Chief Financial Officer, in coordination with the mission directorates, develop Artemis mission-level schedule management guidance.

Management's Response: NASA concurs with this recommendation. Exploration Systems Development Mission Directorate's (ESDMD) Artemis Campaign Development (ACD) Division is currently developing its Schedule Management Plan (SMP) that will contain Artemis mission-level schedule management guidance. The purpose of this SMP is to provide a description of the data, processes, and procedures

necessary to manage the Artemis Mission Schedules (AMSs) throughout the Artemis missions' design, development, and execution phases in accordance with schedule best practices. ACD anticipates baselining the SMP at a Joint ACD/Common Exploration Systems Development (CESD) Control Board in September 2022, with pre-coordination with Office of the Chief Financial Officer (OCFO), followed by the document's release in October 2022. Following publication of SMP, OCFO will lead coordination, with appropriate input from ACD, to incorporate lessons learned for an interim update of the Agency Schedule Management Handbook in August 2023, with the goal of improving guidance for "multi-program missions" schedule management.

Estimated Completion Date: August 2023

Recommendation 2: The NASA Administrator, in coordination with the relevant Mission Directorates, should ensure NASA conducts a schedule risk analysis for the Artemis II mission as close as possible to completion of the Artemis I mission and update it as needed to incorporate schedule updates and new risks.

Management's Response: NASA concurs with this recommendation. ESDMD/(CESD) recognizes the importance of performing an Artemis II SRA and has established plans to complete this SRA within 6 months after the Artemis I launch. The Artemis II SRA completion is driven by the time needed to allow for a data-driven development of risk and uncertainty. Following the Artemis I launch, CESD and CESD programs will conduct a detailed analysis of first-time integrated operations activities. This assessment will help inform Artemis II integrated operations estimates by analyzing differences in operational flows between missions, assumptions used to apply Artemis I performance to Artemis I activities, and any potential opportunities to streamline the second flow. In parallel, the Space Launch System and Orion programs will also continue to assess their risk and uncertainty for Artemis II manufacturing and integration activities based on Artemis I past performance as well as current opportunities and challenges. CESD will then integrate all inputs to perform an enterprise-level Artemis II SRA.

Estimated Completion Date: March 2023

Recommendation 3: The NASA Administrator, in coordination with the relevant Mission Directorates for Artemis III and later missions, should ensure NASA develops guidance for division-level schedule collaboration including setting expectations for data sharing and the type(s) of data required.

Management's Response: NASA concurs with this recommendation. Guidance for division-level collaboration is included in the ACD Division's Schedule Management Plan (SMP). The SMP provides information on the methodologies, techniques, and tools that will be used to produce schedule management products. The ACD SMP documents how the ACD Division will work with programs and supporting organizations to achieve this functionality and what will be expected from each of the programs. ACD anticipates baselining the SMP at a Joint ACD/CESD Control Board in September 2022, followed by the document's release in October 2022.

Estimated Completion Date: October 2022

Recommendation 4: The NASA Administrator should ensure that the Office of the Chief Human Capital Officer develops guidance that identifies a regular and recurring process for long-term Artemis workforce scenario planning to address future uncertainties, at least 5 years beyond the existing 5-year workplace plans.

Management's Response: NASA concurs with this recommendation. NASA's workforce, spread throughout more than a dozen Centers and facilities, represents the space community's most experienced and skilled personnel and is well-positioned to meet the opportunities and challenges to continue global leadership in space science, human exploration, aerospace innovation, and technology development.

To safeguard this position, NASA has developed guidance that provides clarity on future work content and enhances the strategic planning process for Mission workforce to ensure success in all Mission areas, including the Artemis Campaign. NASA's guidance integrates Mission work requirements with Center workforce planning efforts to drive the Agency continuously forward with a demand-driven approach to meet future program content.

As part of the planning process, Mission Directorates will issue written and verbal guidance to Centers for work content and workforce demand, addressing both tactical priorities and strategic direction. The guidance will establish the vector for work in the planning and budgeting horizon and beyond (for year 5 and subsequent years) to prepare for the work demand in the long term. Guidance will be consistent with established Center roles and aligned with Mission Directorate acquisition strategies, major program/project initiation, and the completion of key milestones.

NASA Centers will respond to Mission Directorate guidance in their annual workforce plans. Center responses will provide the Agency with a better understanding of the in-house work, staffing decisions for each Center's technical workforce, and needed capabilities to fulfill future work directions. These responses will also form the basis for periodic "review/check-in" discussions between the Mission Directorates and the Centers on work content and workforce for each Center.

This enhanced guidance and planning process will foster and boost NASA's workforce agility and shape the future by defining clear and challenging workforce roles needed to enable long-term goals in science, exploration, aerospace, technology, and innovation.

Estimated Completion Date: September 2023

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

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

James Free

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James Free

Accessible Text for Appendix III: National Aeronautics and Space Administration Comments

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James Free

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

William Russell at (202) 512-4841 or RussellW@gao.gov

Staff Acknowledgments

In addition to the contact named above, Kristin Van Wychen (Assistant Director), Erin Cohen (Analyst in Charge), Erin Kennedy (Analyst in Charge), Natalie Logan, and Carrie Rogers made key contributions to this report. The following individuals also made significant contributions: Jason Lee (Assistant Director), Lori Fields, Laura Greifner, Sylvia Schatz, and Alyssa Weir.

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