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The case for continuing VIPER - a critical milestone on the journey back to the Moon

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ABSTRACT

NASA's VIPER mission was designed to explore the Moon's south pole, with a primary objective of identifying and characterising volatile compounds such as water ice. Despite having been fully built and having passed all preflight environmental testing, the mission was cancelled by NASA in July 2024, and the rover remains in storage. In this paper, we outline why it remains crucial that a route to flying this mission is found. These reasons include laying the groundwork for both US and international exploration and habitation of the Moon, the development of the lunar economy, and the eventual goal of human exploration of Mars.

Keywords: The Moon (1692) — Lunar regolith (2315)

1. INTRODUCTION

The exploration of the lunar south pole offers unique opportunities to investigate fundamental science questions and to demonstrate capabilities and technologies that will enable long-term sustainable exploration of the wider Solar System (J. Flahaut et al. 2020; D. M. Hurwitz & D. A. Kring 2014). In particular, in-situ resource utilisation (ISRU) is likely to form a crucial part of deep-space exploration efforts, given the enormous advantages that it brings over carrying all resources from Earth (K. Sacksteder & G. Sanders 2007; G. B. Sanders & W. E. Larson 2013). Lunar ISRU will involve making use of resources already available on the Moon as raw materials (M. Anand et al. 2012). Water ice is of particular importance, given its utility as fuel precursor, a thermal working fluid, and for human sustainment. The overarching strategic importance of ISRU, and the exploration and prospecting that underlie it, are recognised in the 2020 United States Space Policy.

The deployment of robotic missions to initiate resource profiling is the first step in many roadmaps for lunar exploration and ISRU (J. Carpenter et al. 2016). NASA's VIPER mission was slated to be a crucial part of the United States' effort, and would have seen the first successful landing of a NASA mission at the lunar south pole and the first real-time teleoperation of a rover on the lunar surface (A. Colaprete et al. 2019). The mission was specifically designed to prospect for water, i.e. to identify and characterise potential ice deposits.

Although now fully built and having successfully passed all preflight tests, the VIPER mission remains cancelled with no clear roadmap to launch. In this paper, we outline the importance of VIPER's continuation, highlighting the core role that both its science investigations and its operational development will play in advancing exploration of the Moon, laying the groundwork for ISRU, and enabling future exploration of Mars.

1.1. *Mission Overview*

VIPER was developed around two key scientific objectives, which would quantify the distribution, availability, and morphology of volatiles at the lunar South Pole (A. Colaprete et al. 2019). These were:

1. To characterise the distribution and physical state of lunar volatiles (e.g., water, carbon dioxide) in cold traps and regolith, in order to understand their origin, and

2. To provide the needed data to evaluate the feasibility of ISRU at the lunar poles.

These objectives are directly traceable to NASA's Artemis objectives, NASA's Moon-to-Mars architecture roadmap, and the National Academies' Planetary Science Decadal Survey questions (see Sec. 1.2.1 and M. Smith et al. (2020); National Academies (2022); NASA (2022); J. L. Heldmann et al. (2025); A. Colaprete et al. (2025)).

As a ground-based vehicle with the ability to sense geological and geophysical properties on scales of meters to kilometres, and at depth; VIPER was designed to provide a crucial overlap in spatial scale between measurements made from orbit and the small-scale properties of the lunar regolith.

Measurements made from orbit include those from the Lunar Reconnaissance Orbiter (LRO), Lunar Prospector, Chandrayaan-1 and -2, Kaguya, Korean Pathfinder Lunar Orbiter, and the Gravity Recovery and Interior Laboratory (GRAIL). This suite of spacecraft placed constraints on the chemical composition of the lunar surface, its topography and morphology, the structures present in the subsurface, and of course the distribution of volatiles (P. O. Hayne et al. 2015; M. T. Zuber et al. 2014; E. A. Fisher et al. 2017; S. Li et al. 2018; M. Ohtake et al. 2024; K. Toyokawa et al. 2024). These datasets were used during VIPER's conceptualisation, design, and operational planning; and in turn VIPER's ground-truthing will enable them to be used even more effectively in the planning of future missions.

The rover's mobility is also crucial to achieving its aims of characterising the distribution of volatiles across the lunar south pole. For example, the Lunar Crater Observation and Sensing Satellite (LCROSS) mission remains our one point of ground truth for polar volatiles (A. Colaprete et al. 2010). LCROSS measured the properties of an impact ejecta plume created by a rocket stage impacting the lunar south pole in 2009, but sampled an area only 25–30 m in diameter (P. H. Schultz et al. 2010). VIPER will yield the more granular data needed to truly characterise the spatial distribution of any volatiles present. VIPER's mobility also enables geodetic measurements, which cannot currently be made from static platforms without significantly more complex and expensive equipment (e.g., K. W. Lewis et al. 2019; B. Fernando et al. 2024a).

1.2. *Mission Relevance*

1.2.1. *Planetary Science*

The science that VIPER was designed to undertake will help to address a number of high-priority, fundamental science questions. The seven that relate to the 2023–2032 Planetary Science Decadal Survey (National Academies 2022) are outlined in Table 1, along with relevant contributions made by members of the VIPER team.

Table 1. VIPER instrumentation and science outputs to date which support answering the high-priority questions of the Planetary Science Decadal Survey (National Academies 2022). Instrument capabilities are outlined in detail in Sec. 2.1.

Decadal Survey Priority Science Questions			**VIPER**
Q4 Impacts and dynamics	Q4.3 How did collisions affect the geological, geophysical, and geochemical evolution and properties of planetary bodies?	Q4.3b How do impacts affect surface and near-surface properties of solar system worlds?	NIRVSS, MSolo, NSS, TRIDENT, VIS, IMU; (C. I. Fassett et al. 2022; C. Talkington et al. 2022; H. Christopher et al. 2023; L. Keszthelyi et al. 2023)
		Q4.3e What exogenic volatile and non-volatile materials are delivered to planetary bodies?	NIRVSS, MSolo; (K. Mandt et al. 2022)
Q5 Solid body interiors and surfaces	Q5.1 How diverse are the compositions and internal structures within and among solid bodies?	Q5.1c How does the presence of porosity, ices, liquids or gases affect the physical (e.g., mechanical, thermal, electromagnetic) properties of the crust?	NSS, TRIDENT, VIS, IMU; (A. N. Deutsch et al. 2021; K. Zacny et al. 2022; K. Gansler et al. 2024; I. King et al. 2024; K. W. Lewis et al. 2024; B. Fernando et al. 2024a; A. Vidwans & J. Gillis-Davis 2025)
	Q5.4: How have surface characteristics and compositions of solid bodies been modified by, and recorded, surface processes and atmospheric interactions?	Q5.4d What are the signatures of chemical weathering/alteration, and how/why have surface mineralogies varied over time?	NIRVSS, NSS, TRIDENT; (A. Camon & M. Lemelin 2024; M. Lemelin et al. 2025; S. Gyalay et al. 2025)
	Q5.5 How have surface characteristics and compositions of solid bodies been modified by, and recorded, external processes?	Q5.5a How do space weathering processes modify surface characteristics and compositions?	NIRVSS, VIS, TRIDENT; (A. Camon & M. Lemelin 2024; M. Lemelin et al. 2025; S. Gyalay et al. 2025)
		Q5.5b How have impacts affected surface and near-surface properties?	NIRVSS, MSolo, NSS, TRIDENT, VIS, IMU; (C. I. Fassett et al. 2022; C. Talkington et al. 2022; H. Christopher et al. 2023; L. Keszthelyi et al. 2023)

Decadal Survey Priority Science Questions (continued)			VIPER Science
		Q5.5c Where and how do volatile deposition, sublimation, transport, redeposition and loss take place, and in the past?	NIRVSS, MSolo, NSS, TRIDENT, VIS, IMU; (M. Siegler et al. 2022; L. Schweitzer et al. 2023; P. Peplowski et al. 2023; S. Dibb & R. Elphic 2024; J. Coyan et al. 2025)

1.2.2. *1.2.2 Artemis III Science*

VIPER's science will also contribute directly to improving our understanding of the 'Character and Origin of Lunar Polar Volatiles' (see J. L. Heldmann et al. (2025) for more details). This is the core of Goal 2 of NASA's Artemis III Science Definition Team Report (NASA Artemis III Science Definition Team 2020), which outlines the scientific motivations for the investigations that the first NASA crew to land on the Moon since 1972 will undertake. Related to the Artemis III goals, the data that the rover will return will help:

Goal 2a: 'Determine the compositional state (elemental, isotopic, mineralogic) and compositional distribution (lateral and with depth) of the volatile component in lunar polar regions'. This will include the following investigation sub-items:

- **Item 2a-2:** 'Identification of surface frost locations in spatial context'
- **Item 2a-7:** 'Determine distribution of micro cold traps across the lunar surface within illuminated regions', and

Goal 2c: 'Understand the transport, retention, alteration, and loss processes that operate on volatile materials near and at permanently shaded lunar regions,' including:

- **Item 2c-1:** '[Determine the] distribution of water/OH within a permanently shadowed region.'

VIPER investigations would also be complementary to the defined science that the Artemis III Geology Team is currently in the process of implementing. The team's Goal D (B. Denevi et al. 2025) is focused on three objectives (characterization of subsurface volatiles in PSRs, transient volatiles at the surface, and volatiles added by exploration efforts), all of which VIPER would help inform prior to astronauts landing.

Beyond scientific objectives, VIPER's data will also offer unique and valuable environmental context for Artemis III operations. In particular, VIPER will provide ground-truth data that can validate current understanding of the thermal environment and volatile properties in permanent shadow, and set limits on any hazards that these areas could present during exploration. This will enhance confidence for astronaut safety, productivity, and exploration efficiency in the lunar polar environment. The absence of results from other recent missions which could have explored smaller sub-sets of these questions (e.g. PRIME-1, Lunar Trailblazer) underscores VIPER's unique capability to provide comprehensive, targeted data that will be key groundwork for Artemis III mission success.

1.2.3. *Moon-to-Mars Strategy*

Finally, VIPER's science will also address numerous objectives identified in NASA's Moon-to-Mars (M2M) Strategy and Objectives Development, which outlines NASA's roadmap to exploring and achieving sustained human presence farther afield in the Solar System (NASA 2022). Specifically, VIPER will directly contribute to the following M2M objectives:

- **Lunar/Planetary Science Objective 3:** Reveal inner Solar System volatile origin and delivery processes by determining the age, origin, distribution, abundance, composition, transport, and sequestration of lunar and Martian volatiles.
- **Applied Science Objective 3:** Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable ISRU on successive missions.
- **Operations Objective 3:** Characterize accessible resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable use of resources on successive missions.

Data from the VIPER mission would also indirectly address the following M2M objectives:

- **Science Enabling Objective 3:** Develop the capability to retrieve core samples of frozen volatiles from permanently shadowed regions on the Moon and volatile-bearing sites on Mars and to deliver them in pristine states to modern curation facilities on Earth.
- **Science Enabling Objective 5:** Use robotic techniques to survey sites, conduct *in-situ* measurements, and identify/stockpile samples in advance of and concurrent with astronaut arrival, to optimise astronaut time on the lunar and Martian surface and maximise science return.
- **Applied Science Objective 3:** Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable ISRU on successive missions.
- **Lunar Infrastructure Objective 6:** Demonstrate local, regional, and global surface transportation and mobility capabilities in support of continuous human lunar presence and a robust lunar economy.

1.3. *Mission heritage and history*

The underlying mission and instrument concepts behind VIPER have been under development for at least two decades, highlighting the significant amount of research and development that has gone into actualising the rover. An early key milestone was the commencement of the Regolith and Environment Science and Oxygen and Lunar Volatiles (RESOLVE) payload project in 2005 (G. B. Sanders et al. 2007). RESOLVE was designed to drill at least one metre into the lunar surface, characterise the volatiles present in the extracted material and the physical and chemical properties of the regolith, as well as extracting oxygen from it.

In 2014, the RESOLVE project was recast as NASA's Resource Prospector mission (D. R. Andrews et al. 2014; J. Captain et al. 2016; J. Davis 2018). Resource Prospector was designed to be a mobile, solar-powered mission carrying RESOLVE as a payload as well as additional systems to extract and analyse oxygen and other volatile gases. Resource Prospector was designed to launch in 2022–23 for a mission lifetime of 1–2 weeks.

Resource Prospector was cancelled in April 2018 due to budgetary constraints at NASA, despite community efforts to save the mission. However, the VIPER mission was announced the following year. In June 2020, it was announced that VIPER would be carried to the Moon onboard Astrobotic's Griffin lander. In January 2024, Astrobotic's first attempted lunar landing, with the smaller Peregrine lander, ended in failure.

1.4. *Mission Cancellation*

In July 2024, NASA cancelled VIPER, citing cost overruns incurred by supply chain delays and the pandemic, delays to the launch date, and the risks of subsequent issues requiring rectification being found during testing. As of 2022, approximately $433.5M had been spent on rover development and construction, with a further $226.5M allocated for the launch and delivery contract (NASA Office of Inspector General 2022).

Nonetheless, the rover was fully built and integrated and had successfully passed all required testing (including operational readiness testing) by early 2025. This includes rigorous thermal, environmental, acoustic, and vibration tests designed to simulate the harshness of launch, cruise, landing, and operations on the lunar surface. The VIPER Mission System, which includes non-rover Earth-based ground segments and systems required to support rover operations, is also feature-complete and has been subjected to over 1,000 hours of integrated simulations and engineering readiness testing.

Following VIPER's cancellation, NASA announced its intention to find a partner organisation (e.g., an industry or international entity) to fly VIPER to the Moon. In the interim, the rover would be replaced on the Griffin lander with a mass model deadweight to meet contractual obligations. NASA stated that if a partnership was not successfully identified, the rover would be disassembled. Despite issuing several iterations of partnership solicitations in various forms, NASA announced in May 2025 that the call for partnerships was being terminated without a decision being made as to the rover's future.

2. MISSION OPERATIONS

In this section, we will outline VIPER's planned Concept of Operations (ConOps), highlighting why its scientific goals and operational tests are so crucial to future exploration of the Moon and further afield. For a detailed review of VIPER ConOps, see Z. Mirmalek et al. (2025).

2.1. *Volatile prospecting and instrumentation*

VIPER will explore four types of ice stability regions (ISRs). ISRs are layers of lunar regolith where thermal models predict that ice may be stable, because peak temperatures are low enough to keep it from sublimating (e.g. A. R. Vasavada et al. (1999); M. Siegler et al. (2015); L. Rubanenko & O. Aharonson (2017)). Exactly how the ice in these regions became emplaced is unclear, though one plausible option is delivery during cometary or asteroidal bombardment in the Moon's distant past and sequestration in PSRs over geological time (L. Ong et al. 2010; A. Berezhnoy et al. 2012). In addition to their potential utility, lunar polar volatiles therefore also likely serve as a record of collisional and environmental processes on the lunar surface.

VIPER's science payload consists of four different instruments for investigating these ISRs. These include the Neutron Spectrometer System (NSS) to map hydrogen and water abundance (P. Peplowski et al. 2023), The Regolith and Ice Drill for Exploring New Terrains (TRIDENT) to excavate

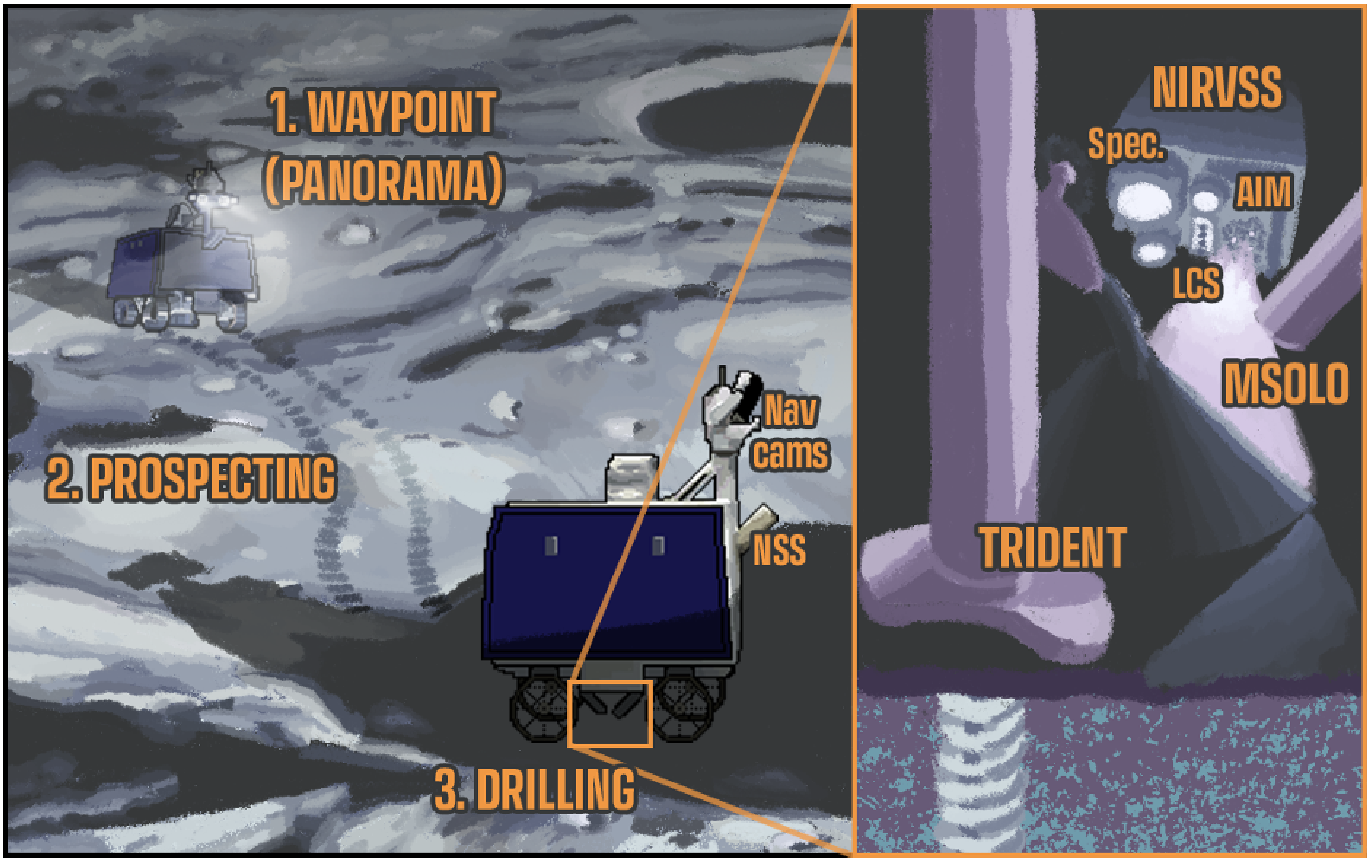

Figure 1. Schematic illustrating the operational modes of VIPER. The two modes of operation are prospecting (which includes waypoint operations) and drilling. The instruments and their roles are defined in Sec. 2.1.

subsurface samples (K. Zacny et al. 2022), plus the Near-InfraRed Volatiles Spectrometer System (NIRVSS) and the Mass Spectrometer Observing Lunar Operations (MSOLO) to analyse mineral and volatile compositions (T. Roush et al. 2021). A sub-component of NIRVSS, the Ames Imaging Module (AIM), provides context imagery for MSOLO and NIRVSS' spectrometer observations. These will be combined with data from navigational and operational components aboard the spacecraft including visible cameras (VIS) and the Inertial Measurement Unit (IMU, a strong-motion accelerometer). This suite of instruments offers insight into volatile properties and distributions from a number of complementary angles; including spectroscopy, terramechanics, geodesy, seismology, and imagery.

It is crucial to note that VIPER offers substantial scientific returns regardless of what form (if any) volatiles are found in on the lunar surface. A positive detection of volatiles in the quantities needed for ISRU will enable future extraction and utilisation. A negative detection, if determined to be statistically significant, will demonstrate that this region is not a promising ISRU target at a far smaller cost than would be incurred if that determination were made by Artemis astronauts.

Fig. 1 illustrates VIPER's operational plan in its regions of study, which consists of both prospecting and drilling. When prospecting, VIPER will travel from waypoint to waypoint whilst collecting data, reorientating itself at each waypoint. Each instrument will have a different role to play within each phase. For example, whilst stopped at a waypoint, the rover's navigational cameras may take panoramic images to determine local topography for navigation. NIRVISS AIM will image at multiple wavelengths to map spectroscopic variations, the LCS (Longwave Calibration Sensor) will measure the surface temperature in the NIRVISS field of view, and the IMU will be used as a passive seismometer and gravimeter. Conversely, whilst driving in the prospecting phase, the IMU will be used for navigation purposes and NIRVISS AIM will image continuously at a single wavelength to generate a video of the traverse. MSOLO, NIRVSS' spectrometer, and NSS can operate continuously at this time.

Unlike prospecting, the drilling phase (using the TRIDENT instrument) will only occur when the rover is stationary. TRIDENT is also able to percuss, injecting small amounts of energy into the lunar regolith. The IMU will be used as an active-source seismometer, listening to the signatures of drilling and percussing (B. Fernando et al. 2024a; K. Gansler et al. 2024). MSOLO and NIRVSS are situated on the rover such that they can monitor TRIDENT's drill tailings (the pile of excavated regolith) to detect volatiles present as well.

This integration of measurements in both the prospecting and drilling phases, especially on a mobile platform, cannot meaningfully be replicated by stand-alone payloads on static landers, as was suggested in NASA's original July 2024 cancellation announcement. This is true for a number of reasons:

1. The geodesy measurements that VIPER will make are necessarily relative, meaning that they can only be interpreted as compared to other observations made by the same instrument at different locations (B. Fernando et al. 2024b; K. W. Lewis et al. 2019). These cannot be meaningfully replicated with one (or even several) static landers, unless each carries a much more complex, massive, and fragile absolute gravimeter.

2. Any replacement static lander will invariably carry only a smaller subset of VIPER's payloads, meaning that an integrated chemical, geological, and geophysical perspective cannot be achieved. Interpolation of piecemeal measurements made by different instruments in different areas — none of which are co-located or directly calibrated against each other — risks introducing substantial uncertainties into our understanding of volatile abundance and availability. Furthermore, no commercial landers are able to land directly in permanently shadowed regions at present. To achieve VIPER's objectives using existing CLPS (Commercial Lunar Payload Services) platforms would therefore require a mobile component as well, further increasing cost and complexity.

3. If instruments similar to those carried on VIPER are spread across different missions, this also reduces the likelihood of overall objectives being met (in addition to reducing the scientific quality of measurements). This is because the same objectives will then require multiple successful launches, cruises, and landings, rather than just a single example as carried by VIPER.

2.2. *Geological context*

VIPER is targeting a landing site at approximately 85.444° S, 30.934° E , as shown in Fig. 2 (A. Colaprete et al. 2025). The broader landing area was selected based on optimisation of a number of requirements, including orbital dynamics, lighting, terrain roughness, communications feasibility, and distance from the boundary of the nearest major PSR (E. Balaban et al. this issue). Within this area, the precise landing site was chosen following a close examination of accessible PSRs, with the goal of maximising the scientific return and robustness of the overall mission. The mission operations area is around 4 km by 5 km in area, with a wider ∼11 km x 14 km "Extended Mission Area" available if needed (R. A. Beyer et al. 2025).

The VIPER landing site and mission area intersect two current Artemis III potential landing regions: 'Mons Mouton' and 'Mons Mouton Plateau'. This region of the Moon is thought to have formed as part of the South Pole—Aitken basin (during a giant impact >4 billion years ago, C. M. Pieters et al. (2001); R. W. Potter et al. (2012)) and is thus of high scientific interest as its geological history is intimately tied to the events that shaped the early Moon.

Lunar Prospector neutron data, although rather coarse at 45 km^2/pixel, show the Mons Mouton area to sit in a significant neutron suppression zone, indicating buried water ice and other hydrogen-bearing volatiles (D. J. Lawrence et al. 2006; R. Elphic et al. 2007). Several potential haematite exposures (S. Li et al. 2020) (possibility indicative of trace water or hydroxides) and direct water ice detections (S. Li et al. 2018) have been identified in this region from orbital datasets. Thus far, no other effort to land at the lunar south pole has succeeded, meaning that VIPER is left to fill this crucial gap that will inform planning for Artemis. China's Chang'E-7 mission is however planned to prospect for water ice at the south pole in 2026 - and this mission has an orbiter, lander, rover, and hopper. It is likely to achieve its aims before the corresponding US effort, whether that takes the form of VIPER or alternate mission(s).

As VIPER's launch becomes increasingly delayed, other missions will slowly contaminate the regolith surface with engine exhaust. Whilst some of these contaminants may be calibrated for, this will make VIPER's analysis more challenging, especially if the missions are from organisations which do not adhere to the same set of planetary protection protocols.

2.3. *Mission timeline*

It is important to note that the VIPER mission will last at most 3 to 6 consecutive terrestrial months, and hence the risk of incurring further costs due to repeated mission extensions is not relevant. As the mission is solar powered, it requires exposure to sunlight during each lunar day to charge its batteries. This is a prerequisite for both spacecraft operations and also survival heating during the frigid lunar night. This is feasible at the Mons Mouton landing site during the austral lunar spring and summer (September–March) but not during the austral winter. As such, the mission plan calls for a September launch window, with the mission ending 3–6 months later, once polar night has fallen on Mons Mouton. There is no likelihood of the rover surviving the lunar night.

2.4. *Capability development and direction*

Unlike the Mars rovers, VIPER will utilise direct-to-Earth (DTE) communication to maximise its duty cycle during the short mission lifetime. DTE communication comes with some risks, but also aenables development and execution of protocols for real-time operations. For VIPER, this is crucial to enabling spacecraft control during real-time activities such as driving and instrument operation. Having these protocols available during future exploration of the Moon by human astronauts will be extremely useful, and hence VIPER is a key demonstrator of this technology.

2.5. *Workforce*

The VIPER mission includes team members from across the United States, Canada, and Switzerland. A geographical distribution of team members is shown in Fig. 3.

The team includes early-career researchers across both science, engineering, and operations activities. As such, it serves as a key vessel for workforce development and upskilling, training the next generation of lunar scientists and engineers to support real-time human operations on the lu-

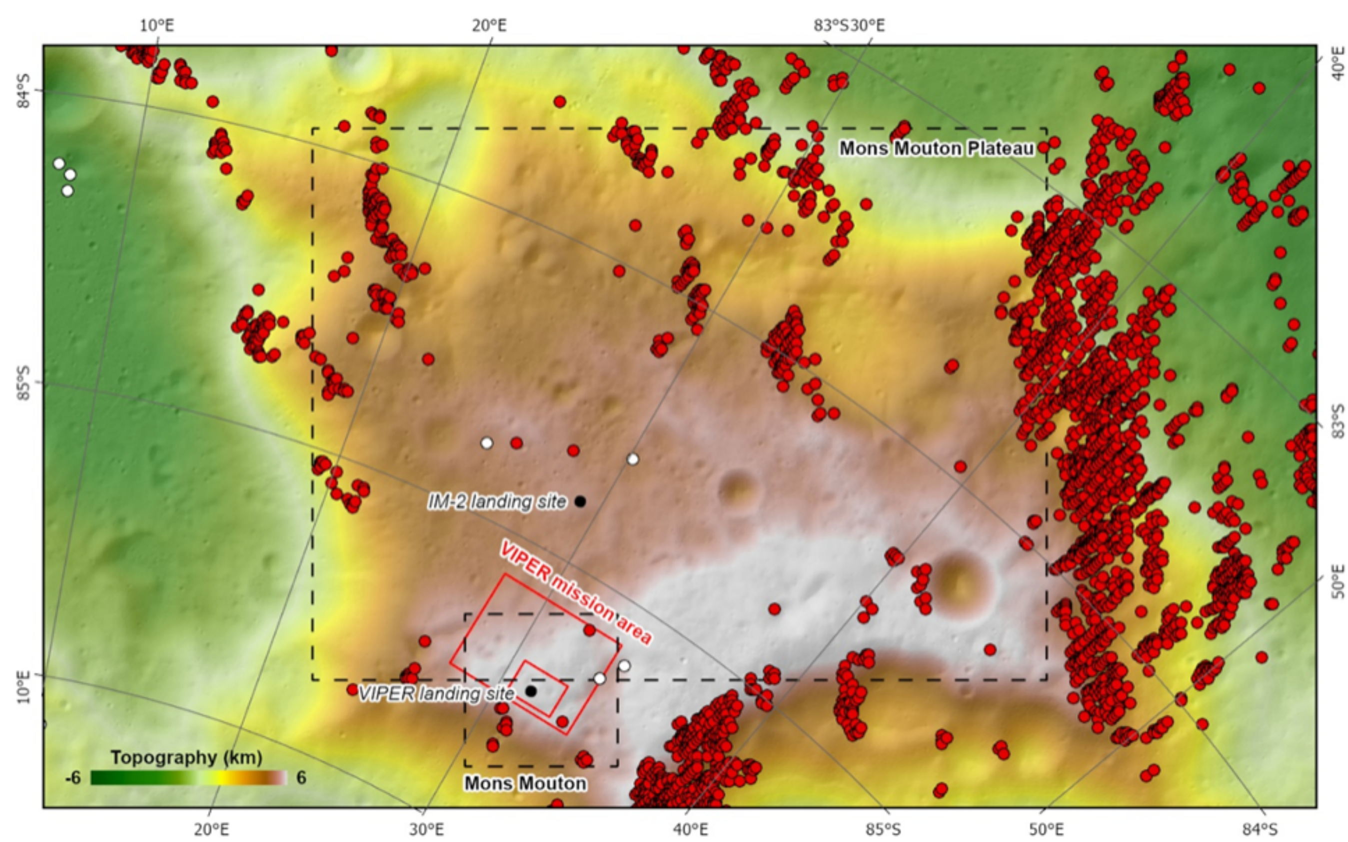

Figure 2. The VIPER landing site and mission area intersect two current Artemis III potential landing regions: 'Mons Mouton' and 'Mons Mouton Plateau'. The VIPER primary and extended mission areas (red rectangles), the VIPER landing site (black circle), as well as potential haematite (red) and water ice (white) detections by (S. Li et al. 2018, 2020), are shown. The Mons Mouton Plateau sits nearly 6 km above the mean lunar radius in one the most well-illuminated south polar regions. The landing site of the failed Intuitive Machines second lander (IM-2) is also shown. The background map is from the Lunar Orbiter Laser Altimeter at a resolution of 80 m/pixel.

nar surface as part of Artemis. Undertaking such training within an operational mission has been recommended as best practice for effective learning (B. Fernando et al. 2022).

Funding for the VIPER team is currently in the sustainment phase, and hence a potential risk to potential mission success is the loss of specialist expertise and knowledge, should funding to continue team development and training not be secured.

3. OUTLOOK

3.1. *Community response*

In response to the unprecedented cancellation of an already-completed rover, a substantial community campaign to save the mission was mounted. An open letter signed by over 5,000 signatories from all fifty US states (and numerous other countries) was delivered to the United States Congress asking it to refuse NASA's request to cancel the mission. Copies of the letter were specifically sent to congressional representatives serving on both the relevant House and Senate committees in September and October 2024.

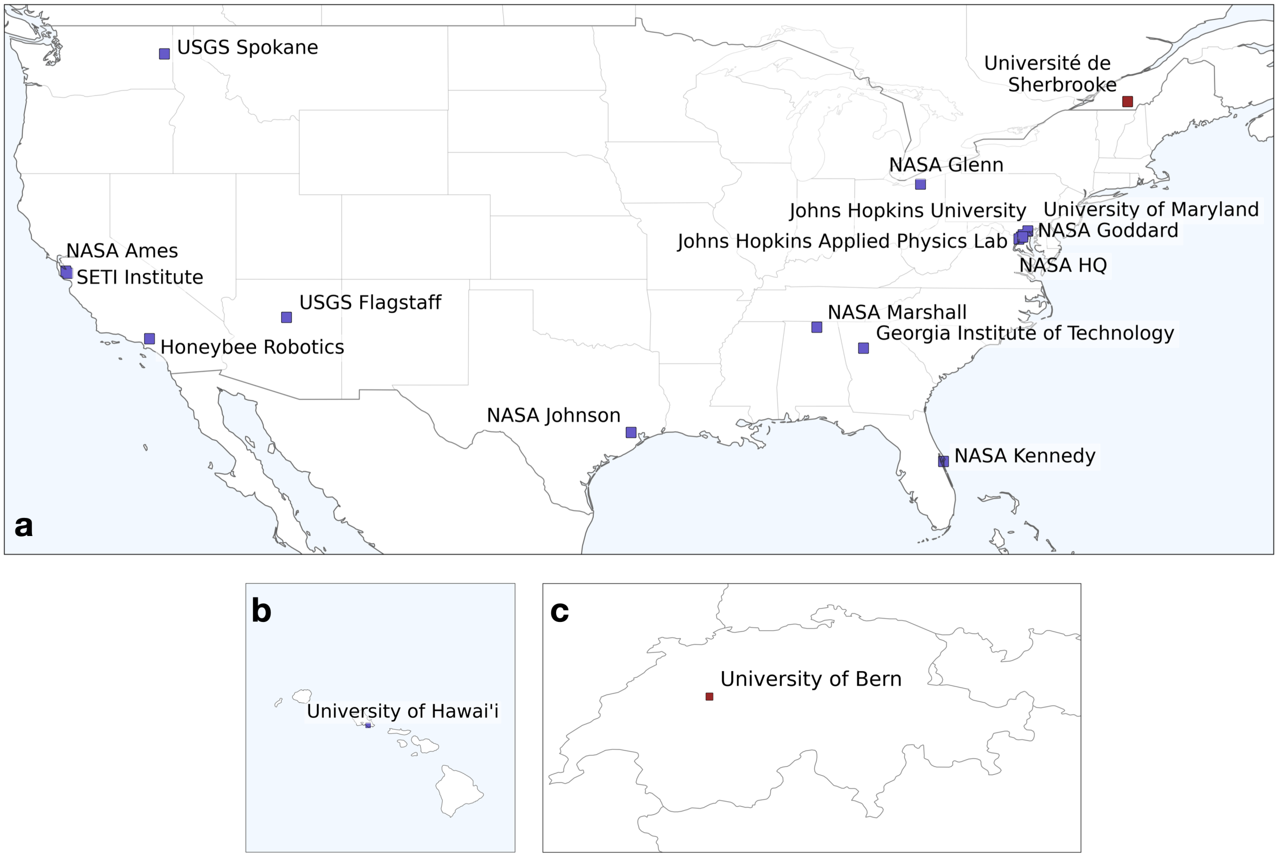

Figure 3. Institutions represented on the VIPER team, in the United States, Canada, and Switzerland. Ten states and five NASA centers are directly represented.

3.2. *Congressional response*

Bipartisan support for saving the mission has been noted on a number of occasions (M. Smith 2024). Strong support for continuing the mission despite budgetary challenges was expressed by Senator Shelley Moore Capito (Republican, West Virgina) during a July budget hearing, who expressed that she was 'disappointed in the recent NASA decision to cancel the VIPER rover'; and by Congresswoman Zoe Lofgren (Democrat, California) who stated that she was 'concerned about that whole process'.

In September 2024, U.S. House representatives in the Committee on Science, Space, and Technology sent a letter to NASA administrator Bill Nelson requesting information regarding VIPER's termination to better evaluate its fiscal and scientific implications (U.S. House Committee on Science, Space, and Technology 2024). In their October 2024 response, NASA replied with a detailed enumeration of expected cost avoidances from alternative launch scenarios. These included flying the Griffin Lander with a deadweight mass simulator (thus meeting contractual obligations), moving projected launch dates to either September 2025 or September 2026; and launch on an alternative lander. NASA projected that the cancellation of VIPER and its replacement with a mass simulator would save at least $104.0 million, though these estimates do not appear to have been externally audited or verified, nor do they account for the potential lost scientific value.

3.3. *Options*

It appears that it is no longer possible to move forward with launching VIPER on a delayed Astrobotic Griffin Lander, as VIPER's payload space onboard has since been allocated to Venturi Astrolab's FLIP rover. As such, a different landing vehicle is required for the rover to reach the surface and be deployed.

Options available include seeking a commercial or international partner organisation who themselves has landing capability or awaiting a NASA platform able to achieve this. A priority for this period should be keeping the science and engineering teams intact, such that no further operational heritage and experience is not lost, the associated mission risk profile is not elevated, and future data returns are maximised. Numerous options for funding the mission through this phase also exist, including through the NASA Lunar Development and Exploration Program budget (as is the case currently), though a direct line item in the NASA budget (which would require congressional approval), or through a commercial or international partner.

4. CONCLUSIONS

In this paper, we have described how the VIPER rover is a key part of the United States' Artemis and Moon-to-Mars program architectures, which will offer insight into the distribution and properties of lunar volatiles that cannot be practically achieved with other platforms that are currently slated for launch in the next $\sim$5 years.

Despite VIPER's delay, the mission remains ready-to-fly and includes science, engineering, and operations teams with experience and heritage of guiding the mission through to launch readiness. We have also discussed a number of options for mission continuation, including maintaining funding and expertise as a NASA-led mission. Doing so is crucial to ensuring NASA is prepared for the scientific and technical challenges that will accompany the first human landing at the lunar south pole and eventual further exploration of Mars. It is also crucial for United States leadership in space exploration.

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AUTHOR CONTRIBUTIONS

Conceptualisation - BFo, CN, JK
Formal Analysis - RP, SG, ML
Writing - Original Draft - BFo, CN, JK, BFz, RP, SG, ML
Writing - Review and Editing - BFo, SG
Project Administration - BFo, JK

REFERENCES

Anand, M., Crawford, I. A., Balat-Pichelin, M., et al. 2012, Planetary and Space Science, 74, 42

Andrews, D. R., Colaprete, A., Quinn, J., Chavers, D., & Picard, M. 2014, in AIAA SPACE 2014 Conference and Exposition, 4378

Balaban, E., Shirley, M., Colaprete, A., et al. this issue, The Planetary Science Journal

Berezhnoy, A., Kozlova, E., Sinitsyn, M., Shangaraev, A., & Shevchenko, V. 2012, Advances in space research, 50, 1638

Beyer, R. A., Shirley, M., Colaprete, A., et al. 2025, The Planetary Science Journal

Camon, A., & Lemelin, M. 2024, in Lunar and Planetary Science Conference, Vol. 55, 1979

Captain, J., Elphic, R., Colaprete, A., Zacny, K., & Paz, A. 2016, in Earth & Space 2016: Engineering, Science, Construction, and Operations in Challenging Environments, 278–289

Carpenter, J., Fisackerly, R., & Houdou, B. 2016, Space Policy, 37, 52

Christopher, H., Hirabayashi, M., Kestay, L., et al. 2023, in 54th Lunar and Planetary Science Conference, Vol. 2806, 1828

Colaprete, A., Andrews, D., Bluethmann, W., et al. 2019, in AGU Fall Meeting Abstracts, Vol. 2019, P34B–03

Colaprete, A., Schultz, P., Heldmann, J., et al. 2010, science, 330, 463

Colaprete, A., et al. 2025, Colaprete et al. (this issue),

Coyan, J., Siegler, M., Martinez-Comacho, J., Beyer, R., & Shirley, M. 2025, The Planetary Science Journal, 6, 105

Davis, J. 2018, A Brief History of Resource Prospector, NASA's Cancelled Lunar Mission,, https://www.planetary.org/articles/20180503-resource-prospector-timeline

Denevi, B., Edgar, L., Fassett, C., et al. 2025, in 56th Lunar and Planetary Science Conference (LPSC)

Deutsch, A. N., Heldmann, J. L., Colaprete, A., Cannon, K. M., & Elphic, R. C. 2021, The Planetary Science Journal, 2, 213

Dibb, S., & Elphic, R. 2024, LPI Contributions, 3040, 2654

Elphic, R., Eke, V. R., Teodoro, L. F., Lawrence, D., & Bussey, D. 2007, Geophysical Research Letters, 34

Fassett, C. I., Beyer, R. A., Deutsch, A. N., et al. 2022, Journal of Geophysical Research: Planets, 127, e2022JE007510

Fernando, B., Daubar, I. J., Irving, J. C. E., et al. 2022, Nature Astronomy, 6, 1339

Fernando, B., Lewis, K., Schmerr, N., & Gansler, K. 2024a, LPI Contributions, 3063, 5046

Fernando, B., Newman, C., Daubar, I. J., et al. 2024b, Nature Astronomy, 8, 1521

Fisher, E. A., Lucey, P. G., Lemelin, M., et al. 2017, Icarus, 292, 74

Flahaut, J., Carpenter, J., Williams, J.-P., et al. 2020, Planetary and Space Science, 180, 104750

Gansler, K., Schmerr, N., Wang, J., et al. 2024, LPI Contributions, 3060, 6028

Gyalay, S., Ennico-Smith, K., Dobrea, E. Z. N., et al. 2025, in 56th Lunar and Planetary Science Conference, Lunar and Planetary Institute, The Woodlands, Texas. https://www.hou.usra.edu/meetings/lpsc2025/pdf/1673.pdf

Hayne, P. O., Hendrix, A., Sefton-Nash, E., et al. 2015, Icarus, 255, 58

Heldmann, J. L., Colaprete, A., Deutsch, A., et al. 2025, This issue

Hurwitz, D. M., & Kring, D. A. 2014, Journal of Geophysical Research: Planets, 119, 1110

Keszthelyi, L., Beyer, R., Black, S., et al. 2023, in Lunar Surface Science Workshop 20, Lunar and Planetary Institute

King, I., Cannon, K., Bickel, V., et al. 2024, LPI Contributions, 3040, 1686

Lawrence, D. J., Feldman, W. C., Elphic, R. C., et al. 2006, Journal of Geophysical Research, 111, E08001, doi: 10.1029/2005JE002637

Lemelin, M., Dobrea, E. N., Li, S., et al. 2025, in 56th Lunar and Planetary Science Conference, Lunar and Planetary Institute, The Woodlands, Texas. https://www.hou.usra.edu/meetings/lpsc2025/pdf/2218.pdf

Lewis, K. W., Peters, S., Gonter, K., et al. 2019, Science, 363, 535

Lewis, K. W., Schmerr, N. C., Fernando, B., et al. 2024, in AGU Fall Meeting Abstracts No. 2828

Li, S., Lucey, P. G., Fraeman, A. A., et al. 2020, Science advances, 6, eaba1940

Li, S., Lucey, P. G., Milliken, R. E., et al. 2018, Proceedings of the National Academy of Sciences, 115, 8907

Mandt, K., Mousis, O., Bouquet, A., et al. 2022, in 53rd Lunar and Planetary Science Conference, Vol. 2678, 2091

Mirmalek, Z., Lim, D. S., Colaprete, A., & Lees, D. 2025, in 18th International Conference on Space Operations

NASA. 2022, Moon to Mars Objectives,

NASA Artemis III Science Definition Team. 2020, Artemis III Science Definition Team Report, Tech. Rep. NASA/SP-20205009602, National Aeronautics and Space Administration, Washington, D.C.

NASA Office of Inspector General. 2022, NASA's Volatiles Investigating Polar Exploration Rover (VIPER) Mission, Tech. Rep. IG-22-010, National Aeronautics and Space Administration, Office of Audits, Washington, D.C. https://oig.nasa.gov/docs/IG-22-010.pdf

National Academies. 2022, Origins, worlds, and life: a decadal strategy for planetary science and astrobiology 2023-2032 (National Academy of Sciences, Engineering, and Medicine)

Ohtake, M., Nakauchi, Y., Tanaka, S., et al. 2024, The Astrophysical Journal, 963, 124

Ong, L., Asphaug, E. I., Korycansky, D., & Coker, R. F. 2010, Icarus, 207, 578

Peplowski, P., Elphic, R., Fritzler, E., & Wilson, J. 2023, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1049, 168063

Pieters, C. M., Head III, J. W., Gaddis, L., Jolliff, B., & Duke, M. 2001, Journal of Geophysical Research: Planets, 106, 28001

Potter, R. W., Collins, G. S., Kiefer, W. S., McGovern, P. J., & Kring, D. A. 2012, Icarus, 220, 730

Roush, T., Colaprete, A., Cook, A., et al. 2021, in Lunar and Planetary Science Conference 52 (LPSC).

Rubanenko, L., & Aharonson, O. 2017, Icarus, 296, 99

Sacksteder, K., & Sanders, G. 2007, in 45th AIAA Aerospace Sciences Meeting and Exhibit, 345

Sanders, G. B., & Larson, W. E. 2013, Journal of Aerospace Engineering, 26, 5

Sanders, G. B., Rosenbaum, B., Simon, T., et al. 2007, in ILEWG 9th International Conference on Exploration and Utilization of the Moon. https://ntrs.nasa.gov/citations/20070025482

Schultz, P. H., Hermalyn, B., Colaprete, A., et al. 2010, science, 330, 468

Schweitzer, L., Dibb, S., Elphic, R. C., & Wilson, J. T. 2023, in AGU Fall Meeting Abstracts No. 2725, P11C–2725

Siegler, M., Paige, D., Williams, J.-P., & Bills, B. 2015, Icarus, 255, 78

Siegler, M., Martinez-Camacho, J., Paige, D., et al. 2022, in Lunar Polar Volatiles Conference, Vol. 2703, 5025

Smith, M. 2024, NASA Provides More Details to Congress about VIPER Decision,, Space Policy Online https://spacepolicyonline.com/news/nasa-provides-more-details-to-congress-about-viper-decision/

Smith, M., Craig, D., Herrmann, N., et al. 2020, in 2020 IEEE aerospace conference, IEEE, 1–10

Talkington, C., Hirabayashi, M., Montalvo, P., et al. 2022, Geophysical Research Letters, 49, e2022GL099241

Toyokawa, K., Haruyama, J., Iwata, T., & Nozawa, H. 2024, Earth and Planetary Science Letters, 648, 119065

U.S. House Committee on Science, Space, and Technology. 2024, Letter to NASA regarding VIPER termination,, Washington, D.C.: U.S. House Committee on Science, Space, and Technology

Vasavada, A. R., Paige, D. A., & Wood, S. E. 1999, Icarus, 141, 179

Vidwans, A., & Gillis-Davis, J. 2025, Authorea Preprints

Zacny, K., Chu, P., Vendiola, V., et al. 2022, in AGU Fall Meeting Abstracts, Vol. 2022, P42C–2419

Zuber, M. T., Smith, D. E., Lehman, D. H., et al. 2014, in GRAIL: Mapping the Moon's Interior (Springer Nature), 3–24