ENABLING TECHNOLOGIES FOR A FUTURE LUNAR & PLANETARY GEOPHYSICS NETWORK

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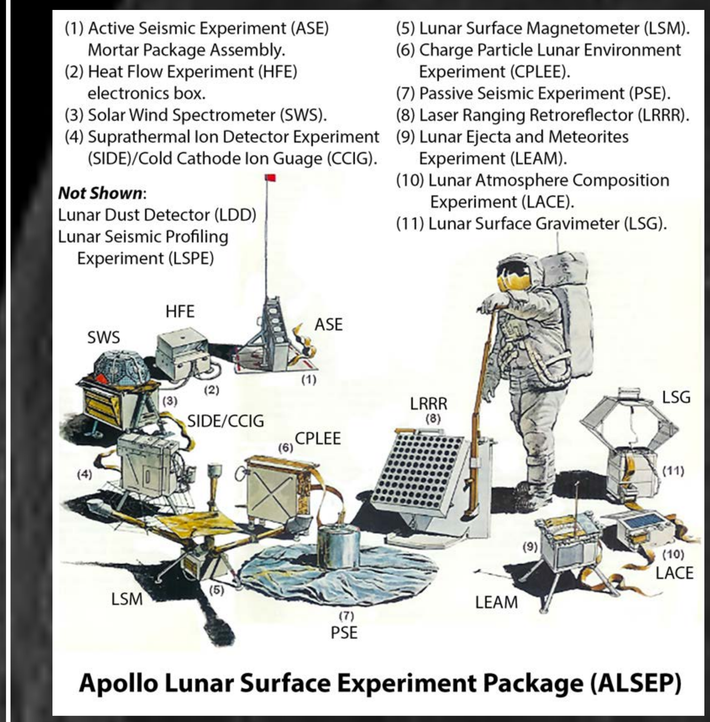
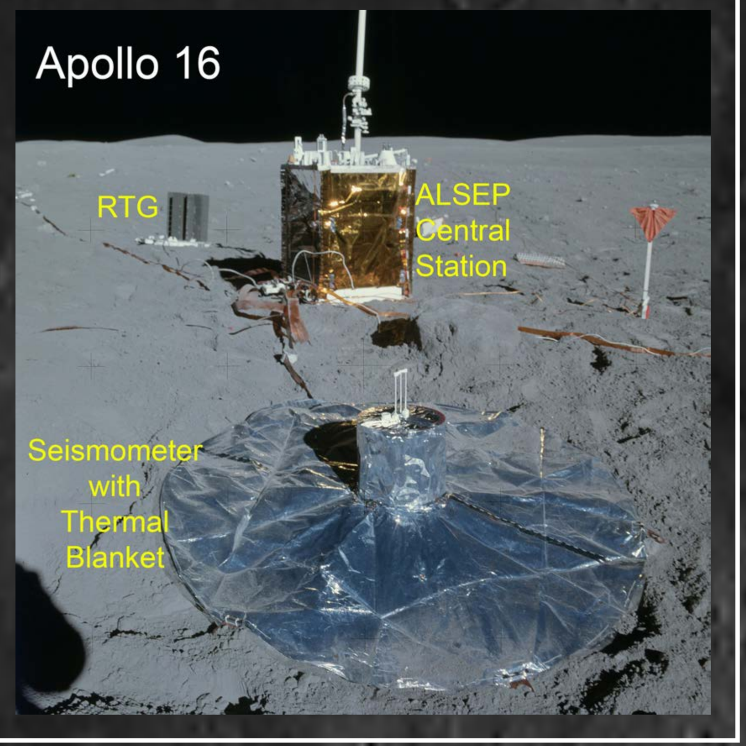
Understanding the 3D structure and composition of planetary bodies is essential for making a fundamental leap forward in planetary science. This requires long-lived geophysical networks.

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 total network.

Must be Better Than Apollo ALSEP

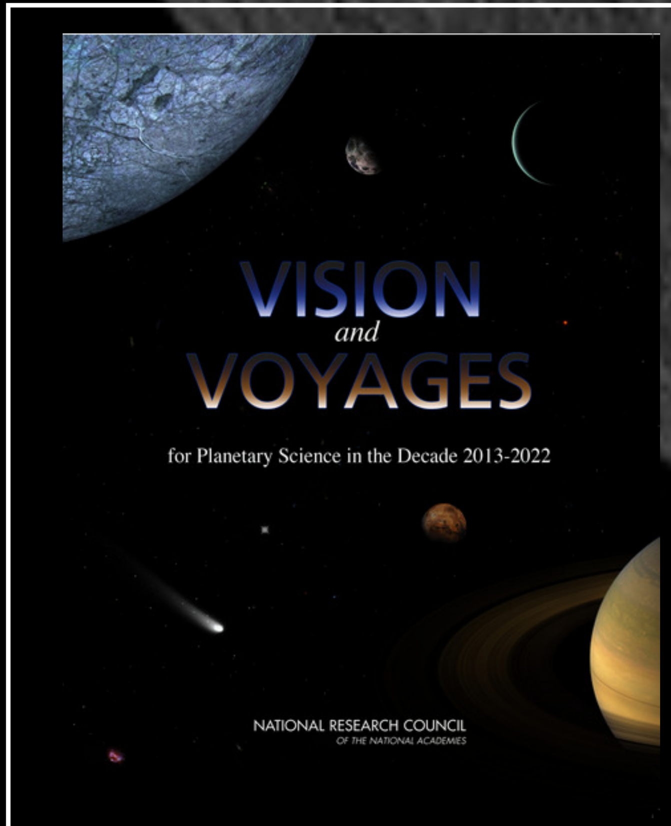


Apollo Lunar Surface Experiment Package (ALSEP)

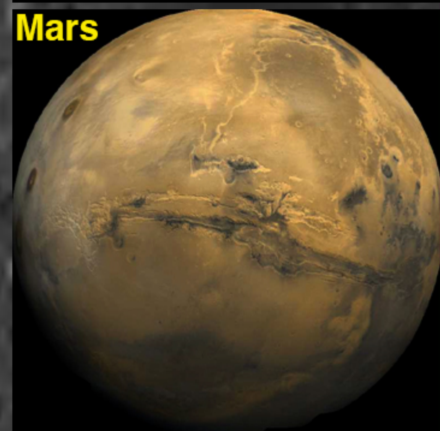


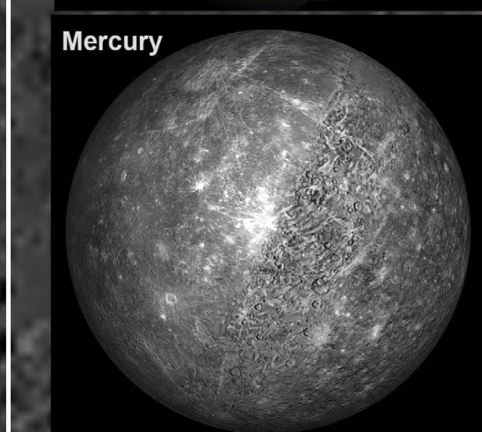
Seismometer: ≥4 sensors; ≥1 order of magnitude better sensitivity than used during Apollo; broader frequency range (0.1 to >10 Hz).
Heat Flow: measure temperature every 20 cm to a depth ≥ 3 m (relative accuracy = 0.01K). Measurements every hour. Thermal conductivity determined at several intervals (e.g., every 50 cm).
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.
Laser Ranging: For the Moon, expansion of the network will constrain tidal librations. New retroreflectors must give at least a factor of two better return signal.

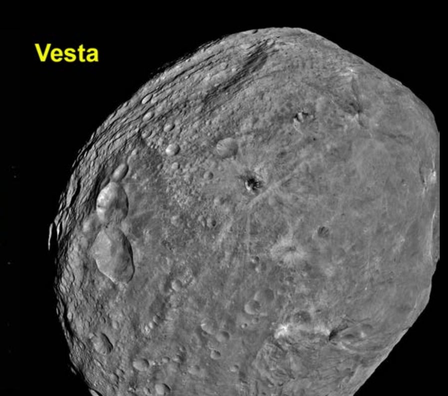
Lunar Science: Heat flow probes yield crustal heat budget estimates. Combined with EMS, the temperature profile of the deep interior can be modeled along with mineralogy. The seismic and LLR data also yield structure and compositional information of the lunar interior and the high fidelity data would enhance the usefulness of the GRAIL and Selene gravity data.



Lunar Geophysical Network (LGN) for a New Frontiers (NF)-class mission in the decade 2013-2022 [1], as part of the NF-5 call. *"This mission consists of several identical landers distributed across the lunar surface, each carrying instrumentation for geophysical studies. The primary science objectives are to characterize the Moon's internal structure, seismic activity, global heat flow budget, bulk composition, and magnetic field."*







Vision 2030 for the Moon

- 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; [7,8]). Establishing infrastructure near SMQ epicenters must be avoided.
- Commercial landers deploy the network allowing more stations distributed across the Moon.

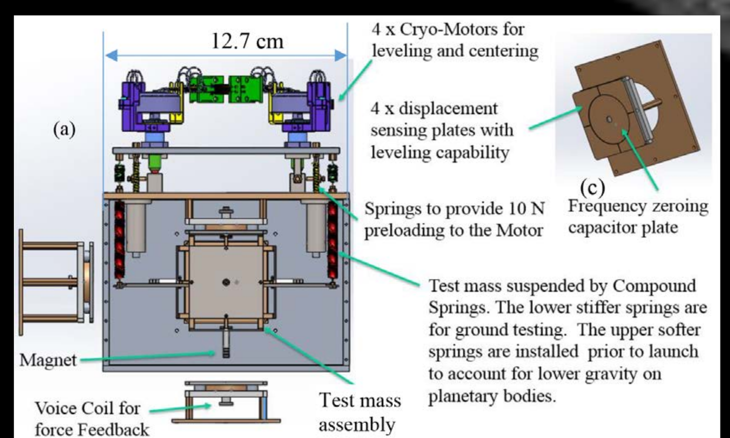
Vision 2050 for the Solar System

- Humans on the Moon would enhance networking options (geophysical, space weather, exosphere, etc.).
- Reliability of deployment, instruments, power, communications allows networks on Mercury, Mars, Ceres, Vesta, Ocean Worlds, etc.

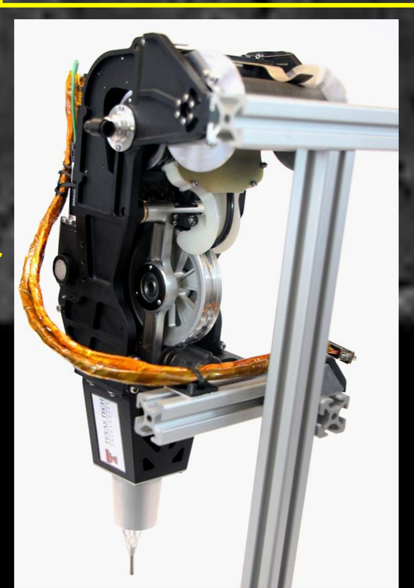
Technology Development

Underway:
- Seismometer [2,3]
- Heat Flow Probes [4]
- Corner-cube laser retroreflectors [5]

Needed:
- Reliable landers. Leverage the MSFC International Lunar Network [6] 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



Planetary Broad Band Seismometer schematic [3]



Heat flow probe prototype – sensor system stowed. 1.2 kg [4]

100 mm CCR (left) next to that of the Apollo era [5]

Silicon Audio (SiA) Ultra Low Noise optical/mechanical sensor is a force feedback accelerometer that allows for very broadband detection and uses a laser interferometer.

References: [1] *Vision and Voyages for Planetary Science in the Decade 2013-2022*. National Academies Press. [2] Zacny K. et al. (2013) *EMP 111*, 47. [3] Chui T.C.P. et al. (2017) LPSC 48, abstract #1660. [4] Nagihara, S. et al. (2014) *Internat. Wksp. Instrumentation for Planetary Missions*, Abst. #1011. [5] Currie D. et al. (2013) *Nuc. Phys. B 243-244*, 218. [6] *ILN Final Report: Science Definition Team for the ILN Anchor Nodes*. NASA. [7] Nakamura Y. et al. (1974) *PLSC 5th*, 2883. [8] Oberst J. & Nakamura Y. (1992) *Lunar Bases & Space Activities*, 231.