

Lunar Discovery and Exploration Program Update

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

Planetary Science Advisory Committee
November 14, 2023

- Plans/Strategies
 - Implementation plan for Integrated Lunar Science Strategy (NASA) – will be issued as Community Announcement for comment, revision
 - Community Science Definition Team: objectives for Endurance-A Mission (South Pole-Aitken Basin sample return)
 - Moon2Mars Architecture Concept Review 23 and Architecture Definition Document (ADD)
 - NASEM Studies
- Competitive Solicitations
 - Artemis III Geology Team selected (A3GT) August 22, 2023
 - Earth-based Artemis III Geologists for Lunar Exploration (EAGLE) [Denevi/APL] (Artemis III)
 - Artemis III Deployed Instruments call released May 30, 2023 (A3DI); selections spring 2024
 - Planning: A4DI
 - Planning: A4 Hand-Held Instruments
 - Planning: LTV instruments
 - Planning: PRISM4 (Stand Alone Site Agnostic (SALSA) instruments call)
- Artemis II
 - Artemis II Lunar Observation Campaign (ALOC) [Lead: Young/NASA GSFC] (Artemis II)
- 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] (CP-21)
 - Lunar Explorer Instrument for Space Biology Applications (LEIA) [Settles/NASA ARC] (CP-22)
- PRISM3 instrument suite selected:
 - Dating an Irregular Mare Patch with a Lunar Explorer (DIMPLE) [Anderson/SwRI] (CP-32)
- CLPS delivery competitions
 - Next: CP-22 (LEIA + others) to South Pole
 - CLPS company proposals received
 - Then: CP-21 (LunarVISE + others) to Gruithuisen Domes
- VIPER progress through SIR; landing Nov 2024
- Lunar Trailblazer to storage; Rideshare on IM-2 [Ehlmann/CalTech]

PRISM 3 Overview

The third PRISM draft solicitation was released in August 2022 for community comment for 30 days. The final announcement was released on Sept. 19, 2022

- Step 1s due Oct. 24, 2022
- Step 2s due Dec. 20, 2022

Soliciting suites of payloads for one delivery to the lunar surface in mid-2027

- Address decadal-level science objectives traceable to *Origins, Worlds, and Life*
- Total mass cap: 50 kg
- Budget cap: \$50M

PRISM 3 Opportunity Highlights

Delivery to a safe landing destination identified and justified by the proposer

Leverage the following services provided by the CLPS provider:

Survive-the-night services

Mobility services



PRISM 3
**Ina Irregular
Mare Patch**

**Dating an Irregular Mare Patch
with a Lunar Explorer (DIMPLE)**

Establish the age, geochemistry of the Ina Irregular Mare Patch and verify the duration of lunar volcanic activity
(Anderson, SWRI)

Definitively resolve how recently the Moon was volcanically active at an enigmatic site

Measure age to within 375 Ma using the ^{87}Rb - ^{87}Sr isochron method

Demonstrate geochronometry technology that can be applied to various geologic terrains across the Solar System

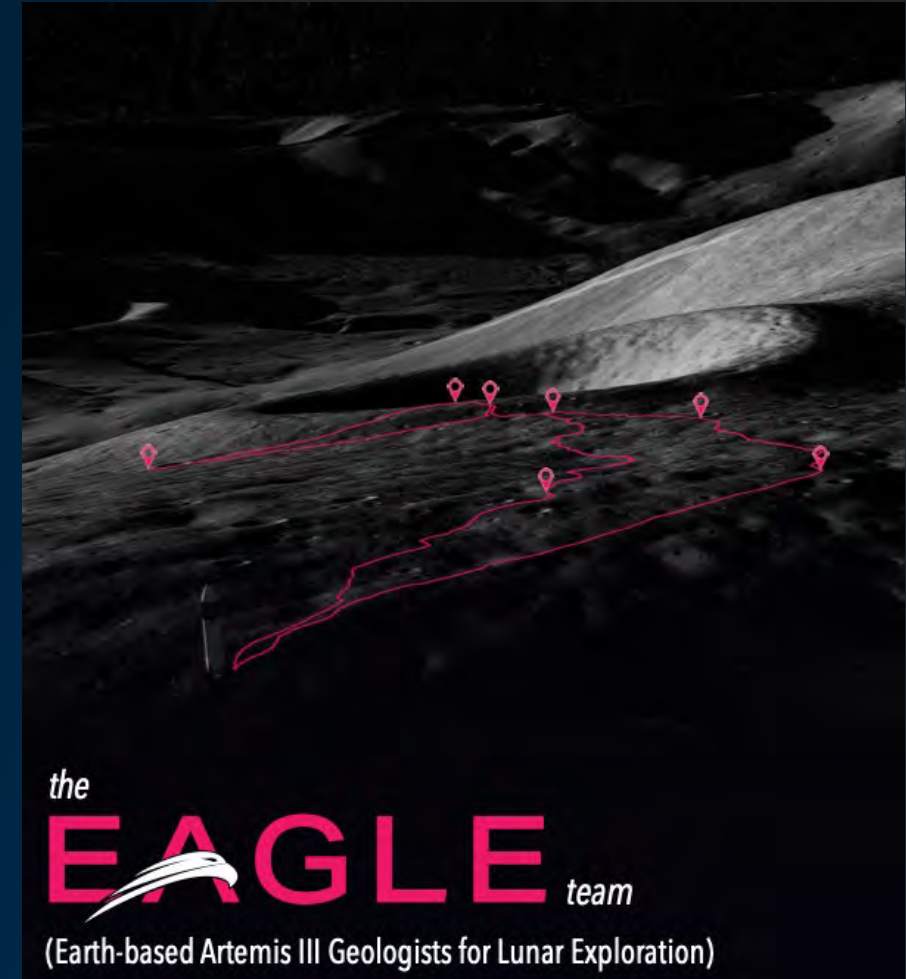
Characterize elemental geochemistry: SiO_2 , $\text{Na}_2\text{O}/\text{K}_2\text{O}$, Ti, Fe, Mg, Ca, Al, Si, Na, K, Th, and oxides

International contributions from University of Bern and University of Manchester, UK

Artemis III Geology Team (A3GT):

EAGLE Team: *Earth-based
Artemis III Geologists for
Lunar Exploration*

PI: Brett Denevi, Johns Hopkins
Applied Physics Laboratory



TO2-AB

PM-1



Peregrine Lander



TO2-IM

IM-1



Nova-C Lander



TO19D

Blue Ghost 1

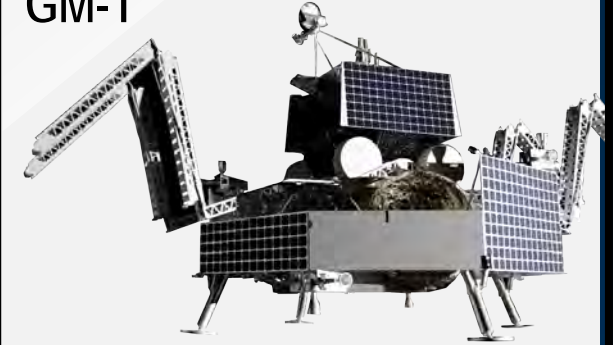


Blue Ghost lander



TO20A – VIPER

GM-1



Griffin Lander



PRIME-1

IM-2



Nova-C Lander



CP-11

IM-3



Nova-C Lander



CP-12

TBA



Series-2 Lander



CS-3 & CS-4

Blue Ghost 2



Blue Ghost Lander



Commercial Lunar Payload Services

First Two Task Orders



Astrobotic Technologies

Peregrine Lander

PM-1 Mission



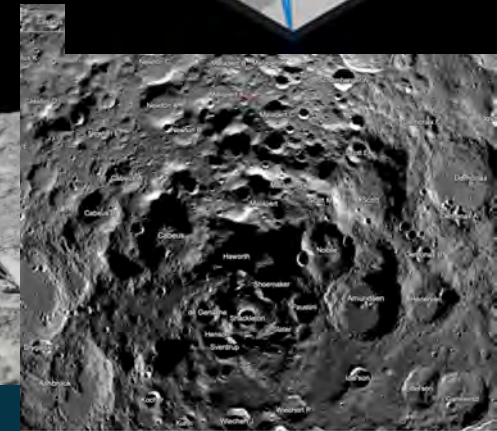
Mission Details

Lander/ Launch Provider: Peregrine / ULA Vulcan-Centaur
Launch Date: December 24-26, 2023
Landing Date: January 25, 2024
Landing Site: Sinus Vicositatis
(35.1°N, 41.8°W)
Surface Ops Duration: ~196 Hours

Intuitive Machines

Nova-C Lander

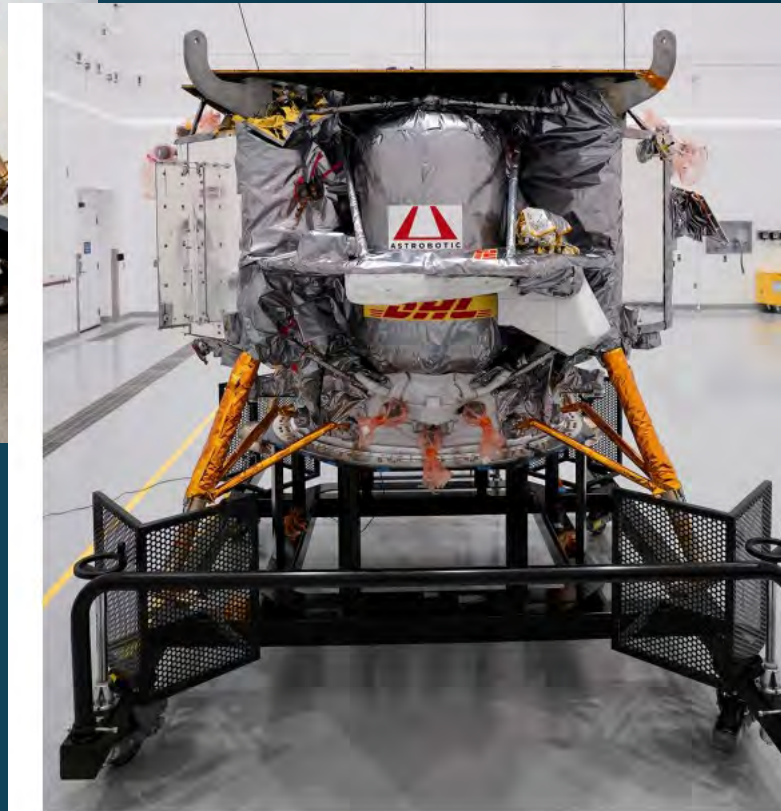
IM-1 Mission



Mission Details

Lander/ Launch Provider: Nova-C / SpaceX Falcon 9
Launch Window: January 12-16, 2024
Landing Date: January 19 or 21, 2024
Landing Site: South Pole - Malapert A
(80.297°S 1.2613°E)
Surface Ops Duration: ~ 264 Hours

Astrobotic's Peregrine Mission-1



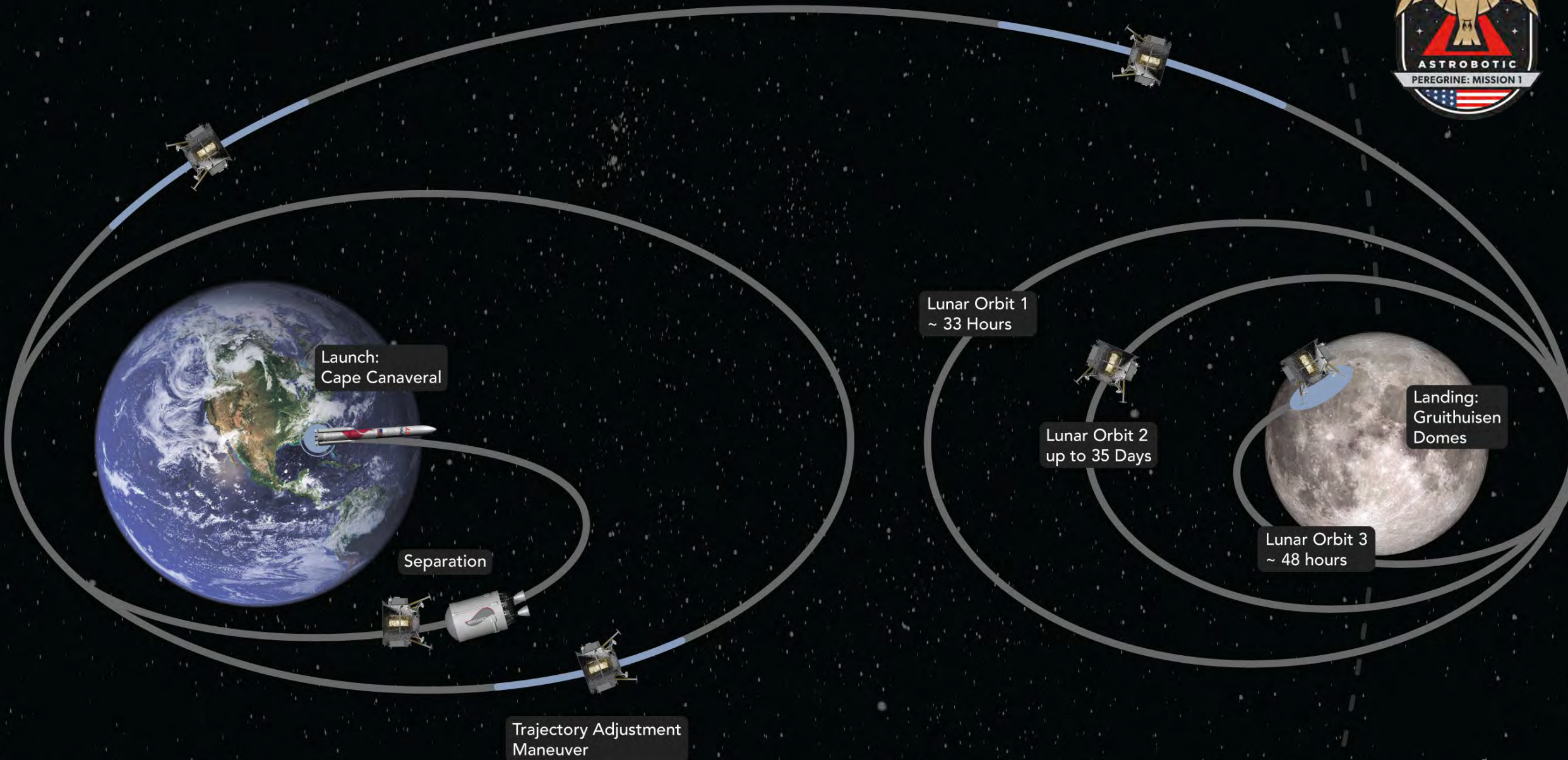
Astrobotic PM-1 Launch windows open

- 12/24: 6:49am UTC
- 12/25: 6:53am UTC
- 12/26: 7:08am UTC

Astrobotic PM-1 Landing window

- 1/25: 8:30am UTC

PM1 PATH TO THE MOON



Launch:
Cape Canaveral

Separation

Trajectory Adjustment
Maneuver

Lunar Orbit 1
~ 33 Hours

Lunar Orbit 2
up to 35 Days

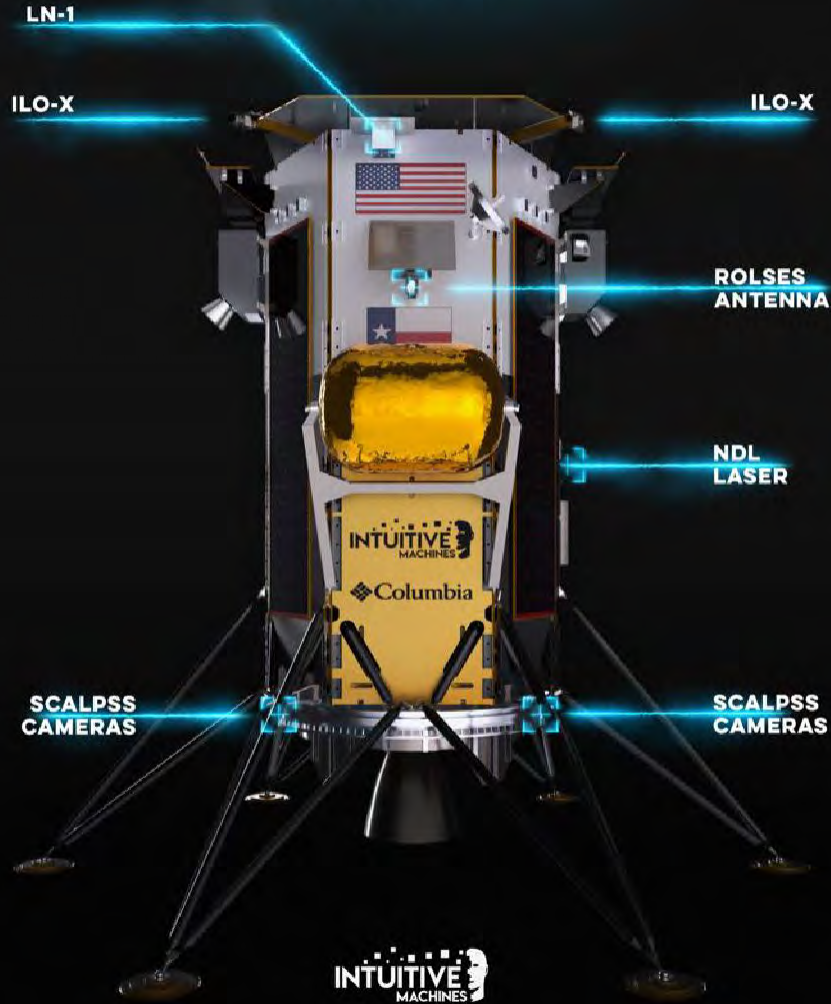
Lunar Orbit 3
~ 48 hours

Landing:
Gruithuisen
Domes

30-TO-54-DAY TRANSIT

NOVA-C

MISSION 1



NASA CLPS Payloads (CLPS TO2)

- Navigation Doppler Lidar (NDL)
- Lunar Node-1 (LN-1)
- Lunar Retroreflector Assembly (LRA)
- Stereo Cameras for Lunar Plume Surface Studies (SCALPSS)
- Radio wave Observations at Lunar Surface of photo Electron Sheath (ROLSES)

Commercial Payloads

- Galaxy Legacy Lab
- ILO-X, International Lunar Observatory Association
- Art Cube, 4Space & Jeff Koons
- EagleCam, Embry Riddle
- Omni-Heat Infinity, Columbia Sportswear
- Lonestar Lunar, Lonestar Data Holdings

NASA CLPS PRIME-1

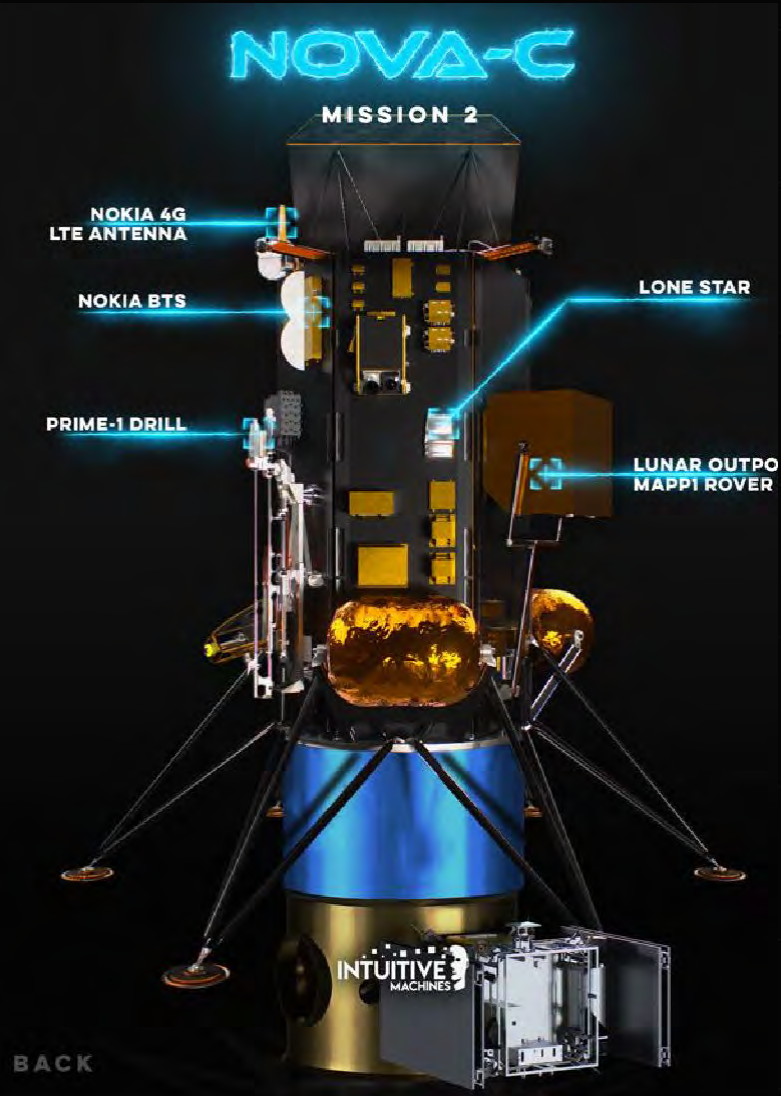
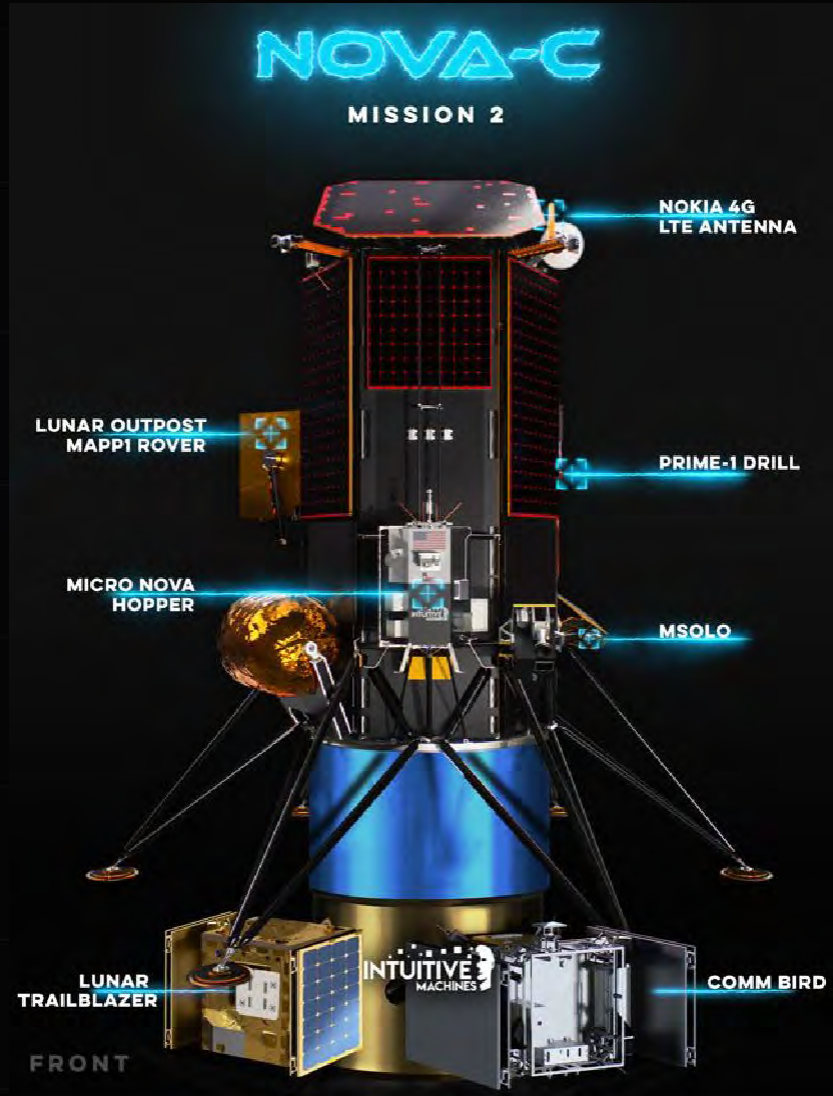
- Polar Resources Ice Mining Experiment. TRIDENT Drill & Msolo mass spectrometer

Non-CLPS Payloads

- STMD IM μ -Nova Hopper– hops into craters and photographs hard-to-reach areas
 - Pyrometer. Temperatures in permanently shadowed regions
 - Neutron spectrometer. Hydrogen measurements in PSR
- STMD Nokia LTE - first LTE/4G communications system in space
- Yaoki Rover, Dymon
- Lonestar

Rideshare Payloads

- NASA Lunar Trailblazer
- Astroforge 1



CLPS Deliveries 2023-2027

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

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

Delivery Site:
Lunar Far Side &
Orbit Insertion
Provider: Firefly
CS-3 & CS-4 | 2025

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

Delivery Site:
Ina Irregular Mare Patch
Provider: TBD
CP-32 | 2027

Delivery Site:
Mare Crisium
Provider: Firefly
TO19D | 2024



Delivery Site:
Shackleton Connecting Ridge
Provider: IM
TO PRIME-1 | 2024

Delivery Site: Malapert A
Provider: Intuitive
Machines (IM)
TO2-IM | Jan 2024



Delivery Site:
Schrödinger Basin
Provider: Draper
CP-12 | 1H 2025

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

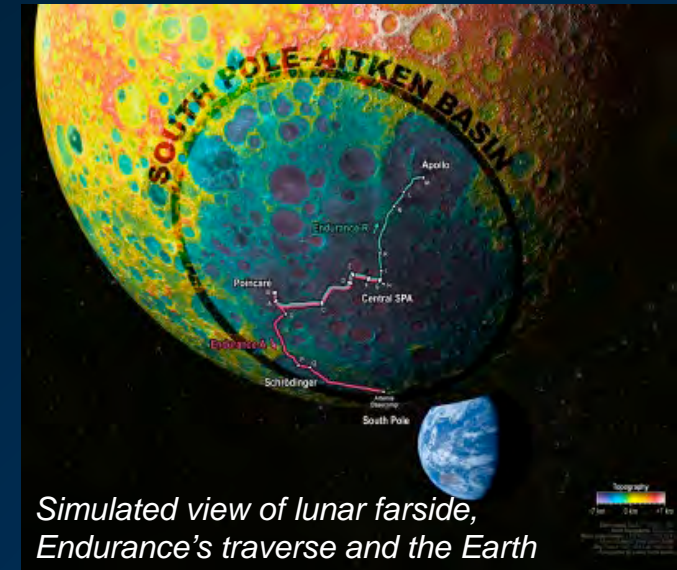
Delivery Site:
Mons Mouton
Provider: Astrobotic
VIPER | Nov 2024



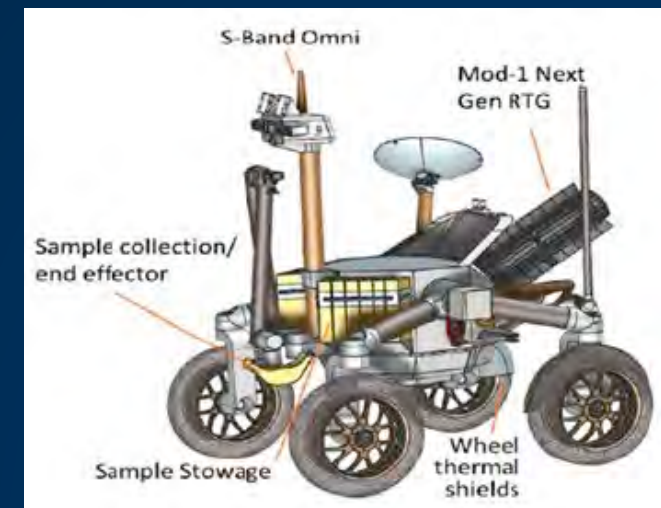
Human Enabled Decadal-Level Science at the Moon Endurance A: South Pole-Aitken Sampling Campaign

- 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



SPA sample return has been highly prioritized in all three Decadal Surveys, as it would address many important science questions, including:

- Was there a cataclysmic bombardment of the inner solar system ~4 billion years ago? If so, what caused it, and what were the effects on early Earth?
- What is the nature of the Moon's lower crust and mantle? What can it tell us about the thermochemical evolution of rocky worlds?
- Why is the Moon's farside so different than the nearside, and how to planetary-scale asymmetries form?

Endurance SCIENCE WORKSHOP | Workshop Goal

The goal of the Workshop was to go beyond the Decadal and bring the entire planetary community together to discuss all aspects of this mission concept, with an emphasis on the science, and to help develop the best mission.

The Workshop was recorded, and recordings and talks will be available on the workshop website soon.

The Science Organizing Committee is preparing a final report summarizing key findings from the report to feed forward to future formulation activities.



Endurance (baseline) implementation highlights

- **Rover mass:** 487 kg (fully margined)
- **Rover size:** 2.7 × 1.8 × 2.5 m
- **Mobility:**
 - Highly autonomous
 - Speed: 1 km/hr (maximum), 0.65 km/hr (daytime average), 0.35 km/hr (nighttime average, with headlights)
 - 4-wheeled driving and steering
 - 80 cm diameter mesh compliant wheels
 - Slope capability: 20° (84% of slopes on traverse are <5°, 98% are <10°, 100% are <13°)
- **Mission duration:** 4.0 years (with 1.1 years margin)
- **Communications:** 2-axis gimbaled 0.75-meter S-band high gain, and omni directional low-gain, communications via orbital relay
- **Power:** NextGen Mod 1 RTG (245 W beginning of life) with secondary battery
- **Lunar landing:** Delivered by CLPS

