



# Lunar Discovery and Exploration Program Update

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**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  
 $^{87}\text{Rb}$ - $^{87}\text{Sr}$  isochron method

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

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

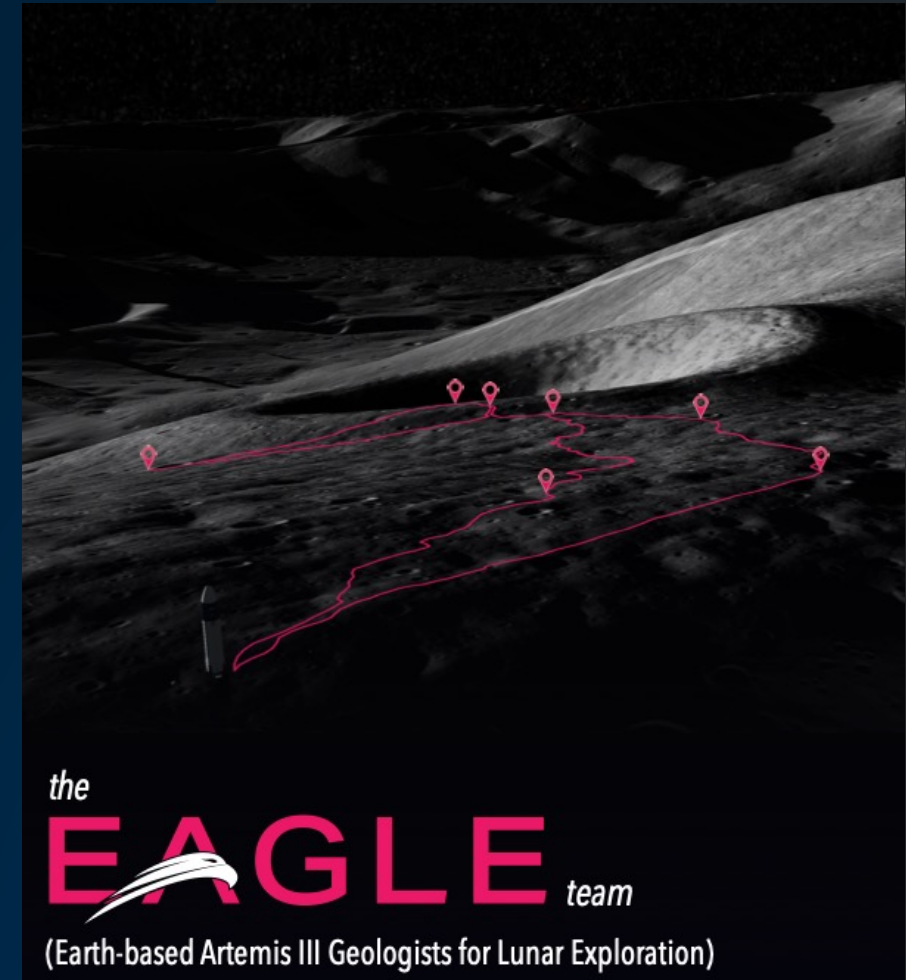
**International contributions** from University of  
Bern and University of Manchester, UK



## 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**

**ASTROBOTIC**

**TO2-IM**

**IM-1**



**Nova-C Lander**

**INTUITIVE  
MACHINES**

**TO19D**

**Blue  
Ghost 1**

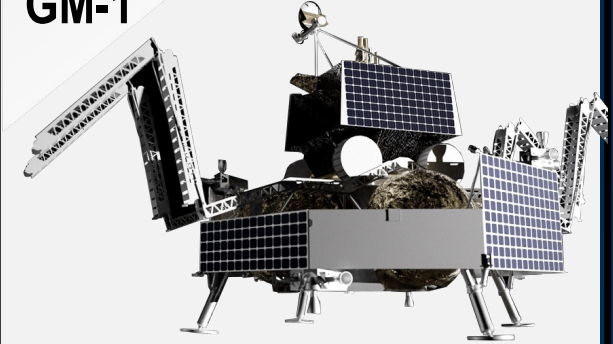


**Blue Ghost lander**

**FIREFLY  
AEROSPACE**

**TO20A – VIPER**

**GM-1**



**Griffin Lander**

**ASTROBOTIC**

**PRIME-1**

**IM-2**



**Nova-C Lander**

**INTUITIVE  
MACHINES**

**CP-11**

**IM-3**



**Nova-C Lander**

**INTUITIVE  
MACHINES**

**CP-12**

**TBA**

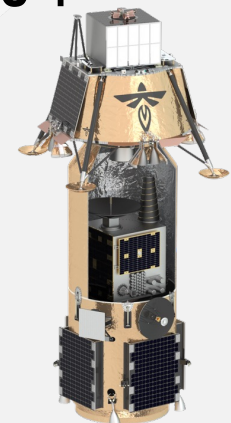


**Series-2 Lander**

**DRAPER**

**CS-3 & CS-4**

**Blue  
Ghost 2**



**Blue Ghost Lander**

**FIREFLY  
AEROSPACE**



# Commercial Lunar Payload Services

## First Two Task Orders

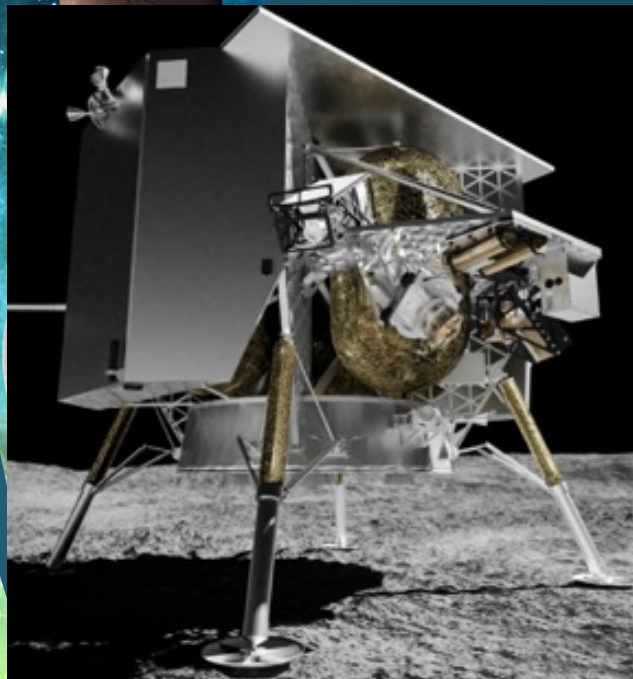


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### Astrobotic Technologies

#### Peregrine Lander

PM-1 Mission



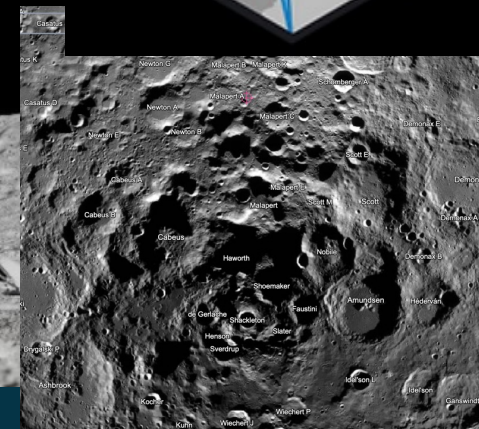
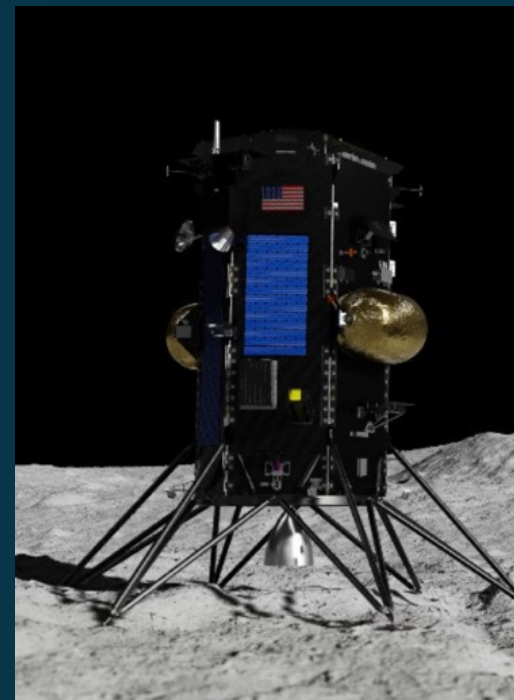
#### Mission Details

*Lander/ Launch Provider:* Peregrine / ULA Vulcan-Centaur  
*Launch Date:* December 24-26, 2023  
*Landing Date:* January 25, 2024  
*Landing Site:* Sinus 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:* 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

As of November 12, 2023



# Astrobotic's Peregrine Mission-1



Photo Credit: United Launch Alliance

## Astrobotic PM-1 Launch windows open

12/24: 6:49am UTC

12/25: 6:53am UTC

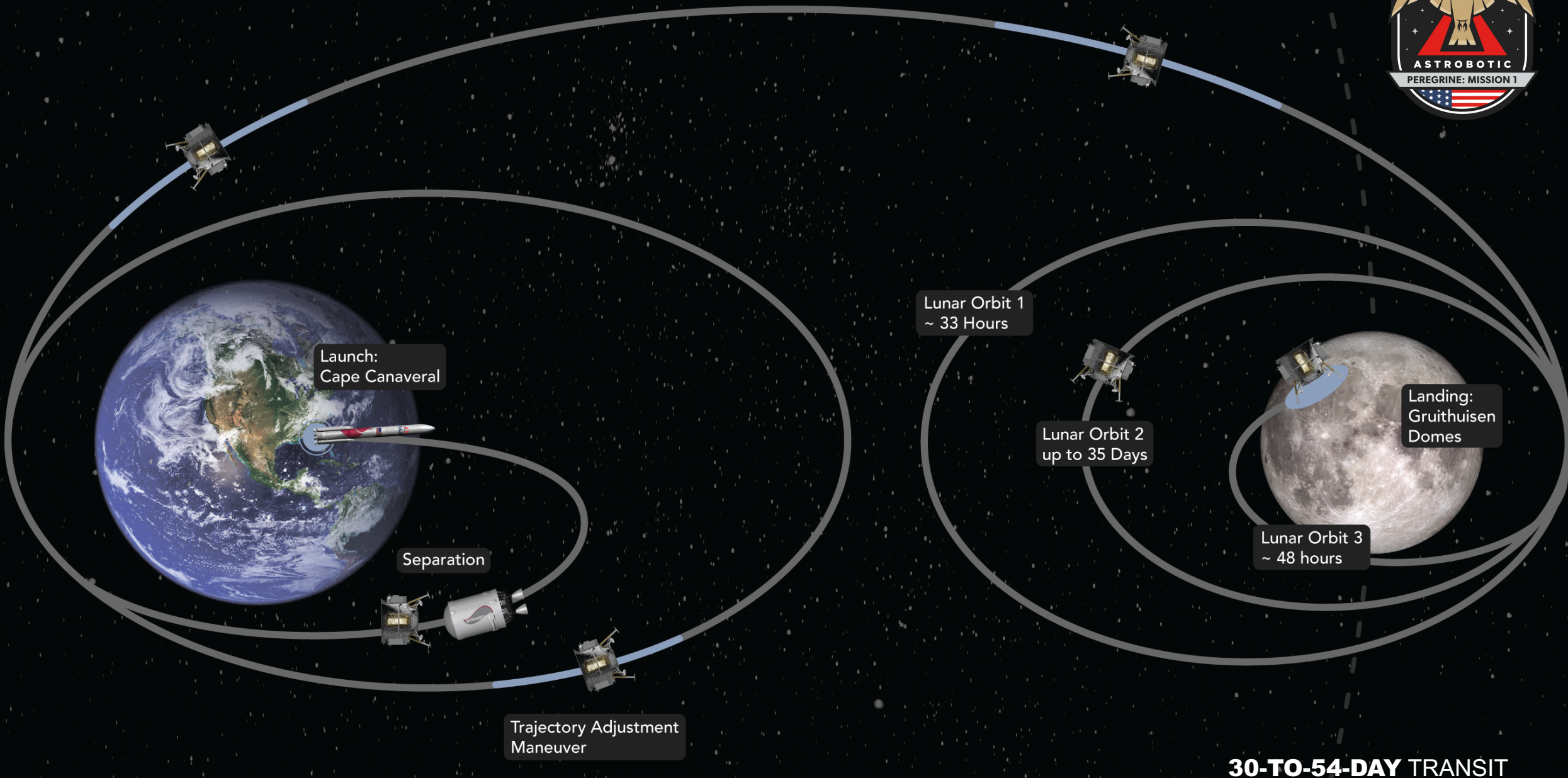
12/26: 7:08am UTC

## Astrobotic PM-1 Landing window

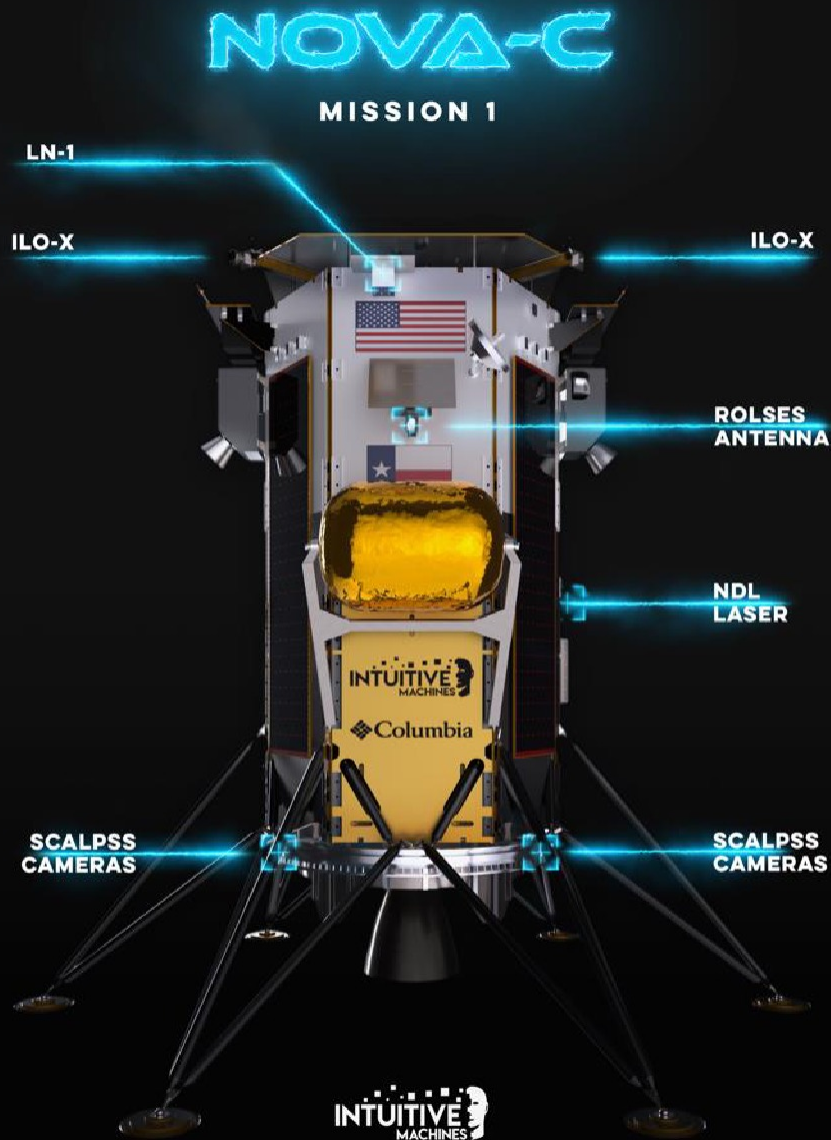
1/25: 8:30am UTC



# PM1 PATH TO THE MOON



**30-TO-54-DAY TRANSIT**



## 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

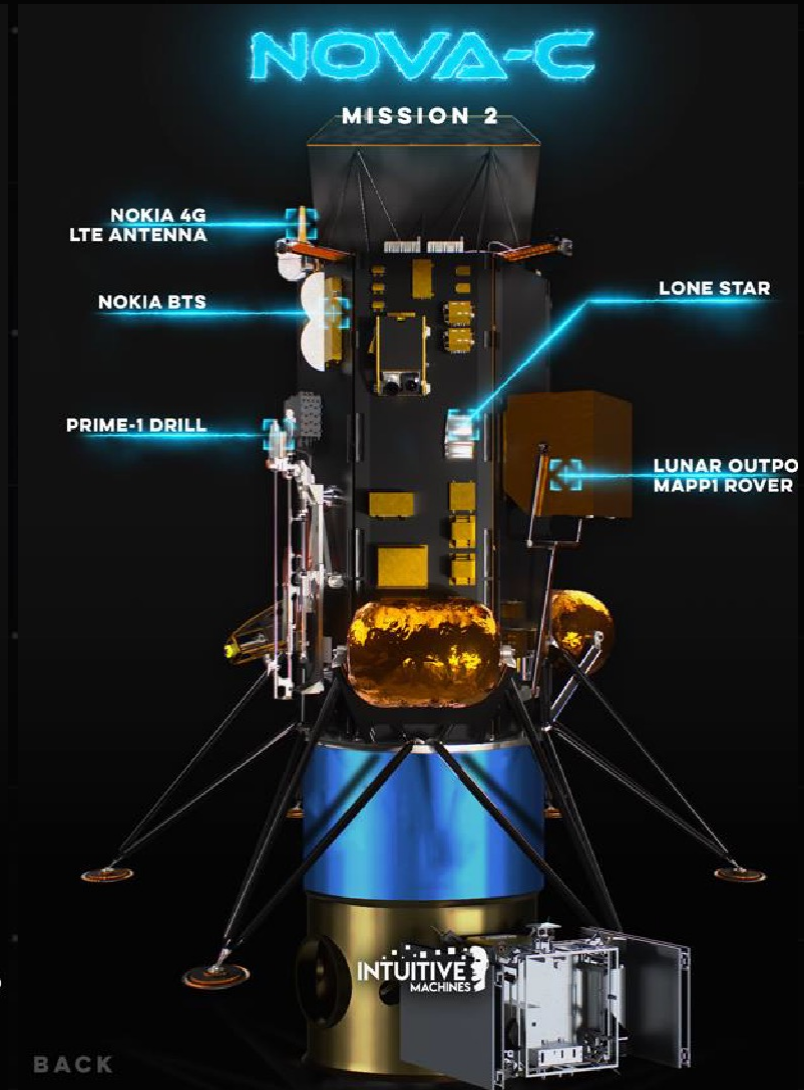
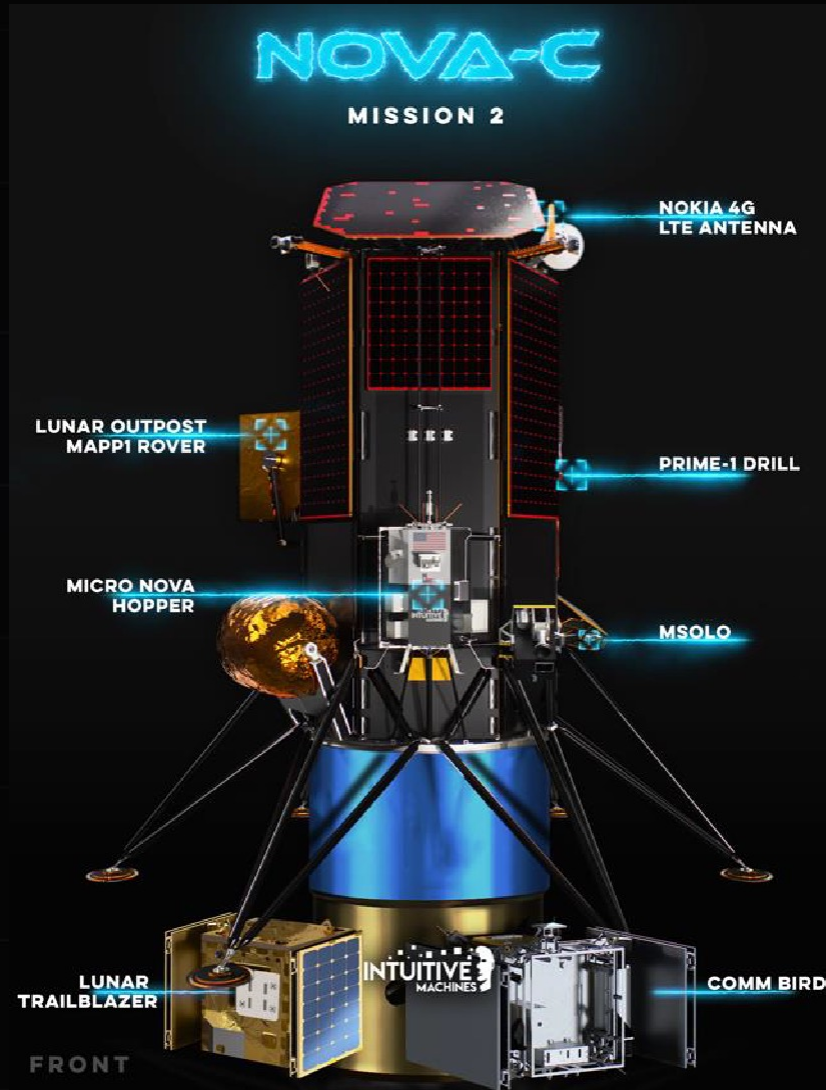
- Polar Resources Ice Mining Experiment. TRIDENT Drill & Msolo mass spectrometer

## Non-CLPS Payloads

- STMD IM  $\mu$ -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

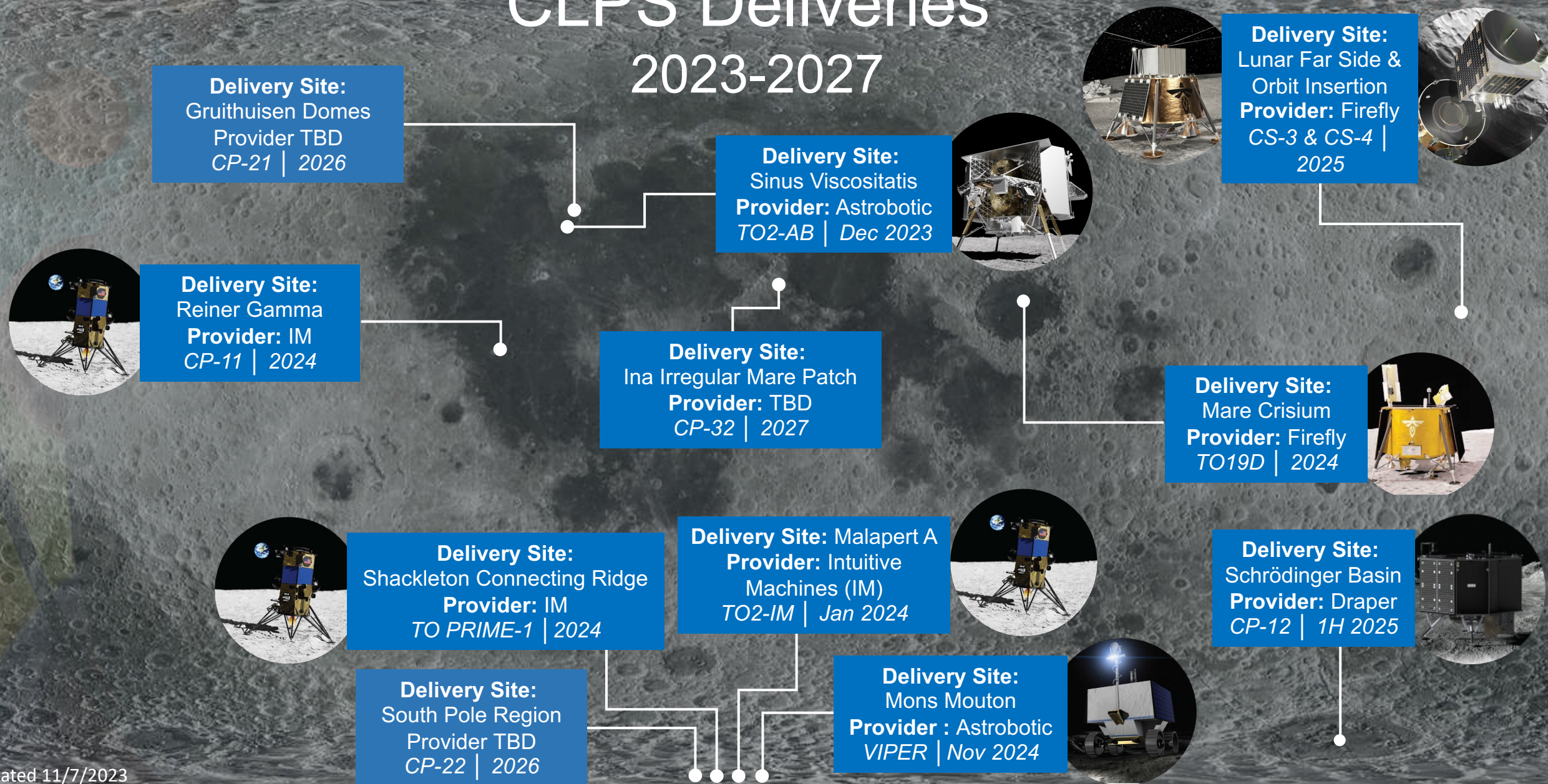
- NASA Lunar Trailblazer
- Astroforge 1





# CLPS Deliveries

## 2023-2027



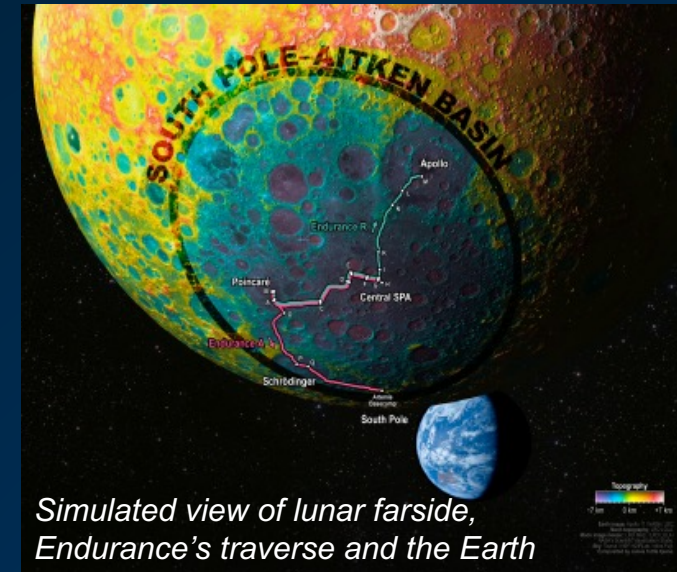


# Human Enabled Decadal-Level Science at the Moon

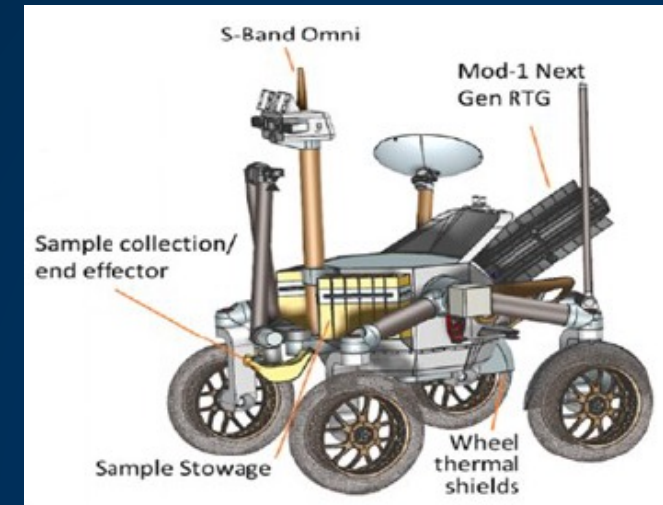
## Endurance A: South Pole-Aitken Sampling Campaign

- 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 | Workshop Goal

SCIENCE WORKSHOP

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:**  $2.7 \times 1.8 \times 2.5$  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:  $20^\circ$  (84% of slopes on traverse are  $<5^\circ$ , 98% are  $<10^\circ$ , 100% are  $<13^\circ$ )
- **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

