National Aeronautics and
Space Administration

Lunar Discovery and Exploration Program Update

Joel Kearns
Deputy Associate Administrator for Exploration
Science Mission Directorate
NASA Headquarters

Planetary Science Advisory Committee
June 21, 2023

- Planning/Strategies
  - Integrated Lunar Science Strategy (NASA)
  - Moon2Mars Objectives (and Decadal Surveys Trace)
  - Community Science Definition Team: objectives for Endurance A Mission (South Pole-Aitken Basin sample return)
  - NASEM Studies (e.g., Science from Humans on Mars)
- Competitive Solicitations
  - PRISM3 selections: June 2023
    - Proposer selects landing site
    - Higher instrument suite cost cap
    - “Mobility as Service” offered by CLPS
    - ”Survive the Night” offered by CLPS
  - Artemis III Geology Team call step 2 proposals received April 25, 2023 (A3GT)
  - Artemis III Deployed Instruments call released May 30, 2023 (A3DI)
  - Planning: Lunar Terrain Vehicle (LTV) Instruments
  - Planning: A4DI
  - Planning: PRISM4
- PRISM1 instrument suites in development:
  - Lunar Vertex - Exploring the Intersection of Geoscience and Space Plasma Physics (Lunar Vertex) [Blewett/APL] (CP-11)
  - Farside Seismic Suite (FSS) [Panning/JPL] (CP-12)
  - Lunar Interior Temperature and Materials Suite (LITMS) [Grimm/SwRI] (CP-12)
- PRISM2 instrument suites in development:
  - Lunar Vulkan Imaging and Spectroscopy Explorer (LunarVISE) [Donaldson-Hanna/UCF]
  - Lunar Explorer Instrument for Space Biology Applications (LEIA) [Settles/NASA ARC]
- CLPS delivery competitions
  - Done: CS-3 to delivery DoE/UCB LuSEE-Night to farside, and ESA Lunar Pathfinder to orbit (Firefly Aerospace)
  - Next: CP-22 (LEIA + others) to South Pole
  - Then: CP-21 (LunarVISE + others) to Gruithuisen Domes
- Masten XL-1 (CLPS TO-19C) will not take place; instruments to be re-manifested
- VIPER progress through SIR; landing Nov 2024
- Lunar Trailblazer in TVAC; Rideshare on IM-2 [Ehlmann/CalTech]

Commercial Lunar Payload Services

First Two Task Orders

Astrobotic Technologies
Peregrine Lander

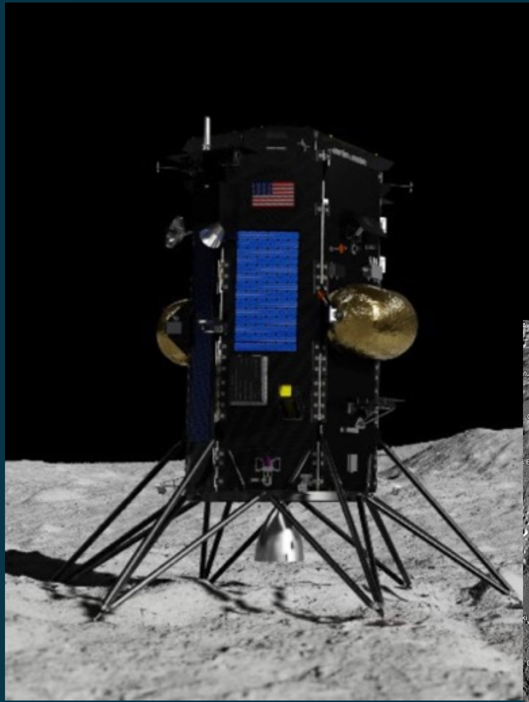
PM-1 Mission

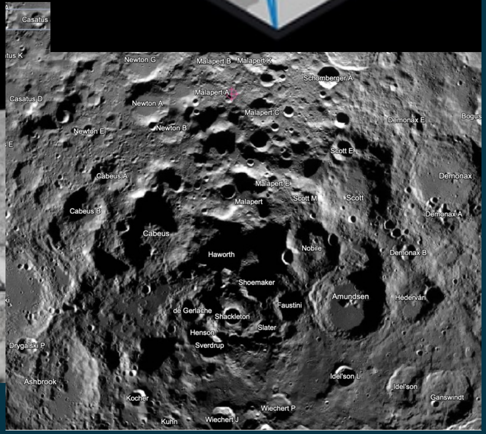
Mission Details

Lander/ Launch Provider:	Peregrine / ULA Vulcan-Centaur
Launch Date:	*TBD 2023 (depends on V-C readiness)*
Landing Date:	*TBD 2023*
Landing Site:	Sinus Viscositatis (35.1°N, 41.8°W)
Surface Ops Duration:	~196 Hours

Intuitive Machines
Nova-C Lander

IM-1 Mission





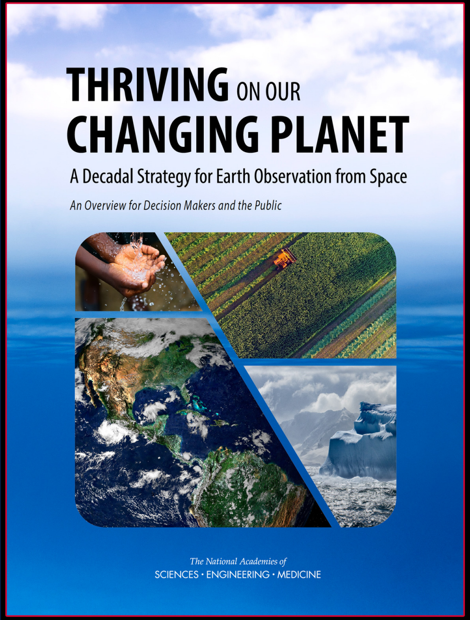
Mission Details

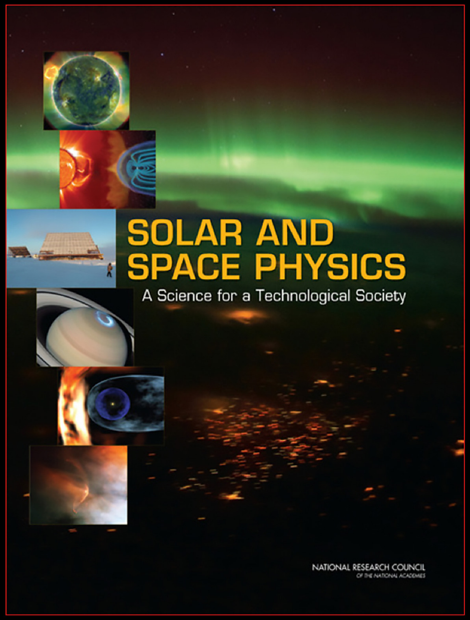
Lander/ Launch Provider:	Nova-C / SpaceX Falcon 9
Launch Window:	*Q3 2023*
Landing Date:	*Q3 2023*
Landing Site:	South Pole - Malapert A (80.297°S 1.2613°E)
Surface Ops Duration:	~ 264 Hours

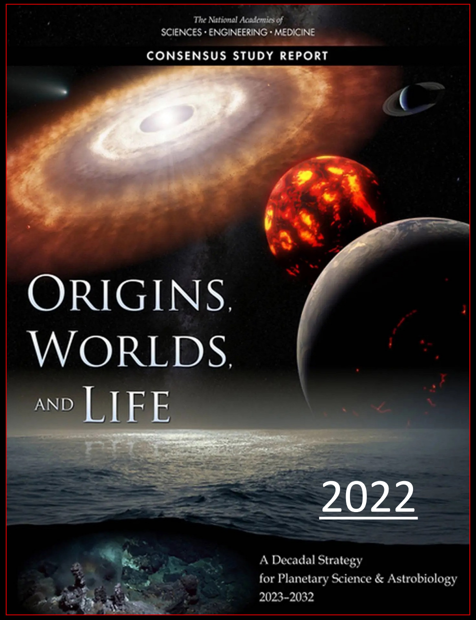
As of April 12, 2023

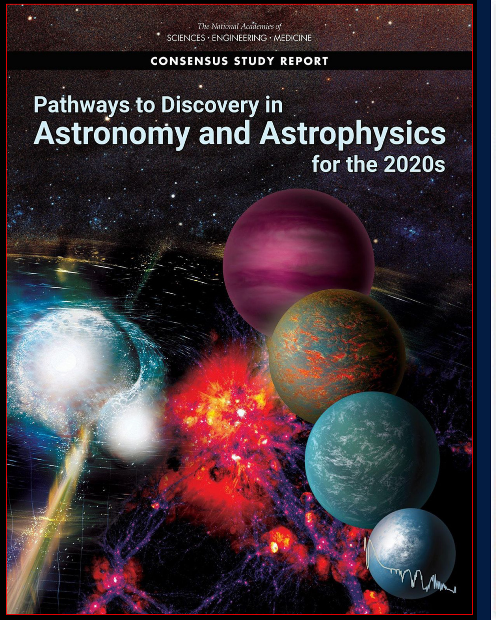
Astrobotic's Peregrine-1 Awaiting ULA Go-Ahead to Ship

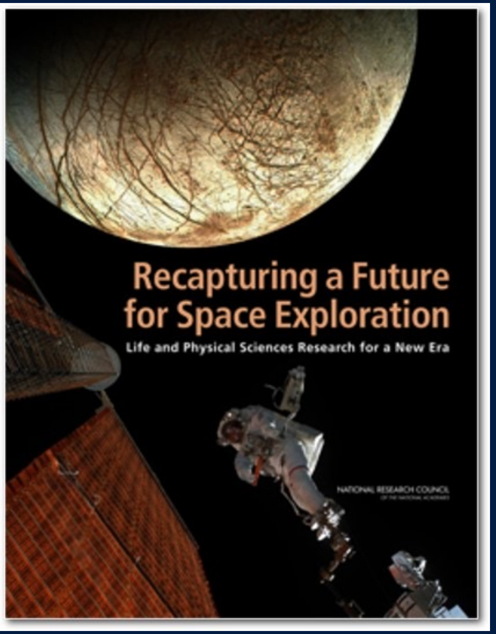
Strategic Research and Priorities from NASEM Decadal Surveys







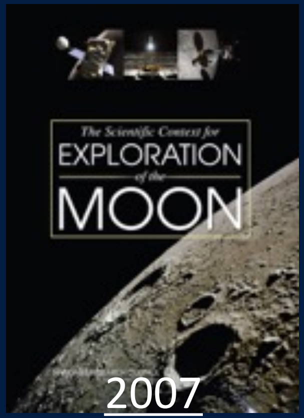




to be updated in 2024

to be updated in 2023

Planetary Science Community reports



NASA reports

Decadal Science Themes for Lunar Exploration (Box 22.2 of OWL)

The central goal of a science-driven program of lunar discovery and exploration is to reveal the history of major events and processes that have shaped the Earth–Moon system and the solar system.

The National Academy of Sciences decadal committee prioritized three overarching Science Themes:

Science Theme 1: Uncover the lunar record of solar system origin and early history. The Moon's composition, structure, and ancient surface preserve a record of early events: from the giant impact that produced the Earth−Moon system to ongoing bombardment as life on Earth emerged and evolved.

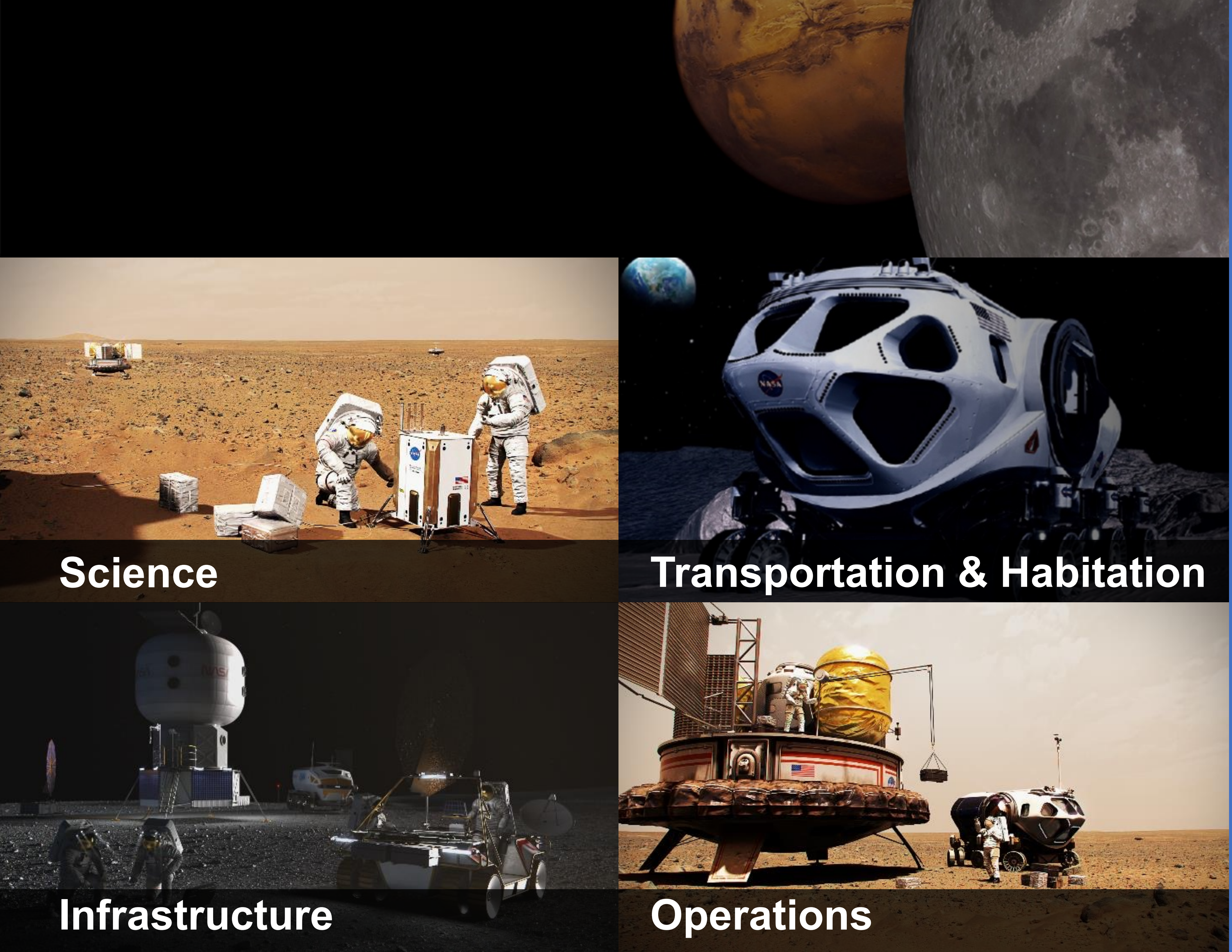
Science Theme 2: Understand the geologic processes that shaped the early Earth that are best preserved on the Moon. The Moon retains a record of processes that set the evolutionary paths of rocky worlds, including volcanism, magnetism, tectonism, and impacts.

Science Theme 3: Reveal inner solar system volatile origin and delivery processes. The Moon hosts water and other volatiles in its interior, across its surface, and in ice deposits at its poles, providing a record that may help constrain the origins of Earth's oceans and the building blocks for life, as well as ongoing volatile delivery processes.

National Aeronautics and Space Administration

NASA's Moon to Mars Strategy and Objectives Development Public Release

@NASAArtemis



Create a blueprint for sustained human presence and exploration throughout the solar system

Example from M2M Objectives Trace to Decadals

M2M Objectives Strategy: Appendix C Table

- LPS-1: Uncover the record of Solar System origin and early history, by determining how and when planetary bodies formed and differentiated, characterizing the impact chronology of the inner Solar System as recorded on the Moon and Mars, and characterize how impact rates in the inner Solar System have changed over time as recorded on the Moon and Mars.
  - Q4. Impacts and dynamics. How has the population of solar system bodies changed through time, and how has bombardment varied across the solar system? How have collisions affected the evolution of planetary bodies?
    - Q4.2. How did impact bombardment vary with time and location in the Solar System?
      - Determine the age of the South Pole-Aitken (SPA) basin to determine the beginning of recorded bombardment on the ancient lunar farside by dating samples formed from or excavated by the SPA basin forming event.
      - Determine a precise absolute chronology for lunar impacts applicable to other worlds by measuring radiometric ages for terrains much older than 3.9 Gyr and younger than 3 Gyr.
      - Determine the absolute age of a martian basin and use it to calibrate the timing of early martian bombardment by dating a surface whose age can be determined by in situ methods or returned samples.

Moon to Mars Objective	2023 Planetary Science and Astrobiology Decadal Questions	2023 Decadal Strategic Questions	2023 Decadal Strategic Research

The Big Challenges in Planetary Science of the Moon (i.e., science that requires a strategy to accomplish)

Specific missions that can be achieved through multiple architecture options:

- SPA Sample Return
- Lunar Geophysical Network
- Cryogenic Volatile Sample Return

Objectives that require a build up of knowledge and global access to samples to achieve:

- Lunar Chronology
- Lunar Formation/Evolution

These implement Strategic Research defined for Decadal Survey Science Questions

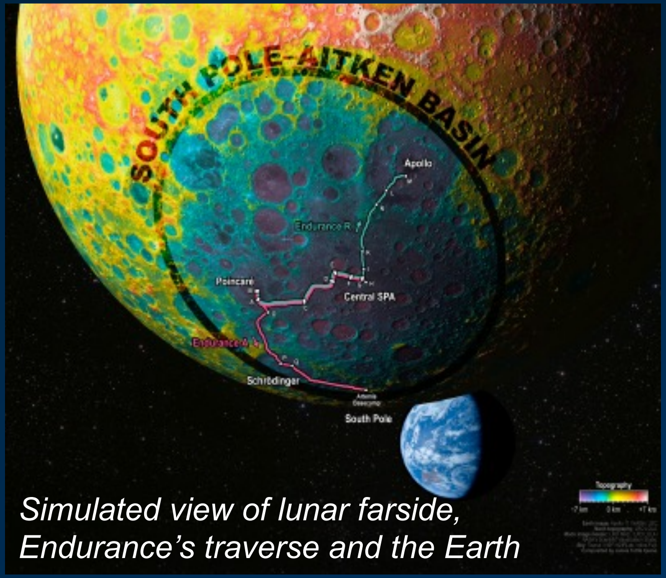
Components:

- *Orbital Strategy*
- *CLPS Strategy*
- *Artemis Human Systems Strategy*
- *R&A Strategy*

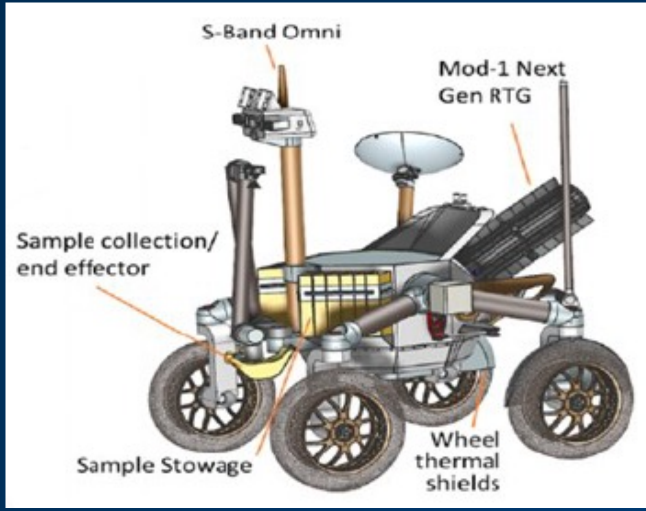
Human Enabled Decadal-Level Science at the Moon
Endurance A: South Pole-Aitken Sampling Campaign

- Top lunar priority of the Planetary Science Decadal Survey: “Endurance A”
  - long-duration rover
  - traverses ~2000km
  - Brings ~100kg of samples, taken at strategic sites throughout the South Pole-Aitken basin, to South Pole for HLS to Earth
- Address five lunar science objectives, including:
  - Solar System Chronology: Anchors the earliest impact history of the Solar System, tests the giant planet instability, impact cataclysm, and late heavy bombardment hypotheses, and anchors the “middle ages” of solar system chronology
  - Planetary Evolution: Tests the lunar magma ocean hypothesis, characterizes the thermochemical evolution of terrestrial planets, and explores the geologic diversity of a giant impact basin from floor to rim

Recommendation: Endurance-A should be implemented as a _strategic medium-class mission_ as the _highest priority_ of the Lunar Discovery and Exploration Program. Endurance-A would utilize CLPS to deliver the rover to the Moon, a long-range traverse to collect a substantial mass of high-value samples, and astronauts to return them to Earth. *– Origins, Worlds, and Life (Planetary Decadal), 22-17*



Simulated view of lunar farside, Endurance’s traverse and the Earth



Artemis Human Systems Strategy

- The capabilities of our human missions will continue to grow, and SMD provides input to ESDMD to maximize the science that can be accomplished through Artemis Human Systems
- Artemis III capabilities will be limited, but will grow with each subsequent mission
    - Freezers, mobility (LTV, PR), power and comms infrastructure, enhanced sample return capabilities, etc.
- Building instrument capabilities through DALI as well as MATTISE/PICASSO and PRISM
- Input from the community through the Lunar Surface Science Workshop (LSSW) series has been invaluable.

Path to decision:

- National Academy study on non-polar sorties for human exploration
- National Academy study on science in the "sustained human presence" phase
- Endurance study and SDT

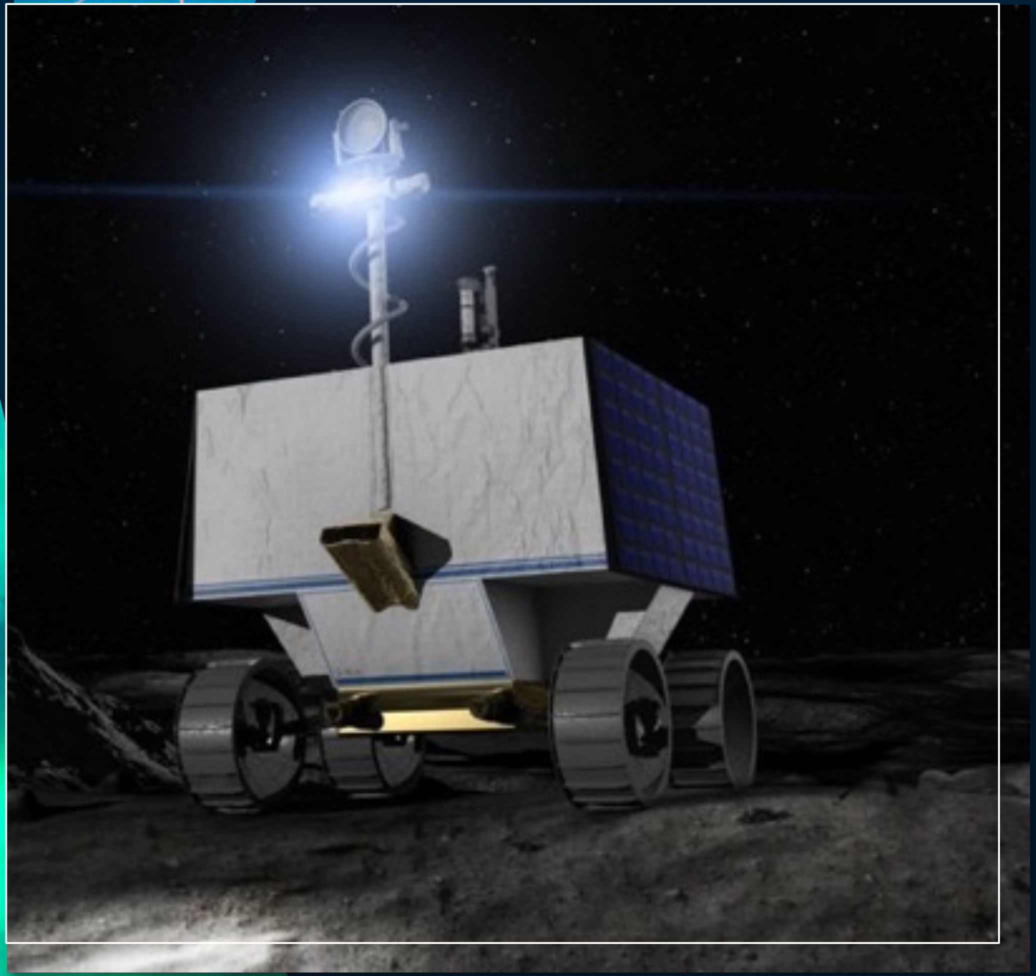
FY 2024 President's Budget Request Moon to Mars Manifest

CY	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
ESDMD	MISSION COMPLETE **Artemis I** (Nov. - Dec. 2022) Uncrewed Test Flight: SLS Block 1 / Orion / ML1 10 CubeSats Deployed		**Artemis II** (Nov. 2024) Crewed Test Flight SLS Block 1 / Orion / ML1 *HLS Uncrewed Lunar Demo*	**Artemis III** (Dec. 2025) Crewed Flight SLS Block 1 / Orion / ML1 HLS Crewed Lunar Demo xEVA Surface Suits *Gateway PPE/HALO Launch*	*Gateway PPE/HALO Arrival in NRHO*		**Artemis IV** (Sept. 2028) Crewed Flight SLS Block 1B / Orion / ML2 I-Hab to Gateway DSL to Gateway Sustaining HLS Crewed Lunar Demo xEVA Surface Suits *TBD Sustaining HLS Uncrewed Lunar Demo*	**Artemis V** (Sept. 2029) Crewed Flight SLS Block 1B / Orion / ML2 ESPRIT to Gateway DSL to Gateway Gateway External Robotics System TBD Sustaining HLS Crewed Lunar Demo xEVA Surface Suits LTV	**Artemis VI** (Sept. 2030) Crewed Flight SLS Block 1B / Orion / ML2 Airlock to Gateway DSL to Gateway TBD Sustaining HLS Services xEVA Surface Suits	**Artemis V** (Sept. 2031) Crewed Flight SLS Block 1B / Orion / ML2 Gateway operations DSL to Gatewa TBD Sustaining HLS Services xEVA Surface Suits Pressurized Ro
SOMD	DSN Upgrades (DLEU) Completed DSS-26 [Goldstone]	Completed DSS-36 [Canberra]	DSS-24 [Goldstone] DSS-56 [Madrid]	DSS-34 [Canberra] Lunar Communications Relay and Navigation Services (LCRNS) Increment Alpha	DLEU Overall Completion DSS-54 [Madrid]	Lunar Exploration Ground Sites 1-3 Increment Beta	Increment Charlie	Ongoing Science, Human Research Program, and Technology Development in LEO (ISS transition to CLD)		
SMD CLPS Flights Outlined	LRO Mars 2020: MOXIE; MEDA	TO 2-AB TO 2-IM	ESCAPADE TO 20A: VIPER TO 19D TO CP-11: Surface Robotic Scouts (CADRE)	Artemis III Surface Science Instruments HERMES ready for integration ESA Lunar Pathfinder delivered for launch TO CP-12 TO CS-3	LRO continued ops TO CP-21 TO CP-22 TO CP-31	Mars Sample Return (MSR): Earth-Return Orbiter (ESA) TO CP-32 TO CP-41	Artemis IV Surface Science Instruments MSR Lander: Sample Retrieval Lander; Mars Ascent Vehicle TO CP-42 TO CP-51	Artemis V Surface Science Instruments Artemis LTV Science Instruments TO CP-52 TO CP-61 TO CP-62	Artemis VI Surface Science Instruments MSR: Mars Ascent Vehicle launch Mars 2020 Sample Delivery	Artemis VII Surfac Science Instrume
STMD	LAUNCHED CAPSTONE LAUNCHED LOFTID	TO PRIME-1: Lunar Trailblazer; PRIME-1 Drill; Nokia LTE/4G Comm; IM Deployable Hopper CFM SpaceX TP Flight Demo	Preliminary DRACO NTP Engine Design NEP Concept Vehicle Design PPE SEP qual. environ. complete CFM Eta Space TP Flight Demo	CFM Lockheed Martin TP Flight Demo CFM ULA TP Flight Demo	PSI Mini-Suite	TO CT-1: Lunar Surface Power Demo (i.e. RFC, VSAT, Wireless Charging); Lunar Surface Scaled Construction Demo 1; ISRU Pilot Excavator; ISRU Subscale Demo		SEP qual. complete	TO CT-2: Lunar Surface Scaled Construction Demo 2; Autonomous Robotics Demo; Deployable Hopper 2; ISRU Subscale Demo 2 Fission Surface Power demo delivered for launch	

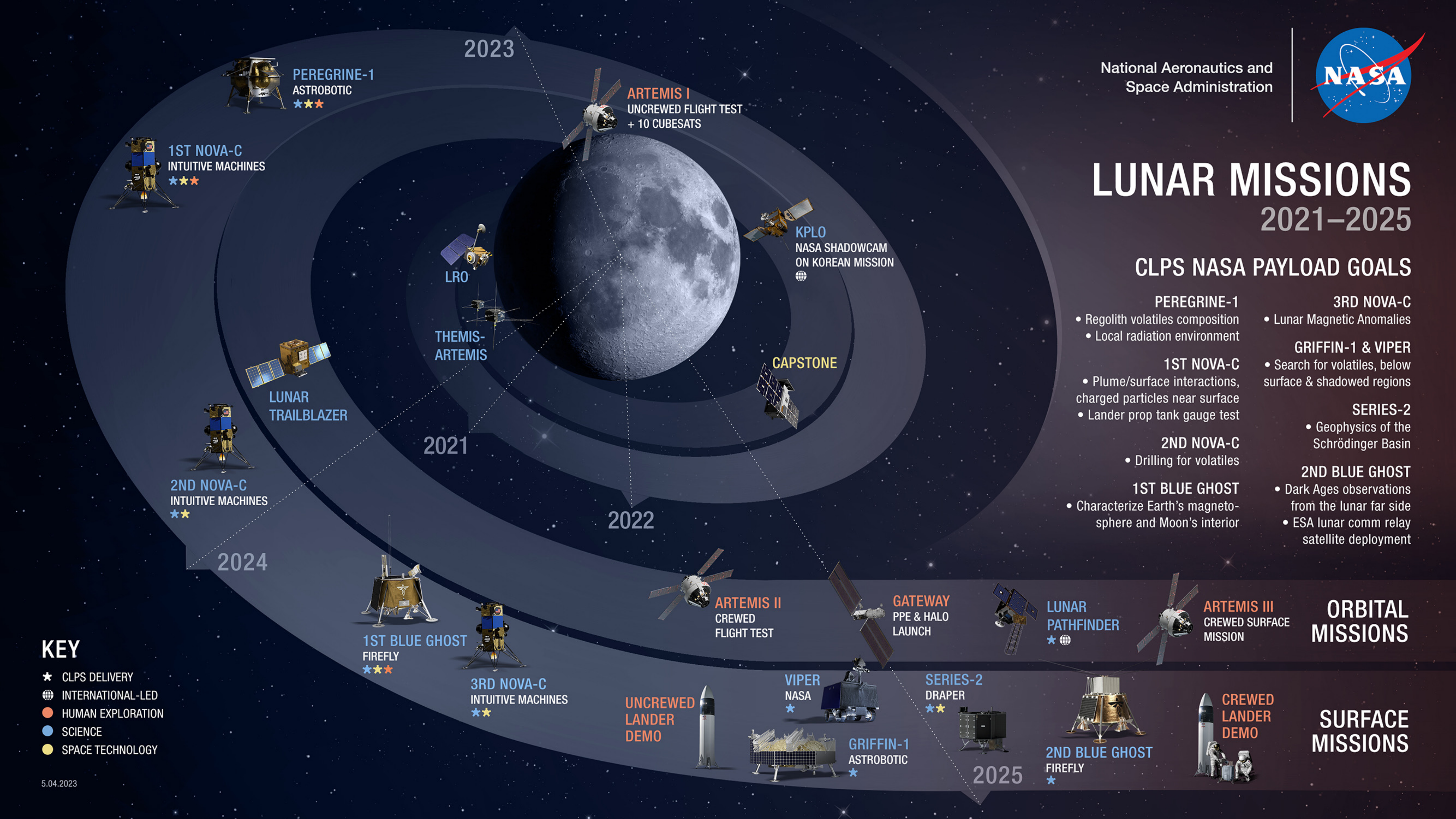
Icons are representative only, and may not reflect final configurations, not to scale \| Icons represent the calendar year in which an event occurs \| Based on FY 2024 President's budget request

Backup

Volatiles Investigation Polar Exploration Rover (VIPER)



- Golf-cart-sized rover (~500Kg) – a first ever resource mapping mission on another celestial body
- Will be delivered by Astrobotic (CLPS) onto the Moon's South Pole in November 2024 for a 100-day mission
- Will explore the South Pole of the Moon in search of water ice and other potential resources, to:
  - Characterize the distribution and physical state of lunar polar water and other volatiles in lunar cold traps and regolith to understand their origin
  - Provide the data and resource maps necessary for NASA to evaluate the potential return of ISRU from the lunar polar regions
- Equipped with 1-meter drill and three instruments:
  - Neutron spectrometer
  - Near-IR spectrometer
  - Mass spectrometer



National Aeronautics and Space Administration
NASA
LUNAR MISSIONS
2021–2025
2021
2022
2023
2024
2025
PEREGRINE-1
ASTROBOTIC
ARTEMIS I
UNCREWED FLIGHT TEST
+ 10 CUBESATS
1ST NOVA-C
INTUITIVE MACHINES
LRO
KPLO
NASA SHADOWCAM
ON KOREAN MISSION
THEMIS-
ARTEMIS
CAPSTONE
LUNAR
TRAILBLAZER
2ND NOVA-C
INTUITIVE MACHINES
1ST BLUE GHOST
FIREFLY
3RD NOVA-C
INTUITIVE MACHINES
ARTEMIS II
CREWED
FLIGHT TEST
GATEWAY
PPE & HALO
LAUNCH
LUNAR
PATHFINDER
ARTEMIS III
CREWED SURFACE
MISSION
ORBITAL
MISSIONS
UNCREWED
LANDER
DEMO
VIPER
NASA
GRIFFIN-1
ASTROBOTIC
SERIES-2
DRAPER
2ND BLUE GHOST
FIREFLY
CREWED
LANDER
DEMO
SURFACE
MISSIONS
CLPS NASA PAYLOAD GOALS
PEREGRINE-1
• Regolith volatiles composition
• Local radiation environment
1ST NOVA-C
• Plume/surface interactions,
charged particles near surface
• Lander prop tank gauge test
2ND NOVA-C
• Drilling for volatiles
1ST BLUE GHOST
• Characterize Earth's magneto-
sphere and Moon's interior
3RD NOVA-C
• Lunar Magnetic Anomalies
GRIFFIN-1 & VIPER
• Search for volatiles, below
surface & shadowed regions
SERIES-2
• Geophysics of the
Schrödinger Basin
2ND BLUE GHOST
• Dark Ages observations
from the lunar far side
• ESA lunar comm relay
satellite deployment
KEY
CLPS DELIVERY
INTERNATIONAL-LED
HUMAN EXPLORATION
SCIENCE
SPACE TECHNOLOGY
5.04.2023

Science Objectives (1 of 4)

Lunar/Planetary Science (LPS) Goal: Address high priority planetary science questions that are best accomplished by on-site human explorers on and around the Moon and Mars, aided by surface and orbiting robotic systems.

LPS-1^LM: Uncover the record of solar system origin and early history, by determining how and when planetary bodies formed and differentiated, characterizing the impact chronology of the inner solar system as recorded on the Moon and Mars, and characterize how impact rates in the inner solar system have changed over time as recorded on the Moon and Mars.

LPS-2^LM: Advance understanding of the geologic processes that affect planetary bodies by determining the interior structures, characterizing the magmatic histories, characterizing ancient, modern, and evolution of atmospheres/exospheres, and investigating how active processes modify the surfaces of the Moon and Mars.

LPS-3^LM: 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.

LPS-4^M: Advance understanding of the origin of life in the solar system by identifying where and when potentially habitable environments exist(ed), what processes led to their formation, how planetary environments and habitable conditions have co-evolved over time, and whether there is evidence of past or present life in the solar system beyond Earth.

Heliophysics Science (HS) Goal: Address high priority heliophysics science and space weather questions that are best accomplished using a combination of human explorers and robotic systems at the Moon, at Mars, and in deep space.

HS-1^LM: Improve understanding of space weather phenomena to enable enhanced observation and prediction of the dynamic environment from space to the surface at the Moon and Mars.

HS-2^LM: Determine the history of the Sun and solar system as recorded in the lunar and Martian regolith.

HS-3^LM: Investigate and characterize fundamental plasma processes, including dust-plasma interactions, using the cislunar, near-Mars, and surface environments as laboratories.

HS-4^LM: Improve understanding of magnetotail and pristine solar wind dynamics in the vicinity of the Moon and around Mars.

Full M2M Objectives: https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf

Superscripts indicate applicability to Lunar (L), Martian (M), or both (LM)

Science Objectives (2 of 4)

Human and Biological Science (HBS) Goal: *Advance understanding of how biology responds to the environments of the Moon, Mars, and deep space to advance fundamental knowledge, support safe, productive human space missions and reduce risks for future exploration.*

HBS-1^{LM}**:** Understand the effects of short- and long-duration exposure to the environments of the Moon, Mars, and deep space on biological systems and health, using humans, model organisms, systems of human physiology, and plants.

HBS-2^{LM}: Evaluate and validate progressively Earth-independent crew health & performance systems and operations with mission durations representative of Mars-class missions.

HBS-3^{LM}: Characterize and evaluate how the interaction of exploration systems and the deep space environment affect human health, performance, and space human factors to inform future exploration-class missions.

Physics and Physical Science (PPS) Goal*:* Address high priority physics and physical science questions that are best accomplished by using unique attributes of the lunar environment.

PPS-1^{L}: Conduct astrophysics and fundamental physics investigations of space and time from the radio quiet environment of the lunar far side.

PPS-2^{LM}: Advance understanding of physical systems and fundamental physics by utilizing the unique environments of the Moon, Mars, and deep space.

Full M2M Objectives: https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf

Superscripts indicate applicability to Lunar (L), Martian (M), or both (LM)

Science Objectives (3 of 4)

Science-Enabling (SE) Goal: Develop integrated human and robotic methods and advanced techniques that enable high-priority scientific questions to be addressed around and on the Moon and Mars.

SE-1[LM]: Provide in-depth, mission-specific science training for astronauts to enable crew to perform high-priority or transformational science on the surface of the Moon, and Mars, and in deep space.

SE-2[LM]: Enable Earth-based scientists to remotely support astronaut surface and deep space activities using advanced techniques and tools.

SE-3[LM]: 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.

SE-4[LM]: Return representative samples from multiple locations across the surface of the Moon and Mars, with sample mass commensurate with mission-specific science priorities.

SE-5[LM]**:** Use robotic techniques to survey sites, conduct in-situ measurements, and identify/stockpile samples in advance of and concurrent with astronaut arrival, to optimize astronaut time on the lunar and Martian surface and maximize science return.

SE-6[LM]: Enable long-term, planet-wide research by delivering science instruments to multiple science-relevant orbits and surface locations at the Moon and Mars.

SE-7[LM]**:** Preserve and protect representative features of special interest, including lunar permanently shadowed regions and the radio quiet far side as well as Martian recurring slope lineae, to enable future high-priority science investigations.

Superscripts indicate applicability to Lunar (L), Martian (M), or both (LM)

Science Objectives (4 of 4)

Applied Science (AS) Goal: Conduct science on the Moon, in cislunar space, and around and on Mars using integrated human and robotic methods and advanced techniques, to inform design and development of exploration systems and enable safe operations.

AS-1^{LM}: Characterize and monitor the contemporary environments of the lunar and Martian surfaces and orbits, including investigations of micrometeorite flux, atmospheric weather, space weather, space weathering, and dust, to plan, support, and monitor safety of crewed operations in these locations.

AS-2^{LM}: Coordinate on-going and future science measurements from orbital and surface platforms to optimize human-led science campaigns on the Moon and Mars.

AS-3^{LM}: Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable In-Situ Resource Utilization (ISRU) on successive missions.

AS-4^{LM}: Conduct applied scientific investigations essential for the development of bioregenerative-based, ecological life support systems

AS-5^{LM}: Define crop plant species, including methods for their productive growth, capable of providing sustainable and nutritious food sources for lunar, Deep Space transit, and Mars habitation.

AS-6^{LM}: Advance understanding of how physical systems and fundamental physical phenomena are affected by partial gravity, microgravity, and general environment of the Moon, Mars, and deep space transit.

Superscripts indicate applicability to Lunar (L), Martian (M), or both (LM)

Artemis III Science Team

Artemis Science Lead (Sarah Noble)
Exploration Representative (Jake Bleacher)

Artemis III Project Scientist (Noah Petro)

Internal Artemis Science Team

- NASA scientists embedded within Artemis
- SMD funded
- Conflicted from competition on teams
- Continue across sorties

Competitively selected Geology Team

- A3GT proposals in review
- Participating scientist call anticipated

Competitively selected Payload Teams

- A3DI call out now
- A4DI in planning stage

Lunar Science Update

Sarah Noble
PSD lunar science lead

Integrated Lunar Science Strategy

- PSD/ESSIO are continuing to build our integrated lunar science strategy
- Near-term activities:
  - Developing statement of task for NAS study on potential non-polar human destinations
  - JPL conducting study to better define Endurance concept
    - Community Workshop August 9th-11th
  - Planning for Endurance SDT
  - GSFC conducting pre-phase A study on “LExSO” (Lunar Exploration Science Orbiter) using the LEAG CLOC-SAT report as a guide
  - PSR Cryo Extraction Roadmapping study being conducted by ESDMD to better understand our knowledge and capabilities gaps
  - Instigating a joint LEAG/ExMag study on Artemis Samples
- We are working on a white paper “snapshot”, which we expect to provide to the community for comment later this year.

Artemis Science Updates

- Artemis II Crew named!
  - Already provided “Lunar Fundamentals” classroom training to them!
- Artemis III and IV project scientists named
  - Artemis III – Dr. Noah Petro
  - Artemis IV – Dr. Barbara Cohen
  - Expect an internal call for deputies for both missions this fall
- Artemis Contamination Control Scientist hired at GSFC –Dr. Andrew Needham
- Artemis Curation Lead should be announced soon

Artemis Science Updates

- Artemis III Geology Team (A3GT) proposals received and in review, announcement expected this fall
- Successful JETT- 3 analog test last fall, gearing up for JETT-5 analog test in Sept/Oct,
  - Science team selected through the Analog Activities call, deep into planning
  - LEAG AOA SAT being updated
- Space has been identified in JSC Bldg 30 for the Science Evaluation Room (SER)
  - Design being worked now based on input from JETT-3
  - Expected to be built next year

Apollo Next Gen Sample Analysis (ANGSA)

ANGSA 1.0 Teams finishing up

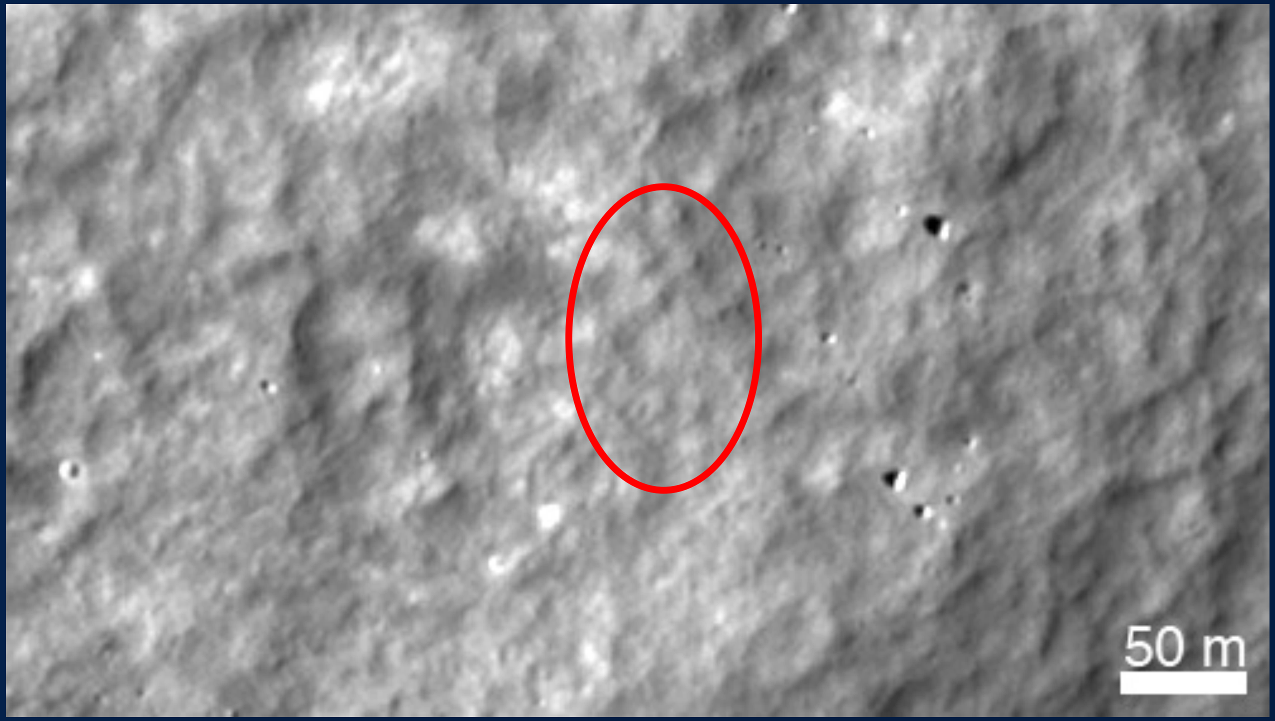
- Lots of new science results (samples are the gift that keeps on giving!)
- Lessons learned for PE and curation being collected and incorporated into Artemis planning

ANGSA 2.0 Selections made:

- **Spectroscopies for Assessing Redox Conditions (SPARC)**
  - **PI: Dyar (PSI)** Co-I's: Lanzirotti (UChicago), Livi (JHU), McCanta (UTenn), Sutton (UChicago)
- **The Enigma of Evolved Lunar Granites: A consortium approach to solving their petrogenesis**
  - **PI: Erickson (Jacobs/JSC)** Co-I's: Barnes (UArizona), Christoffersen (Jacobs/JSC), Crow (UColorado), Eckley (Jacobs/JSC), Hahn (Jacobs/JSC), Prissel (Jacobs/JSC), Simon (JSC), Valencia (UMaryland)Collaborators: Keller (JSC), Kinny (Curtin), Buckley (Jacobs/JSC), Setera (UTexas/JSC)
- **Evaluating geochronologic complexity and impactor diversity of highland impactites**
  - **PI: Zhang (UCLA)** Co-I's: Ash (UMaryland), Bell (UCLA), Warren (UCLA) Collaborators: Bouvier (UBayreuth), Hodges (ASU), McKeegan (UCLA), Walker (UMaryland)

Hakuto-R Impact Site Identification by LROC

- On April 25, 2025 ispace attempted a landing on the lunar surface near the crater Atlas
- During landing an anomaly prevented the lander from successfully touching down
- On April 26th, 12 hours after the landing attempt, LROC acquired 10 images across the landing region
- After ~ 2 weeks of searching, LROC identified multiple changes due to the impact, at least 4 prominent pieces of debris, several smaller low-contrast anomalies, a few ambiguous "smudges"
- The upper circle (B) indicates bright and dark debris. The dark pixels are on the wrong side of the bright pixels to be a shadow. Sun to the right. Debris spread over at least 40 meters
- Regolith disturbance over at least 60 meters

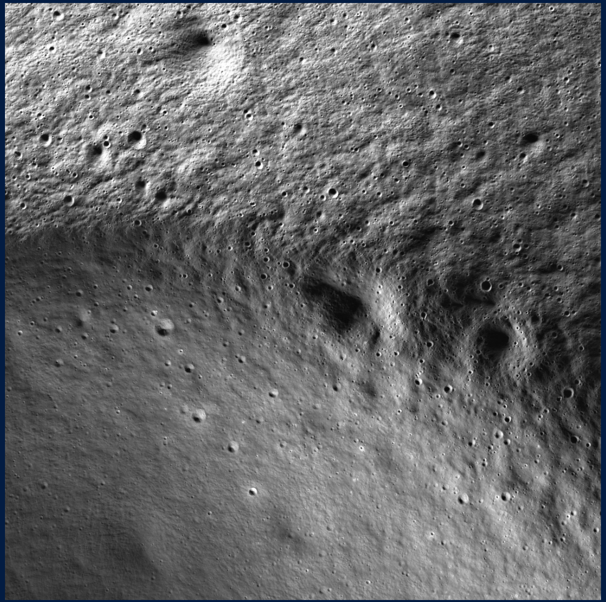


Before and after gif of the HAKUTU-R impact site. The before image was acquired in May 2012, 11 years before the landing attempt! The before image is at a lower spatial resolution than the after images, hence its blurriness.
Red circle outlines the primary area where changes are observed.

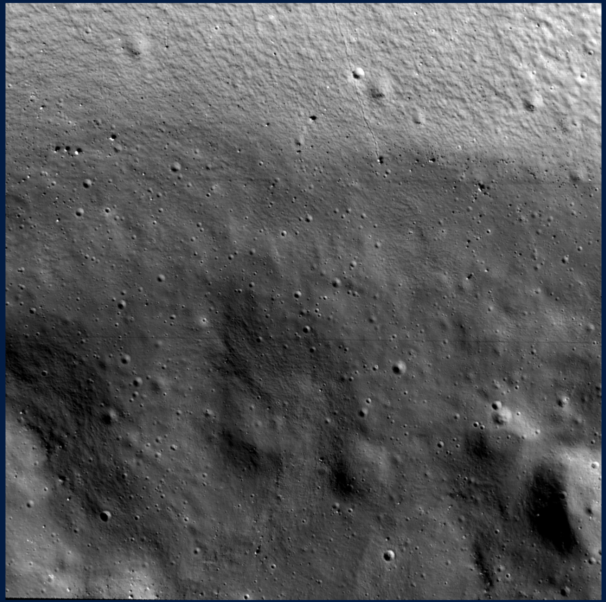
ShadowCam

- US Payload onboard Korean Pathfinder Lunar Orbiter (“Danuri”)
- Built by ASU, funded by ESDMD
- SMD/ESSIO will take over operations in extended mission ops in CY24

- High Resolution imagery of lunar PSRs and deep shadowed terrain
- Images will aid future robotic and human operations in shadowed areas



Marvin Crater. Image credit: NASA/ASU



Shackleton Rim
Image credit: NASA/ASU

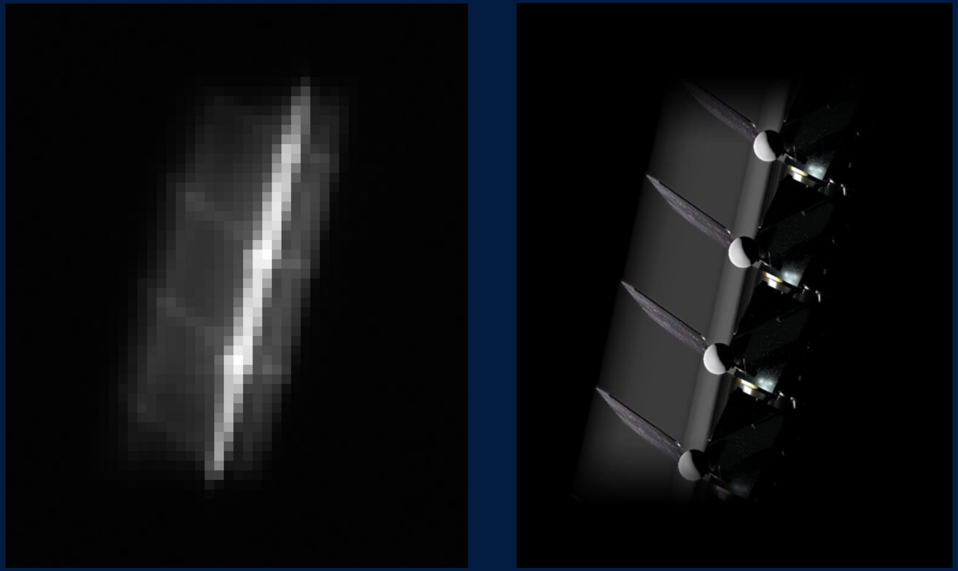
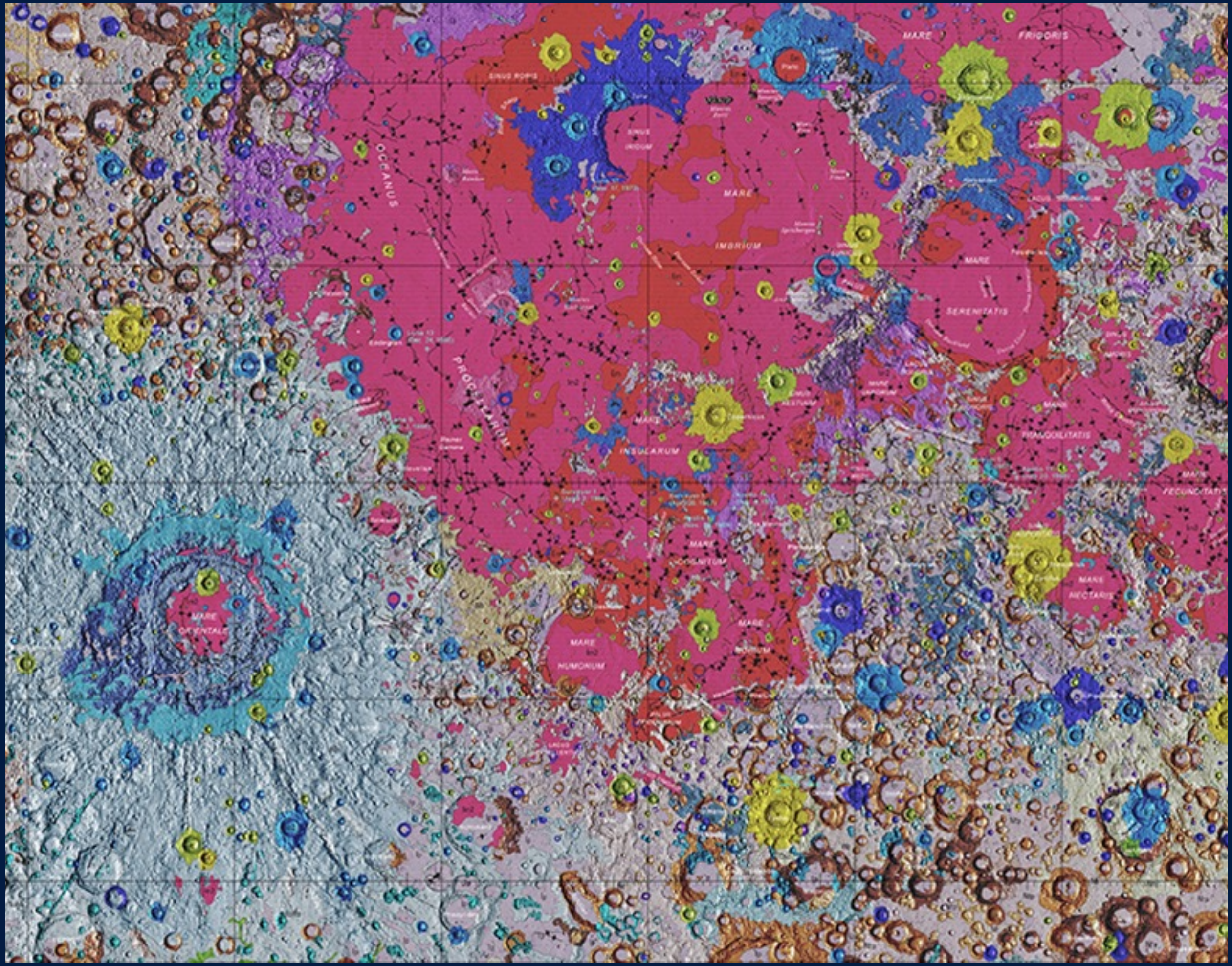


Image of LRO by Shadowcam and simulated image showing config of LRO
Image credit: NASA/ASU

LSSW on Geologic Mapping for Artemis in August

- **Save the Date: August 16-17**
- Call for abstracts out, due July 12th
- The goals of the workshop are to bring together science and technical professionals to jointly discuss cartographic needs related to geologic maps for Artemis exploration in the near- and long-term.
- This workshop aims to result in a recognition that geologic maps are applied science products that help ensure crew and asset safety and maximize science return.
- Help determine stakeholders and map users, the most relevant data layers to satisfy the broadest range of stakeholder needs, approaches to assessing and conveying map accuracy, and a plan to create Artemis geologic map products across a range of scale, similar to those maps produced for each of the Apollo candidate landing sites.



Questions