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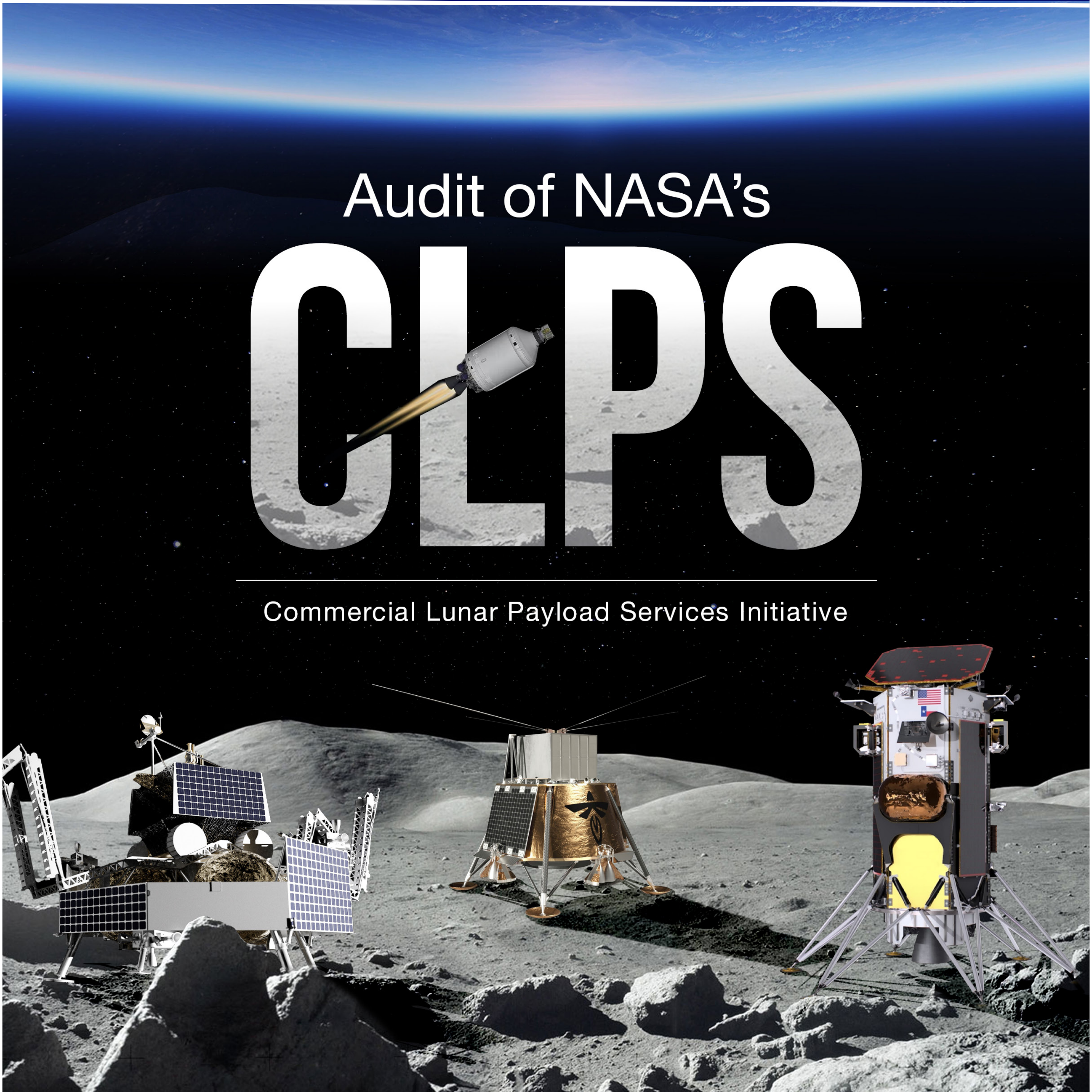

Audit of NASA's CLPS

Commercial Lunar Payload Services Initiative

June 6, 2024

IG-24-013

Office of Inspector General

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RESULTS IN BRIEF

NASA's Commercial Lunar Payload Services Initiative

June 6, 2024 IG-24-013 (A-23-11-00-SARD)

WHY WE PERFORMED THIS AUDIT

NASA began the Commercial Lunar Payload Services (CLPS) initiative as an innovative commercial acquisition approach to enable rapid, affordable, and frequent payload deliveries to the Moon. Rather than closely controlling missions itself, NASA transferred much of the responsibility and risk to the CLPS commercial vendors. CLPS expands NASA's efforts to jump-start lunar commerce and enable a robust lunar delivery industry. Under CLPS, vendors design lunar landers that can meet NASA's needs and procure their own launch vehicles. NASA then works with scientists to build instruments that will conduct lunar science and technology experiments aboard CLPS missions, some of which will support the Artemis campaign. NASA also decides which of its instruments will go on each lander and their lunar landing locations. Vendors may have the opportunity to contract with commercial and international entities to deliver additional payloads to the Moon. The Agency planned to use low-cost, non-critical instruments on initial CLPS deliveries and to develop small- and medium-size landers before proceeding to larger landers for more complex payloads.

NASA selected a pool of 14 commercial vendors to compete and bid on firm-fixed-price task orders. This means the contractor, not NASA, is responsible for the full scope of payload delivery to the Moon. NASA's plan for the CLPS initiative was to award two task orders per year, leading to two lunar deliveries per year. The first round of task orders was awarded in May 2019, with an anticipated first delivery in 2021. As of early 2024, two vendors have launched CLPS missions. The first, Astrobotic's Peregrine lander, failed to make it to the Moon. The second, Intuitive Machine's Nova-C lander, successfully landed on the lunar surface but tipped over onto its side.

In this audit, we assessed the effectiveness of NASA's implementation and management of the CLPS initiative. Specifically, we examined whether NASA's organizational, programmatic, and acquisition approaches were effective in achieving its goals and objectives. We also evaluated progress made, lessons learned, and the effectiveness of NASA's cost and schedule controls. We performed work at Johnson Space Center and NASA Headquarters and conducted site visits at two vendor locations. We interviewed NASA officials from the CLPS initiative, Science Mission Directorate (SMD), the Exploration Systems Development Mission Directorate, and the Space Technology Mission Directorate. To assess benefits and challenges vendors face, we surveyed 13 CLPS vendors and received 8 responses. Finally, we reviewed internal and external CLPS documents, NASA policies and procedures, and other related documents.

WHAT WE FOUND

Despite progress made toward CLPS objectives, numerous challenges have resulted in total initiative cost increases of $208.2 million and an average schedule delay of 14 months per task order. Specifically, five of eight task orders have experienced both schedule delays and price increases since the initiative began in 2018.

Our review found that NASA deviated from its original, hands-off strategy for the initiative and from its plan for incremental progress towards larger missions. Rather, the Agency's aggressive lander development schedules led to increasingly risk-averse practices and policies. For example, NASA insight and oversight increased, and more detailed vendor proposals were required. This resulted in higher costs and delayed delivery schedules while threatening the initiative's ability to achieve its broad objectives. Specifically, inserting a larger lander to accommodate the Volatiles Investigating Polar Exploration Rover (VIPER) into CLPS's early schedule interfered with a progressive development approach. This introduced the added risk of beginning the first large lander delivery before knowledge could be gained from the success (or failure) of smaller deliveries. NASA's planned hands-off approach was also somewhat negated when the Agency added augmented insight and placed added requirements on the vendors' development process. We found that NASA-directed changes, including augmented insight and landing site changes, led to $171.4 million in project cost increases.

NASA officials also set aggressive lunar lander delivery schedules—averaging 30 months from contract award to launch—based on overly optimistic market research studies. This optimistic scheduling did not provide a sufficient margin for unforeseen events such as vendors' supply constraints or technological development challenges. Consequently, seven of the eight task orders have experienced schedule delays as of February 2024, and the average time to launch has been 44 months. NASA chose firm-fixed-price contracts for CLPS even though the initiative's operational conditions were not suitable for the optimal use of these contracts. Optimal conditions include well-defined requirements, a stable market, low financial and technical risks, and experienced contractors. In fact, vendor issues arising from inexperience, financial risk, and lunar delivery being a new economic sector contributed to cost increases and schedule delays. Several vendors faced technical difficulties in developing their landers. Financial pressures affecting these small, relatively new companies contributed to one CLPS vendor bankruptcy and continuing market uncertainty for the others. Vendors also struggled to obtain launch vehicles, which led to additional delays. Finally, the COVID-19 pandemic affected schedule deadlines and vendors' ability to procure vital parts and materials in early task orders.

Our analysis showed these challenges will continue to hinder NASA's ability to meet the initiative's objectives. While the initiative has a contract capped at $2.6 billion through 2028, increased costs on previous task orders jeopardize the plan to issue two task orders per year. Future missions with increased complexity will put further strain on the CLPS budget. Yet, frequent task orders are required to keep the vendors engaged and invested in the lunar delivery economy. We surveyed CLPS vendors, and their responses discussed vendor challenges, including an uncertain commercial market and competition within the vendor pool to win NASA task orders. In the 5 years since CLPS began, NASA has not reassessed market conditions to better understand the Agency's role and changing market conditions. Finally, we found CLPS lacks a detailed management plan that could outline a disciplined approach, promote accountability for how the Agency measures success, and help the initiative weigh competing priorities.

WHAT WE RECOMMENDED

We made six recommendations to improve the CLPS initiative. To increase accountability and transparency for CLPS, we recommended the Associate Administrator for SMD 1) conduct updated market research on the commercial lunar economy and 2) reassess NASA's role in the commercial lunar delivery market. We also recommended that the Deputy Associate Administrator (DAA) for Exploration 3) finalize a management plan for the CLPS initiative with clear performance goals and metrics, a formal lessons-learned process, and other relevant guidelines. We also recommended the DAA for Exploration coordinate with other directorates to 4) prepare and formalize a CLPS Manifest Selection Board charter and process and 5) strengthen procedures to ensure payload interfaces and requirements are mature enough to minimize changes late in the development process. Finally, we recommended the DAA for Exploration, in coordination with the CLPS and VIPER project managers, 6) assess implications of the first Peregrine lander failure on the VIPER mission and impacts to the CLPS initiative's cost and schedule.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned actions to address them. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

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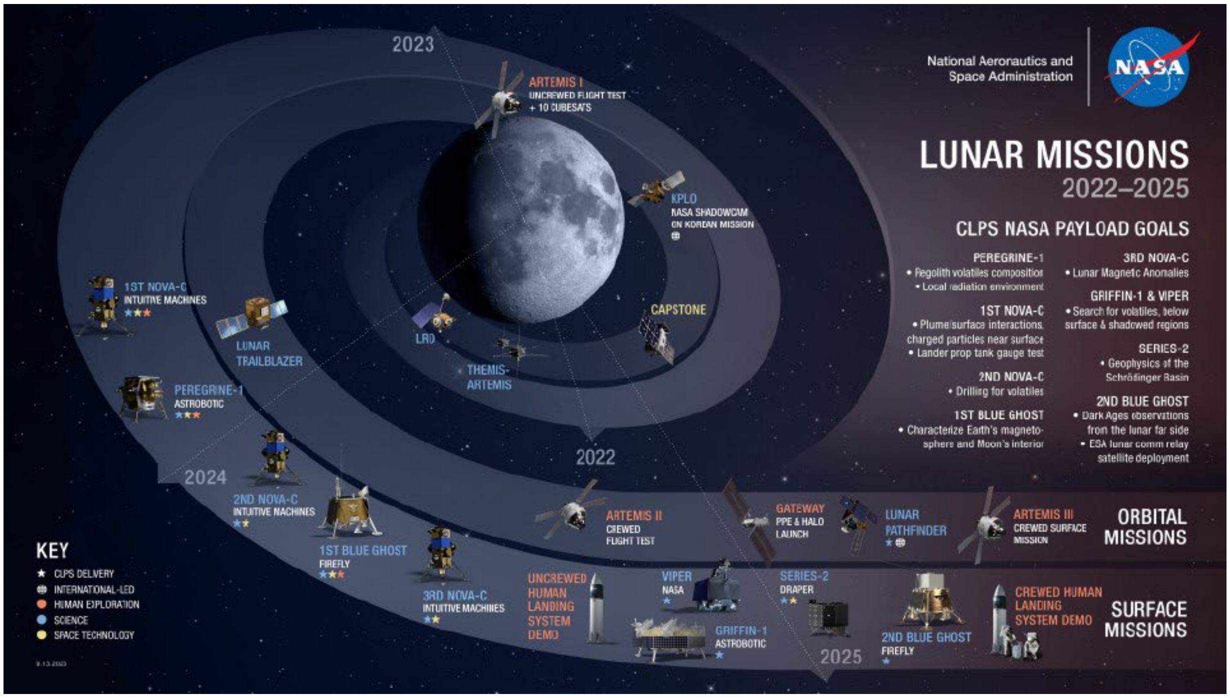
Acronyms

CLIMs	CLPS Integration Managers
CLPS	Commercial Lunar Payload Services
ESA	European Space Agency
ESDMD	Exploration Systems Development Mission Directorate
ESSIO	Exploration Science Strategy and Integration Office
FFP	firm-fixed-price
FY	fiscal year
GAO	Government Accountability Office
LDEP	Lunar Discovery and Exploration Program
LRO	Lunar Reconnaissance Orbiter
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
PMPO	Planetary Missions Program Office
PRISM	Payloads and Research Investigations on the Surface of the Moon
RFTP	request for task plan
SMD	Science Mission Directorate
SOMD	Space Operations Mission Directorate
STMD	Space Technology Mission Directorate
ULA	United Launch Alliance
VIPER	Volatiles Investigating Polar Exploration Rover

INTRODUCTION

NASA's Commercial Lunar Payload Services (CLPS) initiative is designed to use commercially developed spacecraft and landers to deliver research instruments and technologies to the Moon's orbit and surface. In 2018, the Agency created the Lunar Discovery and Exploration Program (LDEP) within the Science Mission Directorate (SMD) to support innovative approaches to achieve human and science exploration goals. The Program manages the Lunar Reconnaissance Orbiter (LRO) and funds the development of Volatiles Investigating Polar Exploration Rover (VIPER) and other long-duration lunar missions.[1] As part of this effort, the Program also manages the CLPS initiative. LDEP funds a portfolio that includes development of small rovers and instruments and commercial contracts for lunar landing transportation services issued by the CLPS project office located at Johnson Space Center (Johnson). Figure 1 below illustrates NASA's planned missions and lunar payload delivery goals from 2022 to 2025.[2]

Figure 1: NASA's Planned Lunar Missions (as of December 2023)



Source: NASA.

Note: Astrobotic's Peregrine 1 and Intuitive Machines' Nova-C were launched in January 2024 and February 2024, respectively.

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[1] NASA launched LRO in June 2009 as the first mission in its plan to return to the Moon. LRO's mission was to orbit the Moon for 1 year to measure lunar topography, resources, temperatures, and radiation. It is still in operation as of February 2024. VIPER is a robotic lunar rover that will explore the Moon in search of water ice and other potential volatile resources. See NASA Office of Inspector General (OIG), *NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission* (IG-22-010, April 6, 2022) for more details.

[2] In January 2024, NASA announced changes to the Artemis missions and associated components that would delay Artemis II to target a launch in September 2025 and Artemis III to September 2026.

Since the CLPS initiative began in 2018, NASA has developed a pool of 14 U.S. commercial vendors that are included on an indefinite-delivery, indefinite-quantity contract with a cumulative contract value of $2.6 billion through 2028 and are allowed to compete for CLPS task orders. NASA awarded the first round of these task orders in May 2019. The requested CLPS budget is $224.1 million for fiscal year (FY) 2024 and ranges from $254.4 million to $259.5 million for the next 4 FYs. In early 2024, two vendors, Astrobotic Technology (Astrobotic) and Intuitive Machines, launched two CLPS missions—the first failing to make it to the Moon due to a lander anomaly and the second successfully landing on the lunar surface, but tipping over onto its side.

We initiated this audit to assess the effectiveness of NASA's implementation and management of the CLPS initiative. Specifically, we assessed whether NASA's organizational, programmatic, and acquisition approaches were effective in achieving its goals and objectives. We also evaluated progress made to date, any lessons learned, and whether CLPS was meeting its established goals and priorities, with the intention to make recommendations for improving the initiative. See Appendix A for details of the audit's scope and methodology.

Background

NASA describes CLPS as an innovative, service-based, competitive commercial acquisition approach that enables rapid, affordable, and frequent access to the lunar surface using a growing market of American commercial providers. CLPS attempts to model common delivery services such as FedEx or the United Parcel Service to the extent practical. NASA is responsible for selecting payloads and awarding them through a competitive process to contractors (referred to as CLPS vendors), who are expected to build landers and fly them to the lunar surface. Vendors are also expected to provide utility services such as power and communications during launch, cruise, and the period of operations at the Moon as designated in their specific task orders.

CLPS deliveries are contractor missions, not NASA's. CLPS vendors are responsible for developing new lander technologies and providing delivery of payloads to the lunar surface without NASA controlling or overseeing the contractors' designs, systems, processes, or infrastructure. CLPS vendors secure all necessary hardware, systems, facilities, and services to perform the delivery. Vendors are also responsible for acquiring commercial launch services licensed by the Federal Aviation Administration, Federal Communications Commission, and other regulatory agencies. The CLPS project office plans to award two task orders annually to enable two Moon landing attempts per year for NASA payloads. According to NASA officials, this delivery cadence is intended to support the commercial vendors and incentivize them to remain competitive through continued investment in the initiative.

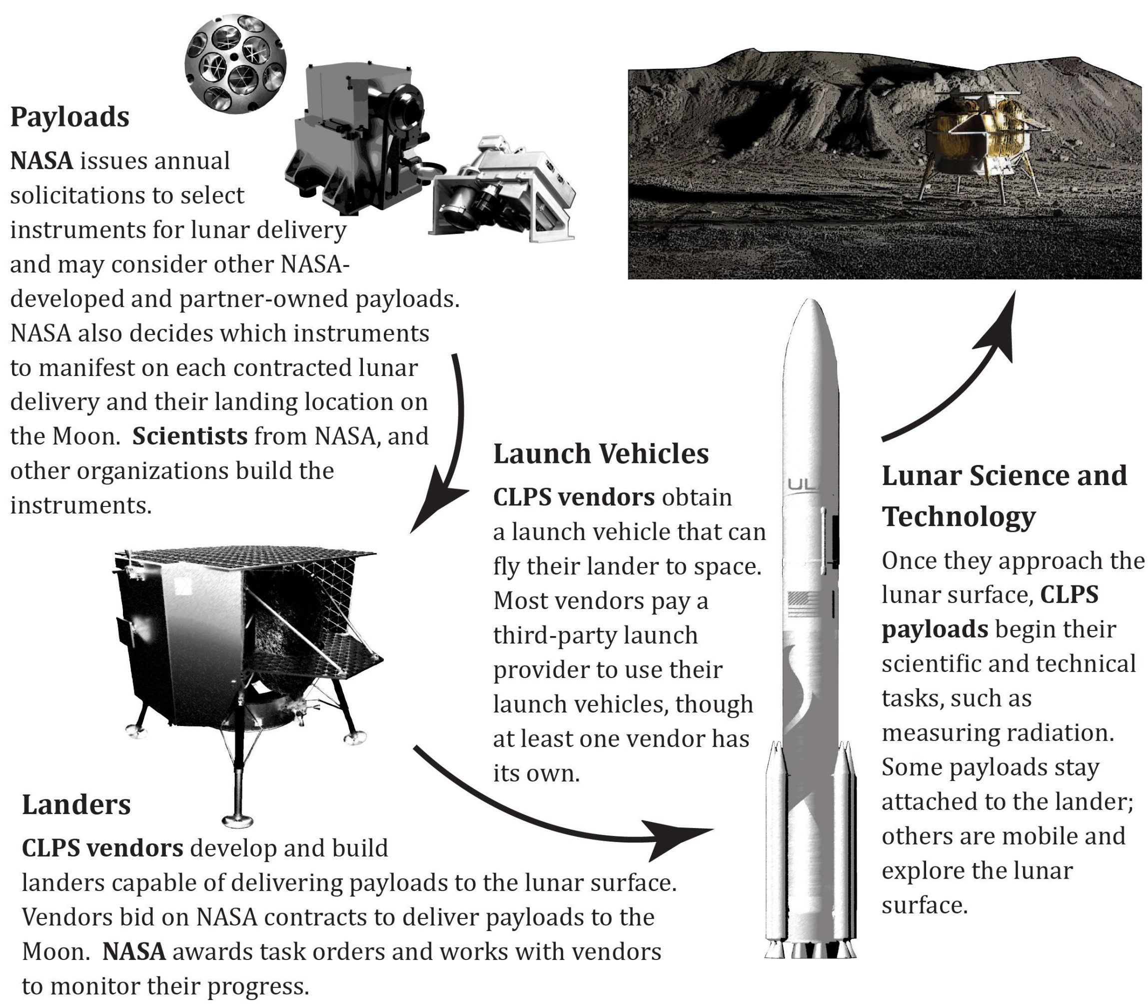
Service task orders are firm-fixed-price (FFP) contracts for the full scope of payload delivery—from payload handover to delivery and operation on the lunar surface or in cislunar space (end-to-end delivery).[3] Since these are commercial service contracts, NASA agrees to accept the risk of vendor-managed payload delivery missions with less engagement or insight than what is customary for a traditional NASA program. NASA imposes no Agency policies that would normally apply to a NASA

[3] Per Federal Acquisition Regulation, 16.202-1, "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. This contract type places upon the contractor maximum risk and full responsibility for all costs and resulting profit or loss." Cislunar space refers to the region of space from the Earth out to and including the region around the surface of the Moon.

mission.[4] This includes launch vehicle procurement, communication, and navigation systems. NASA has contractual authority and some technical insight roles for CLPS task orders, but these roles are purposely less invasive than traditional NASA contracting approaches because each task order is FFP. Ideally, NASA wants to be one of many customers for CLPS services and for CLPS vendors to fly missions to the Moon with and without NASA payloads.

The CLPS model shown in Figure 2 is different from NASA's traditional approach. Specifically, NASA typically provided the vehicles that carried NASA-funded experiments to space. NASA-provided vehicles are often developed in conjunction with the NASA payload to optimize scientific return from the NASA experiment. While early CLPS task orders have payload development occurring in conjunction with first time development of new landers, it is CLPS's future intention to buy "off the shelf" commercial landers and for NASA payloads to optimize their science and fit the lander regardless of the lander's design.

Figure 2: Components of a CLPS Delivery



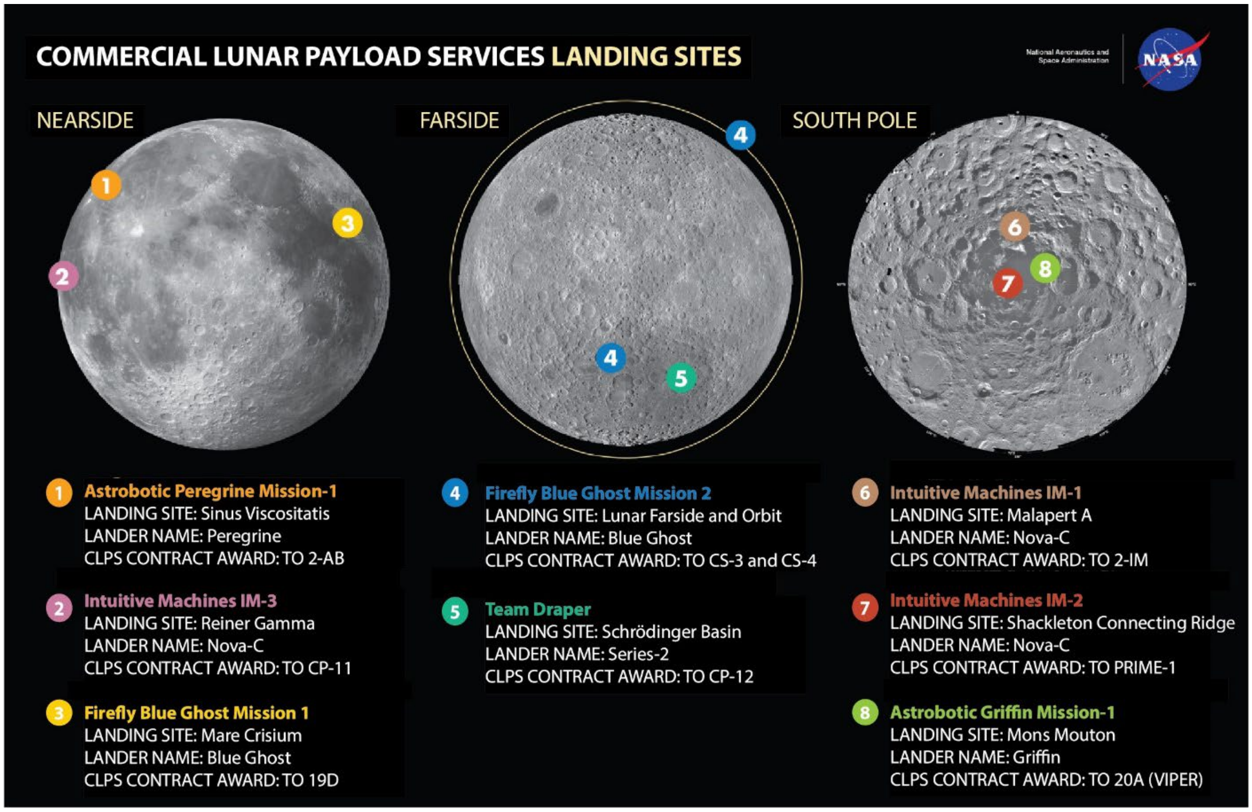
Source: NASA Office of Inspector General (OIG) analysis of NASA processes.

[4] Some policies related to the procurement process and structure are built into the individual task orders, such as the requirement for missions to be launched on vehicles manufactured in the United States.

CLPS expands NASA's efforts to jump-start lunar commerce and enable a robust lunar delivery industry. In fostering the development of this market for the benefit of the Agency and the U.S. economy, NASA hopes to develop a community of commercial service providers for its Artemis campaign.[5] These efforts consist of encouraging space industry participation to leverage Agency investments in commercial lunar landers and expand economic activity to the Moon. Some commercial innovations encouraged or enabled by CLPS include a lunar data center, lunar communication relays, and new 3D-printed parts. Indicators of a growing and sustainable lunar commerce include vendors that fly non-NASA payloads, missions to the lunar surface without a NASA contract, and task orders that increase the depth of the lunar industry supply chain.

The CLPS contract has a maximum value of $2.6 billion through 2028. However, the proposed budget is only $2.19 billion through 2028. Since 2018, NASA has awarded 10 delivery task orders to 6 of the 14 eligible vendors (see Appendix B).[6] However, the Orbit Beyond task order was terminated 2 months after award, and another vendor, Masten Space Systems, filed for bankruptcy in 2022. The remaining eight task orders, including the two recently launched missions, have a total value of approximately $1 billion. Figure 3 depicts the 8 planned flights' lunar landing locations.

Figure 3: Planned CLPS Lunar Landing Locations (as of January 2024)



Source: NASA.

[5] NASA established the Artemis missions to develop systems that will be used to enable humans to live and operate in deep space, land on the Moon, explore the lunar surface, and prepare for Mars exploration.

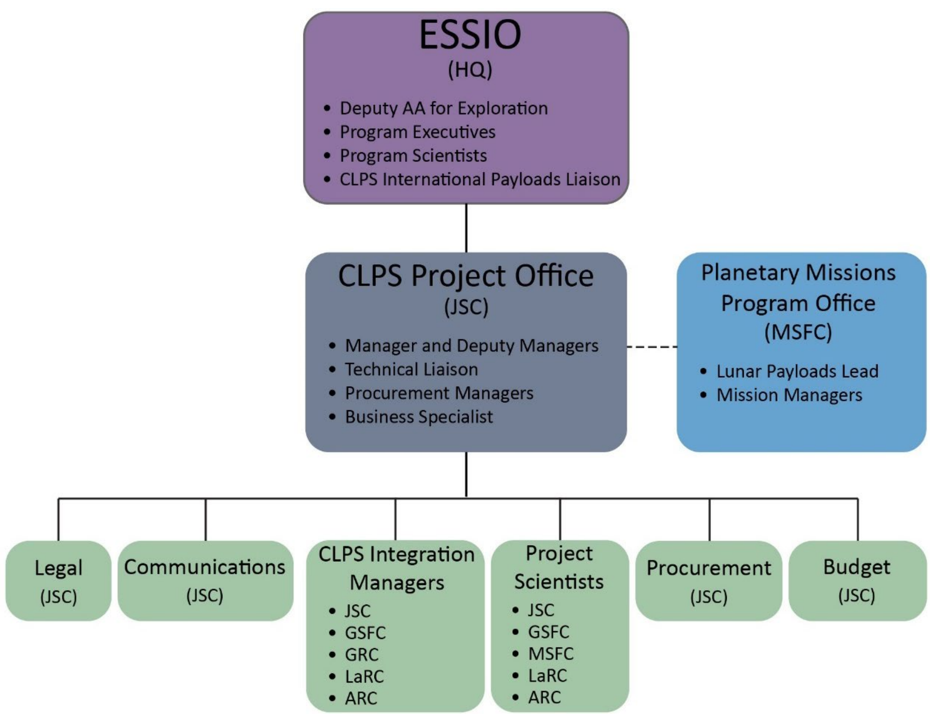
[6] In addition to delivery task orders, the CLPS project office also issued three non-delivery tasks orders that provide additional capabilities for existing delivery missions, such as for advance planning, feasibility studies, or hardware development. For example, NASA awarded Firefly Aerospace an additional $18.4-million task order to provide radio frequency calibration services from lunar orbit as part of their planned January 2026 mission.

Organizational Structure and Operation

As part of the LDEP portfolio, the CLPS initiative is managed under the purview of the Deputy Associate Administrator for Exploration within SMD, who leads the Exploration Science Strategy and Integration Office (ESSIO). The office provides directions related to payload manifesting, landing site selections, budget, and technical guidance to the CLPS project office at Johnson. ESSIO program executives and scientists provide additional support in managing CLPS technical, scientific, budget, and stakeholder communications. This includes coordinating with NASA's other mission directorates, the scientific community, commercial vendors, and the CLPS project office. ESSIO also manages risk exposure without managing the underlying risks associated with CLPS task orders, such as component development delays that impact the task orders' delivery schedules. ESSIO provides funding, as well as technical and schedule guidance, to the CLPS project office. Other participating mission directorates provide funding when required.

The CLPS project office is primarily responsible for developing payload accommodation requirements for lunar deliveries. It also manages and executes the request for task plan (RFTP) process (see the "Delivery" process discussion on page 7), selects the CLPS commercial providers for the delivery of payloads to lunar orbit and the lunar surface, monitors lander development progress, and supports payload integration activities. Although the project office is a major component supporting NASA's CLPS initiative, it is independent from the science payload selection and delivery manifest selection processes. The project office consists of about 30 staff members, some assigned part-time, from Johnson and other NASA Centers as shown in Figure 4.

Figure 4: CLPS Organizational Chart (as of February 2024)



Source: NASA OIG presentation of Agency information.

Note: HQ: Headquarters; JSC: Johnson Space Center; MSFC: Marshall Space Flight Center; GSFC: Goddard Space Flight Center; GRC: Glenn Research Center; LaRC: Langley Research Center; ARC: Ames Research Center.

The CLPS project manager and deputy project managers are responsible for (1) overall planning and execution of CLPS procurement processes, budget, schedule, and technical activities and (2) managing CLPS project activities. One of the deputy project managers also serves as the contracting officer representative for task orders. The CLPS project manager and deputy project managers report to the Director of the Exploration Architecture, Integration, and Science Directorate at Johnson and the Deputy Associate Administrator for Exploration at NASA Headquarters.

The Planetary Missions Program Office (PMPO) at Marshall Space Flight Center operates independently from the CLPS project office and is responsible for developing many of the payloads that are delivered to the CLPS vendors. PMPO manages payloads from Payloads and Research Investigations on the Surface of the Moon (PRISM) and Lunar Surface Instrument and Technology Payloads solicitations (discussed in the following section). The PMPO payloads mission manager oversees payload development costs, schedules, and risks to ensure payloads meet interface requirements.[7] They also conduct contract milestone reviews, including approving milestone payments to instrument developers, and review the technical aspects of contract modifications.

Science Selection and Delivery Processes

NASA uses three processes that result in payloads delivered to the lunar environment—some of which can begin to address decadal survey questions.[8]

Selection. The PRISM solicitation process is SMD's primary method to select science investigations for future deliveries by CLPS vendors. NASA issues annual PRISM solicitations to the lunar science community seeking science-driven suites of instruments that would maximize the science done at high-priority locations on the lunar surface or in lunar orbit. From the solicitation responses, NASA then selects and funds principal investigator-led proposals for science candidate payloads, which can be instruments stationed on a stationary lander or a rover. The FY 2024 budget request for the first three solicitations, PRISM 1 through 3, was $54.5 million. Prior to PRISM, in 2019, science and technology payloads were selected from two other solicitation processes: (1) NASA Provided Lunar Payloads, which identified 13 instruments as ready or nearly ready to fly, and (2) Lunar Surface Instrument and Technology Payloads, which selected 12 instruments.

In addition to those selected via the SMD solicitation processes, payload candidates can also come from international partners who are represented by a "sponsoring" or "representative" NASA mission directorate. In most cases, NASA funds the cost for delivering international payloads—in exchange for other items or services via an international agreement—and includes that cost in the task order's delivery price. For example, NASA and the European Space Agency (ESA) signed an international agreement where CLPS will launch and deliver ESA's Lunar Pathfinder to lunar orbit in exchange for ESA providing NASA communication services via Lunar Pathfinder.[9]

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7 An interface requirement defines the functional, performance, environmental, human, and physical requirements and constraints that exist at a common boundary between two or more functions, system elements, configuration items, or systems, such as where and how the payload mates to the lander.

8 Decadal surveys are community-based studies that look forward to the next 10 years of research in a particular discipline. They are valuable to NASA for the consensus-building process that determines priorities for research and for specific missions within a research discipline. The National Academies' Space Studies Board prepares decadal surveys.

9 ESA's Lunar Pathfinder is on the manifest for Firefly's Blue Ghost-2 mission.

Besides SMD, the Space Technology Mission Directorate (STMD), Exploration Systems Development Mission Directorate (ESDMD), and Space Operations Mission Directorates (SOMD) can also select and submit payloads for CLPS missions. In 2020, SMD established a memorandum of understanding with these directorates to provide them with payload allocations for inclusion in CLPS manifests.[10] For example, STMD has numerous CLPS payload candidates that advance and prove technologies required for human lunar exploration. However, priority for CLPS delivery has generally been given to science-related payloads. These payloads are chosen according to NASA priorities and the available budget from each directorate. In addition to NASA-led payloads, these solicitations also provide opportunities for academia and private companies to lead payload investigation missions. Table 1 lists the number of payloads selected per directorate, along with how many are NASA led, non-NASA led, and international partners.

Table 1: Payloads by Focus Area and Entity (as of December 2023)

Focus Area	NASA Led	Non-NASA Led (Private and Academia)	International	Total Number of Payloads
Science	22	13	—	35
Technology	6	4	—	10
Exploration	5	—	—	5
International	N/A	—	3	3
Total	**33**	**17**	**3**	**53**

Source: NASA OIG analysis of Agency information.

Manifest. Once NASA has a list of candidate payloads, the CLPS Manifest Selection Board refines the list.[11] The Board verifies that payload candidates have a mature and complete set of delivery requirements to mitigate future requirement changes that could result in costly contract modifications. The Board then creates suites of payloads, or manifests, across several CLPS deliveries. Once the Board determines that each proposed payload manifest significantly addresses Agency objectives and that payloads within the suite are compatible with each other, the manifest is finalized and turned over to the CLPS project office.

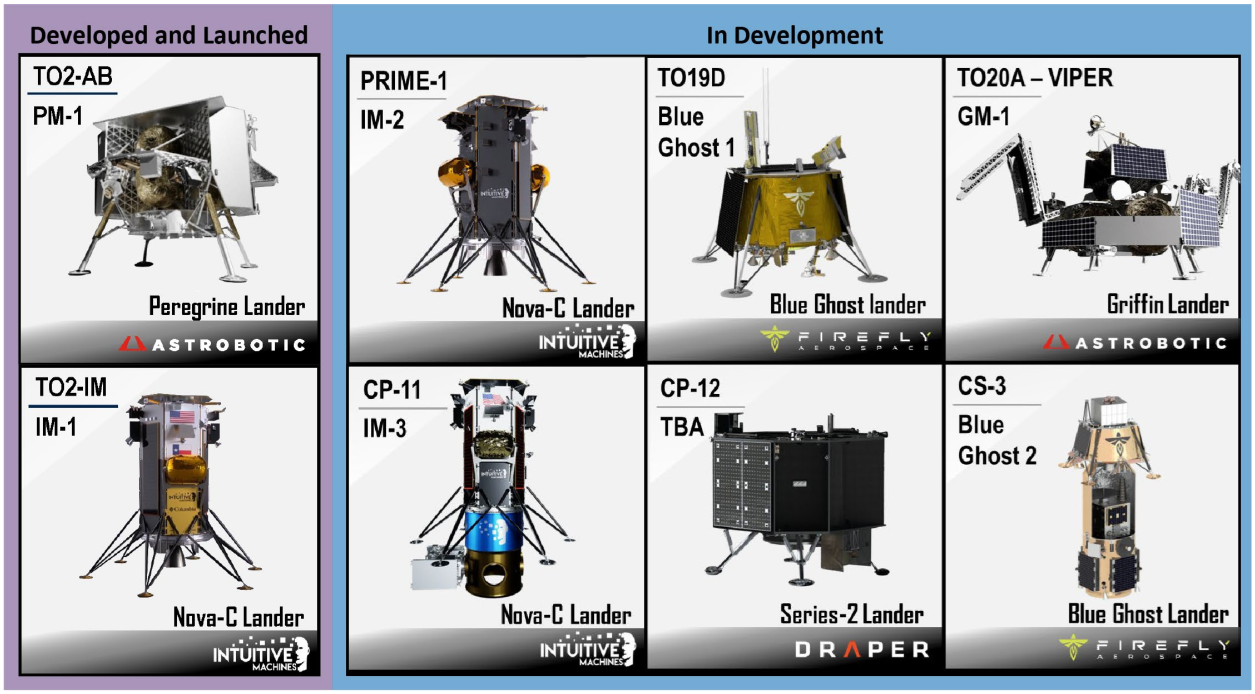
Delivery. After the CLPS project office receives the flight manifest, it develops a draft RFTP outlining the objectives of the proposed lunar delivery, including a description of the payloads that will be flown on the mission. The draft RFTP is then released to CLPS vendors. NASA then hosts a payload workshop for the pool of eligible and interested vendors to ask questions and gather information concerning the proposed mission. After the workshop, a final RFTP is released, and interested vendors can submit their delivery proposals. NASA evaluates these submissions and awards a task order to the winning vendor.

As of April 2024, four vendors have developed or are developing eight landers to deliver these manifested payloads, as shown in Figure 5.

[10] The original agreement was made with the Human Exploration and Operations Mission Directorate, which was reorganized in FY 2022 into ESDMD and SOMD.

[11] The CLPS Manifest Selection Board has voting members from SMD, SOMD, STMD, and ESDMD. The Deputy Associate Administrator for Exploration chairs the Board.

Figure 5: CLPS Lunar Landers (as of April 2024)



Source: NASA OIG presentation of CLPS vendor information.

Task Order Reviews and Monitoring

CLPS task orders have no formal vendor reporting requirements. These deliveries are purely commercial missions, owned and controlled by the CLPS vendors. Task order progress reviews are performed as part of the milestone payment to vendor process, while monitoring occurs through working with vendors as part of required payload integration activities.

According to contract terms and conditions, task order payments are based on performance reviews of a series of milestones defined in the task order.[12] These milestones provide NASA the opportunity to assess progress based on the contracting officer representative's review of a vendor's supporting documents. The CLPS integration managers (CLIMs)—the primary liaison between the CLPS vendors and instrument developers—also support this review process. Milestone completion criteria are defined at the task order level. Under the performance payment terms of task orders issued to date, interim milestone payments should not exceed 90 percent of the total, and the final milestone payment—largely defined as mission success criteria—should not be less than 10 percent.

After NASA awards the task order, the CLPS team monitors the vendor's lander development and integration, contract performance, and efforts to reduce project risks. NASA receives this information through internal and external meetings that review progress, status updates, and discussions of potential innovations and efficiencies that could improve CLPS processes, products, or approaches.

[12] Milestones are specified dates in the contract by which the contractor is required to complete a designated portion or segment of the work to receive payment. If the contractor fails to complete the work agreed to for the given milestone, it could affect when they will get paid.

NASA's intention was for vendors to develop small to mid-size landers and delivery technologies with limited NASA input and oversight. CLIMs assigned to task orders (1) interact directly with the vendor to monitor development and lander progress; (2) support payload integration activities; (3) retain some insight on development issues and potential solutions, as well as integration and testing of systems and interfaces; and (4) review and track flight schedules. The CLIMs also support the contracting officer representative during milestone reviews to verify that vendors have met their objectives prior to receiving payments. CLIMs travel to both payload and vendor locations to provide support during task order execution, including landing and mission operations on the Moon. CLIMs also interface regularly with ESSIO program executives to provide updates on lander and payload development. ESSIO then consolidates the information in a quarterly CLPS Baseline Performance Review to provide status updates to Headquarters officials. Lastly, NASA officials conduct a CLPS Lunar Delivery Readiness Review to ensure the readiness of the CLPS payloads.

CLPS Progress and Approaches

With one successful landing in February 2024, CLPS is making some progress toward achieving its goals. For example, NASA's delivery task orders have led to the development of 8 landers intended to deliver 53 payloads to the lunar surface and orbit over the next 6 years. CLPS vendors have launched one delivery mission that was unable to reach the Moon's surface, and another lander launched and successfully landed in February 2024. NASA has also adopted specific objectives from Agency-commissioned studies that outline key science questions to be addressed with lunar exploration.[13]

CLPS also initiated the following approaches to enable cost-effective commercial science deliveries and exploration of the Moon.

Reduce Costs and Risk for High-Priority Planetary Science

Landers and their payloads will gather raw data that will enable a new level of understanding about the Moon. Two critical conditions must be met to return this valuable scientific data: successful launching and then landing on the lunar surface. To reduce risk, NASA chose low-cost and non-critical, but useful, payloads for initial deliveries that could provide scientific value to the Agency even with the understanding that early CLPS missions may fail or not be delivered as initially planned, as was the case with the first two missions. For example, the Laser Retroreflector Array is designed to be a passive optical instrument that will also function as a permanent location marker on the Moon. The Array was mounted on the Intuitive Machines Nova-C lander to provide precision measurements of distances between orbiting or landing spacecraft. Although

Laser Retroreflector Array Payload

Source: NASA

[13] These studies include those from the Lunar Exploration Analysis Group, the Lunar Surface Innovation Consortium, the Committee on the Scientific Context for Exploration of the Moon, and National Academy decadal surveys for planetary science.

the lander—named Odysseus—tipped over during its February 2024 landing, NASA speculates that the Array can still return laser transmissions from orbiting spacecraft.

For initial payload deliveries, even a failed delivery mission has the potential to provide data points to inform future missions. For example, despite the problems encountered by Astrobotic's Peregrine that prevented its Moon landing, the vendor was able to power four of NASA's five onboard instruments, enabling two instruments to measure the radiation environment in cislunar space. NASA stated that these joint observations would provide complementary insights into the space environment between the Sun and the Earth. While some scientific questions may be resolved with the first generation of lunar landers, according to the National Academies, answering more complex questions such as the geologic diversity of the Moon will likely require greater capabilities than what the first generation of commercial lunar landers offer.

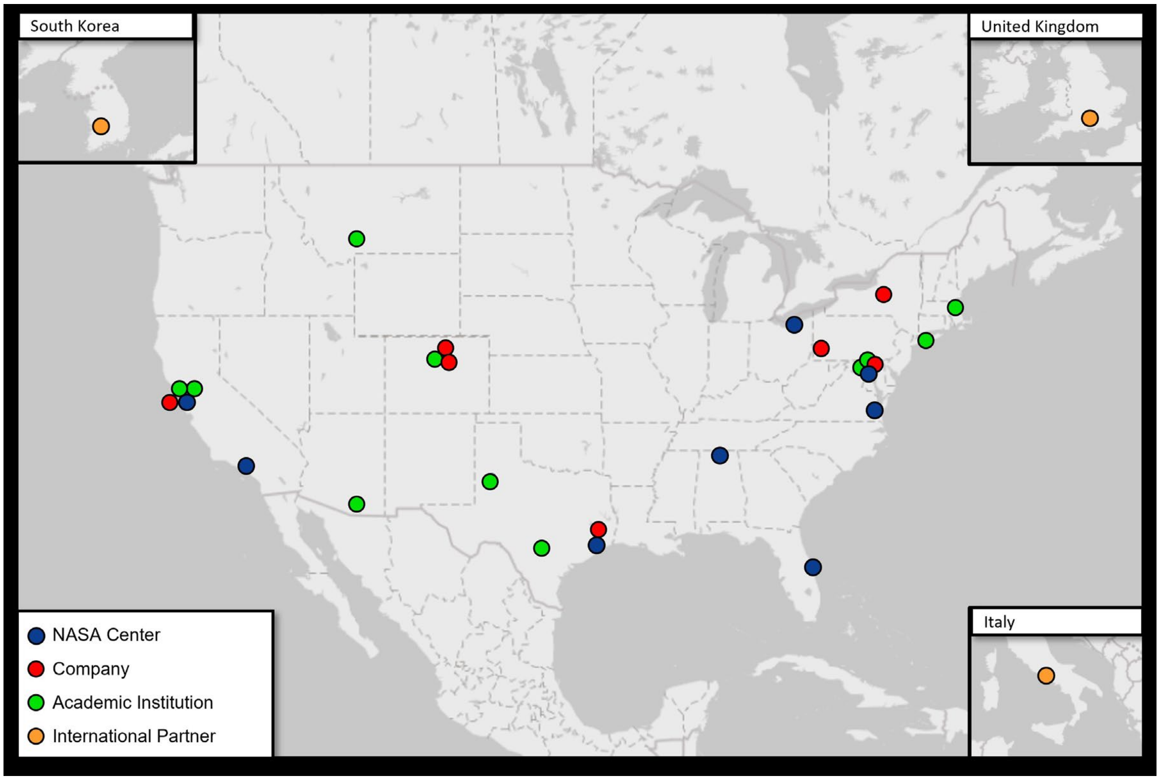
As opposed to typical space flight projects, CLPS's risk management approach is not centered on risk mitigation. Instead, CLPS manages risk exposure and takes steps to make a worst-case scenario more acceptable, such as withdrawing payloads from the task order, manifesting the same payloads on multiple task orders, and instituting augmented insight for high-value payloads when the situation warrants. NASA pursued non-traditional approaches for both management and acquisition, using FFP contracts to transfer the technical risk of completing the assigned mission to each vendor. According to NASA officials, if successful, this approach will significantly lower future mission costs compared to traditional NASA-led missions. For example, although not a perfect comparison, the LRO mission cost NASA about $590 million in 2009, while CLPS paid Intuitive Machines about $122 million to transport six instruments that cost the Agency approximately $9.5 million to develop for the first mission landed on the Moon in February 2024.

Ensure the Strength of the Lunar Science Community

The CLPS model, according to NASA officials, affords planetary scientists more than just the typical one or two chances to deploy payloads during their career. The rapid and regular missions planned under CLPS could provide principal investigators the opportunity for repeated or iterated missions to the same lunar location. NASA funding that supports commercial vendors could lead to increased collaboration between the planetary science community and the commercial space sector.

As of January 2024, NASA has selected 52 payloads worth $245.5 million for delivery to the lunar surface. In addition, NASA's $505.4-million Volatiles Investigating Polar Exploration Rover (VIPER) payload will be delivered to the lunar surface through CLPS as well. Included in these numbers are payloads provided by 18 academic organizations and companies across the United States, as well as international organizations from Korea and ESA, who lead development of the payloads (see Figure 6).

Figure 6: NASA and Science Community Participants Providing Science Payloads for CLPS Deliveries (as of January 2024)



Source: NASA.

NASA mission directorates use the CLPS Manifest Selection Board to manifest payloads and to identify and allocate payload characteristics for each mission. For example, exploring the Moon's polar regions has been a high exploration priority over the past four decades. Early CLPS robotic investigations could help confirm the nature of the Moon's resource potential, helping to inform planning for future Artemis missions. Lunar surface demonstration payloads onboard many CLPS missions could increase the technology readiness needed for most of NASA's Moon to Mars infrastructure objectives. For example, the Navigation Doppler Lidar for Precise Velocity and Range Sensing, a light detection and ranging sensor for descent and landing, was manifested on the first Intuitive Machines mission. Measurements from this instrument allow for precision navigation to the designated landing location and enable a tightly controlled soft touchdown on the surface of the Moon and other planetary bodies.

Precision Landing and Hazard Avoidance

Concept art of Navigation Doppler Lidar for Precise Velocity and Range Sensing (NDL) aiding a lunar landing

Source: NASA

CLPS Missions Have Cost More than Expected and Taken Longer than Anticipated

Despite some progress made toward achieving its objectives, the CLPS initiative has faced numerous challenges that have resulted in $208.2 million in cost increases and an average schedule delay of at least 14 months per task order. Although NASA anticipated the first CLPS deliveries would occur in 2021, it was not until February 2024 when the second attempted CLPS mission successfully landed on the Moon. The cost increases and schedule delays in most of the initiative's task orders occurred primarily because of NASA's decisions to deviate from the initiative's original intent, an optimistic contracting approach and launch schedule, and vendor challenges that included unforeseen COVID-19 and supply chain issues.[14]

Summary of CLPS Cost Increases and Schedule Delays

The total value of NASA's eight delivery task orders increased from an initial value of $781.4 million to $984.3 million as of February 2024, a nearly 26-percent increase, and the Agency has paid $673 million to the vendors based on completed milestones.[15] Since CLPS's inception in 2018, five of eight task orders have experienced cost increases, and seven of eight have experienced schedule delays ranging from 2 months to 29 months. Five of the eight experienced both cost increases and schedule delays (see Table 2 for a summary). Further, two task orders were terminated, one of which had already been paid $66.1 million of the $81.3 million task order value based on milestones performed.

[14] Most project cost increases were attributed to task order price increases for various reasons, as further discussed in this section. As such, we will characterize all price increases as cost increases to the initiative.

[15] An additional $66.1 million was paid for one inactive task order; the vendor filed for bankruptcy in 2022.

Table 2: Status of Current CLPS Task Orders as of February 2024 (in Millions)

Vendor (Task Order No.)	Award Date	Initial Task Order Amount ($ millions)	Current Task Order Amount ($ millions)	Cost Increase	Task Order Launch Date	Actual/Last Estimated Launch Date	Delay from Last Published Launch Date (Months)
Astrobotic (TO2-AB)	May 2019	$79.5	$107.9	35%	September 2021	January 2024	28
Intuitive Machines (TO2-IM/20C/OP)[a]	May 2019	81.7	122.0	49	September 2021	February 2024	29
Astrobotic (TO-20A)	June 2020	199.5	322.8	62	November 2023	December 2024	13
Intuitive Machines (PRIME-1)	October 2020	47.0	50.0	6	November 2022	March 2024	16
Firefly Aerospace (TO19D)	February 2021	93.3	101.5	9	September 2023	May 2024	8
Intuitive Machines (CP-11)	November 2021	77.5	77.5	–	April 2024	June 2024	2
Draper (CP-12)	July 2022	77.0	77.0	–	March 2025	March 2026	12
Firefly Aerospace (CS-3/CS-4)[b]	March 2023	129.9	129.9	–	January 2026	January 2026	—
Delivery Task Orders Total		**$781.4**	**$984.3**	**26%**		**Average Delay**	**14**
Masten Space Systems (TO19C)[c]	April 2020	75.9	81.3	7	November 2022	November 2023	—
Orbit Beyond[d]	May 2019	—	—	—	—	—	—
Total Awards		**$857.3**	**$1,065.6**				

Source: NASA

[a] TO-20C and TO-OP were task orders for additional activities added to the TO2-IM flight.

[b] CS-4 was a task order for additional activities added to the CS-3 flight.

[c] NASA paid $66.1 million to Masten Space Systems who filed for bankruptcy in July 2022.

[d] The Orbit Beyond contract was awarded $97 million task order in May 2019 and withdrew in July 2019.

NASA Deviated from CLPS's Intended Approach

CLPS was designed to use an innovative approach to develop commercial lander capabilities. NASA planned to address risks for vendor-owned development and the potential loss of landers by (1) using instruments for initial deliveries that were low cost and non-critical, but still useful, to minimize scientific impact if instruments are lost and (2) developing small- to medium-size landers first, then progressing to larger landers for more complex payload deliveries. Although NASA allowed CLPS vendors to assume increased responsibility, risk, and accountability with little Agency oversight and limited insight compared to traditional programs, we found that the Agency has not been as hands-off as anticipated. For example, NASA added task order modifications to oversee vendors because the Agency is not willing to accept as much risk as it originally envisioned when the initiative began. Specifically, NASA procured a CLPS delivery to transport VIPER, which has significantly higher costs, schedule constraints, and more critical science compared to the other CLPS task orders, when there was no history of success. Consequently, NASA added task order modifications to include augmented insight and additional tests to better inform NASA of the VIPER mission risk posture and provide the Agency greater confidence of mission success. In addition, NASA also changed delivery requirements, landing sites, and other payload requirements as discussed in detail below. Table 3 shows task order increases directly related to NASA's requirements changes, which total $171.4 million and represent about 82 percent of the $208.2 million in total project cost increases.

Table 3: CLPS Task Order Cost Increase Due to NASA Requirements Changes as of February 2024 (in Millions)

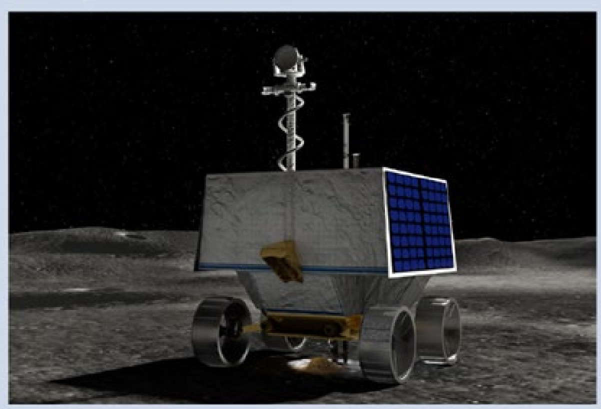
Task Order	Risk Management		Landing site	Payload	Total
	Testing	Augmented Insight			
Astrobotic (TO2-AB)	—	—	$18.2	(0.3)	$17.9
Intuitive Machines (TO2-IM)	—	—	28.4	—	28.4
Astrobotic (TO20A)	$84.7	$6.8	—	$31.8	123.3
Firefly Aerospace (TO19D)	—	—	—	1.8	1.8
Total	**$84.7**	**$6.8**	**$46.6**	**$33.3**	**$171.4**

Source: NASA OIG analysis of Agency information

Risk Management of VIPER Augmented by Insight and Additional Testing

Due to concerns about the criticality and higher cost of VIPER mission, NASA added a requirement for augmented insight—a contract modification allowing NASA to obtain additional information and have some involvement in the task order—and testing for the VIPER delivery task order. Task order 20A was awarded to provide end-to-end delivery of VIPER to the Moon's surface in 2023 using Astrobotic's Griffin lander for an initial price of $199.5 million. Augmented insight allowed NASA to assign a full-time resident CLIM at the vendor's facility to improve communication between NASA and the vendor. In addition, the vendor is now required to provide monthly status reports on the development of its Griffin lander and support three new Independent Assessment Team reviews. These reviews will be held approximately 2 years, 1 year, and 1 month prior to NASA handing over VIPER to Astrobotic for launch. According to CLPS management, this augmented insight gives NASA a greater understanding of the risk environment and the VIPER mission's risk exposure.

Volatiles Investigating Polar Exploration Rover, or VIPER



VIPER will roam several miles, using its four science instruments—including a 1-meter drill—to sample various soil environments

Source: NASA

To monitor the VIPER mission's risks, SMD instituted additional requirements through the CLPS project office. The Griffin lander's main engines are a new design, so SMD added three required propulsion system tests prior to launch. This additional insight and testing added $91.5 million to the $199.5 million task order, a 46-percent increase, and delayed VIPER's launch by one year from November 2023 to November 2024—aligning the mission to the next available lunar South Pole summer to obtain optimal science data.

Landing Site Changes

Landing site changes increased project costs by $46.6 million. Initially, NASA task orders allowed the vendors to determine the payload landing sites. However, as NASA's Artemis campaign activities started to mature, the Agency felt it could increase the scientific value of the NASA payloads if they were delivered to locations of higher scientific value; specifically, areas with special geologic features like Gruithuisen Domes or areas on the lunar south pole could provide scientists with a better understanding of the lunar surface environment for upcoming future Artemis missions.[16] For example, when NASA awarded one of the first CLPS task orders to Astrobotic in May 2019, Astrobotic targeted a site based on Peregrine's projected performance and a desire for a relatively safe landing area.[17] However, in November 2022, NASA decided the Peregrine delivery would increase the mission's scientific value if it landed at the Sinus Viscositatis near the Gruithuisen Domes to study this region's silica properties. This location is approximately 1,500 kilometers west of the original landing site. The task order cost increased by $18 million to accommodate these changes. Furthermore, Peregrine's landing site change also delayed its schedule by more than a year, from December 2022 to January 2024.

Similarly, NASA modified Intuitive Machines' task order to switch the landing site from Oceanus Procellarum in the Moon's western region to Malapert A on the South Pole, adding $28.4 million to the task order. This caused schedule delays to modify the lander to accommodate thermal control and ground operations requirements for this new landing location and required Intuitive Machines and SpaceX, the launch vehicle provider, to negotiate a new launch window that both could support.

Payload Accommodations and Requirements Changes

NASA changes to payload and other Agency requirements have dictated vendors' lander development and led to increased costs. Vendors told us the CLPS payload solicitation process affords scientists and principal investigators wide latitude to impose requirements on landers, which pressures vendors to develop landers that are more customized and unique. Task order modifications then become necessary when NASA changes requirements significantly from what was envisioned in the original contract or when unforeseen events occur.

NASA modified task orders and added technical requirements after making assumptions about lander configurations, implementations, or system-level tests. We believe these issues can be attributed in part to concurrent development of both payload and lander, while each is progressing through their design iterations and mission requirements changes. These modifications cost $33.3 million, approximately 16 percent of total project cost increases as of February 2024. For example, prior to the VIPER project's Preliminary Design Review, Astrobotic informed NASA that the natural frequencies of both the Griffin lander and VIPER were very similar, which could lead to excessive vibration and resonance during

[16] The Gruithuisen Domes are located near the largest impact crater on the near side of the Moon. They appear to be composed of light-colored, silica-rich volcanic minerals that may require water to form.

[17] The original landing location was the Lacus Mortis region, which is a basaltic plain on the northeastern side of the near side of the Moon.

launch.[18] The options were for Astrobotic to change Griffin's design, NASA to change VIPER's design, or both. Since VIPER was much further along in design, CLPS decided to pay Astrobotic to make the necessary lander changes to accommodate VIPER. This change required SMD to pay Astrobotic an additional $27 million for the task order. The design change also triggered a VIPER payload mass increase, which the lander accommodated, contributing to another increase of $4.8 million to the task order.

Although one of the payload selection factors for CLPS is that an instrument's Technology Readiness Level must be at 6 or higher, there have been instances of payloads that had lower readiness levels than expected, were not ready for flight, and required continuous re-design or re-testing.[19] Continuous payload development adjustments have led to changes in lander requirements that increased costs and schedule delays for these payloads. For example, the cost for Firefly's task order 19D increased by $1.1 million to update instrument requirements and another $518,000 to cover the impact on lander development from late payload delivery. Additionally, while Intuitive Machines' task order CP-11 has not yet reflected any task order price increases, delivery schedules for all four payloads have been pushed back 4 to 8 months from their original dates. One of these four payloads will be delivered later than the vendor needs to make the intended launch date.

To minimize future development changes between payloads and landers, CLPS officials developed a document in the appendix of task orders to help address lander and payload developer integration problems. In addition, CLIMs and project scientists now work daily with both the CLPS payload developers and vendors to plan and support payload integration, gaining considerable technical insight into the vendor's progress toward task order completion.

CLPS Implementation and Delivery Schedules were Aggressive and Overly Optimistic

Both NASA and the CLPS vendors were overly optimistic about the industry's commercial lunar delivery service progress and capabilities in early 2017. NASA's business approach shortened CLPS delivery schedules and shifted cost and technology development risks to the vendors using FFP contracts.

NASA conducted a market survey before initiating CLPS that later proved too optimistic about vendors' capabilities and consequently misinformed the initiative's acquisition approach. NASA conducted this market survey between 2017 and 2018 and interviewed potential vendors in the new lunar delivery industry. NASA also issued a request for information to the public regarding industry capabilities. According to the survey and solicitation results, NASA officials believed vendors could land on the Moon as early as 2018 and 2019. The Agency concluded that these capabilities were commercially available and that vendors could support this development. Therefore, NASA's chose a hands-off strategy, utilizing FFP contracts with reduced NASA involvement, less access to vendor information, and limited ability to direct the vendors. The Agency also requested an aggressive delivery schedule of 2 to 3 years

[18] The Preliminary Design Review evaluates completeness and consistency of the planning, technical, cost, and schedule baselines developed during formulation.

[19] Technology Readiness Level is a measurement system used to assess the maturity level of a particular technology. NASA assigns each technology project a Technology Readiness Level rating of 1 through 9 based on the project's progress, with 1 representing an early stage, such as preliminary research of a basic concept, compared to 9, when the technology is integrated into a product and successfully operated in its intended environment.

from task order award to lunar landing—far shorter than NASA's typical development schedule for a flight project. Additionally, NASA requested that vendors develop a large lander for VIPER to support a planned Artemis III landing in 2024, which is now planned for 2026, before developing and demonstrating successful small- to medium-sized landers. In its FY 2020 budget request, NASA asked for an additional $90 million to support the purchase of commercial services to deliver a rover to the Moon that could provide enhanced capabilities to deliver larger payloads, which may include tools, instruments, or other supplies for the Artemis III mission.

Use of Firm-Fixed-Price Contracts

While using FFP contracts has shifted development and cost risks from NASA to vendors, this approach may not be the best match to the nascent CLPS environment. FFP contracts are best used when certain operational conditions exist; for example, when requirements are well defined (see Table 4). Using FFP contracts in less suitable conditions has resulted in NASA absorbing cost and schedule impacts, as previously discussed, and shown in Table 4. Although the 2017 market survey indicated industry and potential vendor readiness to land on the Moon within 1 to 2 years, the CLPS initiative does not yet meet the optimal conditions for success using FFP for service contracts. This is because of the immature market, changing lander requirements, inexperienced vendors, and financial and technical risks. Consequently, NASA has become less risk tolerant and added more policies into the initiative to help ensure vendor success landing on the Moon.

Table 4: Comparing Appropriate Use of FFP Contracts and CLPS Impacts

Generally appropriate for use when:	CLPS	CLPS Impact
Requirements are well-defined ✓	Service was never procured before, and requirements changed	Payload requirements and landing site changes—$79.9 million
Contractors are experienced ✓	Companies had never landed on the Moon successfully when the procurement concept was conceived	Development issues caused schedule delays
Market conditions are stable ✓	Delivery market is uncertain, speculative, and nascent	Supply chain and launch vehicle procurement caused schedule delays
Technical risk is low ✓	Lunar exploration requires complex and advanced landers	Augmented insight and additional testing—$91.5 million and one failed landing opportunity
Financial risks are insignificant ✓	Risks include one bankruptcy and one task order loss	Vendor bankruptcy—loss of $66 million and one flight opportunity to demonstrate science

Source: NASA OIG assessment of Federal Acquisition Regulations, Defense Acquisition University, *Comparison of Major Contract Types*, and Department of Defense, *Guidance on Using Incentive and Other Contract Types*.

NASA made a strategic decision to increase the use of FFP contracts, and CLPS is one example of this acquisition type becoming more common across the Agency. However, using this contract type has reduced insight into contract performance and hindered the CLPS project office's ability to assess project risk and develop realistic cost estimates for future task orders. As a result, NASA has limited tools available to address development challenges, evolving program expectations, and mission requirements. This includes actions such as delaying payload manifests until landers are further into development, having more defined design requirements to minimize changes, and allowing for longer delivery schedules to provide flexibility for vendors to address and overcome technical development challenges.

Launch Schedules

The average task order launch schedules were unrealistic since the CLPS vendors were in the early stages of their lander development. As shown in Table 5, NASA contractually demanded an average of 30 months between the start of the contract and launch. However, based on the current development efforts, the average time to launch is 44 months from the award of the contract. These delays may have a cascading effect on future missions. For example, because of its first mission's delay, Intuitive Machines has not determined the revised launch dates for the next two task order deliveries that were originally planned to launch in 2024.

Table 5: Summary of CLPS Task Orders Status (as of February 2024)

Vendor (Task Order No.)	Award Date	Planned Launch Date	Planned Time to Launch (Months)	Actual/Current Launch Date	Updated Time to Launch (Months)	Schedule Delay (Months)
Astrobotic (TO2-AB)	May 2019	September 2021	27	January 2024	55	28
Intuitive Machines (TO2-IM)	May 2019	September 2021	27	February 2024	56	29
Astrobotic (TO20A)	June 2020	November 2023	40	December 2024	53	13
Intuitive Machines (PRIME-1)[a]	October 2020	November 2022	24	March 2024	40	16
Firefly Aerospace (TO19D)	February 2021	September 2023	30	May 2024	38	8
Intuitive Machines (CP-11)[a]	November 2021	April 2024	28	June 2024	30	2
Draper (CP-12)	July 2022	March 2025	31	March 2026	43	12
Firefly Aerospace (CS-3)	March 2023	January 2026	33	January 2026	33	—
		Average	30		44	14

Source: OIG analysis of NASA information.

[a] Intuitive Machines' TO2-IM delay is expected to create further delay for PRIME-1 and CP-11, which were planned for launch in March 2024 and June 2024, respectively.

The initial CLPS delivery schedules of 24 to 36 months did not allow time for development issues that might arise from new companies producing landers for the first time. There were schedule delays due to redesigns of engines, propellent tanks, and the overall lander, as well as delays in procuring launch vehicles (details of which are discussed in the following sections), in addition to the NASA requirement changes previously discussed.

Aggressive Lander Development

NASA's decision to use CLPS to fly VIPER, a large mission weighing approximately 500 kilograms (kg), is incompatible with an iterative approach that would allow CLPS to demonstrate successes at landing on the Moon, or to progress from smaller to larger lander sizes, which NASA has done in the past (e.g., several Surveyor robotic landers successfully landed on the Moon from 1966 to 1968 before Apollo 11 in 1969). Based on NASA's initial market research, no commercial business had the capacity for payloads over 100 kg. As a result, NASA based its procurement strategy on the assumption that inaugural missions would have smaller payloads. NASA assumed it could add requirements for larger payloads later—after the success of small payloads was demonstrated under these initial requirements. Initial NASA-owned payloads are light, such as the retroreflector and seismometer, estimated to weigh between 10 and 15 kg.

However, NASA SMD added the VIPER delivery as CLPS's fourth task order during 2020, one year after the first two delivery task orders were issued, with an expected launch date 40 months after the award. The VIPER delivery task order requirements for cost, mass, and criticality are significantly higher than other CLPS task orders. Specifically, as of January 2024 the VIPER project cost about $500 million. Consequently, NASA management has a lower risk tolerance for the loss of VIPER than other those payloads and, therefore, added more insight requirements. In our opinion, adding VIPER to an early CLPS task order left little time or margin to demonstrate success of the smaller landers before committing to this larger lander. Such parallel development of large and small landers put the larger lander at higher risk and diverted resources from refining and proving smaller landers' capabilities through additional flight opportunities.

Furthermore, both Astrobotic's Peregrine and Griffin landers use the same engine and tank subcontractors with a scaled up TALOS axial engine for Griffin.[20] Due to engine delivery delays and testing performance issues, the Peregrine TALOS axial engines were never subjected to qualification levels or fired for full duration prior to its flight. Considering the first Peregrine's propulsion system failure experienced after separation from launch vehicle, we are concerned about the risks of using the Griffin lander if planned qualification testing does not occur.

Vendor Issues Contributed to Cost Increases and Schedule Delays

CLPS vendors, as competitors in an emerging industry, are developing modern space transportation capabilities and associated operations that have never before been available, and they are encountering the expected technical issues and resulting delays. At the same time, a large amount of effort and investment are needed to assemble the teams and the facilities required to develop and build landers. Vendors are facing challenges assembling the workforce they need to meet milestones, since skilled aerospace workers are in low supply and great demand. This creates schedule delays and defers attention to other later or lower development priorities. To their credit, many CLPS vendors are relatively small and new companies that built this necessary infrastructure while simultaneously working on task orders. For example, Astrobotic was the first CLPS delivery vendor and started as a small

[20] The TALOS (Thruster for the Advancement of Low-temperature Operation in Space) thruster was a NASA design developed by Frontier Aerospace of Simi Valley, California.

business founded in 2008 in Pittsburgh, Pennsylvania, that grew from 17 employees in 2017 to about 200 while developing both small and large landers.

Lander Development Challenges

Technical difficulties during lander development increased the risk that vendors may not successfully develop system capabilities and could fail to complete their missions. NASA and CLPS vendors noted particular difficulties in early development of propulsion engines, propellant tanks, and avionics.[21]

When NASA officials awarded the first round of task orders in May 2019, the initial CLPS landers had immature and unstable designs. The selected CLPS vendors had various lander designs that were still under development. For example, prior to the CLPS contract, Astrobotic's Peregrine lander changed its initial design to use an engine that was in development, the TALOS thrusters. However, as the thrusters were tested, it became evident the thrusters might not meet performance specifications. Consequently, Astrobotic chose to remove 5 of 10 planned NASA payloads and some commercial payloads from the mission to reduce mass and maintain confidence of a successful landing.

Despite this, the first CLPS payload delivery was unsuccessful, further demonstrating the challenges and difficulties in advancing space exploration, especially when using new vendors. Astrobotic's Peregrine spacecraft was launched on January 8, 2024, but soon encountered what appeared to be a propellant leak in the lander's propulsion system. That leak caused attitude control problems for the spacecraft, and the company ruled out any chance of attempting a soft landing on the Moon. Astrobotic's current hypothesis for the propellant leak involves a valve in a helium pressurization system that failed to close after an initial test. This led to a rush of high-pressure helium that spiked the pressure in an oxidizer tank beyond its operating limit and subsequently ruptured the tank.

Intuitive Machines faced similar technical challenges as it developed its lander. Despite the 29-month planned schedule for Intuitive Machines' first task order, it took the company more than 4 years to work through the financing issues of growing a small space company and to resolve technical challenges such as late propellant tank delivery. During testing, Intuitive Machines discovered a failure of their liquid methane tanks. Although the company followed a parallel path of redesign and of fabricating additional tanks, this redesign contributed to the 29-month launch delay and will further impact schedules for their next two task orders, which originally had planned launch dates of March and June 2024, respectively.

Draper's lander development progress was impacted by lander redesigns that caused a 12-month schedule delay. Draper subcontracted the lander's design and development tasks to ispace, inc. (ispace). According to a NASA official, ispace's original lander design was too small and not adequate for any CLPS delivery. ispace later redesigned a bigger lander, but it still did not meet the payload requirements. In October 2023, Draper officials notified NASA they could not meet the planned March 2025 launch date. Although the company's modified schedule has not been finalized, a NASA official assessed information presented by Draper and estimated at least a 12-month delay. As of December 2023, NASA was reviewing the case and had not made a final decision relative to contract modification.

[21] Avionics provide the "nervous system" for spacecraft, linking diverse systems into a functioning whole.

Limited Business Resources Affect Contract Performance

NASA and vendor officials told us companies need multiple CLPS task orders to sustain their business and remain in operation. For example, vendors that are contracted for only one mission could attempt to land their first spacecraft on the Moon, but then risk losing talent and institutional knowledge without a follow-on CLPS contract, even after making significant early investments to build their workforce, supply chains, and program execution techniques. Additionally, vendors with multiple task orders have faced issues hiring critical, experienced, and qualified engineers that can shift work between different landers. Astrobotic experienced limited personnel availability and hiring difficulties in 2023 as they shifted employees between the Peregrine and Griffin landers.

CLPS vendors rely on subcontractors and third-party launch providers to successfully deliver NASA's payloads to the Moon. One common cause of lander development delays is subcontractors delivering parts or systems late. For example, Draper experienced significant schedule delays due to lander redesigns and when a major subcontractor fell behind schedule in obtaining external capital investments. Several supplier issues, primarily in the propulsion subsystem, also contributed to the 28-month delay in the Astrobotic Peregrine lander's development and testing.

Launch Vehicle Acquisition

Even when CLPS vendors have the technology to develop and build landers for NASA's payloads, few have their own launch vehicle to deliver those landers to the Moon.[22] This means vendors must purchase launch vehicle services to complete the mission. Procuring this service could be 50 percent or more of a total task order's price, with one vendor telling us that launch costs continue to be a challenge for their company. Additionally, delays associated with launch vehicles have increased costs and, according to the National Academies, launch vehicle availability presents a continuing challenge to NASA's exploration goals.[23]

United Launch Alliance's Vulcan Rocket Launch

Astrobotic's Peregrine lander launched on the Vulcan on January 17, 2024, from Cape Canaveral, Florida.

Source: NASA

The first two CLPS task orders with Astrobotic and Intuitive Machines both encountered launch vehicle acquisition issues. In August 2019, Astrobotic selected United Launch Alliance's (ULA) Vulcan Centaur rocket to launch its Peregrine lunar lander in 2021. By January 2023, Astrobotic had completed testing of the lander and was awaiting ULA's notification to ship the lander to Cape Canaveral, Florida, for pre-launch processing. However, ULA's timeline for launch was delayed by a structural issue with the Vulcan Centaur's second stage that exploded on the test stand in

[22] Firefly Aerospace has launch vehicles capable of executing CLPS missions.

[23] National Academies of Sciences, Engineering, and Medicine, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032* (2022).

May 2023. In October 2023, Astrobotic delivered the Peregrine lander to Cape Canaveral to be integrated with the Vulcan rocket, which launched in January 2024.

After lander development schedule delays that prevented Intuitive Machines from meeting their original launch date, they had to negotiate with SpaceX to reschedule for the next available launch opportunity. In November 2023, Intuitive Machines and SpaceX agreed on launch windows in February 2024. Launching payloads later than planned impacts science schedules and has a cascading effect on subsequent launch schedules, as is the case with the next two Intuitive Machines CLPS missions.

Viability of the Vendor Pool is Affected by Financial Stability

CLPS vendors are small, relatively new, and involved in a new economic sector—all factors that come with increased risk and require significant financial investment from the vendors and their investors. We first raised this issue with NASA in a September 2020 report and were assured that the Agency would take a closer look at vendors' financial conditions.[24] Masten Space Systems (Masten), a CLPS vendor contracted in April 2020 to deliver eight Agency payloads to the lunar surface, filed for bankruptcy in July 2022. The company faced difficulties scaling up its workforce and building new facilities after NASA's award. These issues were compounded by the COVID-19 pandemic and Masten's inability to pay the launch vehicle provider. As a result of this bankruptcy, NASA lost the $66 million in milestone payments made to Masten and is in the process of settling recoveries. In late 2020, NASA officials required future CLPS vendor proposals to identify financial risks associated with their task plans, and NASA further revised its RFTP for future proposals and revamped its proposal review process in March 2023 to better ensure vendors have the financial stability to complete task orders. Officials from one vendor told us NASA's multiple task plan updates have added unnecessary oversight to the competitive procurement process.

Masten's financial problems partly contributed to the early CLPS mission challenges associated with concurrently developing payloads and landers. For example, the MoonRanger rover began as a technology demonstration payload and was assigned to Masten's task order. However, the payload team was asked to study the impacts of being re-assigned to Artemis III following the company's bankruptcy.[25] MoonRanger's developers conducted a study to rework many of the rover's components to ensure future compatibility with astronauts onboard Starship, as compared to Masten's XL-1 robotic lander.[26] This included a different payload deployment mechanism, finding new vendors, replacing battery systems, and potential component redesigns. This delivery-vehicle change exemplified payload development challenges with undefined lander requirements and poorly defined capabilities, which made it more difficult to match commercial landers and NASA payloads. As of April 2024, NASA has not yet decided on a final method to deliver MoonRanger to the Moon.

Lastly, a common challenge that affected both NASA and the vendors was the unforeseen COVID-19 pandemic. Our analysis found that COVID increased NASA task orders' total costs by $26.9 million to cover vendors' financial losses and delayed CLPS progress. COVID-19 also led to supply chain delays and

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[24] NASA OIG, *NASA's Planetary Science Portfolio* (IG-20-023, September 16, 2020).

[25] As of October 2023, payloads originally manifest to Masten's mission were under development and will be delayed and assigned to future CLPS or Artemis missions. These payloads include MoonRanger, a micro-rover about the size of a small suitcase that was designed to map the lunar surface using NASA's Neutron Spectrometer System, searching for indications of water ice up to 1 meter beneath the lunar surface.

[26] Starship is a SpaceX-designed human landing system to support landing NASA's Artemis III astronauts on the Moon.

cost increases, affecting the vendors' ability to develop and build components for their lunar landers. Vendors such as Astrobotic, Intuitive Machines, and Firefly experienced issues procuring electric parts, propulsion materials, and other components. COVID-19 was also a major contributing factor in Masten's bankruptcy.

CLPS Challenges Will Continue to Hinder Achievement of the Initiative's Objectives

Cost increases and schedule delays highlight key challenges both NASA and vendors face that have affected the CLPS initiative. We identified three additional areas that will also impact the Agency's ability to meet its CLPS initiative goals. First, rising costs inhibit NASA's ability to maintain the initiative's task order cadence and conduct more complex science. Second, the lunar delivery market is still heavily dependent on NASA task orders to remain financially viable, and Agency officials could better understand NASA's future role in supporting the market. Third, CLPS lacks guidance and structure—such as a formal initiative plan—that could help ensure consistent approaches for NASA officials at Headquarters and Johnson to effectively implement and manage the CLPS initiative.

Task Order Cadence and Costs

SMD stated in its memorandum of understanding with the other mission directorates that frequent deliveries are important to support commercial vendors and potentially lower costs for all participants. According to the memorandum, a high cadence of task orders also incentivizes contractors to remain competitive and continue their own investment in the initiative. Conversely, issuing fewer task orders than stated in the initiative's goals threatens NASA's ability to maintain vendor engagement and build a commercial marketplace through vendor participation. Without frequent missions, NASA has fewer opportunities available to test and advance new technologies, address science questions, and train new scientists and engineers. The National Academies noted the importance of assessing flight programs by their capacity to make steady progress—with planning processes and a cadence of missions that help ensure new scientific discoveries can be followed up rapidly with new missions.

Though CLPS set a goal of issuing two delivery task orders per year, the actual number has slowed since 2022, and total costs for recent task order awards are also higher than NASA originally expected. The initiative has a proposed $2.19-billion budget through 2028; therefore, increased costs lead to more time between task order award issuances and, consequently, fewer flights per year. For comparison, in 2019, NASA estimated that it would cost approximately $1 million to deliver each kg of mass to the lunar surface. However, based on the price for task orders issued in 2023, costs for future missions will be approximately $1.2 million per kg, or 20 percent more, and likely higher in future years. Similarly, if SMD selects more complex payloads to conduct higher-value science, delivery cost estimates may increase further, and officials may be forced to cancel some future task order awards. In fact, one NASA SMD official stated that the Agency has removed at least one future CLPS mission to help pay for and ensure the success of VIPER.

Increasing Costs for More Complex Missions

As CLPS evolves, costs per mission may be affected by additional challenges related to NASA's desire to conduct more complex science as well as the Agency's risk tolerance. Future CLPS missions could require vendors to accommodate more sophisticated NASA payloads, and Agency officials expect CLPS service options to expand as the lunar transportation market and vendor capabilities evolve. Future services could include increased mobility and mass, more complex instrument deployments, sample returns, and the capability to survive throughout the lunar night. These new capabilities could enhance science return and open new avenues for scientific investigations, but vendors will likely charge NASA more to deliver them.

Lunar Surface Electromagnetics Experiment - Night (LuSEE-Night)

Flying aboard the Blue Ghost lander, LuSEE-Night is a science experiment that will operate on the far side of the Moon and potentially measure the Dark Ages, an important era in the history of the universe, for the first time.

Source: NASA/Firefly Aerospace

Future CLPS contract costs are likely to be greater and, without additional funding, could threaten the Agency's ability to maintain a regular cadence of annual task order awards. Given this possibility, NASA officials will likely need to make trade-offs to either maximize science return from each mission or maintain a cadence of task orders needed to establish a sustainable lunar economy. Depending on the tolerance for risks of failure, NASA may decide to purchase augmented insight to reduce uncertainty and ensure an acceptable level of risk—formal criteria for which SMD has not developed—when conducting higher value science with more expensive payloads, similar to what NASA purchased for VIPER. Additionally, vendors may have to build unique and custom landers for each mission and maintain fewer standardized versions.

Furthermore, increased payload complexities and frequent awards will further strain ESSIO and CLPS project office staff. Specifically, numerous changes to the initiative's FFP contracts have adversely affected the project office's ability to maintain a regular cadence of awards. The project office has also been understaffed while administering changes and contract modifications. Although these offices were purposefully kept small and lean to foster flexibility and reduce overhead, the Agency still maintains a technical as well as a procurement role. This includes CLIMs who gain informal insight based on relationships they build working with the vendors, helping provide NASA with visibility into vendor landers and processes. To maintain a regular cadence of awards, NASA has attempted to limit the number of complex payloads and new capabilities added onto CLPS missions.

Building a Commercial Lunar Marketplace

NASA built the CLPS business model assuming the commercial lunar delivery market would mature with time. However, more than 5 years after the initiative was established, the market is still heavily dependent on NASA task order funding. Vendor officials told us that about 20 percent of demand for lunar delivery services come from commercial or international entities, while NASA provides the other 80 percent. NASA officials also have not conducted any new market studies to assess demand or capability growth across this industry since 2017.

To better understand the challenges vendors face under the CLPS initiative, we surveyed the 13 vendors eligible to bid on task orders. Eight of the vendors replied and shared different issues and challenges they faced. Specifically, their varying perspectives provided further insight into the changes needed for

CLPS to be successful in the future. In particular, vendors face the challenges of an uncertain commercial market and competition within the vendor pool to win NASA task orders.

Limited Commercial Market for Services

The opportunity for vendors to fill manifests with non-NASA payloads is limited. Despite NASA issuing eight task orders, there are few opportunities to host non-government payloads that could help expand lunar lander services. As noted above, the Agency wants to be among many customers for lunar transportation services, with the hope that vendors will eventually deliver landers to the Moon without any NASA payloads. However, CLPS vendors have had difficulty making credible business cases to potential customers and investors. Specifically, NASA and vendor personnel concede that the level of commercial interest in purchasing payload space on landers will be difficult to determine until there is higher demand and CLPS vendors can demonstrate sustained successful lunar landings and operations.

> *"We have concerns if NASA continues to be the primary economic driver in the long term."*
>
> **—Vendor 5**

Successful missions could boost interest to explore lunar resources and expand the demand for lunar transportation services. This could potentially include other clients, such as university scientists and private companies. Until then, NASA will continue to be a critical player in establishing early commercial capability, and vendors will rely on NASA funding.

> *"Most all non-CLPS payload customers need to see a fully funded mission from a NASA task order on contract before they are willing to buy payload services with us."*
>
> **—Vendor 1**

Market Competition

Additional RFTP requirements and competition in the CLPS business model make it difficult for new vendors to be awarded task orders. Before awarding CLPS task orders, NASA evaluates vendors' past performance and success in delivering landers to the Moon or performance with similar lunar services—such as establishing a satellite in lunar orbit or communication/data links with an instrument on the lunar surface—experience that may not exist for the many companies in the CLPS vendor pool.

> *"The large pool of vendors increases the competition for mission contracts, making it challenging for [our company] to secure contracts and stand out among other qualified companies."*
>
> **—Vendor 8**

Competition can result in vendors significantly underbidding their actual mission cost to win task orders. NASA requires vendors to identify commercial opportunities in their task plans as evidence for how they plan to pay for the total cost of a mission—which can alert the Agency to the risk of potential vendor financial failure. The vendor's task plan must account for full mission costs, complete with a vendor's ability to finance the difference between how much a lunar mission costs their company and NASA's proposed share, which both Agency and vendor officials admitted is less than the full cost of a mission. As a result, NASA may view new vendors with a limited past performance history as too great a risk and increasingly rely on previously awarded vendors, which may discourage new entrants into the CLPS initiative or cause others to drop out due to lack of funding.

> *"There is a substantial gap between what CLPS vendors can currently, fairly charge and traditional NASA pricing for these missions."*
>
> **—Vendor 3**

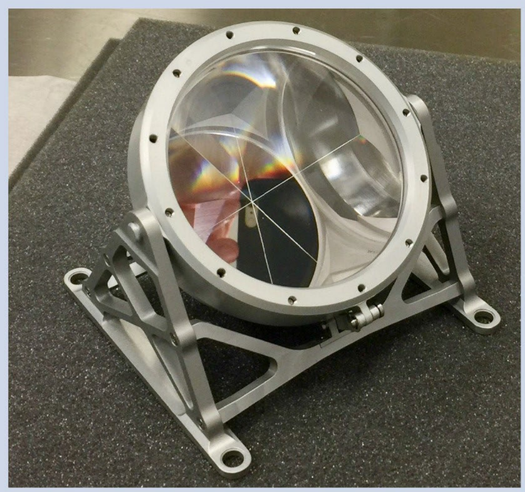
CLPS officials also speculated that future task order pricing may be affected by Masten's bankruptcy. Specifically, while NASA will provide greater scrutiny of vendor financials and be less likely to select a vendor that does not appear to have the financial resources to complete the task order, vendors may react by taking less financial risk and raise their proposed task order costs, further straining the already tight CLPS budget.

> *"Investors don't invest in companies that have not won a task order as they can invest in companies that have won 2-3 task orders. So, competition will not survive."*
>
> **—Vendor 2**
>
> *"We expect the commercial interest to accelerate once CLPS providers demonstrate successful missions."*
>
> **—Vendor 4**
>
> *"The value of non-NASA payloads is an insufficient market to support commercial lunar missions."*
>
> **—Vendor 6**
>
> *"We have not found many customers that are willing to pay for an entire mission."*
>
> **—Vendor 7**

International Payloads

One opportunity for vendors to gain non-NASA revenue is by selling lander payload space to international entities. However, NASA has previously worked directly with these international partners to ensure their payload needs are met. Four vendors in our survey commented on NASA's early pursuit of international payloads for CLPS missions and one said their company's market for substantive non-NASA lunar payloads is solely reliant on international space agencies. For example, NASA paid to deliver international payloads for ESA and the Korea Astronomy and Space Science Institute on Intuitive Machines' third mission. NASA coordinated with the international agencies and funded these deliveries. This arrangement, however, eliminated the opportunity for CLPS vendors to contract directly with the international agencies. While the Agency originally pursued these international payloads because of the limited CLPS budget, doing so reduced the vendors' commercial customer base and limited their non-NASA business opportunities. Ultimately, NASA officials realized the impact on CLPS vendors and subsequently encouraged the Agency's international customers to contract directly with the vendors.

ESA's MoonLIGHT Pointing Actuator



This retroreflector will advance precision testing of light and laser deflection on the lunar surface, furthering the study of general relativity.

Source: NASA/ESA

Establishing a Formal Management Plan Could Help Address Challenges that NASA and Vendors Face

Although NASA anticipates making a $2.19-billion investment in the CLPS initiative, the Agency views CLPS as primarily a service procurement activity, and the Agency has not formalized a CLPS planning or management document. Under NASA Policy Directive 1000.0C, such documentation is required to provide for a continuous assessment and adjustment of the initiative's objectives at both strategic and detailed levels.[27] Such a document could reflect national priorities, congressional guidance, other stakeholder input, and emerging trends. It will be difficult for NASA officials and stakeholders to determine how progress toward the initiative's goals and objectives will be monitored and reported without a formal CLPS management plan that establishes metrics and performance indicators, as well as a process to formally document lessons learned.

CLPS management has not yet published a formal CLPS management plan to outline the processes required to oversee the initiative's interwoven objectives of achieving high-priority science and developing a lunar economy. As a result, there is no clear delineation of responsibilities between ESSIO's management of the three CLPS objectives and the project office's management of task orders. Further, CLPS deviated from traditional Agency approaches by procuring mission transportation, delivery, and operation separately from mission execution; activities that we found involve more than issuing task orders to procure delivery services. They also include achieving and enabling science, working daily with payload and lander teams to support their integration, and building a new industry by engaging a large pool of commercial entities.

More importantly, a formal management plan could align the Agency's actions to its objectives and increases its chance of achieving these objectives. Such a plan would set program goals, such as for science achievement and desired lunar market characteristics, along with the effective and efficient operations necessary to fulfill them.[28] Conversely, the absence of a formal plan makes it more difficult to follow a consistent operational structure. This has been especially problematic as NASA has experienced an evolving environment where (1) both the Agency and vendors are learning to operate together in a new commercial space delivery industry and (2) NASA has responded by implementing new, ad hoc strategies and adjusting processes without a formal project management plan to guide these actions.

While the CLPS project office has drafted a project management plan, it had not yet been published and was still under review as of January 2024. We assessed the draft project management plan and do not believe it is sufficient to fully address implementation of the initiative's objectives. Although the draft CLPS project management plan delineates operational processes and identifies some staff roles and responsibilities, it does not clearly formulate and define plans for how the initiative will strategically achieve its main objectives of enabling lunar science and building a commercial lunar economy. Similarly, officials from other mission directorates outside of SMD said CLPS's processes are too slow and difficult to understand—in particular for payload selection through the CLPS Manifest Selection Board—and inquired why these processes have not been formalized and documented.

[27] NASA Policy Directive 1000.0C, *NASA Governance and Strategic Management Handbook* (January 29, 2020).

[28] Government Accountability Office (GAO), *Standards for Internal Control in the Federal Government*, *Section 2 – Establishing an Effective Internal Control System* (GAO-14-704G, September 2014).

Formalizing a CLPS management plan and ensuring it is integrated within a broader NASA lunar strategy can also help align scientific community recommendations with the Agency's CLPS objectives. For example, the Lunar Exploration Analysis Group's Commercial Advisory Board in its 2023 annual meeting recommended that ESSIO and the CLPS project office actively work with CLPS vendors to develop a technology roadmap that would evolve alongside CLPS capabilities to advance the lunar community's prioritized science and exploration objectives. A formal CLPS initiative management plan could help address the intent of this recommendation by aligning internal NASA processes to technology development and long-standing lunar science objectives. It could also inform current vendors and potential new market entrants about what types of services NASA is seeking.

NASA stated in its reply to the National Academies' most recent Planetary Science Decadal Survey that SMD initiated discussions to update the lunar science strategy for LDEP.[29] Both ESSIO and the Planetary Sciences Division plan to include a strategy for using CLPS to achieve lunar science. We believe a formalized initiative management plan will help NASA ensure the consistent implementation of augmented insight or oversight, maximize science return from CLPS, address scientific community goals, and help the Agency better understand its role in building a commercial lunar service delivery market.

Lastly, a formal management plan could help prioritize CLPS's limited resources as the initiative continues to operate under a fixed budget while taking on more complex science and technology missions. As CLPS intends to maintain a cadence of two flights per year to support development of a commercial market, a formal management plan could define the criteria NASA officials would use to make more informed decisions and investments, such as when to request augmented insight, as was done for VIPER. This would be particularly important as NASA proceeds beyond the initial 10-year period of the initiative and accommodates larger payloads such as Endurance-A—a mission with preliminary cost estimates of about $1.5 billion—for a future CLPS mission, as the National Academies recommended in the 2023 Planetary Science Decadal Survey.[30]

CLPS Lacks Performance Goals

Our audit did not identify any clear CLPS performance goals stakeholders can use to measure success in meeting the initiative's three objectives. For example, we could not determine, and NASA officials could not explain, what success looks like in achieving high-priority lunar science, particularly when NASA does not track how payloads onboard CLPS landers address decadal survey-level questions.

While NASA defined four performance metrics in their August 2022 CLPS initiative Baseline Performance Review, these metrics were not consistently assessed in subsequent reviews. Furthermore, it was not clear what the success criteria was for each metric. For example, only two metrics related to vendors' progress toward successful launches and landings were reported in subsequent reviews, but there was no established quantitative success criteria to determine how many launches or landings CLPS managers would consider successful.

Additionally, while SMD has a memorandum of understanding with mission directorates to collaborate on payload allocations in CLPS manifests, there is no documented process detailing how this is accomplished. Without such guidelines, stakeholders cannot determine if management is properly

[29] National Academies, *Origins, Worlds, and Life* (2023).

[30] Endurance-A is a mission concept for a long-range rover, capable of traversing approximately 2,000 kilometers, designed to explore and collect 12 samples from the South Pole-Aitken basin on the far side of the Moon.

allocating payloads to achieve technology and exploration goals in addition to science goals, or what opportunities exist for non-NASA entities to contribute payloads.

Furthermore, one CLPS objective is to develop a community of commercial service providers to support Artemis. Yet, as of February 2024, NASA has not documented what future services or capabilities these vendors will need to provide. Although we would expect NASA to develop and refine these services and capabilities as Artemis matures, thorough documentation could help quantify vendor community size—whether based on a specific number of available providers or those with successful launches, landings, or deliveries. This vision could help address questions such as (1) the optimal number of vendors in the pool (i.e., if the pool should be narrowed to a sustainable number of vendors) and (2) the number of task orders required to sustain this optimal number of vendors.

Lessons Learned are Not Formally Documented

Since 2018, CLPS has evolved its administrative processes with a relatively small project management team and administrative budget. However, there is no formal process to track and share lessons learned within the project office to ensure experiences and knowledge can be passed to those in other mission directorates, or in the case of CLPS personnel turnover. One NASA official told us some staff capture lessons learned informally, but do not distribute them across the project office. CLPS management has shared programmatic lessons learned about the initiative in forums outside of the Agency, but these are not captured in NASA's Lessons Learned system and accessible across all Centers and mission directorates.[31] Such lessons learned could help improve procurement processes in CLPS and other Agency operations using fixed-price contracts. They could also help inform other areas, such as overseeing vendor performance, integrating payloads, and gathering informal insight.

It is NASA policy to (1) capture lessons learned by managers and engineers to collect, document, and submit project knowledge and (2) organize, host, and actively participate in knowledge sharing activities to learn and contribute to the shared goals of safety and mission success.[32] Several CLPS managers and other officials also told us they could be doing more on lessons learned, including officially documenting these lessons to increase team knowledge.

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[31] Managed by the Office of the Chief Engineer, the NASA Lessons Learned system is a database of lessons learned from contributors across NASA and other organizations, and is accessible at https://www.nasa.gov/nasa-lessons-learned/ (accessed February 23, 2023).

[32] NASA Policy Directive 7120.6A, *Knowledge Policy for Programs and Projects* (December 16, 2019).

CONCLUSION

Over 50 years passed between the last Moon landing and when NASA made its next two attempts to revisit the Moon in early 2024. These recent missions used a new approach to procure delivery of NASA payloads under the CLPS initiative—which the Agency implemented to enable rapid, affordable, and frequent access to the lunar surface using American commercial vendors. This approach was designed to depart from traditional NASA programs by relinquishing Agency control of lander development, accepting higher risks of failure for the sake of learning, and progressing from smaller, simpler requirements to larger, more complex missions in a burgeoning commercial lunar delivery market.

However, we found that NASA did not consistently follow this approach for incremental progress. Rather, the Agency required aggressive lander development schedules that led to increasing risk aversion practices and policies, such as increased Agency insight, oversight, and vendor proposal requirements. This resulted in higher costs and delayed delivery schedules while threatening the initiative's ability to achieve its broad objectives. Similarly, NASA officials set aggressive lunar lander delivery schedules based on optimistic market research results. This optimistic scheduling did not provide a sufficient margin for unforeseen events like the COVID-19 pandemic or the vendors' development-related challenges and financial situations. Delivery schedules were further impacted by NASA-induced requirements changes, such as requiring additional tests and changing lunar landing locations. We recognize schedule delays are often common and, in this case, were partly attributed to a learning process that grew alongside this new grassroots business model and its relatively small and young commercial vendors.

Finally, NASA has not reassessed market conditions to better understand the Agency's role and optimal contribution in building a commercial industry—a significant undertaking that requires substantial investments from both NASA and the vendors. A documented plan that outlines a consistent approach for developing commercial lunar capabilities, promotes accountability, and aligns available resources to program objectives can help the Agency better manage and sustain this initiative.

Recommendations, Management's Response, and Our Evaluation

To increase accountability and transparency of the CLPS initiative, we recommended the Associate Administrator for Science Mission Directorate:

1. Conduct updated market research to assess capability growth across the lunar economy and associated transportation sector since 2017.
2. Reassess NASA's role in, and contribution to, the commercial lunar delivery market.

The Deputy Associate Administrator for Exploration, in coordination with the Director of the Exploration Architecture, Integration, and Science Directorate at Johnson, and the CLPS project manager should:

3. Finalize a management plan with clear leadership authority and responsibility that would delineate CLPS initiative performance goals and metrics that are measurable and targeted, criteria for augmented insight, a formal lessons-learned process, and any other relevant guidelines for the management plan's implementation.

In addition, the Deputy Associate Administrator for Exploration, in coordination with stakeholders from the Exploration Systems Development Mission Directorate, Space Operations Mission Directorate, and Space Technology Mission Directorate should:

4. Prepare and formalize a CLPS Manifest Selection Board charter and processes.
5. Strengthen procedures to ensure science payload interfaces and requirements are mature enough to write an RFTP that would minimize future requirement changes.

Furthermore, the Deputy Associate Administrator for Exploration, in coordination with the CLPS project manager and VIPER project manager, should:

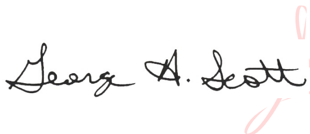
6. Assess technical implications of the first Peregrine lander failure on VIPER mission delivery success and impact to CLPS's overall cost and schedule, as applicable.

We provided a draft of this report to NASA management who concurred with our recommendations and described planned actions to address them. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

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

Major contributors to this report include Ray Tolomeo, Science and Aeronautics Research Audits Director; Stephen Siu, Assistant Director; Jiang Yun Lu; Frank Martin; Marshal Pennock; Courtney Daniels Jeremy Brown; and Adhana Davis.

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



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George A. Scott
Acting Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from May 2023 through May 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe 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 implementation and management of the CLPS initiative. Specifically, we determined whether NASA's organizational, programmatic, and acquisition approaches were effective in achieving its goals and objectives. We also evaluated progress made, lessons learned, and whether CLPS was meeting its established goals and priorities, with the intention of making recommendations for improving the initiative. We determined whether NASA had an effective governance structure to manage CLPS. Specifically, whether CLPS was managed under an organizational structure that includes the necessary management controls, budgeting, monitoring, stakeholder communications, and reporting. We also evaluated progress made according to CLPS's defined goals, objectives, and measurable outcomes. We identified and assessed the effectiveness of cost and schedule controls and NASA's monitoring process of contractor's performance. We further evaluated lessons learned and identified obstacles or potential challenges to success.

To assess NASA's progress made in managing the CLPS initiative, we interviewed NASA personnel working on the initiative at Johnson Space Center and NASA Headquarters. We also interviewed officials from SMD, ESDMD, and STMD. We conducted site visits to two vendors and interviewed officials from these two companies. To assess the potential benefits and challenges vendors face participating in CLPS, we surveyed 13 CLPS vendors, obtained 8 vendors' responses, and incorporated the survey results in our review. Additionally, we reviewed CLPS task order contract files, cost and budget documents, quarterly task order reviews, baseline performance updates, schedule data, and technical risks. We also obtained and examined internal and external documents related to the CLPS initiative.

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

- NASA Science Mission Directorate Management Handbook (April 2021)
- NASA Policy Directive 1000.0C, *NASA Governance and Strategic Management Handbook* (January 29, 2020)
- NASA Policy Directive 1000.5C, *Policy for NASA Acquisition (Updated w/Change 2)* (July 13, 2020)
- NASA Procedural Requirements (NPR) 7120.8A, *NASA Research and Technology Program and Project Management Requirements (Updated w/Change 3)* (September 14, 2018)
- NPR 7123.1D, *NASA Systems Engineering Processes and Requirements (Updated w/Change 2)* (July 5, 2023)
- NPR 8000.4C, *Agency Risk Management Procedural Requirements* (April 19, 2022)

- 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)
- National Academies of Sciences, Engineering, and Medicine, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032* (2023)

Assessment of Data Reliability

We used limited computer-processed data such as paid contract costs and schedule data. We assessed the reliability of this financial data by (1) verifying the data with the original contract documents, (2) reviewing data provided by the CLPS contracting officer, and (3) interviewing Agency officials knowledgeable about the data. We determined that the data was sufficiently reliable for the purposes of this report.

Review of Internal Controls

We assessed internal controls and compliance with laws and regulations necessary to satisfy the audit's objectives. We reviewed internal controls associated with the effectiveness of NASA's implementation and management of the CLPS initiative. Control weaknesses are identified and discussed in this report. However, because our review was limited to these internal control components and underlying principles, it may not have disclosed all internal control deficiencies that may have existed at the time of this audit.

Prior Coverage

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

NASA Office of Inspector General

NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission (IG-22-010, April 6, 2022)

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

Government Accountability Office

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

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

Appendix B: List of CLPS Vendors and Their Proposed Lander Services

Table 6: List of CLPS Vendors (as of April 2024)

	Selection Date	Company	Headquarters	Proposed Services
1	11/29/2018	Astrobotic Technology[a]	Pittsburgh, Pennsylvania	Peregrine and Griffin landers
2		Deep Space Systems[b]	Littleton, Colorado	Lunar technology development services
3		Draper Laboratory[a]	Cambridge, Massachusetts	SERIES-2 lander
4		Firefly Aerospace[a]	Cedar Park, Texas	Blue Ghost lander
5		Intuitive Machines[a]	Houston, Texas	Nova-C lander
6		Lockheed Martin Space	Littleton, Colorado	McCandless Lunar Lander
7		Masten Space Systems[a,c]	Mojave, California	XL-1 lander
8		Moon Express	Cape Canaveral, Florida	MX-1 Scout Class Explorer
9		Orbit Beyond[a]	Edison, New Jersey	Z-01 lander
10	11/18/2019	Blue Origin	Kent, Washington	Blue Moon lander
11		Ceres Robotics	Palo Alto, California	
12		Sierra Nevada Corporation	Louisville, Colorado	
13		SpaceX	Hawthorne, California	Starship
14		Tyvak Nano-Satellite Systems	Irvine, California	

Source: NASA OIG presentation of Agency information.

[a] These vendors were awarded delivery task order(s).

[b] This vendor combined with another company and formed Redwire Corporation.

[c] This vendor went bankrupt, and its assets were acquired by Astrobotic Technology.

Appendix C: Management's Comments

National Aeronautics and Space Administration

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

Reply to Attn of: Science Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Science Mission Directorate

SUBJECT: Agency Response to OIG Draft Report, "NASA's Commercial Lunar Payload Services Initiative" (A-23-11-00-SARD)

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 Commercial Lunar Payload Services Initiative" (A-23-11-00-SARD), dated May 2, 2024.

In the draft report, the OIG makes six recommendations to increase accountability and transparency of the Commercial Lunar Payload Services Initiative (CLPS) initiative.

Specifically, the OIG recommends the following:

The Associate Administrator for Science Mission Directorate should:

Recommendation 1: Conduct updated market research to assess capability growth across the lunar economy and associated transportation sector since 2017.

> **Management's Response:** NASA concurs with this recommendation. NASA will perform market research on the lunar economy with some consideration of the role of NASA in lunar transportation and delivery.
>
> **Estimated Completion Date:** April 30, 2025

Recommendation 2: Reassess NASA's role in, and contribution to, the commercial lunar delivery market.

> **Management's Response:** NASA concurs with this recommendation. Building on the updated market research conducted in response to Recommendation 1, the Science Mission Directorate (SMD) will assess the CLPS initiative within the overall commercial lunar delivery market and economy.
>
> **Estimated Completion Date:** May 31, 2025

The Deputy Associate Administrator for Exploration within SMD, in coordination with the Director of the Exploration Architecture, Integration, and Science Directorate at the Johnson Space Center, and the CLPS Project Manager should:

Recommendation 3: Finalize a management plan with clear leadership authority and responsibility that would delineate CLPS initiative performance goals and metrics that are measurable and targeted, criteria for augmented insight, a formal lessons-learned process, and any other relevant guidelines for the management plan's implementation.

Management's Response: NASA concurs with this recommendation. The Deputy Associate Administrator for Exploration and the CLPS Project Manager will lead the development of a management plan for CLPS.

Estimated Completion Date: March 30, 2025

In addition, the Deputy Associate Administrator for Exploration, in coordination with stakeholders from the Exploration Systems Development Mission Directorate, Space Operations Mission Directorate, and Space Technology Mission Directorate should:

Recommendation 4: Prepare and formalize a CLPS Manifest Selection Board charter and processes.

Management's Response: NASA concurs with this recommendation. The Deputy Associate Administrator for Exploration will formalize the charter for the CLPS Manifest Selection Board.

Estimated Completion Date: August 30, 2024

Recommendation 5: Strengthen procedures to ensure science payload interfaces and requirements are mature enough to write a request for task plan that would minimize future requirement changes.

Management's Response: NASA concurs with this recommendation. The CLPS project office will refine its guidelines for suggested interfaces, which will be used for future payload solicitations and development. This will be part of the Research Opportunities in Space and Earth Science (ROSES) 2025 solicitation for SMD's Payloads and Research Investigations for Research on the Moon (PRISM), which will be delivered by CLPS, and then shared with other prospective payloads.

Estimated Completion Date: June 30, 2025

Furthermore, the Deputy Associate Administrator for Exploration, in coordination with the CLPS Project Manager and Volatiles Investigating Polar Exploration Rover (VIPER) Project Manager, should:

Recommendation 6: Assess technical implications of the first Peregrine lander failure on VIPER mission delivery success and impact to CLPS's overall cost and schedule, as applicable.

Management's Response: NASA concurs with this recommendation. Astrobotic has stated that it will release results from its internal Failure Review Board and that these results will better inform Astrobotic's work on the delivery of the VIPER rover. The Deputy Associate Administrator for Exploration will work with CLPS, Astrobotic, the VIPER Project Manager and NASA leadership to determine if any changes should be made to VIPER delivery plans based on the results of this review. The 2026 President's Budget Request will include cost impacts associated with any changes.

Estimated Completion Date: October 31, 2024

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have 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
Date: 2024.06.03 12:23:48 -04'00'

Nicola Fox

Appendix D: Report Distribution

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
Associate Administrator for Exploration Systems Development Mission Directorate
Associate Administrator for Science Mission Directorate
Associate Administrator for Space Operations Mission Directorate
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Deputy Associate Administrator for Exploration
Director, Exploration Architecture, Integration, and Science Directorate
Project Manager, Commercial Lunar Payload Services Project Office
Project Manager, Volatiles Investigating Polar Exploration Rover Project
Director, Johnson Space Center
Director, Marshall Space Flight Center

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

Astrobotic Technology
Draper Laboratory
Firefly Aerospace
Intuitive Machines

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 Space and Science

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House Committee on Appropriations
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House Committee on Oversight and Accountability
    Subcommittee on Government Operations and the Federal Workforce

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

(Assignment No. A-23-11-00-SARD)