THE LUNAR GEOPHYSICAL NETWORK MISSION

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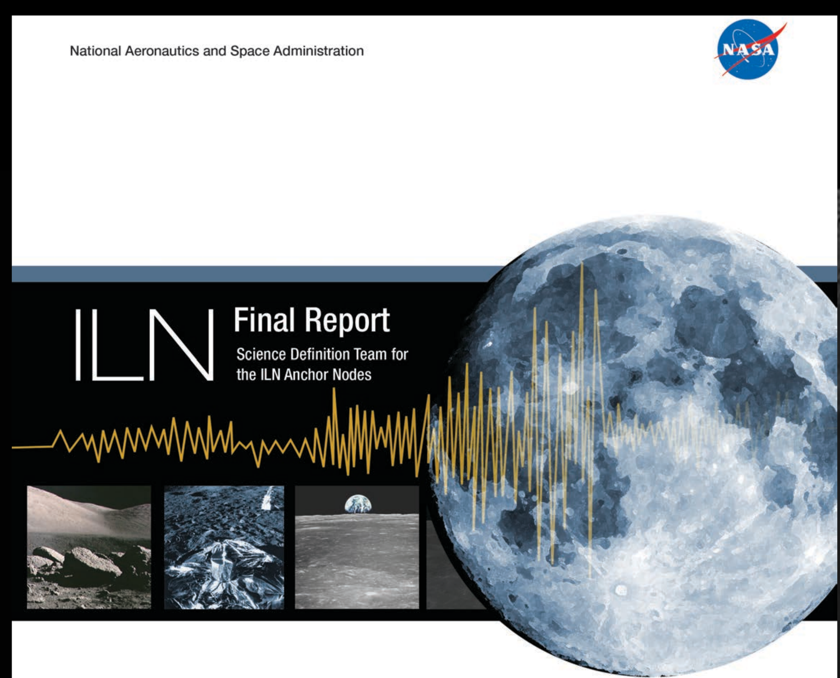
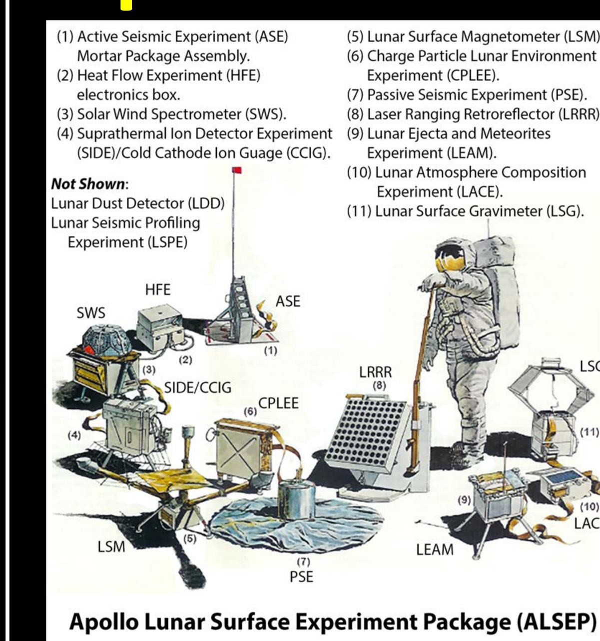
Overarching Principles:

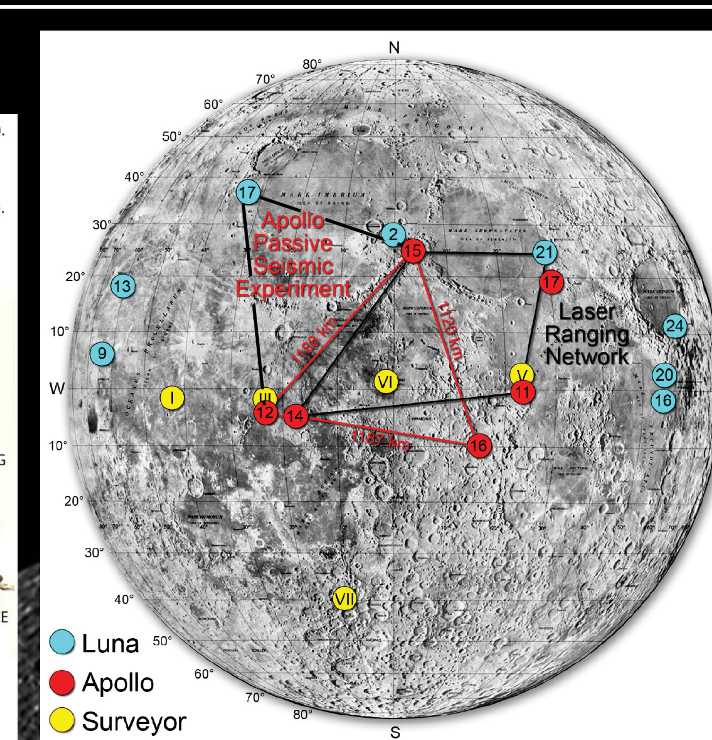
1). Must be better than Apollo (coverage, duration, instrument performance).
2). Learn from the Apollo experience.

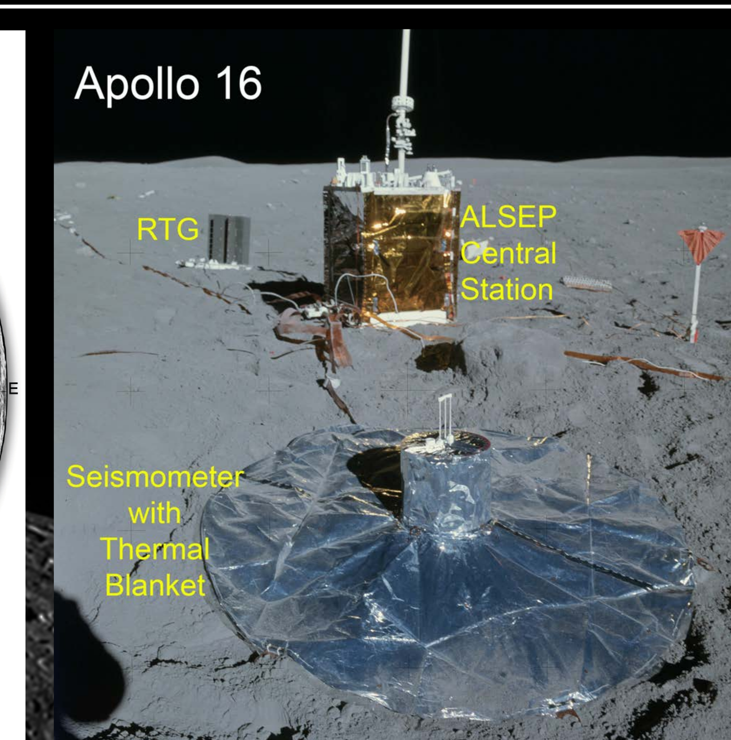


- Global distribution of multiple stations. Each station should contain a seismometer, heat flow probe, electromagnetic sounder, laser retroreflector (lunar nearside).
- Each station must be long-lived (e.g., ~10 years) to allow other stations (from other countries?) to be integrated with the anchor nodes to form the **International Lunar Network.**

Apollo ALSEP







- Narrow aperture of seismic network.
- Restricted selenographical range of the laser ranging network means tidal librations are poorly constrained.
- Magnetometers only deployed at A-12, A-15, and A-16 sites, away from magnetic anomalies.
- Heat flow at A-15 and A-17 close to PKT boundary.

Why LGN?

Planetary Science:

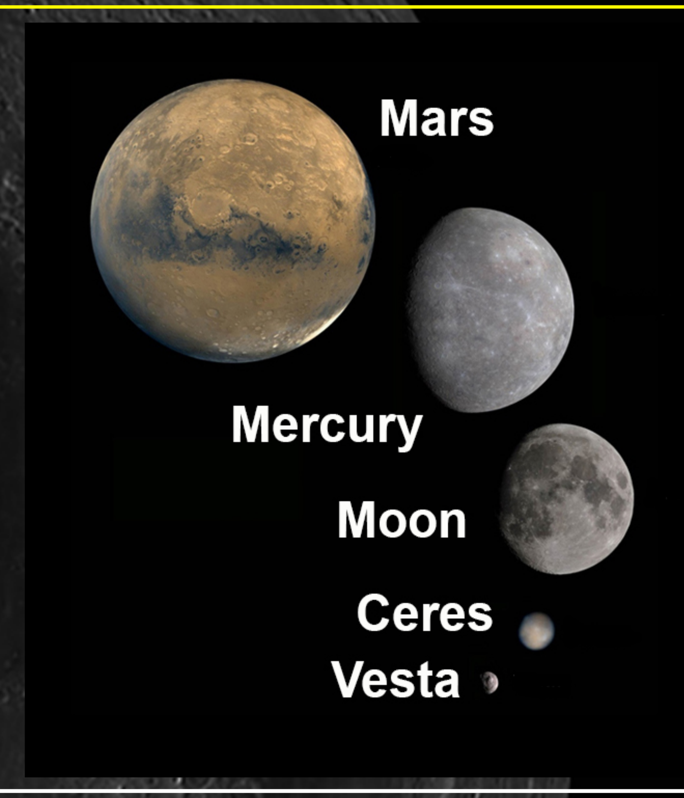
- Moon represents an end-member in planetary evolution (large small body, small rocky planet).
- Primary planetary differentiation preserved.
- Key to understanding terrestrial planet initial differentiation.

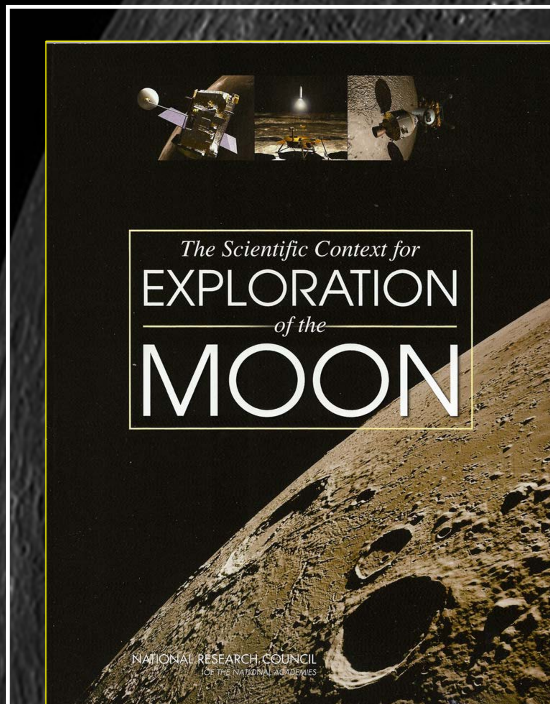
Lunar Science:

- Heat flow probes yield crustal heat budget estimates.
- Combined with EMS, the temperature profile of the deep interior can be modeled along with mineralogy.
- Seismic and LLR data also yield structure and compositional information of the lunar interior.
- High fidelity data from LGN would enhance the usefulness of the GRAIL and SELENE gravity data.

Human Exploration:

- LGN must be established *prior* to renewed human lunar activity; we do not know the exact locations or causes of the shallow moonquakes (SMQs) – the largest magnitude seismic events recorded by Apollo (1 event/year of magnitude ≥5; [4,5]).
- Establishing surface infrastructure near SMQ epicenters must be avoided





Lunar Geophysical Network (LGN) New Frontiers (NF)-class mission [2], as part of the NF-5 call. *"This mission consists of several identical landers distributed across the lunar surface, each carrying geophysical instrumentation. The primary science objectives are to characterize the Moon's internal structure, seismic activity, global heat flow budget, bulk composition, & magnetic field."*

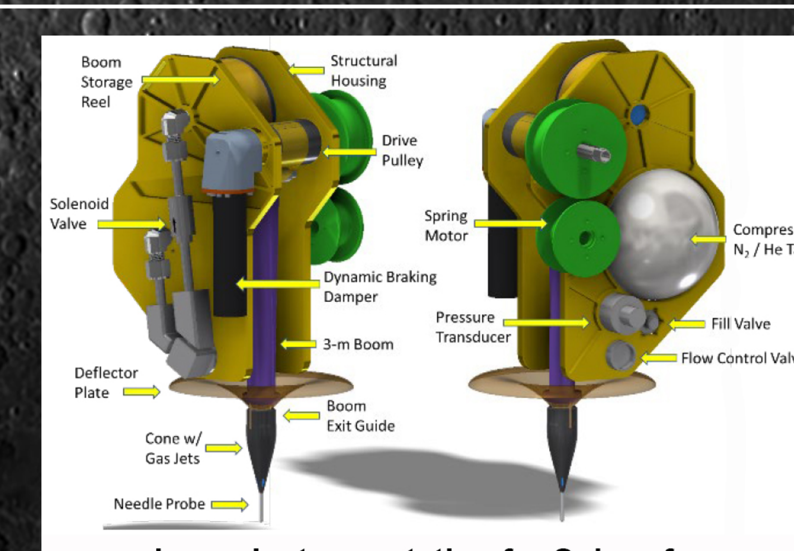
NAS Scientific Context for the Exploration of the Moon (2007) [3] **Prioritized Concept 2**: The structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated planetary body.

Seismometer: ≥4 sensors; ≥1 order of magnitude better sensitivity than Apollo; broader frequency range (0.1 to >10 Hz).

Apollo Passive Seismometer - three long period sensors (X, Y, Z, all with detection limits of 0.3nm at 0.004-2 Hz) and one short period sensor (Z with a detection limit of 0.3nm at 1 Hz).

Heat Flow: measure temperature every 20 cm to a depth ≥ 3 m (relative accuracy = 0.01K). Measurements every hour. Thermal conductivity determined at several intervals (e.g., every 50 cm).

Apollo Heat Flow Experiment - 2 probes ~11 m apart. Absolute temperature to ±0.05K. Thermal conductivity (0.009-0.014 W/mK) determined for 2 depth intervals with ~15% accuracy.



Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity (LISTER)

Electromagnetic Sounding (EMS): Measurement of electric and magnetic fields at each station yields an independent determination of conductivity structure (magnetotellurics) without requiring an orbital asset. Comparison of magnetic data between different stations (geomagnetic depth sounding) provides a complementary result.

Apollo EMS – used surface and orbital magnetometers. Suitable spatial and temporal overlaps have limited the robustness of these data.

Laser Ranging: For the Moon, expansion of the network will constrain tidal librations. New retro-reflectors must give at least a factor of two better return signal.

Apollo LLR – only active Apollo experiment. Limited by spatial distribution of the network.

Technology Development

Underway:

- Seismometer [6,7,8]
- Heat Flow Probes [9,10]
- Corner-cube laser retroreflectors [11]

Needed:

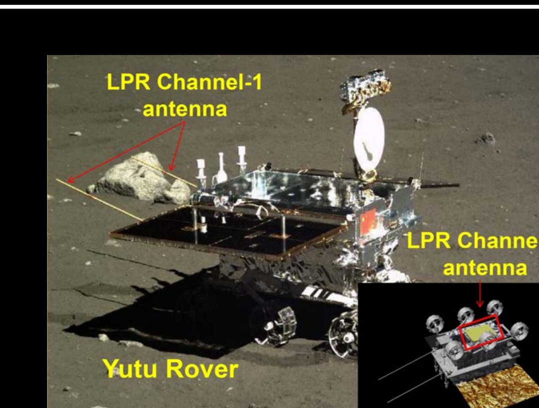
- Reliable landers. Leverage the MSFC International Lunar Network [1] experience, MoonRise, etc.
- EMS deployment mechanisms.
- Long-lived (≥10 years) power supply for each station
- Miniaturization, ruggedization, & cold electronics.
- Autonomous operations, data based decision making, and networking.

Secondary Payloads

Ground/Lunar Penetrating Radar: Aid with heat flow probe deployment and shallow structure determination (e.g., Chang'E-3 Yutu Rover).

Gravimeter: Long duration tidal tomography.

MEMS (Micro-Electro-Mechanical-Systems) Seismometers



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