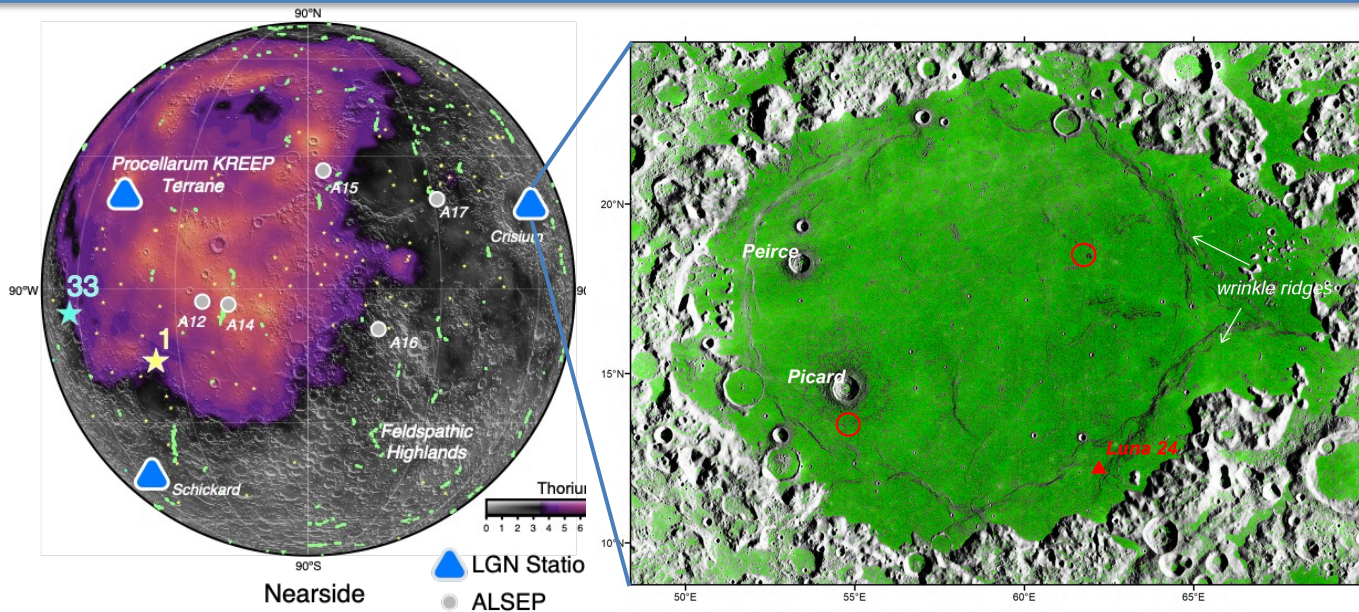




Future Lunar Geophysical Mission Opportunities including the Lunar Geophysical Network, Artemis & CLPS

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**GAGE/SAGE
Workshop
2023**



Haviland, H. F., Renee C. Weber, Clive R. Neal, Philippe Lognonné, Raphaël F. Garcia, Nicholas Schmerr, Seiichi Nagihara, Robert Grimm, Douglas G. Currie, Simone Dell'Agnello, Thomas R. Watters, Mark P. Panning, Catherine L. Johnson, Ryuhei Yamada, Martin Knapmeyer, Lillian R. Ostrach, Taichi Kawamura, Noah Petro, and Paul M. Bremner. (2022). **The Lunar Geophysical Network Landing Sites Science Rationale**. *The Planetary Science Journal*. 3, no. 2: 40. DOI: 10.3847/PSJ/ac0f82.

Neal, C. R., Weber, R., et al. 2020, **The Lunar Geophysical Network**, Final Q23 Report. Planetary Mission Concept Study, <https://science.nasa.gov/science-red/s3fs-public/atoms/files/Lunar%20Geophysical%20Network.pdf>

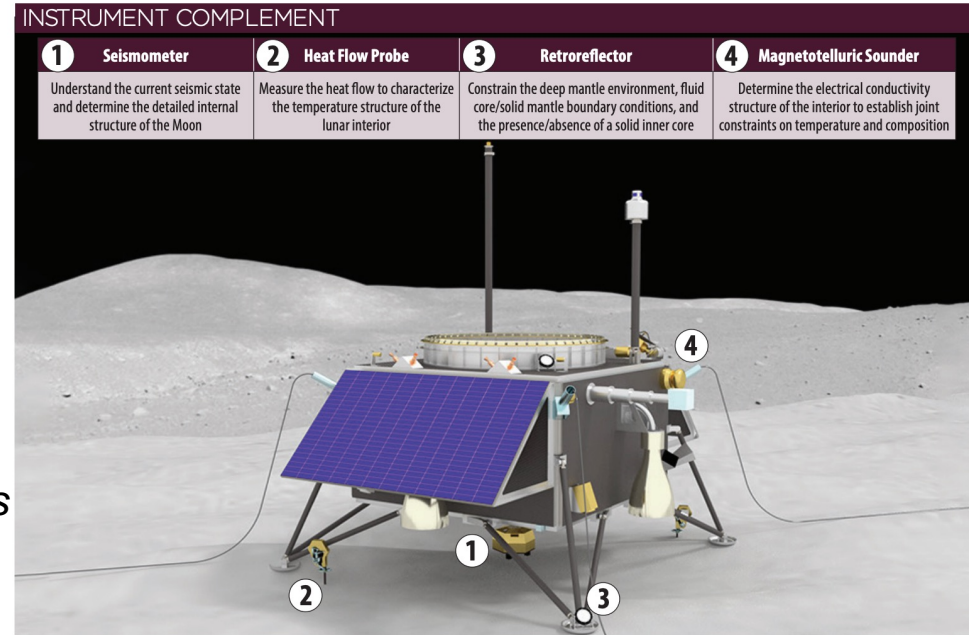
LGN... NF5

- The Lunar Geophysical Network (LGN) is a mission concept highlighted in the Planetary Science Decadal Survey (twice) as a New Frontiers 5 (NF5) mission opportunity.
- The NF5 draft AO has been released with the proposals due later this year.

LGN Mission Objectives

Will allow more intricate questions to be addressed than have resulted from previous work illuminating the lunar interior including:

- *Characterization of deep and shallow moonquakes including trigger mechanisms*
- *Farside seismicity*
- *Thrust fault movement*
- *Global mantle discontinuities*
- *Global Heat flow & bulk geochemical composition*
- *Lateral/vertical structure and composition as revealed by electrical conductivity*
- *Near and farside hemispherical distinctions*
- *Existence of a partially molten layer above the core mantle boundary*
- *Brittle failure within deep mantle*



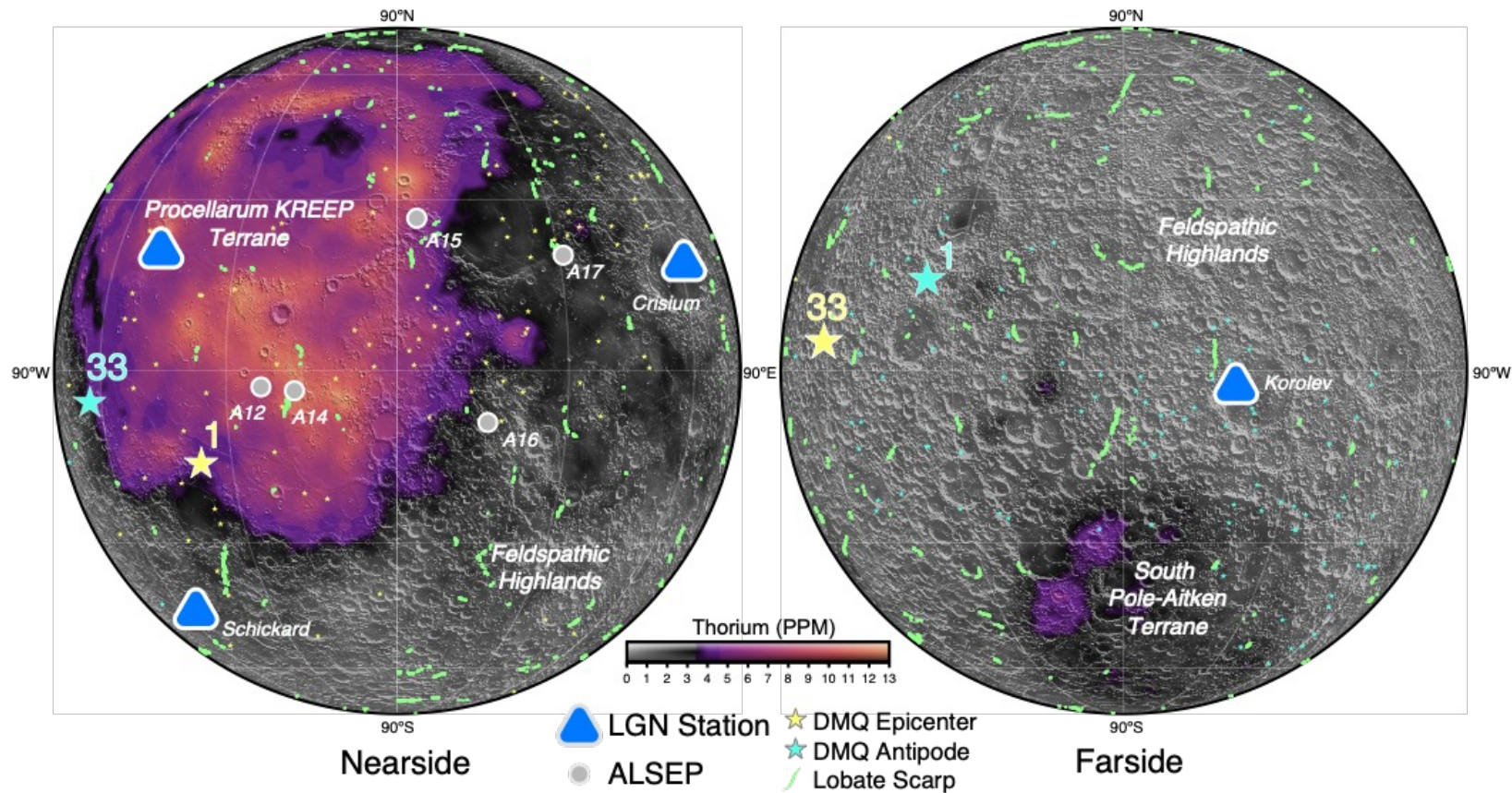
Neal et al., 2020

Landing Site Criteria

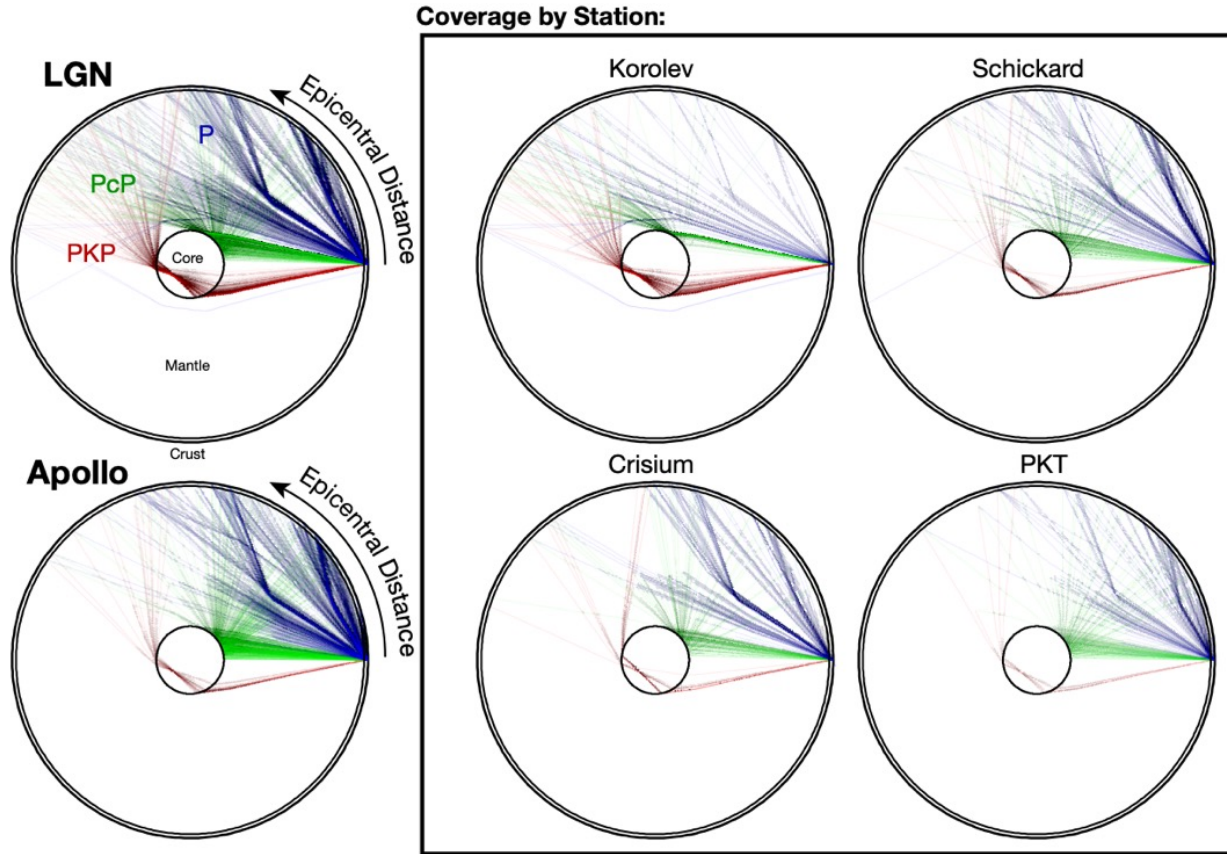
	LGN Landing Site Requirements	
Overarching Criteria	Broader coverage than Apollo Low-risk landing sites (i.e., low boulder and crater density)	
Measurement Type	Primary	Secondary
Seismicity	Use known seismic sources to examine the core, mantle, and crust	Proximity to thrust faults (lobate scarps, wrinkle ridges)
Laser retroreflectometry	3 nearside stations	Place nearside stations near as possible to the limb
Magnetotelluric	Location well within terrane boundaries	Benign magnetic signature at the surface
Heat flow	Location well within terrane boundaries	Regolith available for full deployment

See manuscript for MT, HF

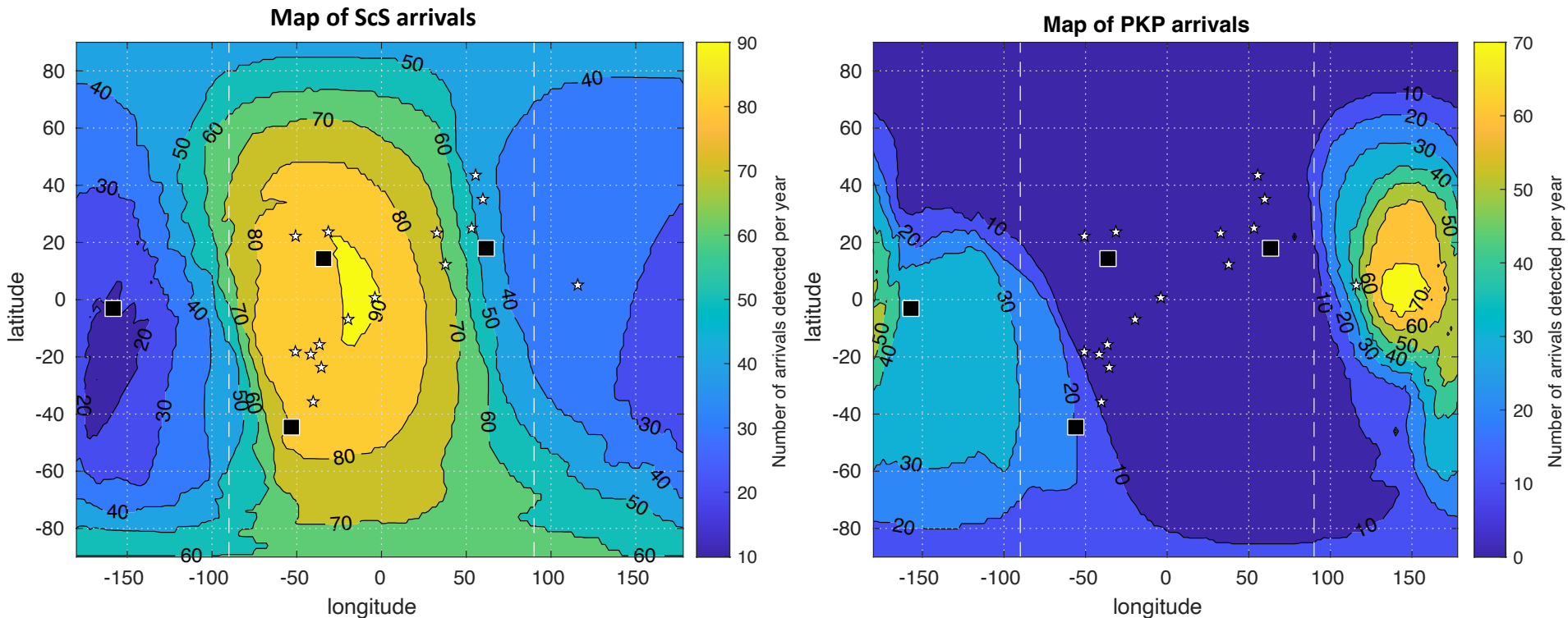
Example LGN locations



Seismic network ray density theoretical comparison



Seismic network optimization for core detection



LGN Summary

- The LGN mission will optimize science of: seismic, geodetic, EM, and heat flow.
- These stations greatly improve upon the previous measurements made during Apollo and will provide key observations advancing knowledge of the lunar interior.
- While some of our science objectives may be accomplished with a single station, the full network, is needed to provide sufficient science return.
- Optimization of network sites will at least double the rate of detection of lower mantle and core phases over the Apollo network.
- The wide distribution of stations improves the density of seismic rays observed.
- These example landing sites will continue to be evaluated and analyzed throughout the development of the LGN mission.

Artemis Phase 1: Path to The Lunar Surface



Upcoming Opportunities: Artemis III & Commercial Lunar Payload System (CLPS)



- The Payloads and Research Investigations on the Surface of the Moon (PRISM) program solicits payloads annually to fly on upcoming CLPS deliveries.
- NASA's Science Mission Directorate will solicit instruments to be deployed by Artemis crew on the surface of the Moon this year (Weber et al. 2023, LPSC).

Upcoming Opportunities: CLPS



2026 | PRISM 2a (CP-21)
Site: Gruithuisen Domes
Provider: TBD

2023 | TO2-AB

Site: Sinus Viscositatis
Provider: Astrobotic



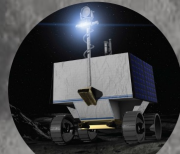
2024 | PRISM 1a (CP-11)

Site: Reiner Gamma
Provider: Intuitive Machines



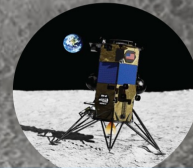
2023 | TO PRIME-1

Site: South Pole
Provider: Intuitive Machines



2024 | VIPER

Site: South Pole
Provider: Astrobotic



2023 | TO2-IM

Site: South Pole
Provider: Intuitive Machines (IM)



2024 | TO-19D

Site: Mare Crisium
Provider: Firefly



2025 | PRISM 1b (CP-12)

Site: Schrödinger Basin
Provider: Draper

2026 | PRISM 2b (CP-22)

Site: South Pole
Provider: TBD

CLPS & ESSIO, 2023, LPSC

Upcoming Opportunities: CLPS Manifested Geodetic Payloads

1. Lunar Retroreflector Array (LRA) (Task Order (TO)2 IM & others)
2. Next Generation Laser Retroreflector (NGLR) (TO 19D), PI Doug Curry
3. MoonLIGHT Pointing Actuator (MPAc) (TO CLPS PRISM (CP) 11), provided by ESA & INFN, PI Marco Muccino

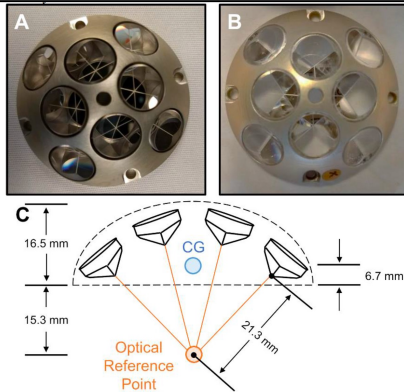
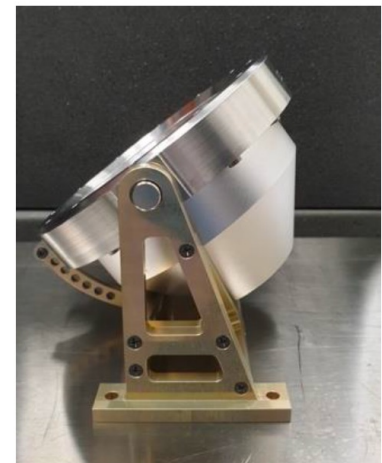
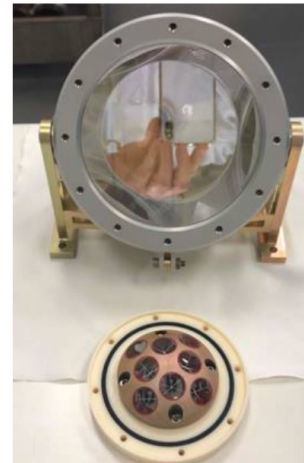


Fig. 1. Laser retroreflector arrays for lunar landers (LRALL). (A) Array with eight metal-coated CCRs. (B) Array with eight TIR CCRs. (C) Illustration showing LRALL geometry and optical reference point. CG stands for center of gravity. CCR illustration is not to scale.

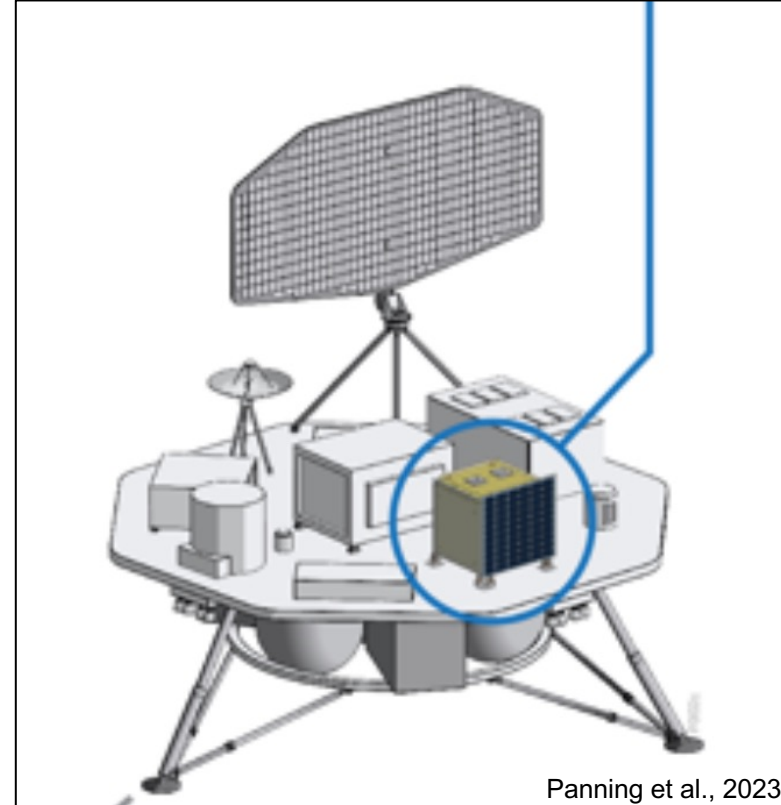
Cremons et al., 2019



NGLR 10-cm solid reflector next to an Apollo 38-mm CCR (left; credits: D. G. Currie) and next to a Martian microprobe board Perseverance and ExoMars (middle; credits: ASI-INFN). Side view of a MoonLIGHT in a fixed-pointing mount launch selectable elevation (right; credits: ASI-INFN).

Upcoming Opportunities: CLPS Manifested Seismic Payloads

1. Farside Seismic Suite (FSS) (TO CP12), PI Mark Panning, (Panning et al., 2023)



Conclusions

- The CLPS missions is scheduled to land seismic and geodetic instruments on the lunar surface in 2023 and 2024.
- Additional seismic and geodetic observations are needed to improve knowledge of the lunar interior, including lunar geophysical networks
- What instrument(s) and instrument suites would you like to send to the Moon and possibly in the future to Mars?