Lunar Community Perspective on NF5 Target List

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New Frontiers Target List Discussion

- **New Frontiers 5**
  - Comet Surface Sample Return (CSSR)
  - Lunar South Pole–Aitken Basin (SPA) Sample Return (pending Artemis landing site selection(s) and science objectives)
  - Ocean Worlds (only Enceladus)
  - Saturn Probe
  - Venus In Situ Explorer
  - Io Observer
  - Lunar Geophysical Network (LGN)
- **New Frontiers 6**
  - Centaur Orbiter and Lander (CORAL)
  - Ceres Sample Return
  - Comet Surface Sample Return (CSSR)
  - Enceladus Multiple Flyby (EMF)
  - Lunar Geophysical Network (LGN)
  - Saturn Probe
  - Titan Orbiter
  - Venus In Situ Explorer (VISE)
- **This perspective is derived from LEAG ExComm discussions and community inputs**
  - Open Community Meeting on May 14
  - Other communications from community members
  - Other communications from some mission concept study team members

NF Target: Lunar Geophysical Network

- **LGN Science Objectives**
  - Determine the internal structure and size of the crust, mantle, and core to constrain the composition, mineralogy, and lithologic variability of the Moon.
  - Determine the distribution and origin of lunar seismic activity in order to better understand the origin of moonquakes and provide insights into the current dynamics of the lunar interior and the interplay with external phenomena such as tidal interactions with Earth.
  - Determine the global heat-flow budget for the Moon in order to more precisely constrain the distribution of heat-producing elements in the crust and mantle, the origin and nature of the Moon's asymmetry, its thermal evolution, and the extent it was initially melted.
- **Types of LGN Geophysical Measurements**
  - Global, long-lived (≥6 years) network of geophysical instruments on the lunar surface.
  - Relevant measurements include seismic, heat flow, laser ranging, and magnetic-field/electromagnetic sounding.

NF Target: Lunar Geophysical Network

- **CAPS Study "Options for the Fifth New Frontiers Announcement of Opportunity (2020)"**
  - **Finding:** CLPS missions by their design (and current implementation approach) cannot replace the integrated New Frontiers–level science investigations of the LGN. But, the CLPS program, if so utilized, represents a potentially important risk reduction mechanism for LGN instruments and technologies.
  - **Finding:** Scientific discoveries from lunar orbit or in terrestrial laboratories and technical advances in instrumentation since the 2011 decadal survey do not replace or obviate the need for the LGN.
  - **Finding:** The scientific rationale in V&V for the LGN has not changed, and if anything has become more compelling, so reconsideration by NASA of inclusion of LGN in the NF5 target list is not warranted. Substantial investment in deployable geophysical instrumentation for the lunar surface over the past decade has made the scientific case for LGN more robust in the sense of being more achievable.
- **Advances in Scientific Understanding since OWL**
  - **No networked geophysical observatories.** Furthermore, there is no current implementation approach or opportunity to perform multi-year networked geophysical observations through CLPS or Artemis.
  - **The constellation of lunar retroreflectors is increasing.** While the design and capabilities of retroreflectors remains varied, it is becoming more routine to place passive retroreflectors on landers.
  - **NASA has not deployed any other surface geophysical instruments.** Retroreflectors alone are not capable of addressing the preponderance of the LGN science objectives.

NF Target: Lunar Geophysical Network

- **Upcoming Geophysical Payloads Beyond Retroreflectors**
  - CLPS CP19D (2024; Mare Crisium) – Heat flow probe, magnetotelluric sounder
  - CLPS CP11 (2025; Reiner Gamma) – Magnetometer (lander), magnetometer (rover)
  - CLPS CP12 (2026; Schrödinger Basin) – Seismometers, heat flow probe
  - Artemis III (2026; South Polar Region) - Seismometers
- **If fully successful, these payloads will increase our understanding of the lunar interior**
  - **If they are successful.** CLPS landers (excluding VIPER) and payloads are developed with a significantly higher risk posture than NF missions.
  - Similar geophysical payloads are unlikely to operate on the surface at the same time and do not meet required observational longevity for LGN.
  - "Substantial investment in deployable geophysical instrumentation for the lunar surface over the past decade has made the scientific case for LGN more robust in the sense of being more achievable."
- **Findings from the CAPS Study "Options for the Fifth New Frontiers Announcement of Opportunity (2020)" remain valid considering advancements since OWL**
- **LGN should remain on the NF 5 Target List**

NF Target: Lunar South Pole–Aitken Basin Sample Return

- **Lunar SPA Basin Sample Return Science (SPA-SR) Objectives**
  - Elucidate the nature of the Moon's lower crust and/or mantle by direct measurements of its composition and of sample ages
  - Determine the chronology of basin-forming impacts and constrain the period of late, heavy bombardment in the inner solar system, and thus, address fundamental questions of inner solar system impact processes and chronology
  - Characterize a large lunar impact basin through "ground truth" validation of global, regional, and local remotely sensed data of the sampled site
  - Elucidate the sources of thorium and other heat-producing elements to understand lunar differentiation and thermal evolution
  - Determine the age and composition of farside basalts to determine how mantle source regions on the Moon's farside differ from the basalts from regions sampled by Apollo and Luna

NF Target: Lunar South Pole–Aitken Basin Sample Return

- **Addressing the preponderance of the SPA-SR target science objectives requires sample return**
  - No SPA Basin samples have been returned. China's Chang'e 6 mission intends to return samples from the Apollo Basin within SPA within the next month. If successful, Chang'e 6 will address aspects of the SPA-SR NF target.
- **However, the OWL already identified and prioritized an alternative approach (Endurance-A) to meeting and exceeding the SPA-SR target science objectives**
  - OWL: "The SPA Sample Return mission addresses the highest priority lunar science. However, achieving the top science objectives with a fixed lander, as has been typically envisioned, is challenging."
  - OWL: "The committee concluded that the Endurance-A rover mission is a superior approach for acquiring abundant samples across diverse terrains to address multiple top-level science questions for the Moon and the solar system."

NF Target: Lunar South Pole–Aitken Basin Sample Return

Chang'e 6

- 2024 launch
- Static lander (duplicate of Chang'e 5)
- Collect up to ~2 kg of samples from 1 site in SPA (Apollo basin)
- Samples returned to Earth via robotic Earth return vehicle
- Samples acquired by drill (2-meter depth) and surface scoop
- Chang'e 6 lander may not survive the lunar night (Chang'e 5 lander did not)
- In-situ instruments (~4 instruments)

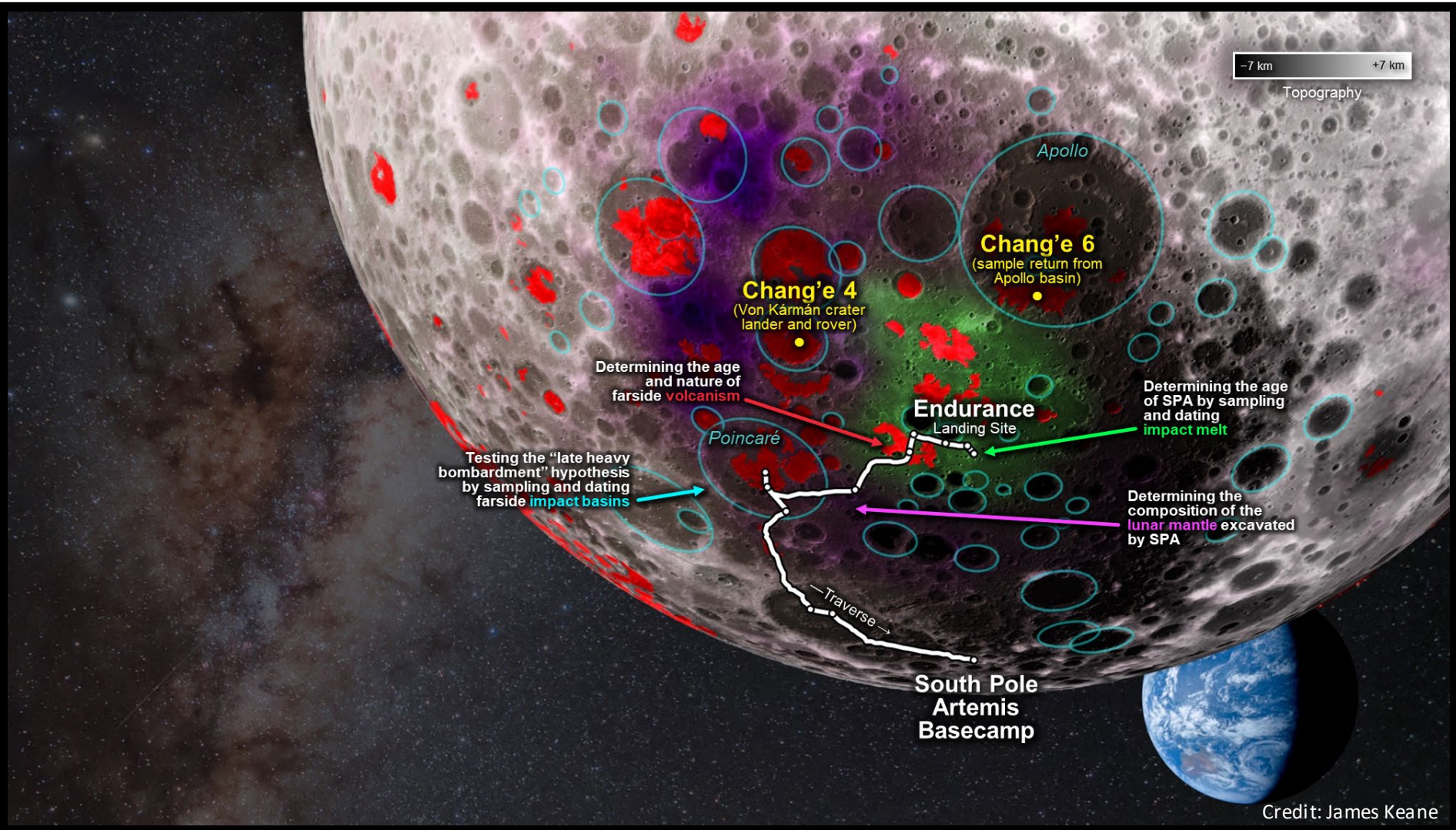
Table B-4: Endurance Concept Study Report

Endurance Science Objectives:		Vision and Voyages SPA Sample Return (SPA-SR)	PMCS In Situ Geochronology	Endurance-R (Robotic Sample Return Option)	Endurance-A (Astronaut Sample Return Option)	Artemis South Pole Basecamp
Science Theme 1: Solar System Chronology	**1.1. Anchor the earliest impact history of the Solar System** by determining the age of (perhaps) the largest and oldest impact basin on the Moon: South Pole–Aitken (SPA).	X		X	X	Contributing
	1.2. Test the giant planet instability and impact cataclysm hypotheses by determining when farside lunar basins formed.	Contributing	X	X	X	Contributing
	1.3. Anchor the "middle ages" of Solar System chronology (between 1 and 4 billion years ago) by determining the absolute age of a cratered, farside lunar mare basalt.	Contributing	X	X	X	
Science Theme 2: Planetary Evolution	**2.1. Test the magma ocean paradigm and characterize the thermochemical evolution of terrestrial worlds** by determining the age and nature of volcanic features and compositional anomalies on the farside of the Moon.	X	Contributing	X	X	
	2.2. Explore a giant impact basin from floor to rim by characterizing the geologic diversity across the South Pole–Aitken Basin.			X	X	
Development (A-D) Cost (FY25		**$1.1B** (this concept has not been fully costed by a decadal survey)	**$1.1B**	**$1.8B**	**$1.1B**	Unknown
Total Project Cost (FY25		**Unknown** (this concept has not been fully costed by a decadal survey)	**$1.2B**	**$2.4B**	**$1.5B** (*if HEO costs are not included*)	Unknown
Mission Class		**New Frontiers**	**New Frontiers**	**Flagship**	**New Frontiers** (*if HEO costs are not included*)	N/A
Sample Area		1 site (~2 × 2 meters)	1 site (~2 × 2 meters)	12 sites along ~1,800 km traverse	12 sites along ~2,000 km traverse	Unknown
Returned Mass		~1 kg	~0 kg	~2 kg	~100 kg (*contingent on Artemis return capability*)	Unknown *Artemis III SDT: inimum mass: 25 g, nominal mass: 83 kg)*

Endurance-A

- Targeting 2030 launch
- Long-range (~2,000 km) rover
- Collect up to 100 kg of samples from 12 sample sites across SPA
- Samples delivered to astronauts for return to Earth
- Samples acquired by scooping and sieving surface material
- Endurance has the potential for an extended mission
- In-situ instruments (exact complement TBD, but likely between 2 and 10 instruments)

NF Target: Lunar South Pole–Aitken Basin Sample Return



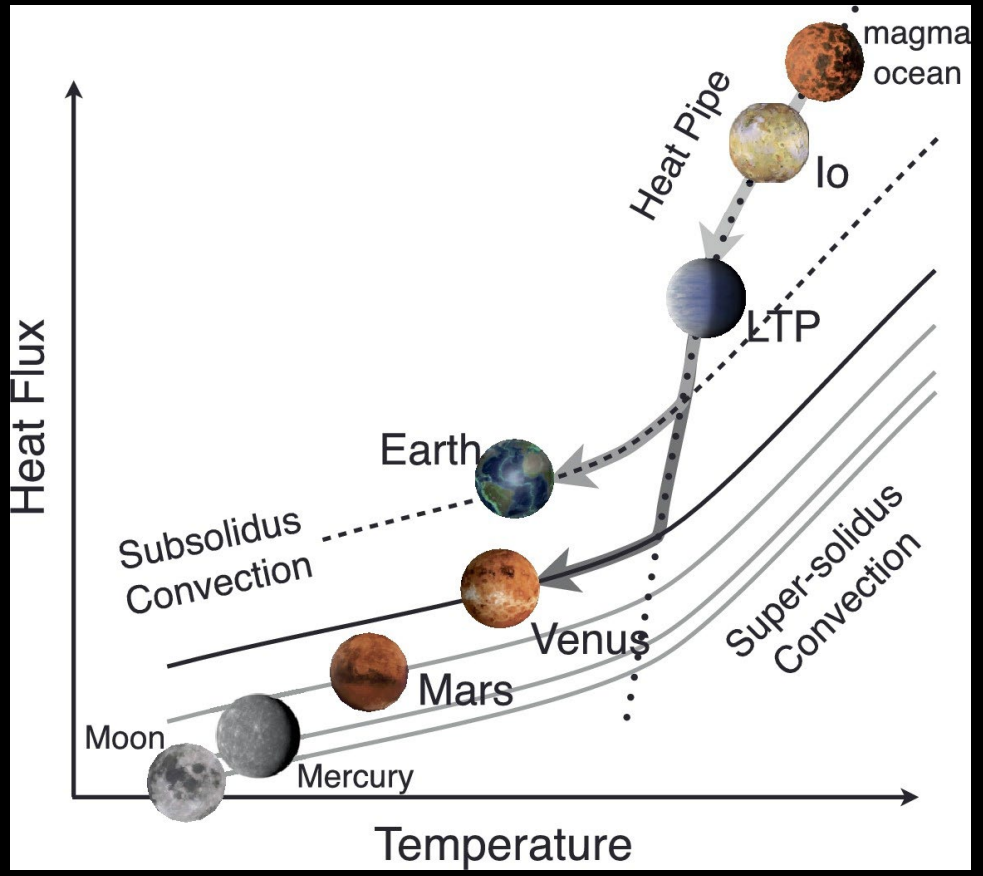
NF Target: Lunar South Pole–Aitken Basin Sample Return

- **OWL recommendations regarding Endurance-A remain valid**
  - OWL identified Endurance-A as “a superior approach” to achieved the science objectives of the NF 5 SPA-SR target (and more). In light of this, OWL did not recommend SPA-SR for NF 6.
  - OWL recommended Endurance-A as the highest priority for the Lunar Discovery and Exploration Program, which NASA has acknowledged repeatedly.
  - OWL recommended Endurance-A as a high priority for all PSD budget scenarios.

- **SPA Basin Sample Return should not be included in a revised NF 5 Target List**
  - NASA is in the process of standing up a Science Definition Team for Endurance-A.
  - Retaining SPA-SR on the NF 5 Target list may delay the development of Endurance-A.

NF Target: Non-Lunar Targets

- **The Moon is the cornerstone of planetary science, and lunar science is advanced by many New Frontiers mission concepts**
  - Io and Venus exhibit extreme active volcanism and may serve as analogs to the early Moon.
    - Large-scale silicate and ultramafic volcanism has been a key process on all terrestrial planets
    - Io as a heat-pipe tectonic end-member is especially relevant to the early Moon
  - Io's volcanism-driven exospheric processes may be relevant to understanding trapped ancient volatiles at lunar poles
  - Sample return missions to comets and Ceres provide important context from cryogenically preserved samples returned from the Moon's poles that retain a record of solar system history.



Moore et al., 2017

Summary

- **OWL Recommendations to retain NF 5 LGN as a NF 6 target is still well-supported**
  - The science objectives of LGN require long-lived, comprehensive geophysical measurements that are not currently available with any identified alternate approach, including CLPS.
- **OWL's recommendation to remove NF 5 SPA-SR as a NF 6 target is still well-supported**
  - OWL identified Endurance-A as "a superior approach" to SPA-SR, NASA has acknowledged this, and mission development is proceeding.
- **Lunar science is also advanced by other NF targets**
  - **Io Observer**, Venus In Situ Explorer, Comet Surface Sample Return, Ceres Sample Return
- **Largest hurdle to lunar NF targets is not based on the quality of the science**
  - V&V: "Because preparation and evaluation of New Frontiers proposals places a substantial burden on the community and NASA, it is important to restrict each New Frontiers solicitation to a manageable number of candidate missions."
  - OWL: "Indeed, with only 3 NASA centers (APL, JPL, GSFC) that can manage NF missions and proposals, a restricted list is needed so they can appropriately allocate resources."