ARTEMIS: ENABLING THE LUNAR GEOPHYSICAL NETWORK.
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Introduction: The Moon has been the cornerstone of our understanding of terrestrial planet formation and initial evolution since the Apollo surface investigations 50 years ago. Geophysical instruments deployed by astronauts as part of the Apollo Lunar Surface Experiment Package (ALSEP) contributed key information that advanced our knowledge of the lunar interior. Still, significant questions regarding the nature of the Moon's global structure remain unanswered, including: the nature of the extinct lunar dynamo; the origin of the Moon's crustal magnetic anomalies; unambiguous observations of a mid-mantle discontinuity, a partial melt layer, or an inner core; whether and how surface hemispherical dichotomies propagate into the interior; and the origin of shallow moonquakes.

The current Planetary Decadal Survey prioritizes a future Lunar Geophysical Network (LGN) mission [1] to gather new information that will permit us to better determine how the overall composition and structure of the Moon inform us about the initial differentiation and subsequent evolution of terrestrial planets. Thus, LGN is not just a lunar mission, it is a planetary mission [2].

Robotic vs. crewed: Currently in formulation for response to the anticipated NASA New Frontiers 5 Announcement of Opportunity, LGN consists of a globally distributed network of robotic landers, each of which deploys an identical suite of geophysical instruments: a seismometer, a heat flow probe, a laser retroreflector, and a magnetotelluric sounder (Fig. 1). To maximize science return, the landers should operate continuously for a minimum of 10 years, and at least one lander should be located on the lunar far side [4].

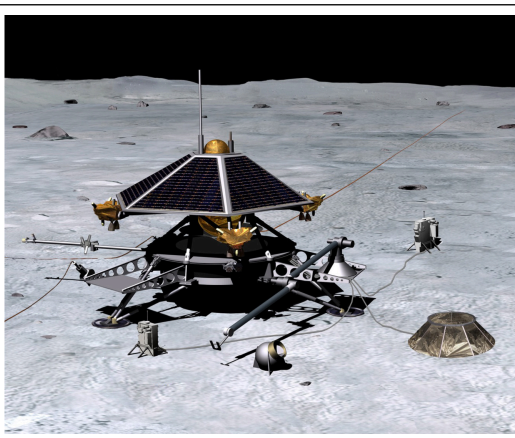
Figure 1: The LUNETTE mission concept [3], showing instruments robotically deployed to the surface.


Figure 2: Manual deployment of an Apollo 15 heat flow probe into a predrilled borehole. The drill is shown next to the bore stem.

Terrestrial geophysical survey instruments are traditionally deployed by humans *in situ*. Seismometers, heat flow probes, and magnetotelluric sounders require good ground coupling and are almost universally buried, isolating them from atmospheric and anthropogenic noise, as well as diurnal temperature variations. They can require leveling and orientation with respect to geographic coordinates and sun angle.

Completing these tasks robotically poses a technological challenge (and risk) to landed missions. While atmospheric noise is not an issue on the Moon, the extreme temperature variations are problematic and instruments still ideally need to operate in direct contact with the ground. Deployment mechanisms introduce cost and complexity to robotic missions, and are often not robust to unanticipated obstacles. The Mars InSight mission's heat flow probe, for example, has not been able to penetrate to its intended depth despite repeated attempts [5], and deployment would have been greatly facilitated by an astronaut, as was done during the Apollo missions (Fig. 2).

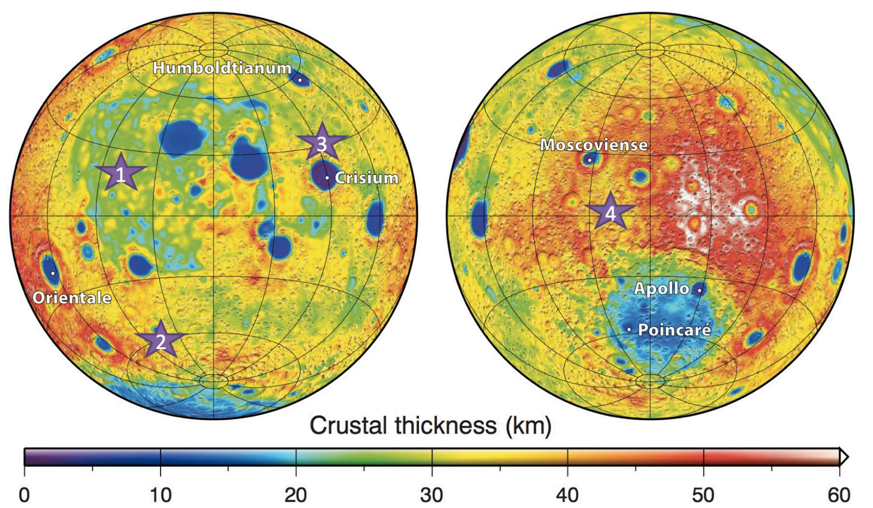

Figure 3: LGN candidate landing sites. 1: PKT. 2: Schickard (antipode to A33 deep moonquake source). 3: In or near Crisium. 4: Far side (antipode to A1 deep moonquake source). For further discussion see [11].

Payload	Mass	Dimensions (cm)	Power (Watts)	Crew Interaction
MT Sounder + plasma inst. + mag.	5.5 kg	40L x 35W x 15H	9W, (4W night)	deployment (running line & positioning sensors)
Heat Flow Probe	3.5 kg (includes robotic deployment)	sensor: 33L x 15W x 33H Avionics: 16L x 6.4W x 24H	12W during measurement, standyby 2W. 30W for 60s if using robotic deployment.	deployment (either using robotic gas-jet or via drilling/coring)
VBB Seismometer	10 kg	36D x 33 H cylindrical	11 W	placement, leveling, orientation
SP Seismometer (options)	1-5 kg	5D x 20H cylindrical (max)	5 W (max)	placement, leveling, orientation
Laser Retroreflector	4.5 kg	17W x 15L x 20H	none	placement and positioning

Table 1: Payload specifications.

Artemis enables LGN: Many of the instruments in development for LGN (Table 1) will soon fly to the Moon under NASA's Commercial Lunar Payload Services (CLPS) program [6,7,8]. Others are in work under NASA's Development & Advancement of Lunar Instrumentation (DALI) program [9,10]. Our goal is to have all LGN primary payloads at TRL 6 (or higher) in time to be responsive to an anticipated AO in 2022.

Humans will land at the south pole of the Moon in 2024, during LGN's Phase B. A human-deployed station at the south pole would enable an evaluation of seismic risk to a future lunar outpost, and be a fantastic addition to a robotically deployed LGN. Multiple human landings, likely spread across several years, and located at a geographically diverse set of landing sites (Fig. 3), would be required to establish an Artemis geophysical network. For comparison, the Apollo network of long-lived instruments was deployed over a period of 2.5 years (Apollo 12 to Apollo 16). All four stations only operated concurrently for an additional five years.

Artemis can reduce risk for LGN through a variety of means: 1) by raising the TRL of instruments; 2) by crew testing candidate deployment mechanisms; 3) by crew establishing the first node of a long-lived network which LGN can later augment. LGN likewise enables future long-term lunar exploration via monitoring of seismic and impact hazards. Artemis and LGN jointly provide a unique opportunity to open a new era of lunar planetary geophysical exploration.

References: [1] Vision and Voyages for Planetary Science in the Decade 2013-2022. Nat. Acad. Press. [2] Neal, C. et al. (2020) *LPSC* #2355. [3] Neal, C. et al. (2010) *Ground-based Geophysics on the Moon* #3036. [4] ILN Final Report: Science Definition Team for the ILN Anchor Nodes. NASA. [5] Common Questions About InSight's 'Mole.' NASA. [6] UMD Physicist for Apollo Experiment Gets Chance to Send Next Gen Version to Moon. [7] Nagihara, S. et al. (2019) *LPSC* #1557. [8] Grimm, R. E. et al. (2019) *LEAG* #5026. [9] Weber, R. C. et al. (2019) *AGU* #P33D-07. [10] Yu, N. et al. (2018) DALI abstracts (p.11). [11] Jawin, E. R. et al. (2019) *Earth & Space Sci. 6*, 2–40.