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NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission

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RESULTS IN BRIEF

NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission

April 6, 2022 IG-22-010 (A-21-009-00)

WHY WE PERFORMED THIS AUDIT

NASA seeks to achieve a long-term sustainable presence on the Moon as part of its Artemis program. As a precursor to returning humans to the Moon, the Agency is developing new science instruments, systems, and capabilities in collaboration with commercial and international partners. One such project is a mobile robot or rover known as the Volatiles Investigating Polar Exploration Rover (VIPER) which will survey the Moon's South Pole and its concentration of water ice. Water on the Moon (in the form of water ice) may provide humans not just liquid to drink, but also when broken into its component elements oxygen to breathe and hydrogen and oxygen to fuel future landers and rockets. The VIPER mission, which includes the rover, four science instruments, launch and delivery of the rover to the Moon by a commercial vendor, and lunar surface operations, will help determine whether it is practical to use the Moon's water ice to "live off the land," thereby reducing the need for multiple missions to ferry oxygen, food, fuel, and other supplies needed to sustain long-term human exploration on the Moon and potentially missions to Mars.

In June 2020, NASA awarded a task order to Astrobotic Technology, Inc. (Astrobotic), 1 of 14 providers on contract under the Agency's Commercial Lunar Payload Services (CLPS), for VIPER launch and lunar delivery services. CLPS is a new initiative to encourage the U.S. commercial space industry to develop lander technologies to deliver payloads to the surface of the Moon. Under the program, NASA contracts with CLPS providers to provide end-to-end delivery of NASA instruments and spacecraft to the lunar surface, including the purchase of launch vehicle services.

In this audit, we assessed NASA's management of the VIPER project, including development of the rover, science instruments, and lunar surface operations, relative to achieving technical objectives, meeting established milestones, and controlling costs. To complete this work, we interviewed NASA and Astrobotic personnel and reviewed risks provided by the VIPER project's risk management system; internal and external documents related to the VIPER project; and federal and NASA criteria, policies, and procedures. We also evaluated whether the VIPER project was on track to meet its scheduled launch date, life-cycle cost estimate, and science requirements, and whether identified risks were properly considered, tracked, and mitigated in developing the baseline cost and schedule.

WHAT WE FOUND

The VIPER mission continues to progress toward its planned November 2023 launch, passing multiple life-cycle reviews while spending less money than expected and maintaining planned schedule reserves. All four science instruments were also on schedule for delivery to Johnson Space Center by May 2022 for integration and testing with the rover, while Astrobotic officials said development of its Griffin Lander—which will ferry VIPER from a commercial launch vehicle to the Moon and deploy a ramp for the rover to roll onto the lunar surface—remains on track to meet the current launch timetable.

NASA modified its usual acquisition and management approaches for the CLPS initiative so Astrobotic would assume the risk of completing its portion of the overall mission, own and control lander designs, and choose the launch provider. While this creates opportunities to reduce cost by collaborating with commercial entities, the Agency and Astrobotic each assume significant risks with the VIPER mission, which carries higher costs, criticality, and schedule risks compared to other current CLPS task orders. Further, NASA made several modifications to Astrobotic's task order that has increased its value by $36.1 million from the original $199.5 million cost established at the initial award in June 2020, with more modifications possible as VIPER and Griffin complete designs and finalize requirements.

Moreover, as of January 2022, NASA's lessons learned database did not contain any records related to the CLPS initiative or the VIPER mission. Timely submission and NASA-wide sharing of lessons learned by VIPER personnel using this new acquisition model would help follow-on projects make more effective, experience-driven decisions regarding collaboration with CLPS contractors.

Additionally, NASA is required to provide Congress a Major Program Annual Report (MPAR) for programs and projects with estimated life-cycle costs exceeding $250 million that includes a detailed breakout of development cost and program or project reserves and an estimate of annual costs until development is completed. However, in March 2021 NASA established a VIPER project life-cycle cost estimate of $433.5 million that included development of the rover, science instruments, lunar operations, and applicable cost reserves but not costs for Astrobotic's launch and delivery services, which at that time were valued at $226.5 million but has since risen by $9.1 million. A complete life-cycle cost and accurate MPAR for the VIPER mission should include the cost of Astrobotic launch and delivery services, thereby improving transparency into the full cost of the mission.

Finally, NASA leadership has promoted the benefits of Agency project oversight tools, specifically the Joint Cost and Schedule Confidence Level (JCL) analysis that generates a statistical representation of the likelihood a project will achieve its objectives within budget and on time and Earned Value Management (EVM) that assesses project performance through the integration of technical scope with schedule and cost objectives. NASA is managing the VIPER mission in accordance with NASA Procedural Requirements (NPR) 7120.8 for research and technology programs and projects, which does not require a JCL or EVM. In an effort to streamline processes and because NPR 7210.8 does not require it, the Science Mission Directorate (SMD) choose not to employ either oversight tool for VIPER. We believe that this was a missed opportunity to help establish the project's cost estimate with a comprehensive JCL and monitor project cost and schedule performance using EVM. Failing to use these tools means NASA does not have full visibility into the risks and their potential costs to the VIPER mission.

WHAT WE RECOMMENDED

To enable more experience-based decision-making when collaborating with CLPS providers, we recommended the Associate Administrator for SMD direct Planetary Science Division and VIPER project management to coordinate with the Chief Knowledge Officer to submit and at appropriate intervals publish lessons learned associated with using a CLPS provider, particularly on major acquisitions. To enable greater stakeholder transparency, we also recommended the Associate Administrator for SMD in coordination with the Chief Financial Officer develop a VIPER mission cost estimate that includes all critical mission components and risks associated with the Astrobotic task order and update the MPAR accordingly. In addition, to ensure consistency with major project development best practices, we recommended the Chief Engineer in coordination with the Chief Financial Officer and Mission Directorate Associate Administrators update NPR 7120.8 to require major acquisition projects that cost over $250 million to complete a JCL analysis and implement EVM.

We provided a draft of this report to NASA management who concurred with our recommendation to publish lessons learned and partially concurred with our recommendation to develop a comprehensive VIPER mission cost estimate and and update the MPAR. The respective planned actions address our concerns; therefore, these recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions. Management did not concur with our recommendations to update NPR 7120.8 and these two recommendations are unresolved pending further discussion with the Agency.

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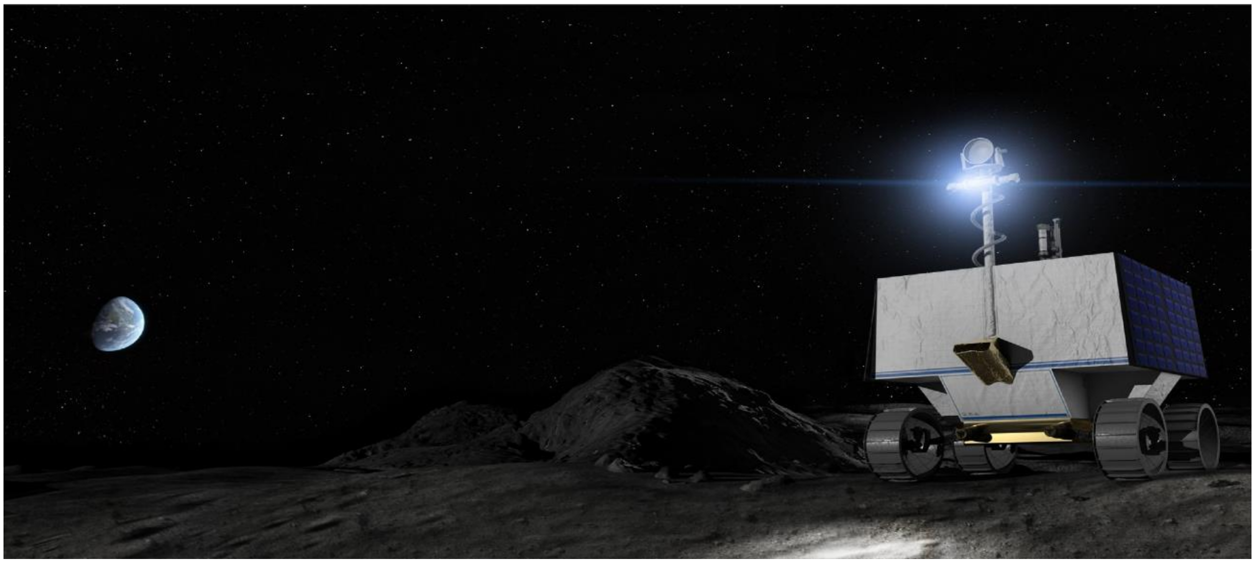
Acronyms

ABC	Agency Baseline Commitment
CLPS	Commercial Lunar Payload Services
COVID-19	Coronavirus Disease 2019
ESSIO	Exploration Science Strategy and Integration Office
EVM	Earned Value Management
GAO	Government Accountability Office
JCL	Joint Cost and Schedule Confidence Level
KDP	Key Decision Point
MPAR	Major Program Annual Report
NPR	NASA Procedural Requirements
OCFO	Office of the Chief Financial Officer
OIG	Office of Inspector General
PSD	Planetary Science Division
SLS	Space Launch System
SMD	Science Mission Directorate
STEEP	Schedule Task Execution Evaluation Process
TRL	Technology Readiness Level
VIPER	Volatiles Investigating Polar Exploration Rover
VRT	VIPER Review Team
WBS	Work Breakdown Structure

INTRODUCTION

NASA's Artemis program, which plans to return astronauts to the Moon more than 50 years after the last lunar landing, signals a new era of human and robotic space exploration.[1] In collaboration with commercial and international partners, the Agency seeks to achieve a long-term sustainable presence on the Moon—another step to enable humans to travel to Mars and beyond. As a precursor to a lunar landing, NASA is developing a number of new science instruments, systems, and capabilities including the Volatiles Investigating Polar Exploration Rover (VIPER).

Figure 1: Illustration of VIPER



Source: NASA.

VIPER is a mobile robot (or rover) expected to land at the South Pole of the Moon to survey the location and its concentration of water ice that could eventually be harvested to sustain human exploration on the Moon and potentially support missions to other planets. Water on the Moon (in the form of water ice) may possibly provide humans not just liquid to drink, but also when broken into its component elements oxygen to breathe and hydrogen and oxygen to fuel future landers and rockets. The VIPER mission, which includes the rover, four science instruments, launch and delivery of the rover to the Moon by a commercial vendor, and lunar surface operations, seeks to answer the question of whether it is practical to use the Moon's water ice to "live off the land," thereby reducing the need for multiple missions to ferry oxygen, food, fuel, and other supplies needed to sustain long-term human exploration.

[1] NASA's Artemis program relies on private industry, academia, and international partnerships to land humans on the Moon in the mid- to late 2020s and establish a sustainable human presence. The Agency's lunar strategy includes development of the Space Launch System (SLS) heavy-lift rocket, the Orion Multi-Purpose Crew Vehicle (Orion) capsule, a Human Landing System to transport astronauts from lunar orbit to the Moon's surface, the Gateway outpost orbiting the Moon, next-generation spacesuits, and multiple science investigations and technology demonstration projects delivered to the lunar surface using commercial landers.

In March 2021, NASA established a life-cycle cost estimate of $433.5 million for the VIPER project with a planned launch in November 2023. These costs do not include activities under the Commercial Lunar Payload Services (CLPS) initiative for launch and lunar delivery services provided by Astrobotic Technology, Inc. (Astrobotic), which was valued at $235.6 million as of December 2021—$36.1 million more than its initial June 2020 price.[2] Our overall objective in this audit was to assess NASA's management of the VIPER project relative to achieving technical objectives, meeting established milestones, and controlling costs. See Appendix A for details of the audit's scope and methodology.

Background

In December 2017, the Trump Administration announced Space Policy Directive 1, which directed NASA to lead an integrated program with private sector and international partners to return astronauts to the Moon, with later missions to Mars and beyond.[3] Prior to the Directive, NASA was working toward a crewed lunar landing in 2028; however, in March 2019, the Administration directed the Agency to land humans on the Moon's South Pole by 2024. In response, the NASA Administrator rebranded the Agency's return-to-the-Moon mission as Artemis and announced that NASA would use innovative acquisition practices to help accelerate the timetable. NASA's plan was twofold, with the Agency focused first on returning humans to the lunar surface during the Artemis III mission in late 2024 (a date NASA has since pushed back to no earlier than 2025), while simultaneously working toward establishing sustainable lunar exploration in the mid- to late 2020s.[4] Prior to astronauts' arrival on the Moon, NASA intends to explore the proposed lunar landing area with robotic systems.

NASA initiated the Lunar Discovery and Exploration Program within the Science Mission Directorate (SMD) in 2018 to support innovative approaches to achieve human and science exploration goals by funding contracts for commercial transportation services and the development of small rovers and instruments. Under the Lunar Discovery and Exploration Program, NASA selected 14 providers—9 U.S. companies in November 2018 and 5 more in November 2019—to facilitate the rapid acquisition of science and technology systems delivery services to the Moon through a new initiative known as CLPS.[5] The CLPS initiative is intended to encourage the U.S. commercial space industry to develop new lander technologies to deliver NASA and commercial payloads to the surface of the Moon. Rather than NASA controlling or overseeing the contractor's designs, systems, processes, or infrastructure, the

[2] The CLPS initiative allows rapid acquisition of lunar delivery services from American companies for payloads that advance capabilities for science, exploration, or commercial development of the Moon. Astrobotic is headquartered in Pittsburgh, Pennsylvania.

[3] Space Policy Directive 1, *Presidential Memorandum on Reinvigorating America's Human Space Exploration Program* (December 11, 2017). This policy directed the NASA Administrator to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities."

[4] As of February 2022, NASA plans to launch Artemis I no earlier than May 2022, an uncrewed test flight of the integrated SLS/Orion system that will include a series of orbits around the Moon and return of the capsule to Earth. Artemis II, planned for no later than May 2024, will be the first crewed test flight of the integrated SLS/Orion system and will also orbit the Moon. Artemis III, the scheduled lunar landing mission, is planned for no earlier than 2025.

[5] The CLPS initiative provides companies individual task orders for end-to-end payload delivery services, including payload integration, mission operations, launch, and landing on the surface of the Moon. NASA has established a maximum contract value of $2.6 billion for the CLPS initiative through 2028. As of February 2022, NASA had 14 companies on the indefinite-delivery, indefinite-quantity contract able to bid for individual task orders. In a September 2020 report, we reported that NASA needed to address several significant risks with the CLPS initiative, including inadequate oversight of contractors and lack of common interfaces between instruments and landers. See *NASA's Planetary Science Portfolio* (IG-20-023, September 16, 2020).

Agency would simply buy a service from the company using a firm-fixed-price contract.[6] In June 2020, the Agency announced that it had selected Astrobotic, one of the preapproved CLPS providers, to deliver VIPER to the Moon's South Pole by November 2023.

VIPER Mission

In October 2019, NASA announced SMD would sponsor the VIPER mission as a follow-on to past lunar missions such as Lunar Prospector (1998), Lunar Crater Observing and Sensing Satellite (2009), and Lunar Atmosphere and Dust Environment Explorer (2013).[7] The VIPER mission will also leverage investments made in the Resource Prospector, a research and technology effort previously managed by the Human Exploration and Operations Mission Directorate until it was canceled in 2018.[8] A goal of the VIPER mission is to search for volatiles—chemical elements and compounds such as water and carbon dioxide—on the Moon's permanently shadowed polar regions.[9]

Two primary science objectives of the VIPER mission are to:

- Characterize the distribution and physical state of lunar polar water and other volatiles in lunar cold traps (permanently shadowed craters) and regolith (loose, fragmented material on the Moon's surface) to understand their origin.
- Provide the data necessary for NASA to evaluate the potential return of in-situ resource utilization (the extraction and processing of space resources into useful products) from these lunar polar regions.

[6] A firm-fixed-price contract provides for a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. Under this contract type the contractor carries the maximum risk and full responsibility for all costs and resulting profit or loss. It provides maximum incentive for the contractor to control costs and perform effectively and imposes a minimum administrative burden upon the contracting parties. Changes required or initiated by the agency can change the price of the contract.

[7] Lunar Prospector, launched in January 1998, performed a polar orbit investigation of the Moon to improve understanding of its origin, evolution, and state. Lunar Crater Observing and Sensing Satellite launched in June 2009 with the Lunar Reconnaissance Orbiter and identified potential areas where water ice exists in permanently shadowed craters at the Moon's South Pole. Lunar Atmosphere and Dust Environment Explorer, launched in September 2013, was a robotic mission that orbited the Moon to gather detailed information about the structure and composition of the thin lunar atmosphere and determine whether dust is lofted into the lunar sky.

[8] On September 21, 2021, the NASA Administrator announced that the Agency would split the Human Exploration and Operations Mission Directorate into two separate directorates. The Exploration Systems Development Mission Directorate is responsible for integrating the early Artemis missions, defining and managing systems development for programs critical to NASA's Artemis program, and planning for NASA's Moon to Mars exploration approach in an integrated manner. The other space flight mission directorate—Space Operations Mission Directorate—will focus on launch and space operations, including the International Space Station, commercialization of low Earth orbit, and eventually operations around the Moon. The implementation process for this organizational change will take months. For purposes of this report, we refer to the organization using its pre-reorganization terminology.

[9] Craters near the Moon's poles are referred to as cold traps because they do not receive any sunlight. Volatiles—chemicals like water, carbon dioxide, and methane that boil at low temperatures—generally break down and escape into space when exposed to sunlight but if frozen may end up in the cold traps of the Moon's permanently shadowed regions. Volatiles in the traps or on the lunar surface could potentially be harvested for drinking water and methane for fuel. Determining the nature of these volatiles is a Decadal Survey high priority science goal. National Academies of Sciences, Engineering, and Medicine, *Visions into Voyages for Planetary Science in the Decade 2013-2022: A Midterm Review* (2018).

The VIPER mission seeks to achieve these goals by answering the following science questions:

- Where is the water and how much is there?
- In what form is the water?
- What other resources are present?
- Where did the Moon's water come from?
- What are the prospects for using resources found on the Moon and how can we access them?

The scientific data collected from the VIPER mission will be used to inform the first global water resources map of the Moon and potentially assist in choosing Artemis III lunar landing sites. Although data from the VIPER mission is not a requirement for the Artemis III mission to launch, these early robotic investigations are designed to increase NASA's knowledge of the lunar environment and confirm the nature of the Moon's resource potential, informing planning for future human and robotic expeditions including missions beyond Artemis III.[10]

For ease of distinguishing different aspects of VIPER, in this report the "VIPER mission" refers collectively to the work accomplished through NASA's development of the VIPER project—which includes the rover, science instruments, and lunar surface operations—and the launch and delivery services the Agency contracted with Astrobotic to supply. The VIPER project will design, build, integrate, and execute a lunar volatiles detection, measurement, and mapping mission hosted on a lunar rover that will carry the science instruments used to collect scientific data. Astrobotic is responsible for integrating the rover onto its lunar lander known as the Griffin Lander, procuring launch services, and then delivering the rover to the surface of the Moon.[11] Once on the Moon, NASA will take over operation of the solar-powered rover, which will run for up to 100 days. See Figure 2 for a timeline of the VIPER mission.[12]

[10] In November 2021, the NASA Administrator stated that the Agency was planning for at least 10 Moon landings.

[11] In April 2021, Astrobotic announced the selection of the Space Exploration Technology Corp. (SpaceX) Falcon Heavy rocket as the launch vehicle.

[12] NASA divides the life cycle of its projects into two major phases—Formulation and Implementation—that are further divided into Phases A through F. Formulation consists of Phases A and B, and Implementation is Phases C through F. This structure allows managers to assess the progress of their projects at Key Decision Points (KDP) throughout the process. Periodic reviews, such as the Preliminary Design Review and Critical Design Review, assess the maturity of the design and determine whether the project is ready to proceed to the next phase.

Figure 2: VIPER Projected Mission Timeline as of December 2021

Formulation		Implementation			
Sept. 2019 - March 2021		March 2021 - July 2023		July 2023 - Nov. 2023	Nov. 2023 - March 2024
Phase A *Concept and Technology Development*	Phase B *Preliminary Design and Technology*	Phase C *Final Design and Fabrication*	Phase D *Rover System Assembly, Integration, and Test*	Phase D *Rover Integrated with Lander; Landing on the Moon*	Phase E *Operations and Sustainment*
NASA • VIPER Requirements Checkpoint *(September 2019)*	**NASA** • Preliminary Design Review *(August 2020)*	**NASA** • Key Decision Point-C *(March 2021)* • Critical Design Review *(October 2021)* • System Integration Review *(June 2022)*	**NASA** • Rover Delivery to Astrobotic *(July 2023)*	**Astrobotic** • Launch *(November 2023)*	**NASA**

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

VIPER Project

Science Instruments. The VIPER project includes the rover, its science instruments, and exploration and science operations on the Moon. The rover will carry four instruments as shown in Table 1. Two are being developed by staff at Ames Research Center (Ames); one at Kennedy Space Center (Kennedy); and one by Honeybee Robotics, a contractor in Altadena, California.

Table 1: VIPER Science Instruments

Instrument	Photo of Instrument	NASA Center/ Contractor	Description
Neutron Spectrometer System		Ames	A two-channel neutron spectrometer prospects for hydrogen-rich materials (e.g., water) while roving and mapping distributions of materials to assist in excavation site selection.
Near-Infrared Volatile Spectrometer System		Ames	A spectrometer uses different wavelengths of light to prospect for surface water “frosts” and evaluates excavated material to determine surficial material composition.

Instrument	Photo of Instrument	NASA Center/ Contractor	Description
Mass Spectrometer Observing Lunar Operations		Kennedy	A quadruple mass spectrometer makes direct measurements of excavated volatiles as well as when those volatiles transition from a solid to gas state over time.
Regolith and Ice Drill for Exploring New Terrain		Honeybee Robotics	A hammer drill excavates lunar regolith to a depth of 1 meter and measures force, displacements, and temperatures for regolith properties.

Source: NASA.

Management Organization and Governance. NASA's SMD assigned programmatic management of the VIPER project to the Planetary Science Division (PSD). The VIPER Review Team (VRT) is tasked with conducting ongoing independent assessments of the VIPER project.[13] The VRT was chartered by the SMD Associate Administrator, who also has decision authority for the project. The VRT Chair works closely with the VIPER Project Manager to not only gain insight for assessment purposes, but to share knowledge, make recommendations, and generally add value to the VIPER team to help assure mission success. The VIPER Project Manager and project office reside at Ames.

NASA manages the VIPER project in accordance with NASA Procedural Requirements (NPR) 7120.8—the Agency's management requirements for research and technology programs and projects—with additional requirements directed by SMD.[14] One of the guiding principles of NPR 7120.8 is requiring a minimum set of essential requirements while providing maximum flexibility for research and technology development projects. This NPR follows a different philosophy than NPR 7120.5—NASA's management requirements for space flight programs and projects—which compiles a comprehensive set of requirements for space flight projects that may need to be "tailored down" for smaller development efforts or projects that do not involve astronauts.[15] Rather than tailoring NPR 7120.5 requirements, research and technology projects often need to add additional requirements, particularly on larger

[13] The VRT is a small team of nine subject matter experts (NASA employees; retired NASA employees; and employees from The Aerospace Corporation, Booz Allen Hamilton, and the Johns Hopkins University Applied Physics Laboratory) who assess the technical and programmatic health of the VIPER project. Rather than waiting for formal key reviews, the VRT has conducted quarterly reviews and engaged the project team in frequent, less formal settings. For example, prior to the formal Preliminary Design Review, the VRT and other project-chartered independent experts provided over 500 comments through a series of reviews, including 11 preliminary design assessments from April through August 2020. Prior to the formal Critical Design Review, the VRT conducted critical design assessments.

[14] NPR 7120.8A, *NASA Research and Technology Program and Project Management Requirements (Updated w/Change 2)* (September 14, 2018).

[15] NPR 7120.5F, *NASA Space Flight Program and Project Management Requirements* (August 3, 2021). Tailoring is the process of adjusting requirements to meet the needs of a specific project to achieve mission success in an efficient and economical manner.

projects or projects that may transition to flight, such as the VIPER project. The NASA Chief Engineer is responsible for establishing NPR 7120.8 and NPR 7120.5, implementing the engineering technical authority process, and advising senior officials on matters pertaining to the technical capability and readiness of NASA projects.

The NASA Chief Financial Officer oversees all financial management, budget, strategic planning, and performance activities related to Agency programs and projects. The Office of the Chief Financial Officer (OCFO) provides programmatic (cost and schedule) analysis; establishes cost policies; and analyzes and monitors the methods, standards, and processes used to record cost as well as the project life-cycle schedule.

CLPS Provider

CLPS providers are responsible for end-to-end delivery of NASA instruments and spacecraft to the lunar surface, including the acquisition of a launch vehicle and related launch services. As of February 2022, NASA had 14 CLPS providers that were on contract and eligible to bid on payload deliveries to the Moon. NASA solicits bids from the companies as needed and awards task orders for lunar surface deliveries.

The Agency has awarded seven task orders for payload deliveries and the first three flights are expected to occur in 2022. In May 2019, NASA awarded task orders for lunar scientific payload deliveries to Astrobotic (separate from VIPER) and Intuitive Machines, LLC.[16] Both flights were originally targeted to land on the Moon in 2021 but have since been rescheduled for 2022. In October 2020, NASA awarded another task order to Intuitive Machines for delivery of a drill in 2022. Three additional task orders have been awarded for payload deliveries in 2023—one each to Astrobotic (for delivery of VIPER), Firefly Aerospace Inc., and Masten Space Systems. Also, in November 2021 the Agency issued Intuitive Machines its third task order, valued at $77.5 million, to deliver four more investigations to the Moon in 2024. Going forward, the Agency plans to send science instruments and technology experiments on CLPS flights to the lunar surface at a rate of about twice per year through 2028.

[16] Along with Astrobotic and Intuitive Machines, NASA awarded a $97 million task order to Orbit Beyond in May 2019 to deliver up to four payloads to the Moon. However, just 2 months later, NASA terminated its contract with Orbit Beyond after the contractor notified the Agency that it would not be able to comply with the delivery schedule.

Astrobotic/VIPER Task Order. NASA awarded a CLPS task order to Astrobotic in June 2020 to provide end-to-end delivery of VIPER to the Moon's surface in 2023 using the company's Griffin Lander, as shown in the illustration. The structure of the contract allows Astrobotic to receive payment after successfully completing a series of milestone tasks. The VIPER task order was initially valued at $199.5 million and contained 11 milestones. VIPER was the second CLPS award for Astrobotic and is planned to be its second lander mission, the first being the company's smaller Peregrine Lander carrying 11 NASA payloads now expected to launch by the end of 2022.[17]

Illustration of the Griffin Lander on the Moon Deploying a Ramp for the Rover

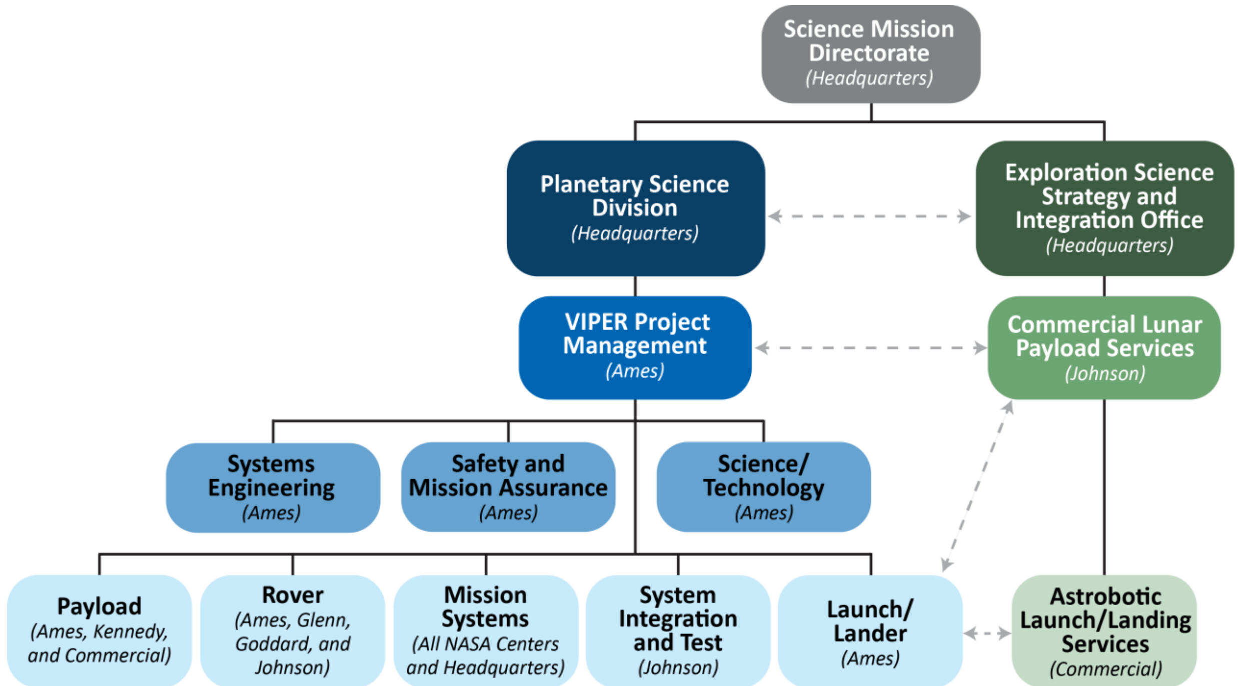
VIPER will be mounted onto the Griffin Lander. After its arrival on the Moon, the lander will deploy its ramp for the rover to roll onto the lunar surface.

Source: NASA/Astrobotic.

Management Structure. The CLPS project office, located at Johnson Space Center, reports to SMD's Exploration Science Strategy and Integration Office (ESSIO) at NASA Headquarters. ESSIO manages coordination between the VIPER project team developing the rover and instruments and the CLPS firm-fixed-price contract regarding Astrobotic/Griffin interface requirements and other project needs. See Figure 3 for the organization and relationship of the VIPER project and CLPS initiative.

[17] Peregrine has a payload mass capacity of 90 kilograms as compared to Griffin's 475 kilograms. Astrobotic was planning to launch its Peregrine Lander in June 2021 on the inaugural Vulcan Centaur rocket from United Launch Alliance, whose development has been delayed by issues with its BE-4 main engine. United Launch Alliance has suggested that customer payload delays, and not Vulcan issues, would delay its first launch into 2022.

Figure 3: Management Organization for the VIPER Mission



Source: NASA OIG presentation of Agency information.

Note: Glenn Research Center (Glenn), Goddard Flight Research Center (Goddard), Johnson Space Center (Johnson), and the commercial sector (Commercial).

VIPER Mission Making Significant Progress Towards 2023 Launch but Cost, Schedule, and Technical Risks Remain

The VIPER mission continues to progress toward a November 2023 launch, passing multiple life-cycle reviews while using less money than expected to this point and maintaining planned schedule reserves. As of December 2021, the science instruments were on schedule for delivery to Johnson Space Center by May 2022 for integration and testing with the rover. In addition, Astrobotic officials said development of the Griffin Lander remains on track to meet the current launch timetable. For the CLPS initiative, NASA modified its acquisition and management approaches so Astrobotic would assume the risk of completing its portion of the overall mission, own and control lander designs, and choose the launch provider. While this non-traditional approach creates opportunities to potentially reduce cost by collaborating with a variety of commercial entities, the Agency and Astrobotic each assume significant risks with the VIPER mission, which carries higher costs, criticality, and schedule risks compared to other current CLPS task orders. Further, NASA's modifications to Astrobotic's task order have increased its value by $36.1 million since initial award, with more modifications possible as VIPER and Griffin complete designs and finalize requirements, and lessons are learned regarding this new acquisition model.

VIPER Making Progress Toward November 2023 Launch

Two years into development, the VIPER project has made significant advances and is progressing toward its planned July 2023 delivery to Astrobotic and a November 2023 launch. Between September and November 2019, the VIPER project completed a VIPER Requirements Checkpoint with officials from ESSIO, the NASA Ames Chief Engineer, and the VRT. This review focused on level-1 and level-2 requirements such as the science requirements document and some level-3 requirements such as verification methods.[18] The Requirements Checkpoint resulted in the VIPER project moving forward to preliminary design under the Formulation Phase.

In April 2020, SMD directed the VIPER project to include additional requirements such as conducting formal life-cycle reviews and associated Key Decision Points (KDP) typically imposed on space flight projects managed under NPR 7120.5 to improve the probability of successful mission implementation. These included a Preliminary Design Review, KDP-C, Critical Design Review, Systems Integration Review,

[18] Level-1 requirements are the scientific determinations or results required for successful completion of the mission's objectives. PSD and the VIPER project jointly created these requirements. Level-2 requirements include margin design for ground data system requirements, while Level-3 requirements define the key functional and performance requirements placed on the ground data system as a whole.

and KDP-D.[19] During 2020, the VIPER project also successfully completed a VIPER Sync Point Review, not a typical SMD flight project life-cycle review, that focused on VIPER mission goals and requirements. During this review, the project demonstrated how the rover and instruments were designed to operate with each other to meet VIPER mission requirements. The VRT verified that the project was utilizing a sound approach to meet mission goals and requirements.

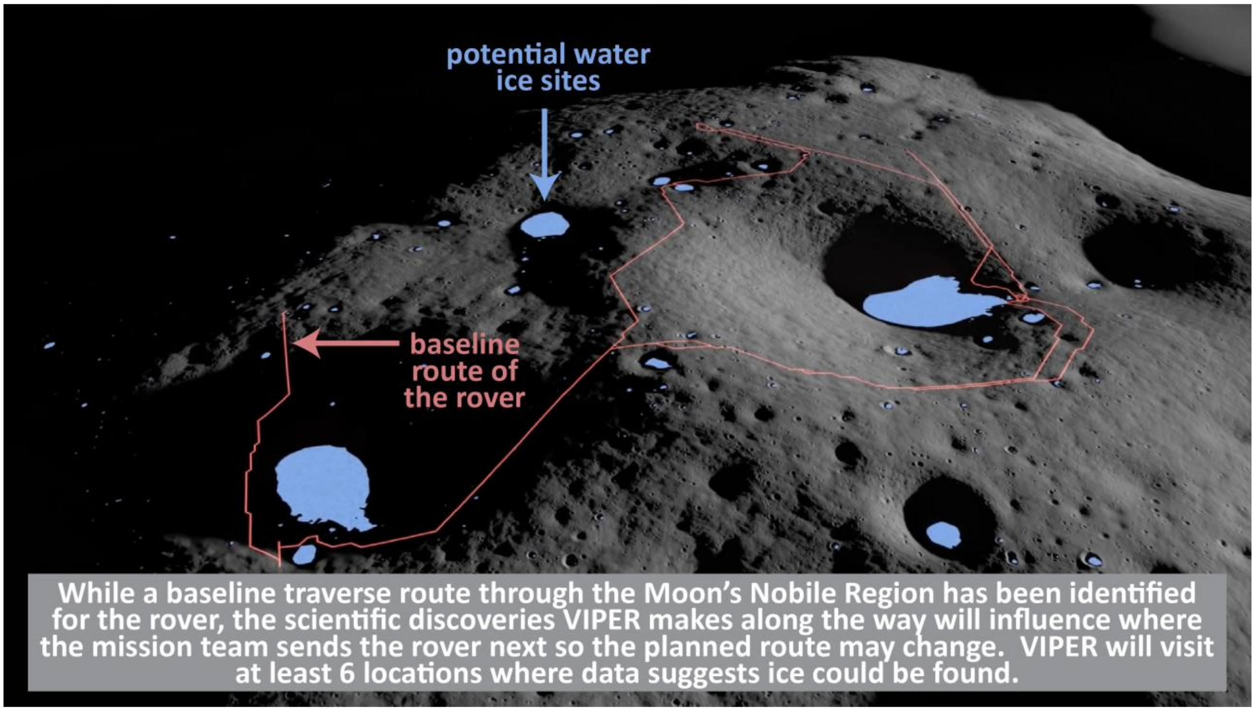
Subsequently, the VIPER project completed its Preliminary Design Review in August 2020, which verified system design maturity, cost, schedule, and acceptable risk levels. The objectives of the Preliminary Design Review are to (1) evaluate the completeness and consistency of the planning, technical, cost, and schedule baselines developed during Formulation; (2) assess compliance of the preliminary design with applicable requirements; and (3) determine if the project is sufficiently mature to begin Phase C (Final Design and Fabrication). By this time the VIPER project matured its four critical technologies—the rover's four science instruments—to Technology Readiness Level (TRL) 6 (out of 9).[20] VIPER's science instruments had been under development for several years and as of December 2021, were on schedule for delivery to Johnson Space Center for integration and testing with the rover by May 2022.

The SMD Program Management Council completed its KDP-C review of the VIPER project in March 2021, which confirmed the project was ready to enter the Implementation Phase. Six months later, NASA selected a landing region near the Nobile Crater at the Moon's South Pole (see Figure 4).

[19] A KDP is defined as the point in time when the Decision Authority makes a decision on the readiness of the project to progress to the next life-cycle phase. KDPs serve as checkpoints or gates through which projects must pass during their development. During KDP-C, the VRT will evaluate the completeness and consistency of the planning, technical, cost, and schedule baselines developed during Formulation to determine if the project is sufficiently mature to begin Phase C. During KDP-D, the VRT will evaluate the integrity of the project design and its ability to meet mission requirements and determine if the design is appropriately mature to continue with the final design and fabrication phase. After the Critical Design Review, the System Integration Review takes place during which the readiness of the project to start flight system assembly, test, and launch operations is assessed.

[20] TRL is a widely used metric for measuring the readiness of new technologies or applications of existing technologies to be incorporated into a product. NASA categorizes its technologies into TRLs 1 through 9. At TRL 1, preliminary research of a basic concept is in the early stage compared to TRL 9 when the technology is integrated into a product and successfully operated in its intended environment. NASA and Government Accountability Office (GAO) guidelines state that critical technologies should be at least at a TRL 6—a fully integrated prototype demonstration in a relevant environment—at the time a project completes its Preliminary Design Review.

Figure 4: VIPER's Planned Route in the Moon's Nobile Region



Source: NASA OIG depiction of Agency information.

Site selection is critical to the mission's success. According to mission personnel, the Nobile landing site is the area most likely to answer the VIPER mission's science questions about the location, amount, form, and origin of water on the Moon; other volatile resources; and NASA's potential for accessing these resources. The Nobile site also offers flexibility to replan the rover's route as the mission unfolds.

Following landing site selection, the VIPER project completed and passed its Critical Design Review in October 2021. The Critical Design Review demonstrates the project's design is sufficiently mature to proceed to full-scale fabrication, assembly, integration, and testing, and that the technical effort is on track to meet performance requirements within identified cost and schedule constraints.

Based on our review of planned versus actual costs presented in the VIPER project's monthly status reports, as of November 2021 the VIPER project used about $7.6 million less (about 5 percent) than what the project had planned. In addition, of the 100 days of funded schedule reserve the VIPER project established at Preliminary Design Review in August 2020, the project had used 28 days from August to December 2020 primarily due to a delay in receiving the Integrated Avionics Unit from the manufacturer.[21] While the project team was initially able to revise the project schedule and add those 28 days back to the reserve by identifying test activities that could be done in parallel, the project has used another 37 days since April 2021 primarily due to Coronavirus Disease 2019 (COVID-19) supply chain delays and maintained 63 days of funded schedule reserve as of November 2021.

[21] Funded schedule reserve is a separately planned quantity of time above the planned duration estimate reflected in the Integrated Master Schedule and used for future situations that are impossible to predict (unknown unknowns). The Integrated Avionics Unit controls the rover.

To complete its mission, the VIPER project is dependent on Astrobotic for lunar transportation and landing services to the Moon. As of September 2021, Astrobotic had met 4 of 11 milestones established in its task order and expressed confidence that they will be able to complete their Critical Design Review of the Griffin Lander on time in March 2022. In addition, in September 2021 Astrobotic managers stated they had over 3 months of schedule margin remaining and were on track to meet a launch in November 2023.

As of November 2021, the VIPER project team was generally meeting baseline costs and schedule. However, the team will need to manage risks from critical VIPER and Griffin integration activities, as detailed in the following sections, to enable mission success.

Management Strategies and Processes for the CLPS Initiative and Astrobotic Provides Opportunities but Exposes Both NASA and the Contractor to Risks

NASA established the CLPS initiative to facilitate the rapid acquisition of lunar delivery services from U.S. companies for payloads that advance capabilities in science, exploration, and the commercial development of the Moon. For the initiative, NASA modified both its acquisition and management approaches and chose to pursue a non-traditional approach that transfers the technical risk of completing the assigned mission to the designated commercial contractor. Because VIPER is significantly higher in cost and criticality with lower risk tolerance than the other missions currently awarded CLPS task orders, SMD instituted additional requirements on the Astrobotic task order to help ensure the VIPER mission succeeds. These additional requirements have contributed to the increase in the cost of the task order, which has risen by $36.1 million or 18.1 percent from the task order's original $199.5 million cost established in 2020.

Acquisition and Management Approach for the CLPS Initiative

While the VIPER project is following NASA's in-house development processes, the CLPS initiative is a competitive commercial service model in which the designated contractor, rather than NASA, assumes the cost and technical risks of completing the assigned mission of delivering a payload to the lunar surface. In addition, NASA does not own, control, or influence the contractor's design nor choice of subcontractors, including the launch vehicle provider. Rather, NASA simply buys a service from one of the CLPS providers, similar to a customer purchasing one of multiple shipping options available when mailing a package at the post office.

As a result, the nature of risk management for CLPS is different than that for many other NASA projects. For CLPS, NASA does not actively manage any of the risks associated with the design, development, or actual operation of Astrobotic's Griffin delivery system. Instead, NASA acts in more of an advisory capacity, monitoring the contractor's risk management process and the amount of risk exposure it is willing to accept.

Although NASA is not following its standard project development risk management processes for CLPS because the Agency has designed the CLPS initiative as a service rather than as a development project, NASA has several options available to manage its risk posture, with many of these methods applied prior to awarding a CLPS task order.[22] For example, NASA recognizes the risks of failure are higher for commercial vendors performing their first lunar missions; therefore, for the initial CLPS task orders the Agency chose low-cost, non-critical payloads that could potentially provide value even if the missions failed or were not delivered when initially planned. In fact, of the first three CLPS task orders issued, one was canceled and two have been delayed beyond their planned 2021 delivery dates without significantly impacting NASA's larger lunar exploration goals.

NASA also uses evaluation criteria during the selection process to award task orders to contractors that demonstrate a clear awareness of potential risks throughout design and development. In addition, NASA has several options for handling task orders that are not performing adequately or appear to be failing, including informing the contractor of possible or actual termination if NASA deems the Agency's overall risk exposure is no longer acceptable. As of November 2021, NASA had terminated one contract—Orbit Beyond—at the company's request and none for performance.

Augmented Insight of Astrobotic

VIPER is significantly higher in cost and criticality than the low-cost, non-critical payload task orders the CLPS initiative selected for its initial missions.[23] As a result, in June 2021 NASA implemented "augmented insight" for the VIPER's CLPS task order per a contract modification. To expand its insight, NASA assigned a Payload Integration Manager to reside full-time at the contractor's facility to improve communication between NASA and Astrobotic. In addition, Astrobotic is required to provide monthly status reports on the development of its Griffin Lander, and Independent Assessment Team reviews will be held approximately 2 years, 1 year, and 1 month prior to NASA handing over VIPER to Astrobotic for launch.[24] The additional information gathered through this augmented insight can give NASA a fuller understanding of the risk environment and the VIPER mission's risk exposure.

While Astrobotic has full responsibility to mitigate risk for its lander, this is not to say that NASA and the contractor are not working together to minimize potential risks and ensure mission success. For example, the Integration Working Group consisting of VIPER, CLPS, and Astrobotic personnel meet three times a week to share information. Additionally, VIPER personnel have frequent discussions with CLPS officials on issues as they arise. As an example of the group's collaboration, the VIPER project agreed to manufacture a rover wheel for Astrobotic to assist with the design of their Griffin Lander and ensure that the rover will successfully roll down the ramp once the lander is on the lunar surface.

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[22] NPR 8000.4B, *Agency Risk Management Procedural Requirements* (December 6, 2017) provides the requirements for risk management for the Agency, its institutions, and its programs and projects.

[23] The first two CLPS task orders were issued to Astrobotic and Intuitive Machines. Astrobotic, which plans to launch its Peregrine Lander on a United Launch Alliance Vulcan Centaur rocket, will carry 11 NASA payloads to the lunar surface, while Intuitive Machines, which will launch its Nova-C Lander on a SpaceX Falcon 9 rocket, will carry 5 NASA payloads to the Moon. The payloads are each about the size of a shoebox and range in mass from 2 to 33 pounds. Initially targeted to launch in 2021, both missions are now planned for mid-2022.

[24] The Independent Assessment Team is one facet of augmented insight developed for CLPS deliveries of high priority and low-risk tolerant payloads. For the VIPER mission, the Independent Assessment Team will assess Astrobotic's readiness to safely receive, integrate, and deliver VIPER to the lunar surface. The Independent Assessment Team serves the SMD Associate Administrator and Deputy Associate Administrator for Exploration, and assesses the risks associated with the CLPS provider meeting NASA's objectives. For risks deemed unacceptable by the Associate Administrator or Deputy Associate Administrator for Exploration, the Independent Assessment Team will share those risks with Astrobotic to give them an opportunity to respond to the concerns prior to NASA's decision to release the rover into the custody of the CLPS provider. This differs from the VRT, which is tasked with performing assessments of the VIPER project itself and not of the CLPS provider.

Ongoing Risks to the VIPER Mission

The VIPER project team is closely communicating with the CLPS office and Astrobotic leadership to minimize several risks related to Astrobotic and the Griffin Lander. One risk which the team is monitoring concerns the possibility of future rover design changes driven by CLPS to accommodate possible issues with Griffin's design—a result of NASA's decision to issue the task order to Astrobotic prior to completing VIPER mission requirements. In October 2021, Astrobotic stated that they will meet all of the requirements of the CLPS task order and are confident that the VIPER project will not require any design changes as a result of the Griffin Lander while it continues in development; however, several risks remain.

Although Astrobotic personnel explained that Griffin's development schedule is largely independent of its Peregrine mission, the Peregrine Lander—planned to launch in 2022—has multiple systems and subsystems that will also be used on Griffin. Therefore, any technical problems with these systems may adversely affect development of the Griffin Lander because Astrobotic would only have about a year, depending on the Peregrine launch date and start of lunar operations, to resolve the issues prior to NASA delivering VIPER for integration and launch. Furthermore, any failures during the Peregrine mission may lead to Griffin delays as NASA and Astrobotic investigate the failures and develop corrective actions.

In addition, VIPER long-lead acquisitions—such as the rover solar power array and avionics unit—have been affected by aerospace industry supply chain delays caused by COVID-19 as have delivery of computer boards and motor parts. Both of these issues have impacted design verification testing needed for the mission's Critical Design Review, while COVID-19 also delayed some component development schedules. As of November 2021, VIPER project managers estimated the total COVID-19 cost impact at $16.3 million. VIPER project and Astrobotic personnel responsible for rover/lander interface development reported they experienced collaboration challenges due to limitations of remote, virtual interactions caused by the pandemic and resulting mandatory telework for much of the NASA workforce. Furthermore, VIPER project management reported a delay in hiring new staff to support both the instruments and rover teams that has impacted the design and development critical path.[25]

Cost of CLPS Task Order Has Increased

NASA awarded the $199.5 million CLPS task order to Astrobotic in June 2020 for delivery of VIPER to the Moon's surface in 2023. Since then, NASA has made three modifications to the task order that have increased its total value by 18.1 percent to $235.6 million. Additional modifications remain a possibility, as the rover and Griffin Lander have yet to complete their designs and finalize their requirements. Also, because CLPS is a new acquisition model for NASA, additional revisions may become necessary as the project matures and lessons are learned.

Optimally, VIPER design and mission requirements should have been completed and baselined prior to CLPS awarding a firm-fixed-price task order to Astrobotic. However, the VIPER project had yet to complete its design and baseline its requirements when CLPS awarded the task order to deliver the rover to the lunar surface. Specifically, VIPER's Critical Design Review was held in October 2021, more than a year after the task order was awarded to Astrobotic. NASA chose to proceed this way to give Astrobotic more time to develop its lander so the VIPER project would be ready to launch and the

[25] The critical path refers to the sequential series of tasks in a schedule that represents the longest overall duration from the present time through project completion. Any slippage of these tasks will increase the project's duration.

mission completed prior to landing humans on the Moon during Artemis III, recently targeted for no earlier than 2025. As the VIPER project completes its design phase, potential changes in its requirements may lead to more contract modifications to incorporate those changes into Astrobotic's Griffin Lander design, which in turn would increase the mission's overall cost and timeline.

As of October 2021, three issues have arisen that have required NASA to increase the value of the task order:

- *Risk of excessive vibration.* Prior to the VIPER project's Preliminary Design Review, Astrobotic informed the VIPER project team about the risk of excessive vibration between VIPER and Griffin during launch. The options were for Astrobotic to change the lander's design, the VIPER project to change the rover's design, or both parties to make changes. Since VIPER was much further along in its design, ESSIO decided to pay Astrobotic to make the necessary changes to its lander to accommodate VIPER. This March 2021 change to the CLPS task order added $27 million to the mission's cost.
- *Increase in the VIPER project's mass.* The task order initially called for the Griffin Lander to deliver VIPER at a weight of 475 kilograms (1,047 pounds) to the lunar surface. However, the task order was modified in September 2021 when the VIPER project team requested that Astrobotic provide the capability to deliver an additional 15 kilograms to the lunar surface if needed. Astrobotic proposed and NASA accepted an equitable adjustment to initial requirements in exchange for addressing the additional mass. Specifically, NASA agreed to reduce the required data from Griffin to the VIPER team prior to landing on the lunar surface in exchange for longer communication window durations, which will not impact the likelihood of mission success or the baseline concept of operations. Additionally, several of the adjustments allowed Astrobotic to reduce the mass of Griffin subsystems, positively contributing to mass management and offsetting the majority of the additional 15 kilograms of VIPER mass added compared to the original task order requirement.
- *Augmented Insight.* With the Agency's decision to implement augmented insight for the VIPER mission, Astrobotic's task order was modified to incorporate requirements for the company to allow a Payload Integration Manager to reside full-time at the contractor's facility, provide monthly status reports on development of its Griffin Lander, and support the Independent Assessment Team reviews as needed. The addition of these requirements coupled with the increase in mass margin (as noted above) added approximately $9 million to the task order. NASA management said that similar to the VIPER mission, augmented insight will be incorporated into all future high-value, low-risk tolerant CLPS payload deliveries.

We believe that moving forward, task order modifications related to unknown capabilities and requirements changes may become less common as the CLPS initiative matures and payloads are successfully delivered to the lunar surface. In addition, long lead times for landers may decrease as additional landers are developed and the need for lengthy design and development phases are reduced, enabling NASA to fully develop payload and mission requirements prior to issuing CLPS task orders. Lastly, timely submission and NASA-wide sharing of lessons learned that VIPER personnel have been encouraged to capture throughout the life cycle of the project should help follow-on projects make more effective, experience-driven decisions regarding collaboration with CLPS contractors.[26]

[26] As of January 2022, NASA's lessons learned database did not contain any records related to CLPS or VIPER.

VIPER Mission Would Have Benefited From a More Complete Cost Estimate and the Use of Leading Project Management Tools

NASA's Agency Baseline Commitment (ABC) for the VIPER mission includes costs only for development of the rover, science instruments, lunar operations, and applicable cost reserves, and not those associated with Astrobotic's contract to launch and deliver VIPER to the Moon.[27] By excluding the contractor's task order—valued at $226.5 million or 34 percent of the mission's overall cost when the ABC was completed—stakeholders including Congress and the Office of Management and Budget do not have visibility into the total cost of the VIPER mission. Additionally, while NASA leadership has promoted the benefits of its Joint Cost and Schedule Confidence Level (JCL) analysis and Earned Value Management (EVM) project oversight tools, SMD chose not to implement either for VIPER in an effort to streamline processes and because NPR 7120.8 does not require it.[28] As a result, NASA may not have full visibility into the risks and their potential costs to the mission and may not be accurately monitoring mission cost and schedule performance to make timely risk-informed decisions.

NASA Did Not Establish a Complete Baseline for the VIPER Mission

Establishing a total cost baseline for the VIPER mission, including costs associated with the Astrobotic task order, would provide NASA and external stakeholders greater visibility into the total costs and risks of the mission. However, the Agency has not developed a cost estimate for the total VIPER mission, choosing instead to define the project as to exclude the Astrobotic launch and lunar delivery services—an essential portion of the overall mission—which resulted in exclusion of those costs and risks from the project's baseline.

As part of the VRT, The Aerospace Corporation (Aerospace) developed independent cost and schedule estimates with confidence analysis—the likelihood (percentage) that a project will achieve its objectives on time—for the VIPER project's KDP-C. The analysis resulted in a project life-cycle cost estimate of $378.5 million with a 44 percent confidence level. As a result, NASA Headquarters added $55 million in unallocated future expense (cost reserves) to reach a 70 percent confidence level—an Agency

[27] The ABC, established at KDP-C, documents an integrated set of project requirements, cost, schedule, technical content, and an agreed-to Joint Cost and Schedule Confidence Level—that calculates the probability that cost will be equal to or less than the targeted cost and schedule will be equal to or less than the targeted schedule date—and forms the basis for NASA's commitment to the Office of Management and Budget and Congress. The ABC is the only official baseline that exists for a NASA program or project.

[28] JCL analysis is an integration of cost, schedule, risk, and uncertainty, which provides the probability that a project's cost will be equal to or less than the targeted cost and that the schedule will be equal to or less than the targeted finish. EVM is an integrated management control system for assessing, understanding, and quantifying what a contractor or field activity is achieving with money spent. EVM integrates technical, cost, schedule, with risk management while allowing objective assessment and quantification of current project performance and helps predict future performance based on trends.

requirement for space flight projects projected to cost at least $250 million—bringing the March 2021 ABC for the VIPER project to $433.5 million.[29] While the VRT validated the credibility of the basis for the project's integrated cost and schedule estimate, it also noted the estimate did not consider risks associated with Astrobotic's development of the Griffin Lander. Also, OCFO officials stated that while Aerospace's methodology was sound for performing a schedule-adjusted cost estimate, they commented that it did not consider specific risks. Similar to Aerospace and VRT analyses, those risks included those related to the Astrobotic task order and Griffin development.

NASA did not include the costs of Astrobotic's launch and delivery services in the ABC, which was $226.5 million at the time the baseline was established. NASA officials told us they are not managing the CLPS effort as a part of the VIPER project since Astrobotic provides end-to-end lunar delivery services based on a firm-fixed-price contract, and therefore the Agency did not include the costs for these services in its baseline.[30] Essentially, because CLPS is operated under a competitive services model, NASA does not view it as a traditional project and believes the costs for contracted lunar delivery services do not need to be added into project baselines. In our opinion, NASA's approach is not consistent with the life-cycle cost definitions provided in law and Agency policies (see Table 2) that require life-cycle cost estimates to include all costs of a project or system from start to finish. Including the cost of the Astrobotic firm-fixed-price task order at the time the project's $433.5 million ABC was established increases the total VIPER mission cost by 34 percent to $660 million.

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[29] NPR 7120.5F. Unallocated future expense is the portion of estimated cost required to meet a specified confidence level that cannot yet be allocated to the specific project sub-elements because the estimate includes probabilistic risks and specific needs that are not known until these risks are realized.

[30] As noted by GAO, the baseline also excludes $90.6 million in funding used for development of Resource Prospector. VIPER project officials stated that these costs are not included because the scope of the project has significantly changed from what was planned for Resource Prospector. See GAO, *NASA: Assessments of Major Projects* (GAO-21-306, May 20, 2021).

Table 2: NASA's Life-Cycle Cost Criteria

Criteria Source	Definition
U.S. Code Title 51[a]	The term "life-cycle cost" **means the total of the direct, indirect, recurring, and nonrecurring costs**, including the construction of facilities and civil servant costs, and other related expenses incurred or estimated to be incurred in the design, development, verification, production, operation, maintenance, support, and retirement of a program over its planned lifespan, **without regard to funding source or management control.**
Office of Management and Budget Circular A-11[b]	Life-cycle costs of an asset are **all direct and indirect initial costs, including planning, procurement, development, construction, and other costs**; all periodic or continuing costs of operation and maintenance; and costs of decommissioning and disposal. The life-cycle cost estimate provides the total cost to the government of acquisition and ownership of the system over its full lifetime and helps management to make the right decision.
NPR 7120.5F	The total of the direct, indirect, recurring, nonrecurring, and other related expenses both incurred and estimated to be incurred in the design, development, verification, **production, deployment,** prime mission operation, maintenance, support, and disposal of a project, including closeout, but not extended operations. The life-cycle cost of a project or system can also be defined as the total cost of ownership over the project or system's planned life cycle from Formulation (excluding Pre-Phase A) through Implementation (excluding extended operations). The life-cycle cost includes the cost of the launch vehicle.
NPR 7120.8A	The total of the direct, indirect, recurring, nonrecurring, and other related expenses both incurred and estimated to be incurred in the design, development, verification, **production, deployment,** operation, maintenance, support, and disposal of a project, including closeout. The life-cycle cost of a project or system can also be defined as the total cost of **ownership over the project or system's life cycle from Formulation through Implementation**. It includes all design, development, **deployment,** operation and maintenance, and disposal costs.

Source: NASA OIG analysis of various documents.

[a] U.S. Code Title 51, *National and Commercial Space Programs*, §30104 Baselines and cost controls.

[b] Office of Management and Budget Circular A-11, *Preparation, Submission, and Execution of the Budget* (August 6, 2021).

In 2004, the Government Accountability Office reported that a lack of disciplined project cost estimating processes resulted in NASA project management problems, schedule slippage, and cost growth.[31] Soon after, Congress passed the National Aeronautics and Space Administration Authorization Act of 2005, which created the first external reporting requirements to Congress.[32] As part of those requirements, NASA must provide Congress a Major Program Annual Report (MPAR) for programs and projects in development with an estimated life-cycle cost exceeding $250 million.[33] For new major programs and projects, the MPAR must provide a Baseline Report that, at a minimum, includes an estimate of the

[31] GAO, *NASA: Lack of Disciplined Cost Estimating Processes Hinders Effective Program Management* (GAO-04-642, May 28, 2004).

[32] National Aeronautics and Space Administration Authorization Act of 2005, Pub. L. No. 109–155 (2005).

[33] NASA provides the MPAR to Congress as part of its annual budget request. Another significant requirement of the 2005 Act was that NASA must notify Congress if management projections show an overrun greater than 15 percent of a program's baseline development cost or a delay of more than 6 months. If projections show a 30 percent cost overrun for development, then, beginning 18 months after the date the Administrator transmits a report to Congress, the Administrator shall not expend any additional funds on the program, other than termination costs, unless Congress has subsequently authorized continuation of the program by law.

program's or project's life-cycle cost with a detailed breakout of development cost and program or project reserves, as well as an estimate of the annual costs until development is completed. U.S. Code Title 51 defines development cost as the total of all costs, from the period beginning with the approval to proceed to implementation through the achievement of operational readiness, without regard to funding source or management control. Despite these requirements and because NASA did not consider the CLPS provided services as part of the project, SMD did not include the cost of the Astrobotic task order for launch and delivery services to the lunar surface in the MPAR.

Similar to the VIPER mission, the Mars 2020 mission developed a rover (Perseverance), suite of science instruments, and sky crane to land the rover on Mars and deliver scientific data on the planet's potential for past life.[34] However, consistent with federal law and NASA policy, ABC and MPAR reporting for Mars 2020 included all critical mission components in its life-cycle costs and did not exclude the costs of the launch vehicle, providing stakeholders full transparency into mission costs. A complete ABC and accurate MPAR for the VIPER mission would improve decision makers' and stakeholders' visibility into the full cost of the mission while enhancing their ability to monitor mission performance.

NASA Could Have Improved Oversight of the VIPER Mission by Using Leading Project Management Cost and Schedule Tools

Major space flight programs and projects costing at least $250 million are required by NPR 7120.5 to conduct a JCL analysis in support of KDP-C—an estimation tool Agency leadership has touted to improve project cost and schedule outcomes—and implement EVM to monitor cost and schedule performance during project development. However, in contrast with its decision to implement certain life-cycle reviews from NPR 7120.5 not typically included on research and technology projects, SMD chose not to implement JCL and EVM on VIPER largely because they are not a requirement of NPR 7120.8. The VIPER mission is a first-of-its-kind, potentially one-of-a-kind effort reliant on a new contractor that has never developed a lunar lander working under a novel acquisition strategy. Given this, the Agency's choice not to utilize its JCL tool calls into question the credibility of the VIPER project's ABC. In addition, had SMD chose to implement EVM, management may have received its resultant cost and schedule performance monitoring data months earlier than that provided by Aerospace.

NASA Project Management Tools

Joint Cost and Schedule Confidence Level. A JCL analysis generates a statistical representation of the likelihood a project will achieve its objectives within budget and on time. The process uses software tools and models that combine cost, schedule, risk, and uncertainty estimates to evaluate and illustrate how expected threats and unexpected events affect a project's cost and schedule. To generate this data, project managers develop comprehensive project plans, inputs, and priorities that integrate costs, schedules, risks, and uncertainties. NASA officials believe that gathering this data encourages better communication among project personnel; improves cost, schedule, risk, and uncertainty analyses; and fosters an understanding of how project elements impact one another. NASA requires projects to

[34] NASA launched the Mars 2020 mission in July 2020, and in February 2021 the Perseverance rover landed in Jezero Crater to study the geology of Mars, identify evidence of ancient life, collect Martian surface samples, and test new technologies.

develop budgets consistent with a 70 percent JCL—in short, a 70 percent likelihood the project will launch on cost and on the planned schedule.

Earned Value Management. EVM is a project management tool and approach for measuring and assessing project performance through the integration of technical scope with schedule and cost objectives during the execution of the project. EVM allows an objective assessment and provides quantification of technical progress, enabling management to gain insight into a project's status and completion costs and schedules. Two essential characteristics of successful EVM are EVM system data integrity and carefully targeted monthly EVM data analyses (i.e., identification of risky Work Breakdown Structure (WBS) elements).[35] To generate this data, project managers develop comprehensive project plans, inputs, and priorities that integrate costs, schedules, risks, and uncertainties.

The concept of earned value is fundamental to understanding how EVM works. The value of a task is how much project personnel initially estimated the task would cost to complete with the project "earning" that value when it completes the task. In other words, earned value is the estimated cost of the actual work completed. Among the various data that EVM produces are two key performance metrics—cost and schedule—using the earned value concept to inform managers and decision makers about the project's performance.[36] Cost performance is measured by comparing a project's estimated or budgeted cost to complete a task (the earned value) with the actual cost to perform that work. Schedule performance is measured by comparing how much work a project has completed at a specific point in time to the work or tasks it had planned to complete by that point. The result of these measurements are a Cost Performance Index and Schedule Performance Index that provide a ratio which indicates how efficiently a project is completing its tasks. If the project is over budget or behind schedule the respective ratio would be less than one, on budget or schedule the ratio would be equal to one, and under budget or ahead of schedule the ratio would be greater than one.

NASA Is Managing VIPER as a Research and Technology Project Rather than a Space Flight Project

As discussed previously, managers of research and technology projects directly funded by a space flight program or project have flexibility to decide whether to implement the requirements of NPR 7120.5, NPR 7120.8, or a hybrid of the two. While research and technology projects that tie directly to a space flight mission's success are typically managed under NPR 7120.5, NASA SMD decided instead that the

[35] EVM system is an integrated management system and its related subsystems that allow for planning all work scope to completion; assignment of authority and responsibility at the work performance level; integration of the cost, schedule, and technical aspects of the work into a detailed baseline plan; objective measurement of progress (earned value) at the work performance level; accumulation and assignment of actual costs; analysis of variances from plans; summarization and reporting of performance data to higher levels of management for action; forecast of achievement of milestones and completion of events; forecast of final costs; and disciplined baseline maintenance and incorporation of baseline revisions in a timely manner. EVM system data integrity involves an analyst performing data validity checks on monthly EVM in-house and contractor reporting to assess reliability of EVM data. WBS is a product-oriented hierarchical breakdown of the hardware, software, services, and other work tasks that organizes, displays, and defines the products to be developed and/or produced and relates the elements of the work to be accomplished to each other and the end products. WBS divides the project into manageable pieces of work to facilitate planning, control, and performance measurement of cost, schedule, and technical content.

[36] While we focus on cost and schedule efficiency performance in this report, EVM produces other valuable metrics such as the expected or anticipated costs needed to complete the remainder of work on a project and the baseline execution index, which compares the cumulative number of baselined tasks actually completed each month to the cumulative number of baselined tasks scheduled to be completed each month.

VIPER project would be subject to NPR 7120.8 to better align with SMD's risk tolerance relative to the mission, including delivery of the rover with the science instruments using a CLPS provider, and to minimize fiscal and personnel resources needed to implement requirements of NPR 7120.5.

Tailoring is both an expected and accepted part of establishing proper oversight requirements. We found that SMD tailored its management approach with additional requirements from NPR 7120.5 to include project life-cycle reviews and associated KDP reviews to help achieve mission success. As noted in our audit of NASA's Low-Boom Flight Demonstrator (an X-plane), the Aeronautics Research Mission Directorate used NPR 7120.5 and tailored "down" its full requirements to fit their project.[37] Our position then and now remains the same—the specific policy the Agency uses to develop its projects matters less than ensuring managers consistently use leading project management practices and tools, such as JCL and EVM.

NASA Established the VIPER Project's Agency Baseline Commitment without a Comprehensive JCL Analysis

Although the VRT and OCFO officials performed an independent analysis of the cost estimate for the VIPER project, that analysis did not include a comprehensive JCL that would have included cost and schedule risks associated with the Griffin Lander. This is in spite of NASA policy that requires risk-informed decision-making for major acquisitions—defined as those costing $250 million or more—that includes the identification, analysis, and management of programmatic, institutional, technical, cost, schedule, environmental, safety, management, industry, security, supply chain, and external policy risks that might jeopardize the successful execution of the Agency's acquisition strategy.[38] This policy also requires that major acquisitions use probabilistic cost and schedule estimate(s) and confidence level(s).

The JCL analysis is specifically designed to incorporate all project-managed risks as well as those uncertainties that may not be managed by the project. According to NASA, JCL serves as a valuable project management tool that helps enforce best practices of program planning and control and enhance vital communication with stakeholders. Recognizing NASA's long-standing challenges managing large acquisition programs and in response to the Agency's designation on the Government Accountability Office's High Risk List, NASA senior leadership developed a new Corrective Action Plan in December 2018 to drive improvements in NASA's program and project management.[39] One of the Plan's initiatives was to "Update Probabilistic Programming Policy," noting "the policy has been empirically successful as measured by an observable reduction in the number and magnitude of project baseline overruns since the implementation of the policy. Additionally, the JCL policy has assisted in communicating Agency risk posture and quantifying the need for unallocated future expenses."

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[37] The Low-Boom Flight Demonstrator is an experimental aircraft or X-plane designed to produce a quieter sonic boom while flying at supersonic speeds. In our review, *Management of the Low-Boom Flight Demonstrator Project* (IG-20-015, May 6, 2020), we found that while management implemented a sound and robust JCL analysis it did not implement required in-house internal EVM reporting.

[38] NASA Policy Directive 1000.5C, *Policy for NASA Acquisition* (July 13, 2020).

[39] GAO originally designated NASA's acquisition management as a "high-risk" area in its inaugural High Risk List released in 1990, citing what was at the time considered a history of persistent cost growth and schedule delays in the majority of the Agency's major products. GAO's most recent report is *High-Risk Series: Dedicated Leadership Needed to Address Limited Progress in Most High-Risk Areas* (GAO-21-119SP, March 2, 2021). *NASA Corrective Action Plan* (December 14, 2018). The most recent Corrective Action Plan is *2020 High Risk Corrective Action Plan* (August 2020).

The Agency has also highlighted the benefits of its JCL practices to Congress and the NASA Office of Inspector General. For example, at a congressional hearing in June 2018, the NASA Associate Administrator stated, "since the agency established its JCL policy, programmatic performance has significantly improved…."[40] In its response to questions for the record from that hearing, NASA further noted that JCL analysis improves program or project planning by systematically integrating cost, schedule, and risk products and processes; facilitates transparency with stakeholders; and provides a cohesive and holistic picture of the program's or project's ability to achieve cost and schedule goals. Moreover, in response to our September 2015 report assessing the Agency's JCL process, NASA management stated that JCL is well suited to address several project management challenges, including annual budget and funding issues, changing technical complexity, and project changes in scope and design.[41] Further, in response to our November 2020 report on NASA's top management challenges, NASA stated that since implementation of the 70-percent JCL requirement, major SMD missions have, on average, cost 2 percent less than the NASA commitment and that by adopting the JCL methodology NASA is able to effectively manage its portfolio.[42]

While the cost and schedule analysis NASA used for the VIPER mission may be adequate for future iterations of Griffin deliveries to the Moon, we believe the Agency would have benefitted by conducting a comprehensive JCL analysis given Astrobotic's lack of a track record in delivering a lander to the Moon coupled with the fact that Griffin is still in development. While NPR 7120.8 does not require a JCL, project management's decision not to utilize the tool resulted in an ABC for the VIPER project devoid of risks and costs of the Griffin Lander, which would have added at least $226.5 million to the mission's overall cost that the Agency reported to Congress and the Office of Management and Budget in the MPAR.

NASA Did Not Implement EVM to Monitor VIPER Project Cost and Schedule Performance

VIPER project managers implemented some standard project management principles to monitor cost and schedule performance utilizing the following data:

- *WBS and WBS Dictionary*. The VIPER project team developed a product-oriented WBS defining all hardware, software, services, and data required to produce the rover and instruments, as well as the manpower and data collection systems needed during lunar operations, structured to align with the project's cost, schedule, and risk accounting.[43]
- *Integrated Master Schedule*. This schedule is populated with data from VIPER project system and subsystem managers and then captured within the aggregate schedule and reviewed weekly to assure giver-receiver tasks are accurate and timely.

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[40] NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges. Before the Subcommittee on Space, Committee on Science, Space, and Technology, 115th Congress (2018) (statement of NASA Associate Administrator Stephen Jurczyk).

[41] NASA OIG, *Audit of NASA's Joint Cost and Schedule Confidence Level Process* (IG-15-024, September 29, 2015).

[42] NASA OIG, *2020 Report on NASA's Top Management and Performance Challenges* (November 12, 2020).

[43] WBS Dictionary is a document that describes the definition and content of each activity associated with each WBS element, in product-oriented terms, and relates each element to the respective, progressively higher levels of the WBS as well as to the Statement of Work, if applicable.

- *Schedule Performance Reporting*. The integrated master schedule is updated weekly.
- *Funded Schedule Reserve and Unallocated Future Expense Trending and Reporting*. The VIPER project funded schedule reserve and unallocated future expense usage are closely monitored and managed.

However, VIPER project managers are not using EVM to track cost and schedule performance. To provide additional performance monitoring analysis, SMD contracted with Aerospace for a Schedule Task Execution Evaluation Process (STEEP) for cost and schedule monitoring in addition to the project's cost and schedule tracking.[44] STEEP is a proprietary construct in which Aerospace used the project's April 2021 cost plan as the baseline and manually processed cost and schedule data provided by the VIPER project using a Microsoft Excel spreadsheet.[45] Aerospace calculated an Execution Index as a percentage of actual tasks completed divided by planned tasks. Aerospace then calculated the Cost Performance Index and Schedule Performance Index by using the Execution Index in combination with the cost plans and actual cost incurred to assess performance.

While STEEP was helpful in providing another layer of performance monitoring, this process has its limitations. For example, STEEP relied solely on the number of tasks in the project's initial baseline—any new tasks added or old tasks dropped were not included in the Aerospace calculations limiting its usability. Furthermore, the comparison of budget versus actual expenditures merely indicates planned versus actual expenditures at any given time. It does not indicate what work was actually produced for the amount of money spent, as is done in EVM, nor does it indicate whether it was produced at the expected rate according to schedule as originally planned.

NASA chose not to implement EVM on the VIPER project largely because NPR 7120.8 does not require it. In addition, PSD consulted with OCFO and determined that the work required to implement EVM does not add enough value and contribution towards mission success given the project size and tight timeline. We disagree. OCFO stated that the cost of implementing EVM for industry was typically only 0.5 to 2 percent of the project's cost. However, the cost of implementing in-house EVM is significantly less because of the tools and personnel resident in their office and would amount to essentially the analyst(s) required to perform the EVM duties.

In addition, NPR 7120.8 states that how cost and schedule metrics are tracked will vary depending on the type of project. Specifically, costs may be tracked using EVM for very large projects or a comparison of planned costs versus actual costs and schedule may be tracked using an integrated master schedule or through tracking key milestones. NPR 7120.5 requires space flight projects with a life-cycle cost estimated to be greater than $250 million, such as the VIPER project, to perform an EVM and comply with Electronic Industries Alliance 748, *Standard for Earned Value Management Systems*, for all portions of work including in-house and contracted portions of the project.[46] However, the NASA EVM Implementation Handbook does not differentiate between policies—NPRs 7120.8 and 7120.5—

[44] Aerospace has provided this type of information on past NASA project and instrument development efforts that did not produce EVM data.

[45] The April 2021 cost plan is the project's time-phased cost and schedule estimate as of April 2021 without contingencies.

[46] Electronic Industries Alliance 748, *Standard for Earned Value Management Systems*, is the standard for U.S. Department of Defense EVM programs and was adopted in August 1998 for application to major defense acquisition programs.

and specifically states that EVM is required on in-house development activities when the life-cycle cost of the project is $250 million or greater.[47]

EVM provides program managers with early warning of developing trends—both problems and opportunities—allowing them to focus on the most critical issues. Similar to JCL, one of the 2018 Corrective Action Plan initiatives was to "Enhance Earned Value Management Implementation," stating that "NASA will improve and strengthen the Earned Value Management (EVM) discipline, and work to foster a culture at NASA where EVM is accepted by Programs and Projects and embraced by managers and employees."[48] The initiative goes on to state that EVM use is required on all acquisitions for development designated as major in accordance with Office of Management and Budget Circular A-11.

In August 2021, NASA's OCFO provided Aerospace an assessment of their performance monitoring, which included a list of shortcomings with the company's approach to cost and schedule monitoring as it compares to the Agency's EVM policy. Among the many identified issues was that the process was manually intensive, leaving margin for error in the data entry given the data needed to be correctly entered into the Aerospace-developed Excel spreadsheet. In addition, Aerospace's methodology treats all tasks with equal weight, which can skew the cost and schedule performance metrics. Aerospace recognized the limitations of the STEEP methodology in its own documentation. We believe that without knowing the planned cost of completed work and work in progress (that is, earned value), NASA cannot determine the true project status.

Lastly, EVM reporting for a major acquisition project was typically expected to commence within 60 days following KDP-C approval.[49] Not only was Aerospace's STEEP monitoring of cost and schedule delayed as VIPER completed its KDP-C in March 2021, but the company did not provide SMD its first set of metrics until November 2021. As a result, NASA management did not have the benefit of this cost and schedule monitoring tool for decision-making until approximately 7 months after it could have had EVM.

Implementing EVM would have provided NASA managers with more accurate and complete cost and schedule performance information needed to make informed decisions on the allocation of resources. NASA policy and statements support and identify the value of EVM. Additionally, although we have not identified any overruns to date, cost overruns may not be detected by other performance monitoring controls because of incomplete baselines. Without an effective cost and schedule monitoring tool, NASA has less insight into cost and schedule variances during development of the VIPER project, which could result in delays in making risk-informed decisions.

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[47] NASA/SP-20210024466, *Earned Value Management (EVM) Implementation Handbook* (November 2021).

[48] *NASA Corrective Action Plan* (December 14, 2018).

[49] In August 2021, NASA changed the requirement for projects with estimated costs greater than $250 million to begin EVM reporting during Phase B of the project life cycle—a phase earlier than previously required.

CONCLUSION

NASA's development of the VIPER mission is a first-of-its-kind, potentially one-of-a-kind effort reliant on both a new contractor that has never developed a lunar lander and a more "hands-off" commercial acquisition strategy. Despite these challenges, we found that as of December 2021 both NASA and Astrobotic have made significant progress toward VIPER's scheduled November 2023 launch date. That said, NASA has increased the cost of its task order with Astrobotic for launch and delivery services of the Griffin Lander to the lunar surface by $36.1 million and risks to the overall mission remain as the VIPER project moves toward integration with Griffin and mission requirements are further refined.

At the same time, we are concerned about the potential precedent that NASA has set by establishing an ABC that lacks the cost of the CLPS task order that includes integration, launch, and delivery services to the Moon—a critical and integral element of the VIPER mission—thereby obscuring the full cost of the mission. Likewise, we believe SMD management would have benefitted from conducting a comprehensive, mission-wide JCL analysis and using EVM—two tools that NASA has shown to be of significant value—on this critical science project that will exceed $660 million. It is incumbent upon the Agency to timely apply the lessons learned from this project and ensure the consistent implementation of sound project management principles and tools on future major space flight acquisitions, regardless of which developmental policy they are managed under.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To enable more experience-based decision-making when collaborating with CLPS providers, we recommended NASA's Associate Administrator for Science Mission Directorate direct Planetary Science Division and VIPER project management to:

1. Coordinate with the Chief Knowledge Officer to submit and at appropriate intervals document and publish lessons learned associated with using a CLPS provider, particularly on major acquisitions.

In addition, to enable greater stakeholder transparency we recommended NASA's Associate Administrator for Science Mission Directorate in coordination with the Chief Financial Officer:

2. Develop a VIPER mission cost estimate that includes all critical mission components and risks, specifically associated with the Astrobotic task order, and update the MPAR accordingly.

To ensure consistency with major project development best practices, we also recommended NASA's Chief Engineer in coordination with the Agency's Chief Financial Officer and Mission Directorate Associate Administrators:

3. Update NPR 7120.8 to require major acquisition projects that cost over $250 million to complete a JCL analysis.

4. Update NPR 7120.8 to require major acquisition projects that cost over $250 million to implement EVM.

We provided a draft of this report to NASA management who concurred and partially concurred with Recommendations 1 and 2, respectively, and described planned actions to address them. We consider management's comments responsive; therefore, these recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions. Management did not concur with Recommendations 3 and 4 to update NPR 7120.8, but instead described a process whereby the respective Decision Authority would be advised by the newly established Office of the Chief Program Management Officer as to whether a new development project should follow requirements of NPR 7120.5 or NPR 7120.8 as well as the applicability of JCL and EVM by the Office of the Chief Financial Officer. While we find this proposal somewhat promising, these recommendations remain unresolved pending further discussion with the Agency regarding implementation details.

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

Major contributors to this report include Raymond Tolomeo, Science and Aeronautics Research Director; Mindy Vuong, Project Manager; Jiang Yun Lu; Frank Martin; Jobenia Parker; and Lauren Suls.

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

PAUL MARTIN

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Paul K. Martin
Inspector General

Appendix A: Scope and Methodology

We performed this audit from January 2021 through March 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.

The scope of this audit included assessing NASA's management and oversight of the VIPER project relative to achieving technical objectives, meeting established milestones, and controlling costs. We evaluated whether the VIPER project is on track to meet both its technical and schedule milestones including the November 2023 launch date and its life-cycle cost estimate of $433.5 million (excluding the CLPS task order costs for integration, launch, and lunar delivery services) while meeting its level-1 requirements. We also assessed whether project management properly considered, tracked, and mitigated identified risks in developing the baseline cost and schedule.

In addition, we interviewed NASA personnel working on the VIPER project and CLPS initiative at Ames Research Center, Glenn Research Center, NASA Headquarters, and Johnson Space Center. We also interviewed personnel from Astrobotic, the VRT, and NASA OCFO. We reviewed the active risks provided by the VIPER project's risk management system as of July 2021. For a select number of these risks identified as "Top Level," we reviewed risk management reports for consequence and likelihood ratings, mitigation plans, and status updates; interviewed project personnel; and reviewed other relevant documents, such as discussions provided in monthly status reports and independent assessments. We obtained and examined internal and external applicable documents related to the VIPER project.

Finally, we reviewed federal and NASA criteria, policies, and procedures and supporting documentation; prior audit reports; external reviews; and other documents related to the VIPER project. The documents we reviewed included, but were not limited to, the following:

- President Trump, *National Space Policy of the United States of America* (December 9, 2020)
- Consolidated Appropriations Act, 2020, Pub. L. No. 116-93 (2019)
- Commercial Space Act of 1998, Pub. L. No. 105-303 (1998)
- NPR 7123.1C, *NASA Systems Engineering Processes and Requirements (w/Change 1)* (February 14, 2020)
- NPR 7120.8A, *NASA Research and Technology Program and Project Management Requirements (Updated w/Change 2)* (September 14, 2018)
- NASA Procedural Requirements 8000.4B, *Agency Risk Management Procedural Requirements* (December 6, 2017)
- NASA/SP-2016-6105 Rev 2, *NASA Systems Engineering Handbook* (February 2017)
- NASA/SP-2014-3705, *NASA Space Flight Program and Project Management Handbook* (September 2014)
- NASA/SP-2011-3422, *NASA Risk Management Handbook* (November 2011)

- Ames Technical Standard ARC-STD-8070.1, *Space Flight System Design and Environmental Test* (December 18, 2018)
- NASA Associate Administrator, memorandum to Officials-in-Charge of Headquarters Offices and Directors of NASA Centers, *Independent Assessment of NASA Programs and Projects* (October 26, 2015)
- Aerospace Safety Advisory Panel, *Annual Report for 2020* (January 1, 2021)

Assessment of Data Reliability

We used limited computer-processed data such as risk detail reports produced from the VIPER project's risk management system, performance metrics, and cost and schedule data. Generally, we concluded the data was valid and reliable for the purposes of the review.

Review of Internal Controls

We reviewed internal controls associated with NASA's management of the VIPER project relative to achieving technical objectives, meeting established milestones, and controlling costs. Control weaknesses are identified and discussed in this report. Our recommendations, if implemented, will improve those identified weaknesses.

Prior Coverage

During the last 5 years, the NASA Office of Inspector General; Government Accountability Office; and National Academies of Sciences, Engineering, and Medicine have issued 14 reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html, https://www.gao.gov, and https://www.nationalacademies.org/publications respectively.

NASA Office of Inspector General

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

2021 Report on NASA's Top Management and Performance Challenges (November 15, 2021)

COVID-19 Impacts on NASA's Major Programs and Projects (IG-21-016, March 31, 2021)

2020 Report on NASA's Top Management and Performance Challenges (November 12, 2020)

NASA's Planetary Science Portfolio (IG-20-023, September 16, 2020)

2019 Report on NASA's Top Management and Performance Challenges (November 13, 2019)

NASA's Heliophysics Portfolio (IG-19-018, May 7, 2019)

NASA's 2017 Top Management and Performance Challenges (November 6, 2017)

Government Accountability Office

NASA LUNAR PROGRAMS: Significant Work Remains, Underscoring Challenges to Achieving Moon Landing in 2024 (GAO-21-330, May 26, 2021)

NASA: Assessments of Major Projects (GAO-21-306, May 20, 2021)

National Academies of Sciences, Engineering, and Medicine

Report Series: Committee on Astrobiology and Planetary Science, Review of the Commercial Aspects of NASA SMD's Lunar Science and Exploration Initiative (2019)

Report Series: Committee on Astrobiology and Planetary Science, Review of the Planetary Science Aspects of NASA SMD's Lunar Science and Exploration Initiative (2019)

Visions into Voyages for Planetary Science in the Decade 2013-2022: A Midterm Review (2018)

Report Series: Committee on Astrobiology and Planetary Science, Getting Ready for the Next Planetary Science Decadal Survey (2017)

APPENDIX B: MANAGEMENT'S COMMENTS

National Aeronautics and
Space Administration

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

April 1, 2022

Reply to Attn of: Science Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Science Mission Directorate
Chief Engineer
Chief Financial Officer

SUBJECT: Agency Response to OIG Draft Report, "NASA's Volatiles Investigating Polar Exploration Rover Mission" (A-21-009-00)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Volatiles Investigating Polar Exploration Rover Mission" (A-21-009-00), dated March 4, 2022.

In the draft report, the OIG makes four recommendations addressed to NASA intended to increase the sustainability, accountability, and transparency of the Volatiles Investigating Polar Exploration Rover (VIPER) Program.

Specifically, the OIG recommends the following:

To enable more experience-based decision-making when collaborating with Commercial Lunar Payload Services (CLPS) providers, the OIG recommends the Associate Administrator for the Science Mission Directorate (SMD) direct the Planetary Science Division and VIPER project management to:

Recommendation 1: Coordinate with the Chief Knowledge Officer to submit and at appropriate intervals document and publish lessons learned associated with using a CLPS provider, particularly on major acquisitions.

Management's Response: Concur. SMD will coordinate with the Chief Knowledge Officer and document lessons learned associated with using a CLPS provider for delivery to the Moon, particularly on major acquisitions. CLPS has already begun implementing lessons learned before the first delivery is made. Lessons learned on formulation and early CLPS development will be accomplished by December 2022. Additional lessons learned will be documented after VIPER delivery.

Anticipated Completion Date: December 31, 2022

To enable greater stakeholder transparency, the OIG recommends the NASA Associate Administrator for the Science Mission Directorate in coordination with the Chief Financial Officer:

Recommendation 2: Develop a VIPER mission cost estimate that includes all critical mission components and risks, specifically associated with the Astrobotic task order, and update the MPAR accordingly.

Management's Response: Partial concur. NASA embraces transparency and accountability throughout the design development and operation of our programs.

NASA has consistently maintained documentation of both the CLPS delivery service cost and the VIPER Agency Baseline Commitment (ABC) in NASA's decision memoranda at key decision points to reflect the total cost of the mission in a single document. The VIPER payload will be accommodated on CLPS Task Order (TO) 20A, which contracts Astrobotic to deliver the VIPER rover. VIPER's Key Decision Point-C Decision Memorandum included both the CLPS TO cost to deliver VIPER ($226.5M) and the VIPER ABC ($433.5M). The CLPS TO has since been increased by NASA to $235.65M, a cost which is reported annually in the publicly available congressional justification and will be included on subsequent project decision memoranda.

NASA acknowledges the intent of the Inspector General's recommendation which is to ensure costs associated with major acquisitions are publicly available for performance tracking. This can be accomplished in several ways such as including CLPS delivery in the VIPER ABC, tracking delivery costs of CLPS as part of a CLPS program similar to ISS payloads, as well as other options consistent with NASA best practices. NASA will study the options and implement a solution to ensure transparency.

Estimated Completion Date: March 31, 2023

To ensure consistency with major project development best practices, the OIG also recommends the Chief Engineer in coordination with the Chief Financial Officer and Mission Directorate Associate Administrators:

Recommendation 3: Update NPR 7120.8 to require major acquisition projects that cost over $250 million to complete a JCL analysis.

Management's Response: Non-concur. NASA Procedural Requirements (NPR) 7120.8 policy follows a different philosophy than NPR 7120.5, which compiles a comprehensive set of requirements for space flight that may need to be tailored down for smaller scale efforts that are not crewed. NPR 7120.8 applies the principle of a minimum set of essential requirements and maximum flexibility for Research and Technology (R&T) development programs and projects that tend to be exploratory, requiring more management flexibility, and tend to have higher risk acceptance by the Agency. Rather than tailoring down from the directive's requirements, R&T projects may need to pull in additional requirements from NPR 7120.5 for more robust or structured project management, particularly on larger projects or projects that may transition to flight.

Specifically concerning cost and schedule requirements, NPR 7120.8 does not specify any required probabilistic analysis technique.

In January 2022, NASA designated a Chief Program Management Officer, a new role to cover the Program Management Improvement Officer functions and additional functions to strengthen NASA's enterprise-wide oversight, management, and implementation of program management policies and best practices across the agency. Going forward, for major acquisition projects, and in concert to Authority to Proceed, NASA's Chief Program Management Officer will advise project Decision Authority (DA) on applicability of the project following NPR 7120.5 or NPR 7120.8 and the Office of Chief Financial Officer will advise the project and DA on if Joint Confidence Level (JCL) requirement should be applied.

Estimated Completion Date: N/A

Recommendation 4: Update NPR 7120.8 to require major acquisition projects that cost over $250 million to implement EVM.

Management's Response: Non-concur. NPR 7120.8 policy follows a different philosophy than NPR 7120.5, which compiles a comprehensive set of requirements for space flight that may need to be tailored down for smaller scale efforts that are not crewed. NPR 7120.8 applies the principle of a minimum set of essential requirements and maximum flexibility for R&T development programs and projects that tend to be exploratory, requiring more management flexibility, and tend to have higher risk acceptance by the Agency. Rather than tailoring down from the directive's requirements, R&T projects may need to pull in additional requirements from NPR 7120.5 for more robust or structured project management, particularly on larger projects or projects that may transition to flight. Specifically concerning EVM, NPR 7120.8 provides projects flexibility on how to track cost and schedule metrics *(Section 4.2.7.6 Cost and Schedule Metrics. The form of these metrics will vary depending on the type of project. For example, costs may be tracked using Earned Value Management (EVM) for very large projects or may be a comparison of planned costs versus actual costs. Schedule tracking may be performed using an integrated master schedule or through tracking key milestones. The metrics should be periodically reviewed to ensure the cost and schedule are progressing according to plan and is under control)).*

In January 2022, NASA designated a Chief Program Management Officer, a new role to cover the Program Management Improvement Officer functions and additional functions to strengthen NASA's enterprise-wide oversight, management, and implementation of program management policies and best practices across the Agency. Going forward, for major acquisition projects, and in concert to Authority to Proceed, NASA's Chief Program Management Officer will advise project DA on applicability of the project following NPR 7120.5 or NPR 7120.8 and the Office of Chief Financial Officer will advise the project and DA on if EVM requirement should be applied.

Estimated Completion Date: N/A

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 Peter Meister at (202) 358-1557.

Sandra Connelly Digitally signed by Sandra Connelly
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Dr. Thomas Zurbuchen

APPENDIX C: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
Chief Engineer
Chief Financial Officer
Chief Knowledge Officer
Chief Program Management Officer
Associate Administrator for Aeronautics Research Mission Directorate
Associate Administrator for Exploration Systems Development Mission Directorate
Associate Administrator for Science Mission Directorate
Associate Administrator for Space Operations Mission Directorate
Associate Administrator for Space Technology Mission Directorate

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Climate, Energy, Environment and Science Division

Government Accountability Office
    Director, Contracting and National Security Acquisitions

Congressional Committees and Subcommittees, Chairman and Ranking Member

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

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

Senate Committee on Homeland Security and Governmental Affairs

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

House Committee on Oversight and Reform
    Subcommittee on Government Operations

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

(Assignment No. A-21-009-00)