National Aeronautics and Space Administration

NASA

EXPLORE SCIENCE

Exploration Science Strategy and Integration Office

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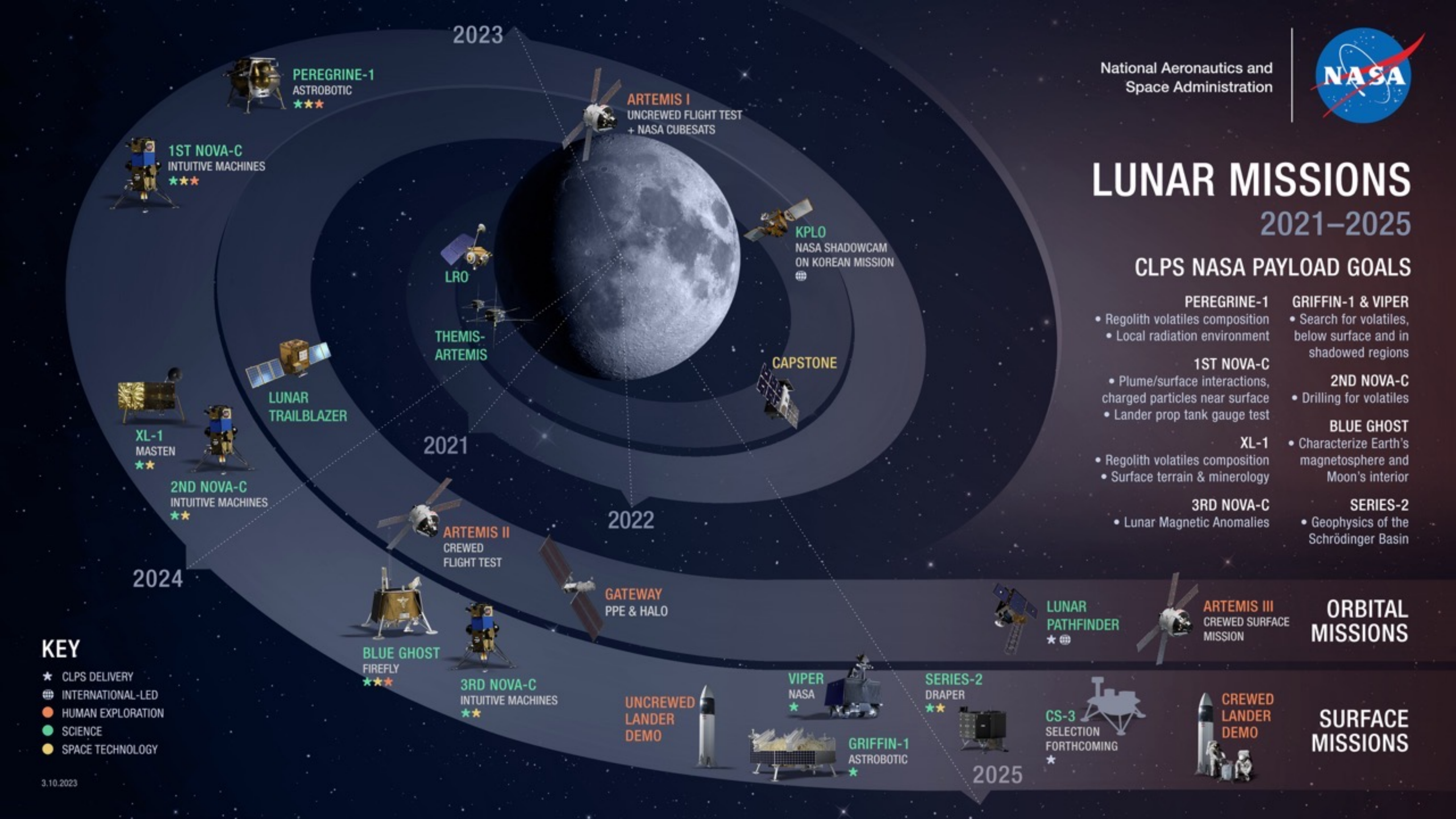

National Aeronautics and Space Administration
NASA
LUNAR MISSIONS
2021–2025
CLPS NASA PAYLOAD GOALS
PEREGRINE-1
• Regolith volatiles composition
• Local radiation environment
1ST NOVA-C
• Plume/surface interactions, charged particles near surface
• Lander prop tank gauge test
XL-1
• Regolith volatiles composition
• Surface terrain & minerology
3RD NOVA-C
• Lunar Magnetic Anomalies
GRIFFIN-1 & VIPER
• Search for volatiles, below surface and in shadowed regions
2ND NOVA-C
• Drilling for volatiles
BLUE GHOST
• Characterize Earth's magnetosphere and Moon's interior
SERIES-2
• Geophysics of the Schrödinger Basin
2021
2022
2023
2024
2025
LRO
THEMIS-ARTEMIS
KPLO
NASA SHADOWCAM ON KOREAN MISSION
CAPSTONE
ARTEMIS I
UNCREWED FLIGHT TEST + NASA CUBESATS
PEREGRINE-1
ASTROBOTIC
1ST NOVA-C
INTUITIVE MACHINES
LUNAR TRAILBLAZER
XL-1
MASTEN
2ND NOVA-C
INTUITIVE MACHINES
ARTEMIS II
CREWED FLIGHT TEST
GATEWAY
PPE & HALO
BLUE GHOST
FIREFLY
3RD NOVA-C
INTUITIVE MACHINES
UNCREWED LANDER DEMO
VIPER
NASA
GRIFFIN-1
ASTROBOTIC
SERIES-2
DRAPER
CS-3
SELECTION FORTHCOMING
LUNAR PATHFINDER
ARTEMIS III
CREWED SURFACE MISSION
CREWED LANDER DEMO
ORBITAL MISSIONS
SURFACE MISSIONS
KEY
CLPS DELIVERY
INTERNATIONAL-LED
HUMAN EXPLORATION
SCIENCE
SPACE TECHNOLOGY
3.10.2023

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 Gateway 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:	TO 2-AB TO 2-IM	ESCAPADE TO 20A: VIPER TO 19D TO CP-11:	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	MOXIE; MEDA LAUNCHED CAPSTONE LAUNCHED LOFTID	TO PRIME-1: Lunar Trailblazer; PRIME-1 Drill; Nokia LTE/4G Comm; IM Deployable Hopper CFM SpaceX TP Flight Demo	Surface Robotic Scouts (CADRE) 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

Commercial Lunar Payload Services (CLPS)

- CLPS is an innovative, service-based, competitive acquisition approach that enables rapid, affordable, and frequent access to the Lunar surface via a growing market of American commercial providers
  - To the greatest legal and practical extent CLPS attempts to model common terrestrial deliveries such as FedEx, UPS, etc.
- Service task orders are Firm Fixed Price (FFP) for the full scope of payload delivery: from payload hand-over to delivery (and often operation) on the lunar surface or in CIS lunar space.
- NASA wants to be one of many customers for CLPS services
  - Ideally, CLPS contractors will eventually deliver manifests that include no NASA payloads.
- CLPS deliveries are CLPS Contractor missions (not NASA missions); NASA imposes no NASA policies that would normally apply to a NASA mission.
- CLPS providers secure all necessary hardware, systems, facilities and services to perform the delivery; including launch vehicle and comm/nav systems.
  - NASA has no oversight and limited insight into CLPS vehicle/mission designs and processes.
  - NASA LSP (Launch Services Program) is not engaged in launch vehicle acquisition
- CLPS launches are commercial launches acquired/provided by CLPS provider and approved/licensed by the U.S. Gov't FAA , FCC, and other agencies (not NASA)

A CLPS contractor's business model and regulatory obligation should be the same whether NASA is a customer or not.

CLPS IDIQ Contract and Portfolio

- 14 domestic companies eligible to compete for lunar surface delivery task orders
- 9 awarded lunar surface deliveries actively in work with initial deliveries as soon as this year.
- NASA expects to continue cadence of ~2 flights per year subject to funding availability.
- CLPS contractors are encouraged to sell lunar delivery services outside of the CLPS IDIQ to non-NASA and non-USG customers.

Initial CLPS companies (Nov 2018):

- *Astrobotic*
- *Deep Space Systems*
- *Draper*
- *Firefly Aerospace*
- *Intuitive Machines*
- *Lockheed Martin Space*
- *Masten Space Systems*
- *Moon Express*
- *Orbit Beyond*

First On-Ramp (Nov 2019):

- *Blue Origin*
- *Ceres Robotics*
- *Sierra Nevada Corporation*
- *SpaceX*
- *Tyvak Nano-Satellite Systems, Inc.*

Awarded Deliveries:

TO2 2023
Astrobotic
Peregrine

TO2/20C 2023
Intuitive Machines
NOVA-C

TO PRIME-1 2023
Intuitive Machines
NOVA-C

TO19C 2023
Masten
XL-1

CP-11 2024
Intuitive Machines
NOVA-C

TO19D 2024
Firefly Aerospace
Blue Ghost

TO20A 2024
Astrobotic
Griffin

CP-12 2025
Draper
Series-2

TOCS3 2026
Firefly Aerospace
Blue Ghost

CLPS Deliveries
2023-2026

Delivery Site:
Gruithuisen Domes
Provider TBD
CP-21 | 2026

Delivery Site:
Sinus Viscositatis
Provider: Astrobotic
TO2-AB | May 2023

Delivery Site:
Lunar Far Side &
Orbit Insertion
Provider: Firefly
CS-3 | 2026

Delivery Site:
Reiner Gamma
Provider: IM
CP-11 | 2024

Delivery Site: Malapert A
Provider: Intuitive Machines (IM)
TO2-IM | June 2023

Delivery Site:
Mare Crisium
Provider: Firefly
TO19D | 2024

Delivery Site:
Shackleton Connecting
Ridge **Provider:** IM
TO PRIME-1 | Q4 2023

Delivery Site:
Nobile Crater
Provider : Astrobotic
VIPER | Nov 2024

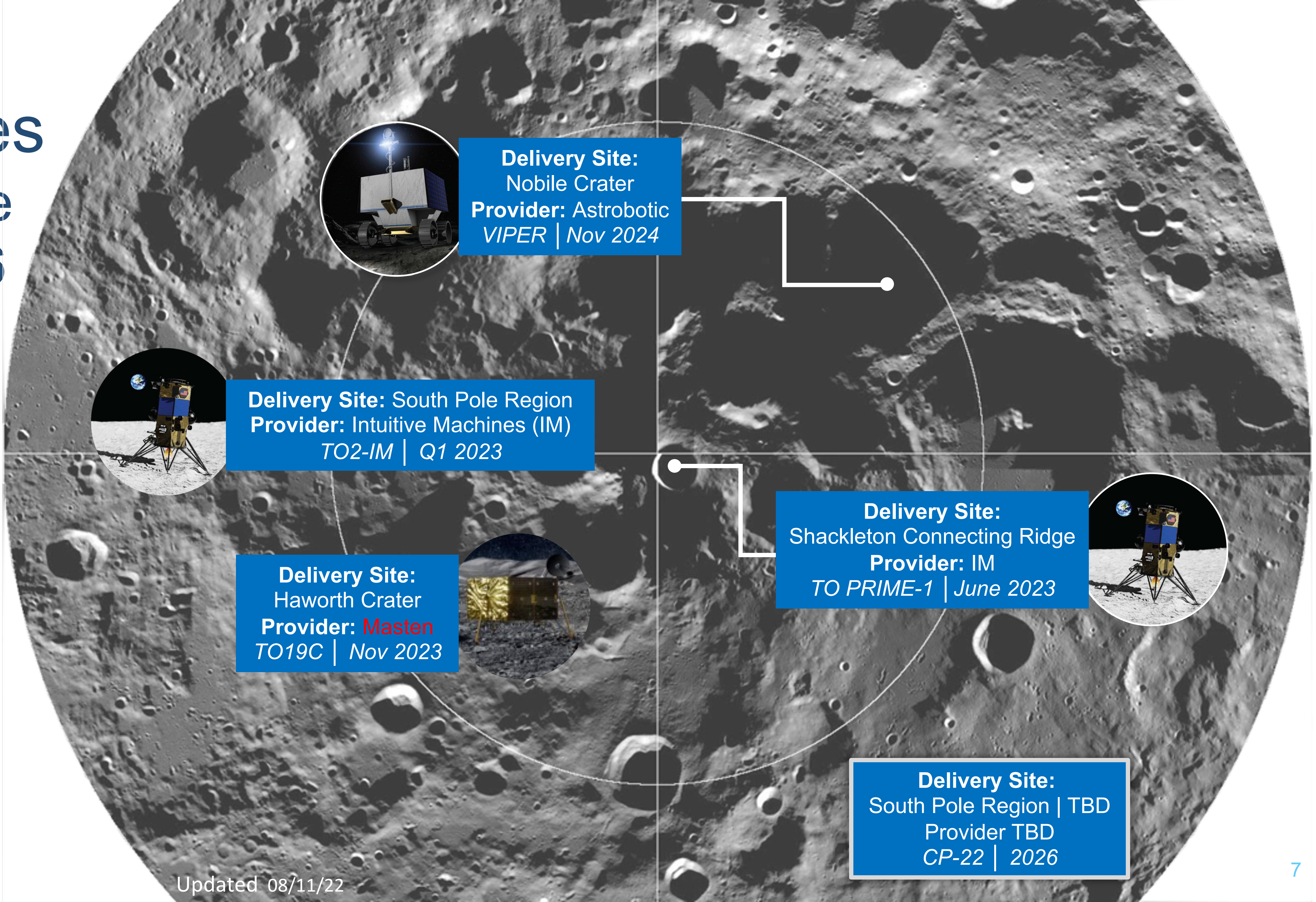
Delivery Site:
Schrödinger Basin
Provider: Draper
CP-12 | 2025

Delivery Site:
South Pole Region
Provider TBD
CP-22 | 2026

Delivery Site:
Haworth Crater
Provider: Masten
TO19C | Nov 2023

Updated 3/17/2023

CLPS Deliveries
South Pole 2023-2026

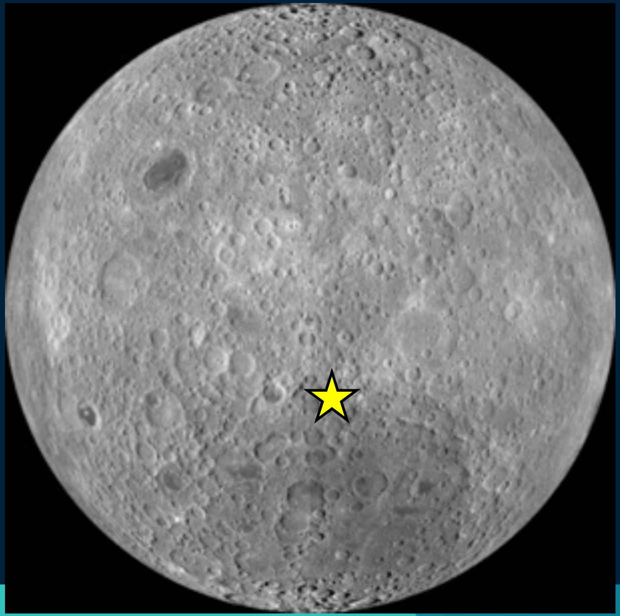


Future Definition of CLPS

- Continue building the commercial market; CLPS service options are expected to expand as market and company capabilities evolve
- Estimating periodic on-ramp opportunities into the CLPS Vendor Pool going forward depending upon need and service availability
- Maintain flexibility of the CLPS IDIQ to award Task Orders for upcoming capabilities, data buys
- SMD manifests will continue to be competitively-selected payloads
- Expect to continue cadence of ~2 flights per year
- Support of other mission directorates and international partners through delivery of priority science/technology investigations to the lunar surface
- Support of Artemis crewed activities through delivery of scientific equipment, supplies for longer duration missions, human-centric infrastructure
(e.g., LTV, ISRU demos/equipment, etc.)
- New capabilities that would enhance science return, ops, and open new avenues for scientific investigations
  - Mobility
  - Orbital Drop-off
  - Comm Relay
  - EMI Quiet Operation
  - Increased Delivery Mass
  - Surviving/operation throughout the lunar night
  - Articulation / Regolith Manipulation
  - PSR/Cold Operations
  - Sample Return

Key Updates: CLPS

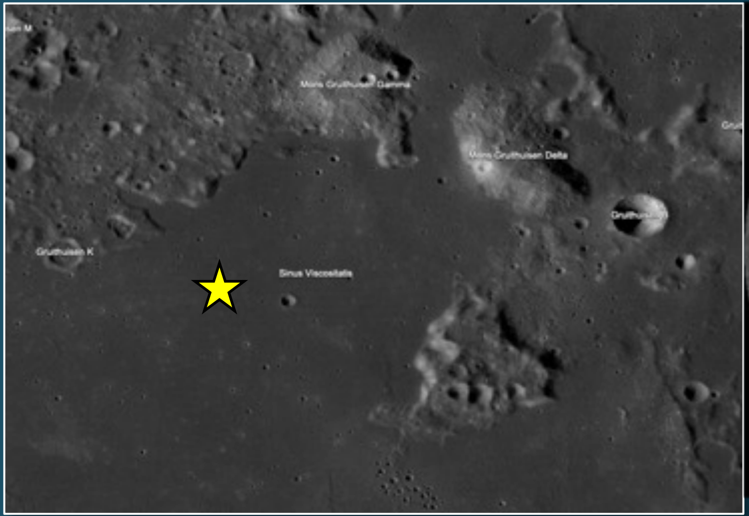
NASA selected Firefly Aerospace and their Blue Ghost Lander to deliver a joint NASA and Dept. of Energy instrument called “LuSEE-Night” to the radio quiet far side of the Moon to make cosmological radio observations of the Dark Ages of the Universe.

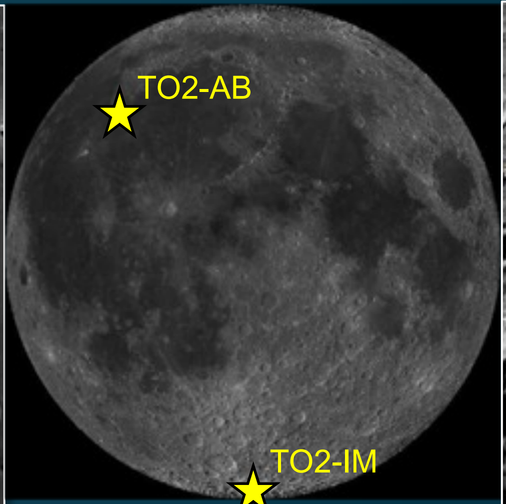


The CLPS delivery will launch in late 2025 and will also deliver ESA’s Lunar Pathfinder into lunar orbit as well as carry a NASA user terminal for radio communications. LuSEE-Night is expected to take measurements throughout several lunar nights of a previously un-observed portion of the highly-redshifted Cosmic Microwave Background (CMB).

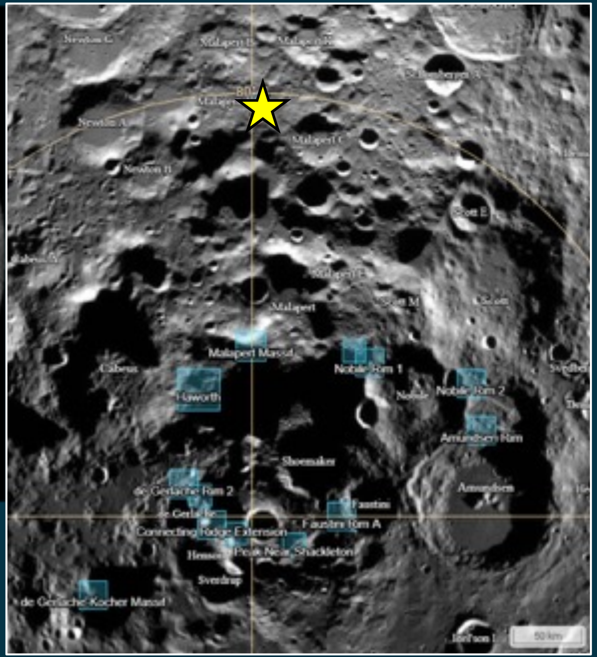
CLPS First Two Launches/Landing Sites

Astrobotic PM-1





Intuitive Machines IM-1



- Astrobotic will land in Sinus Viscositatis near the Gruithuisen Domes with five NASA payloads with their Peregrine lander
  - First launch window opens May 4, 2023: ULA Vulcan Centaur Status
- Intuitive Machines will land in the lunar south polar region near Malapert A while carrying five NASA payloads with their Nova-C lander
  - First launch window opens June 2023

Key Updates: CLPS

Astrobotic's Peregrine Mission 1 (PM-1) lander complete and awaiting ULA go-ahead to ship.

Intuitive Machines Nova-C lander (IM-1) is in the process of completing integration and test

CLPS Lessons Learned

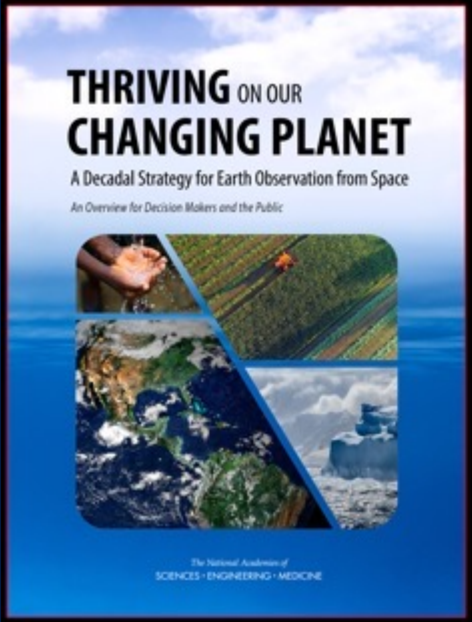
Recommendation: NASA should continue to support commercial innovation in lunar exploration. Following demonstrated success in reaching the lunar surface, NASA should develop a plan to maximize science return from CLPS by, for example, allowing investigators to propose instrument suites coupled to specific landing sites. NASA should evaluate the future prospects for commercial delivery systems within other mission programs and consider extending approaches and lessons learned from CLPS to other destinations, e.g., Mars and asteroids. (Ch 22, CLPS Rec.)

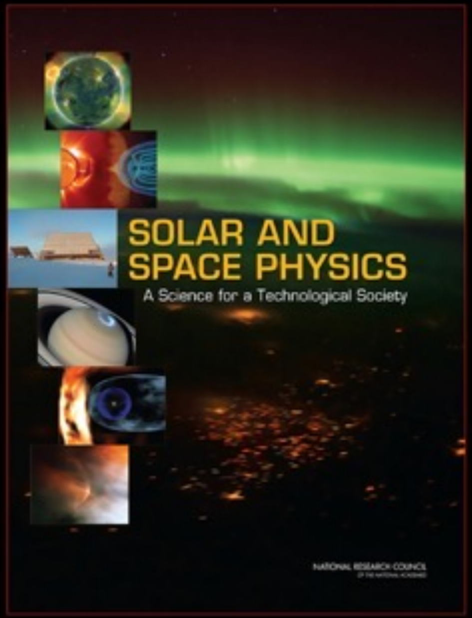
- Origins, Worlds and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032

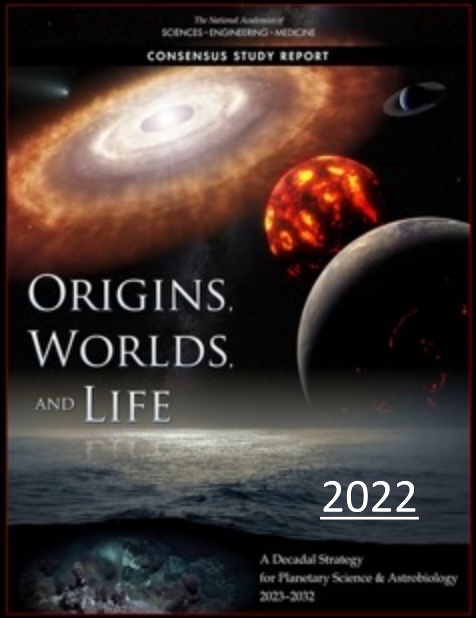
Lessons Learned (Thus far)

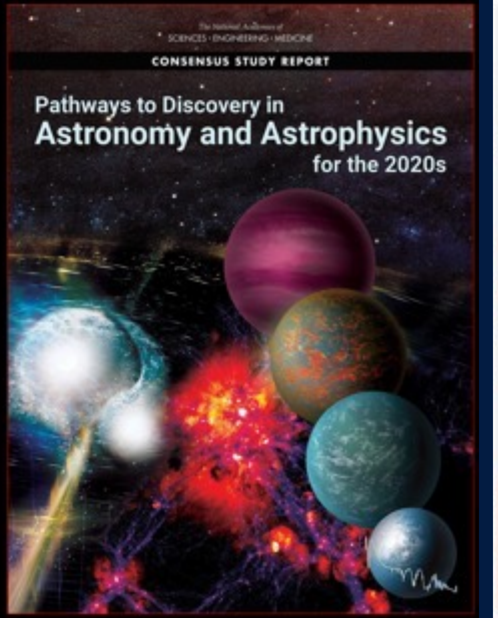
- Extra time between payload selection and RFP to vendors allows more mature interface definition
- Cost is not linear with any particular metric
- Cost does not go down as we continue to add new desired capabilities
- Augmented Insight
- Establishment of lunar economy and international contributions

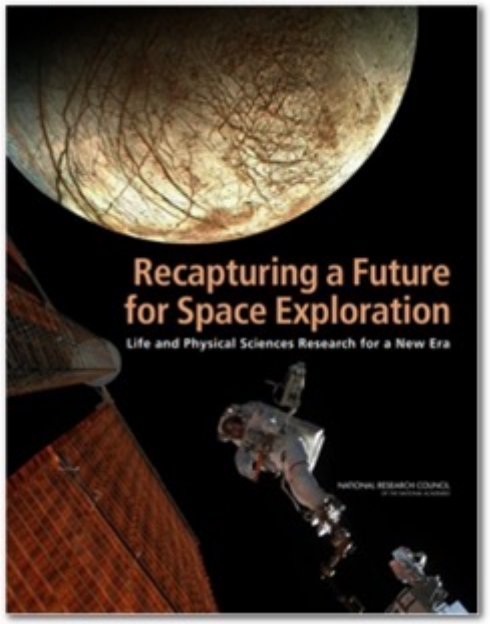
Strategic Research and Priorities from Decadal Surveys











to be updated in 2024

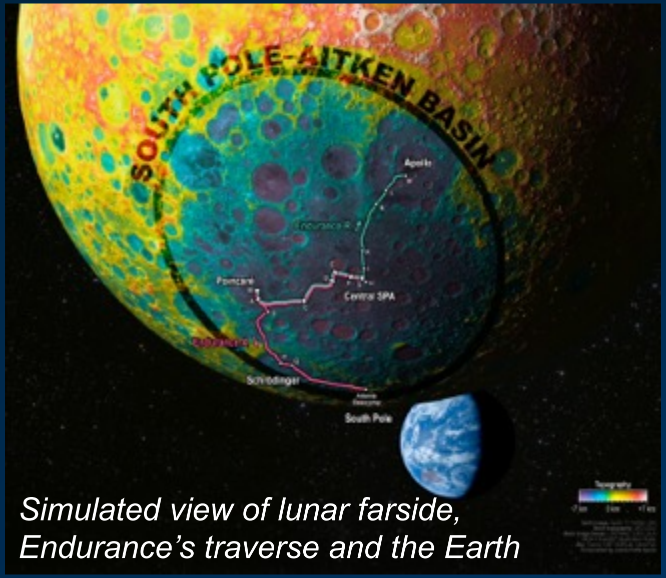
to be updated in 2023

Planetary Science Community reports

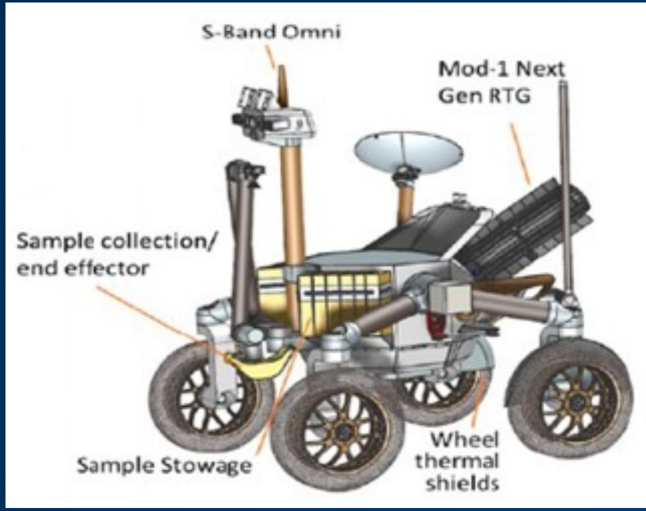
NASA reports

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

- One of the top lunar priorities of the Planetary Decadal is Endurance A, a long-duration rover capable of traversing ~2000km and returning ~100kg of samples taken at strategic sites throughout the South Pole-Aitken basin to 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



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

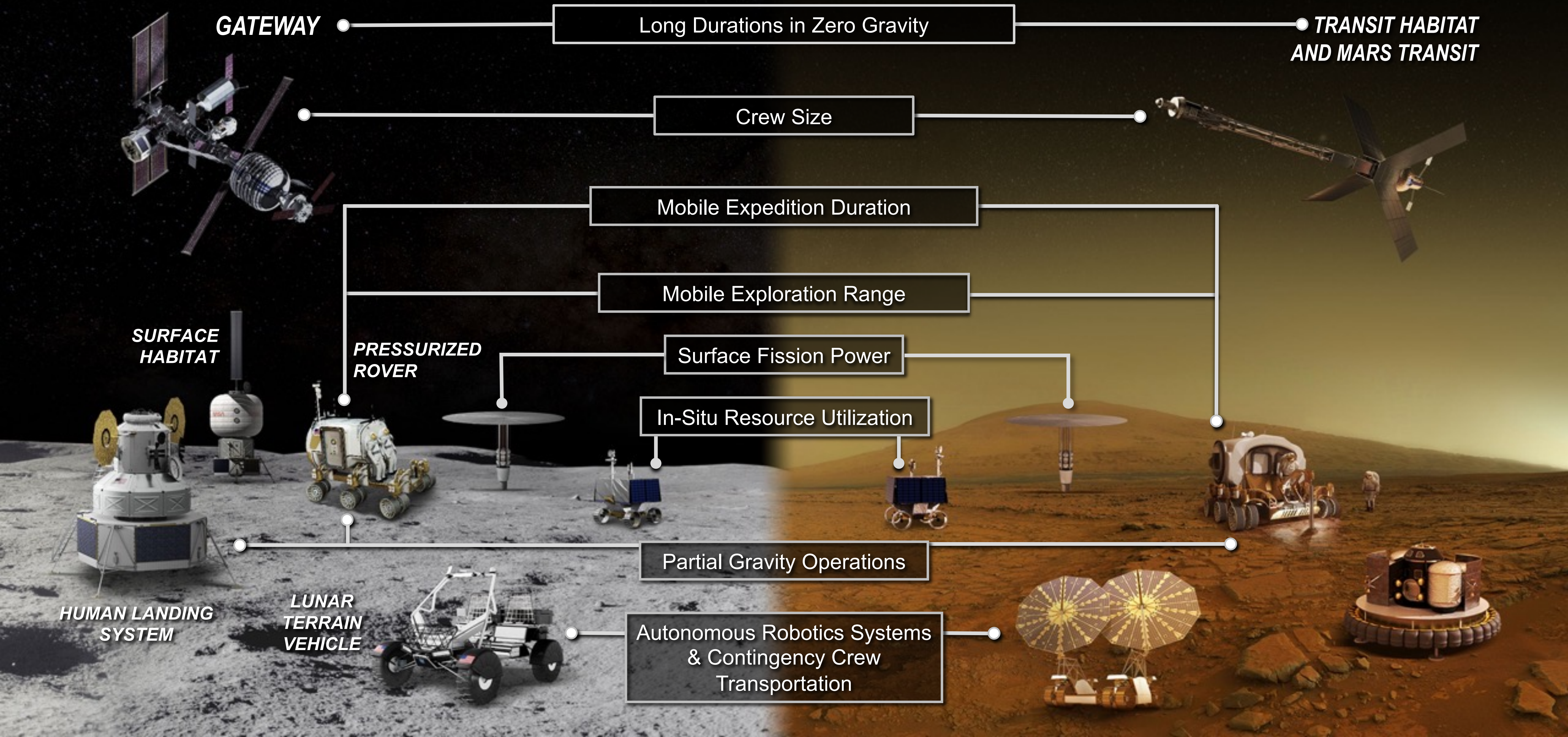


***Recommendation*: Endurance-A should be implemented as a *strategic medium-class mission* as the *highest priority* of the Lunar Discovery and Exploration Program. Endurance-A would utilize CLPS to deliver the rover to the Moon, a long-range traverse to collect a substantial mass of high-value samples,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

The full Endurance Report is available at https://tinyurl.com/2p88fx4f

MOON AND MARS EXPLORATION

Operations on and around the Moon will help prepare for the first human mission to Mars

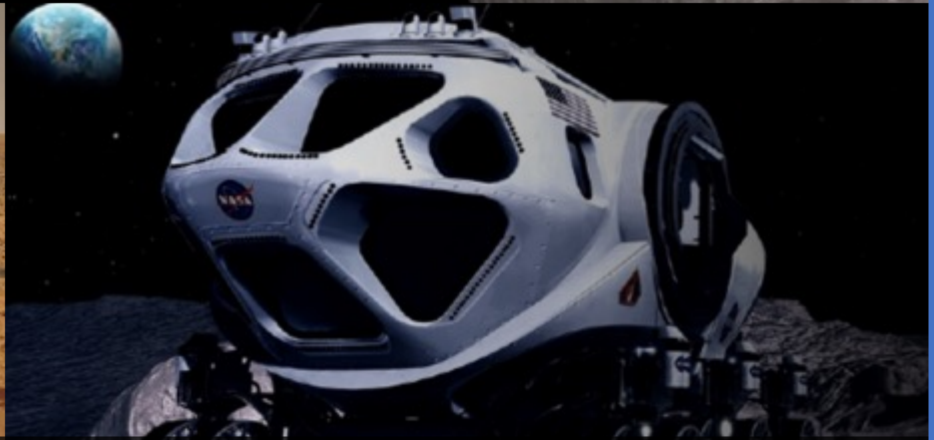


National Aeronautics and
Space Administration

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

@NASAArtemis

Science



Transportation & Habitation

Infrastructure

Operations

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

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.

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 (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.

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)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