SPARTA: A Planetary Regolith Characterization Multitool for Space Resource Utilization and Infrastructure Development

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XXV Space Resources Roundtable
June 3, 2025

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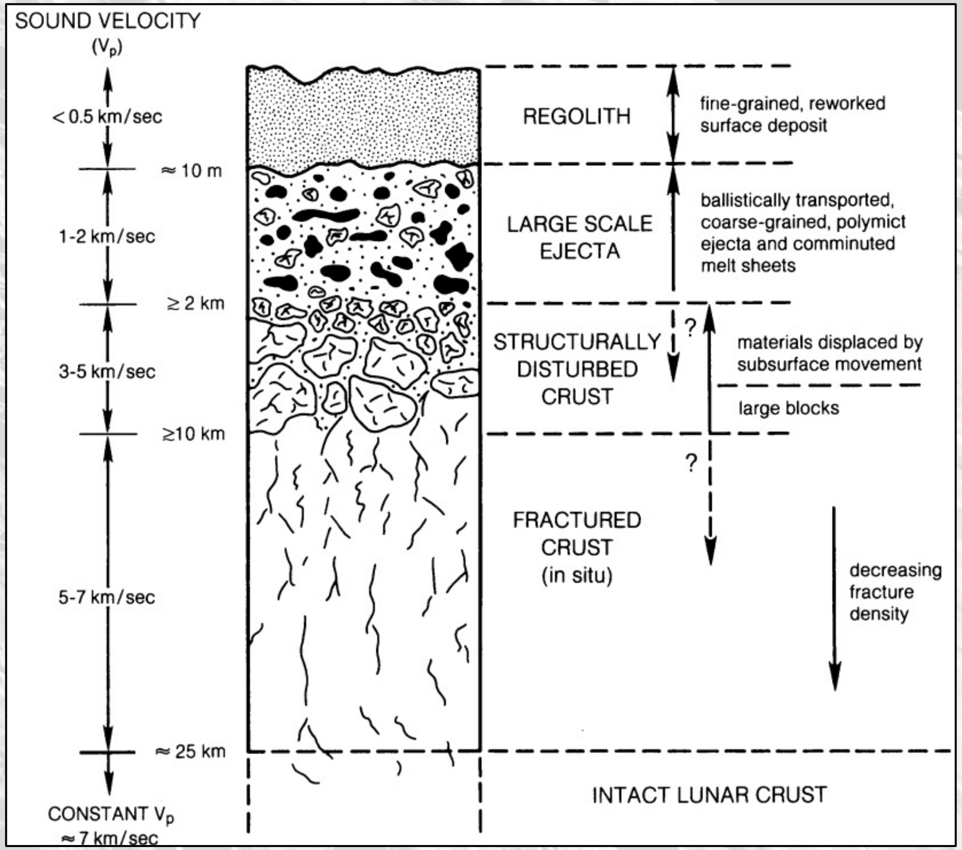
Background and Motivation

- **Lunar surface geology dominated by impact processes**
  - **Extremely fine particles, with wide particle size distribution [Carrier et al., 1991]**
  - **Physical properties VERY different from those of Earth's soils [Carrier et al., 1991]**
  - **Bedrock ~10-25 km deep and highly fractured [Horz et al., 1991] → need to work with regolith**
- **Site-specific variations in physical and compositional properties [Carrier et al., 1991]**



From: Horz et al. [1991]

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Background and Motivation

SPARTA

- **Need dedicated tools to characterize the physical properties of lunar regolith**
  - **Lack of dedicated instrumentation to quantify mechanical, thermal, and dielectric properties which are needed for exploration, ISRU, and infrastructure development**
  - **Using non-specialized equipment leads to high uncertainties in parameter estimates [Sullivan et al., 2011; Bickel et al., 2019; Long-Fox et al., In Review]**
  - **Can borrow from terrestrial experiences, but cannot lose sight of the fundamental differences in regolith properties, geology, and environment**

From: NASA GSFC

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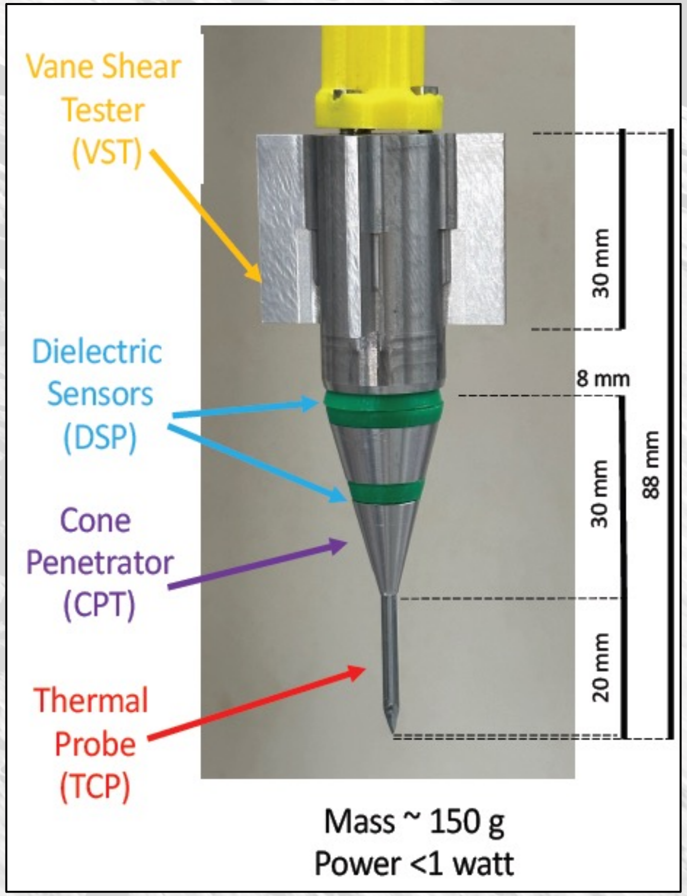
Soil Properties Assessment, Resistance, and Thermal Analysis (SPARTA)

SPARTA

- **Low mass, low power planetary regolith characterization probe [Anderson et al., 2024]**
- **Quantifies gradients of mechanical, thermal, and electrical properties of any rocky surface**



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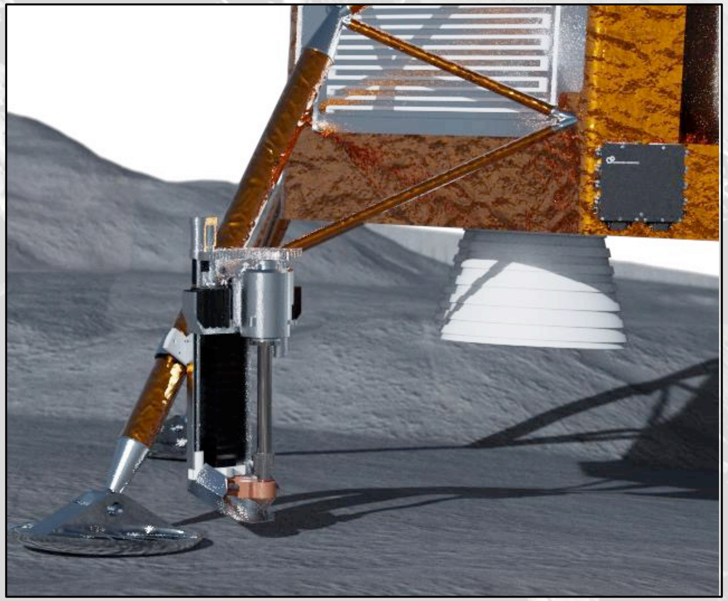
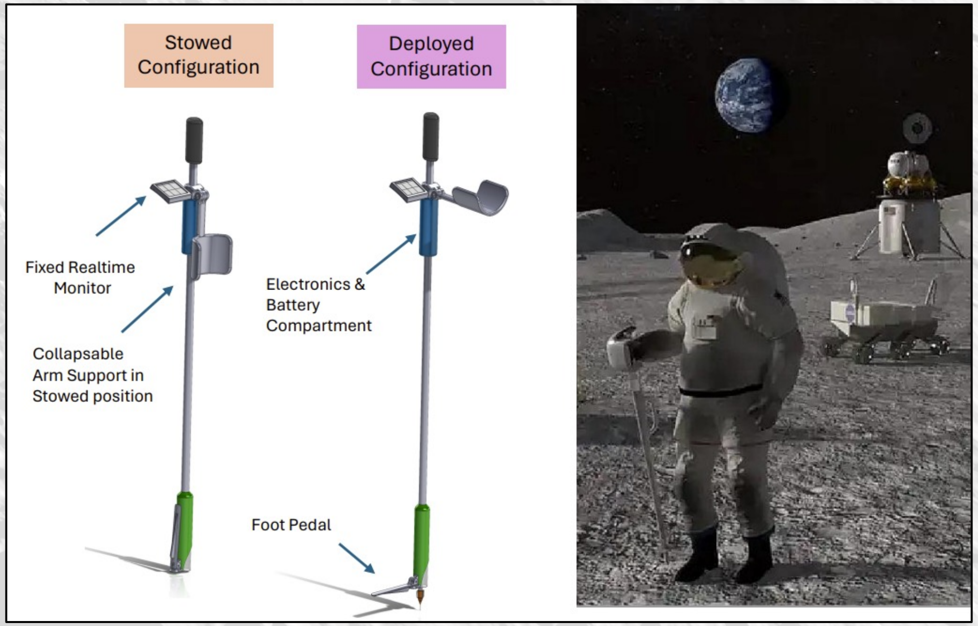
Soil Properties Assessment, Resistance, and Thermal Analysis (SPARTA)

SPARTA

- **Simultaneous *in situ* shallow subsurface (≤ 15 cm) measurements at unprecedented spatial resolution on any rocky body (Moon, Mars…)**
- **Deployment mechanism can vary (astronaut, rover/lander)**



Credit: Honeybee Robotics



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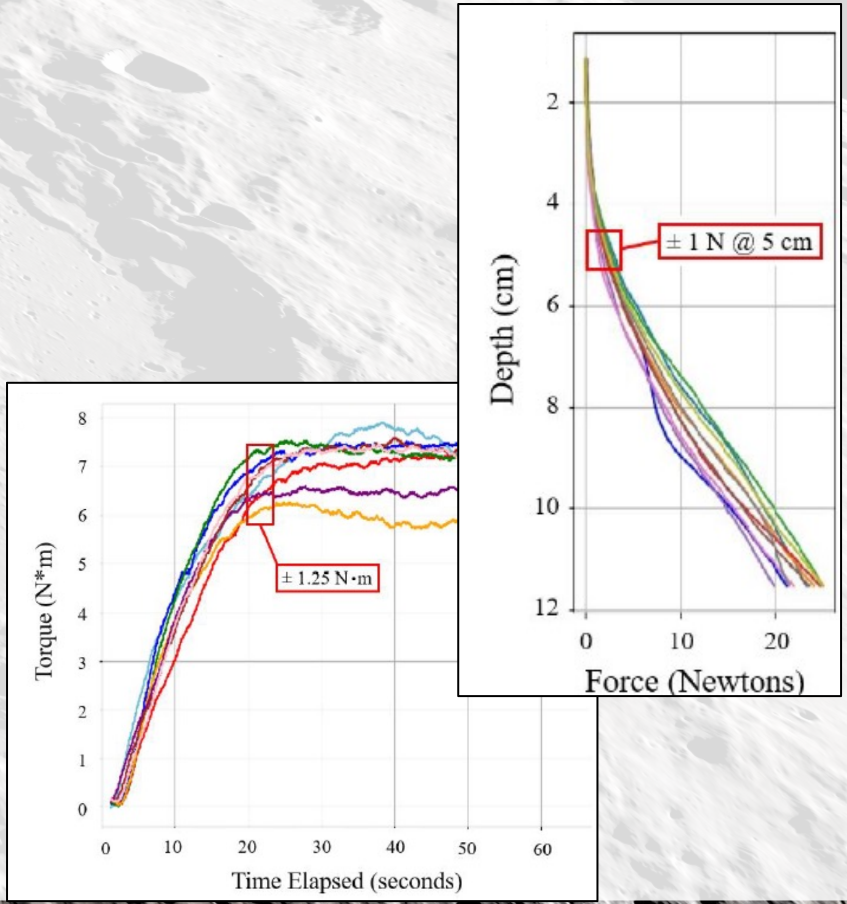
SPARTA Cone Penetration Tester (CPT) and Vane Shear Tester (VST)

SPARTA

- **SPARTA CPT**
  - **Measures: Force (0-222 N; ± 1.1 N) → Stress vs depth (0-15 cm; ± 0.005 cm)**
  - **Science: geologic history, stratigraphy**
  - **Engineering: bearing capacity, trafficability, site evaluation**
- **SPARTA VST**
  - **Measures: Torque (0-200 Nm; ± 1 Nm) and rotation (0-1440°; ± 0.12°) → Shear strength**
  - **Science: geologic history, mapping**
  - **Engineering: trafficability, site evaluation**



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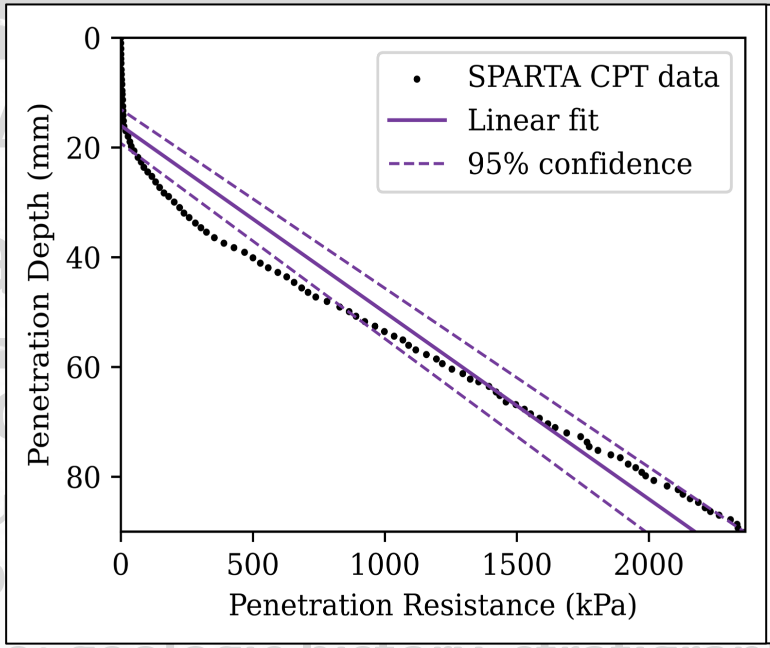

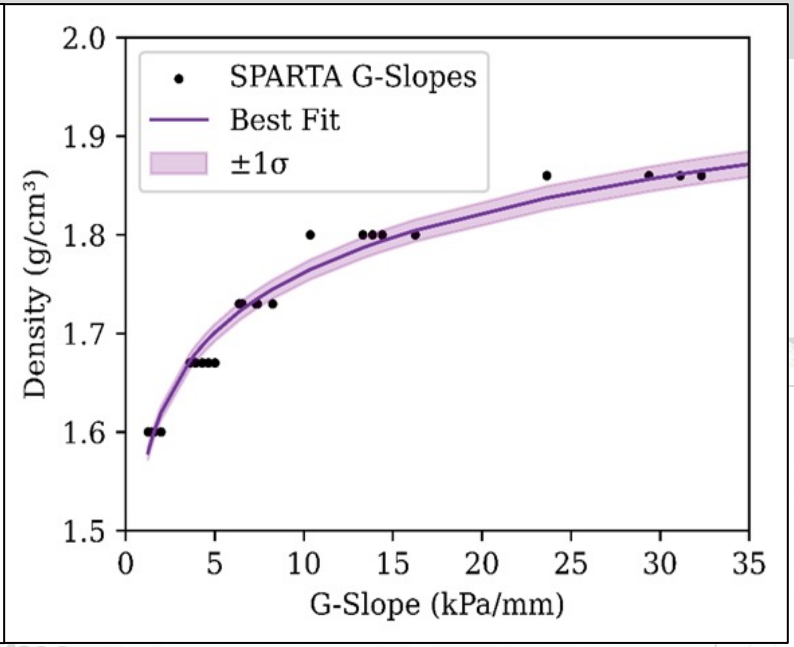

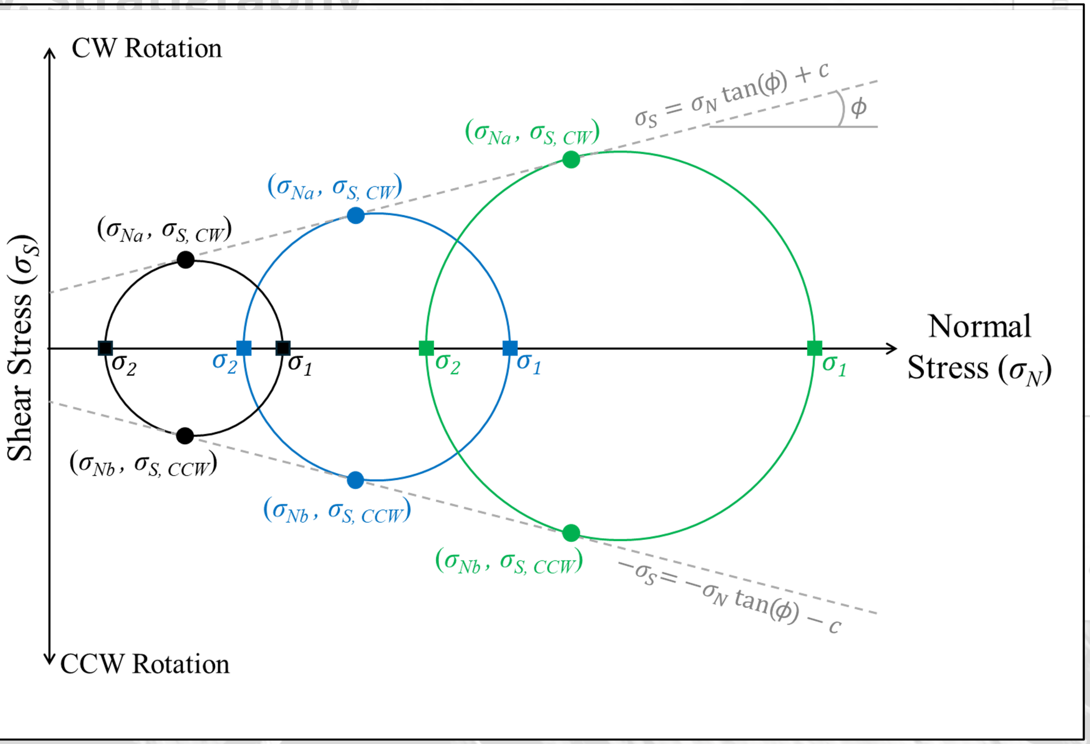

$$\sigma_1 = \frac{\sigma_{Na}+\sigma_{Nb}}{2} + \sqrt{\left(\frac{\sigma_{Na}-\sigma_{Nb}}{2}\right)^2 + \sigma_S^2}$$

$$\sigma_2 = \frac{\sigma_{Na}+\sigma_{Nb}}{2} - \sqrt{\left(\frac{\sigma_{Na}-\sigma_{Nb}}{2}\right)^2 + \sigma_S^2}$$

SPARTA

±1 N @ 5 cm

Force (Newtons)

Image credit: LPI

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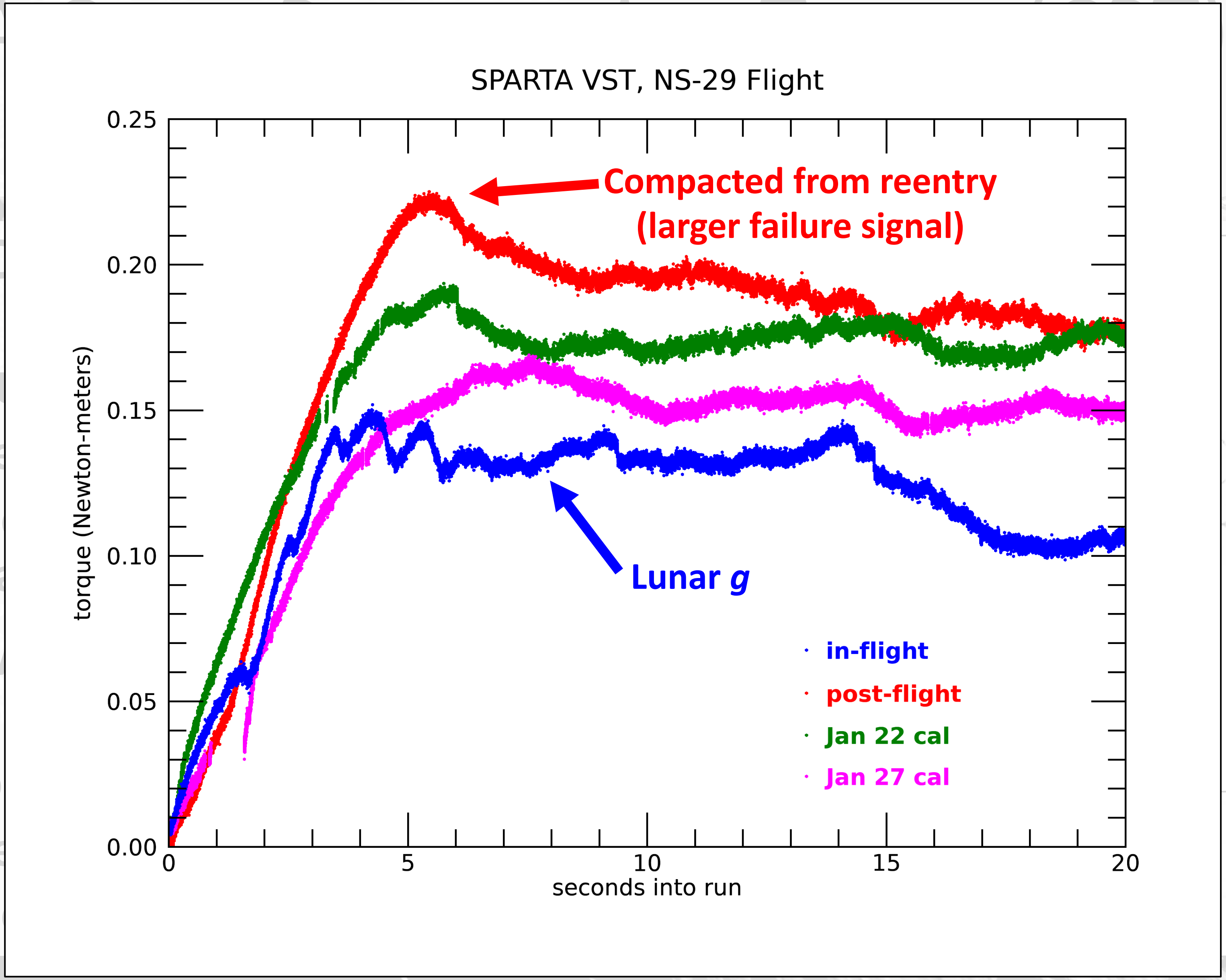


Image credit: LPI

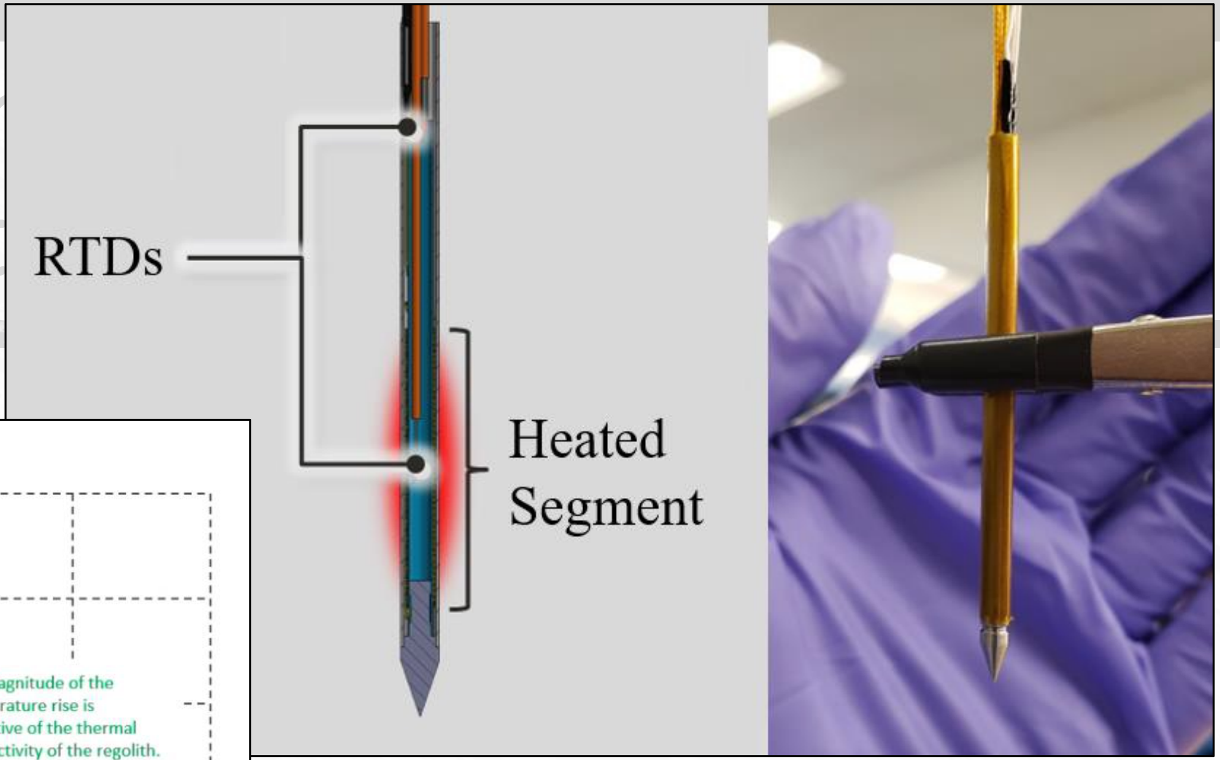
SPARTA Thermal Conductivity Probe (TCP) and Dielectric Spectroscopy Probe (DSP)

- **SPARTA TCP**
  - **Measures: Temperature (-200-370 °C; ±0.1 °C), thermal conductivity (10^{-4} to 0.4 W/m K) and diffusivity, specific heat (if density is known)**
  - **Science: Thermal history, heat flux, composition (including volatiles)**
  - **Engineering: Construction materials (e.g., sintering), resource extractions**
- **SPARTA DSP**
  - **Measures: Dielectric constant, conductivity (10^{-15} to 10^{-10} Ω^{-1}/m), relative permittivity (1-5)**
  - **Science: Geologic history, volatile mobility and storage, electromagnetics**
  - **Engineering: Resource prospecting (e.g., water ice)**

Image credit: LPI

SPARTA Thermal Cor
and Dielectric Spect

- SPARTA TCP



Credit: Honeybee Robotics

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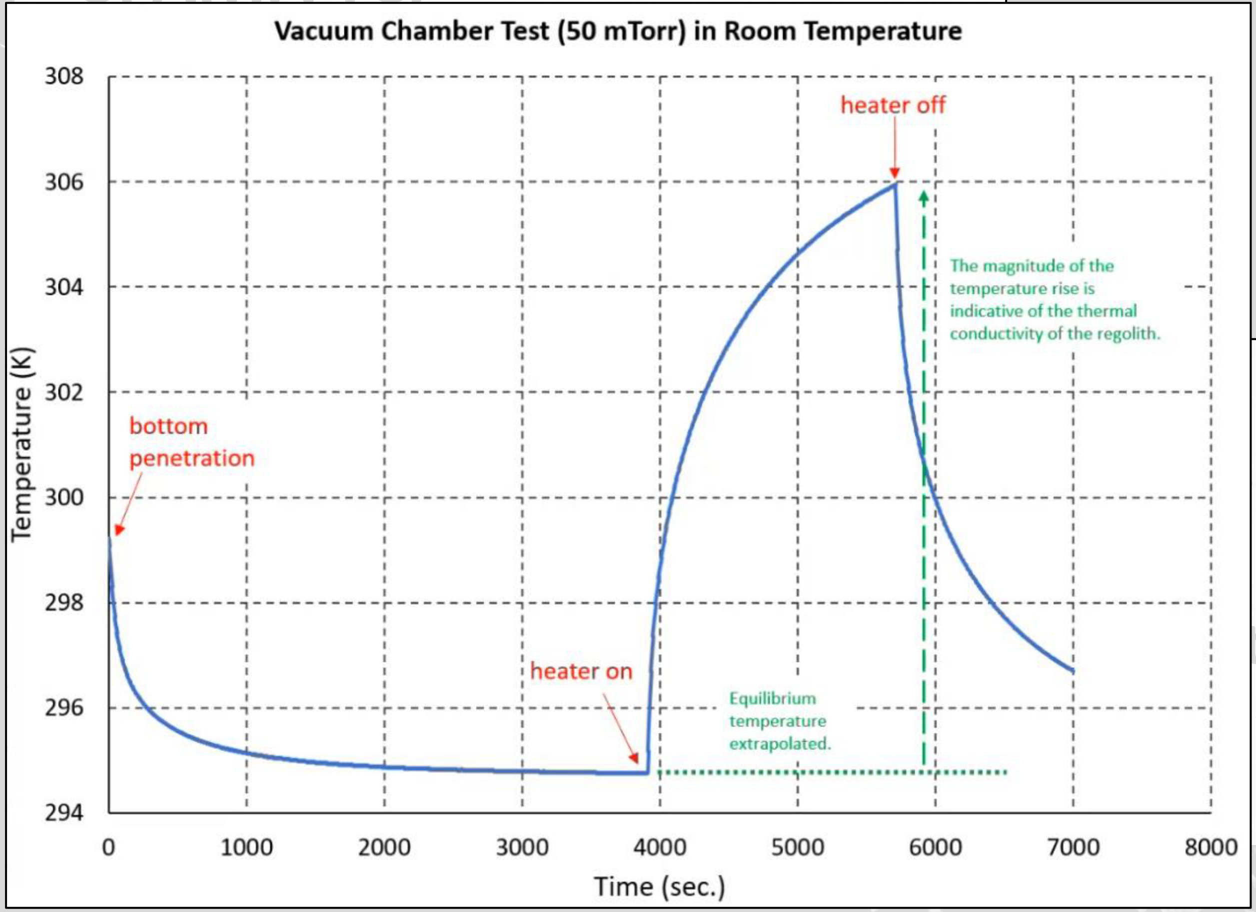

Credit: Honeybee Robotics

Image credit: LPI

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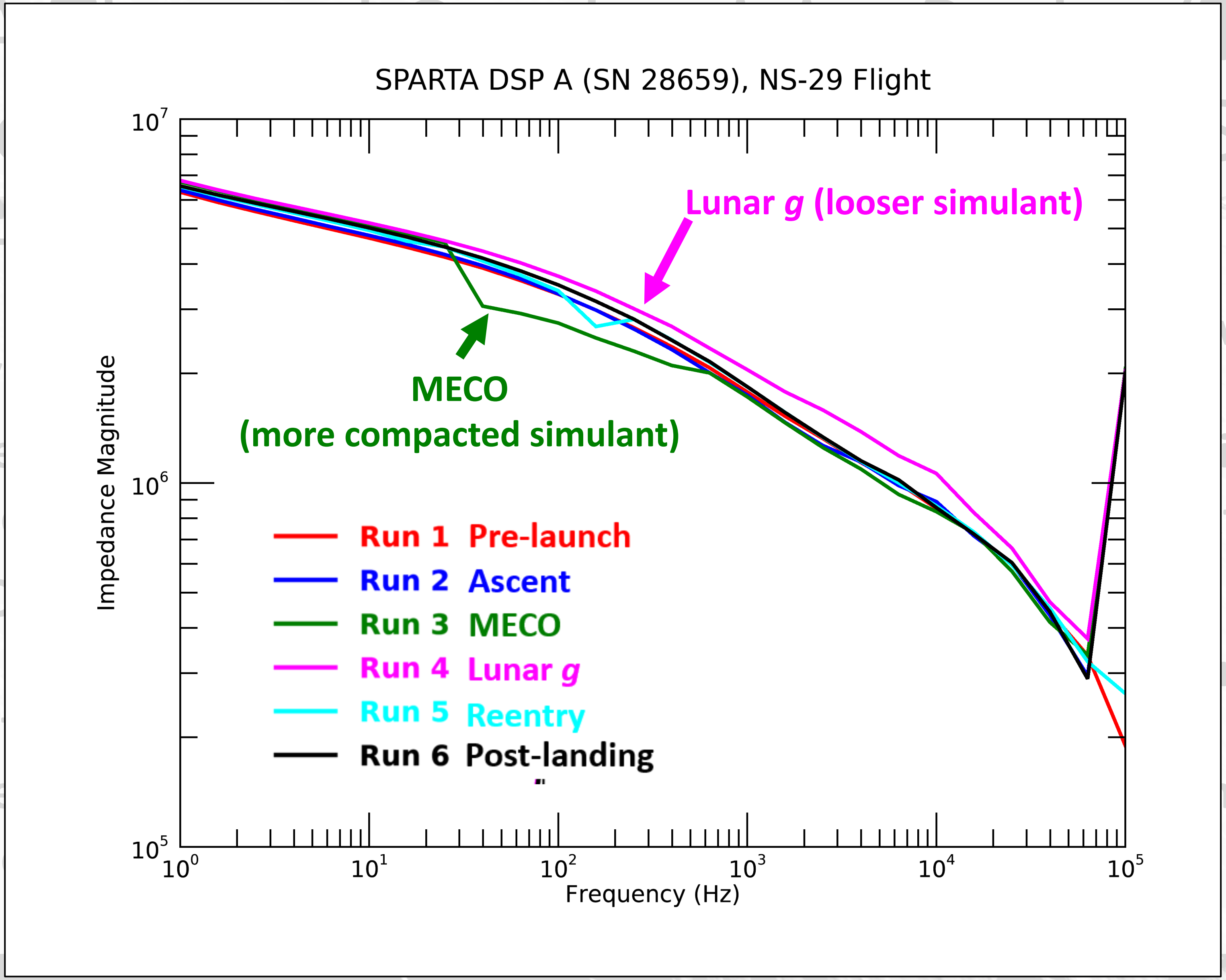

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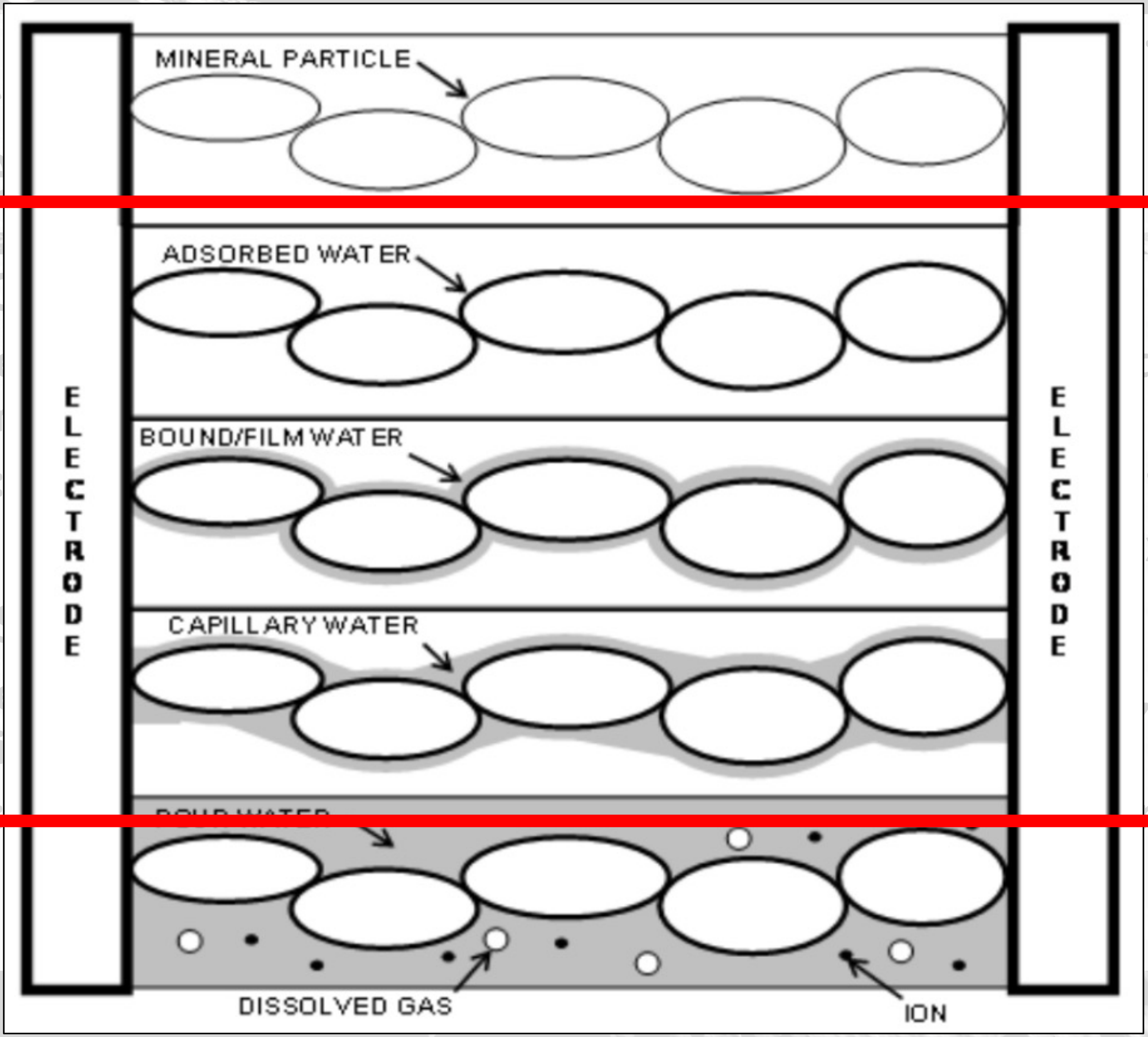
Decreasing impedance



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SPARTA Testing and Tech. Maturation

SPARTA

- **Flight**
  - **Parabolic Flight (December 2022, TBD 2025)**
  - **Suborbital Flight (February 2025)**
- **Field**
  - **JPL Mars Yard (January – May 2024)**
  - **Lava Beds National Monument (May 2022, May 2024)**

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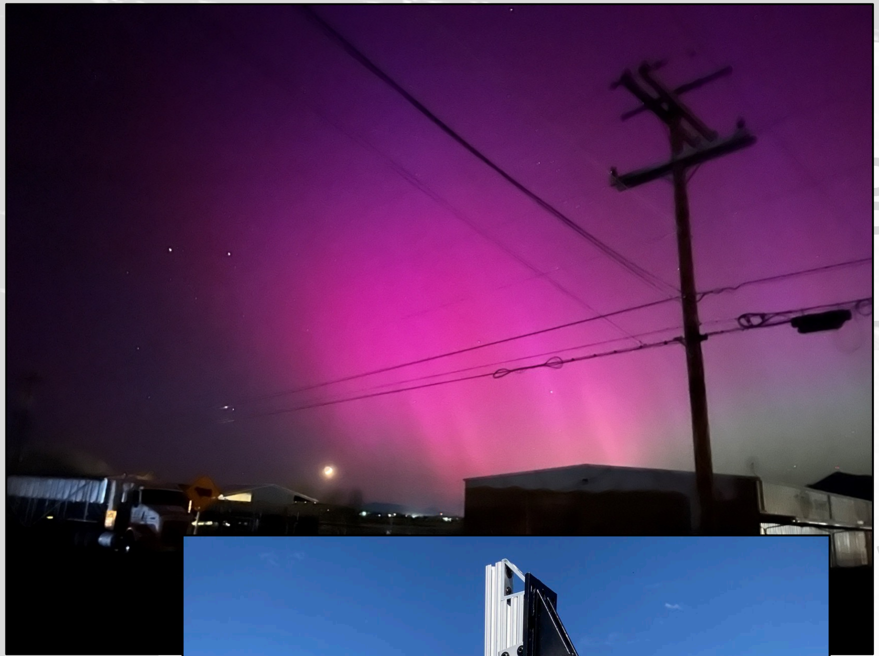

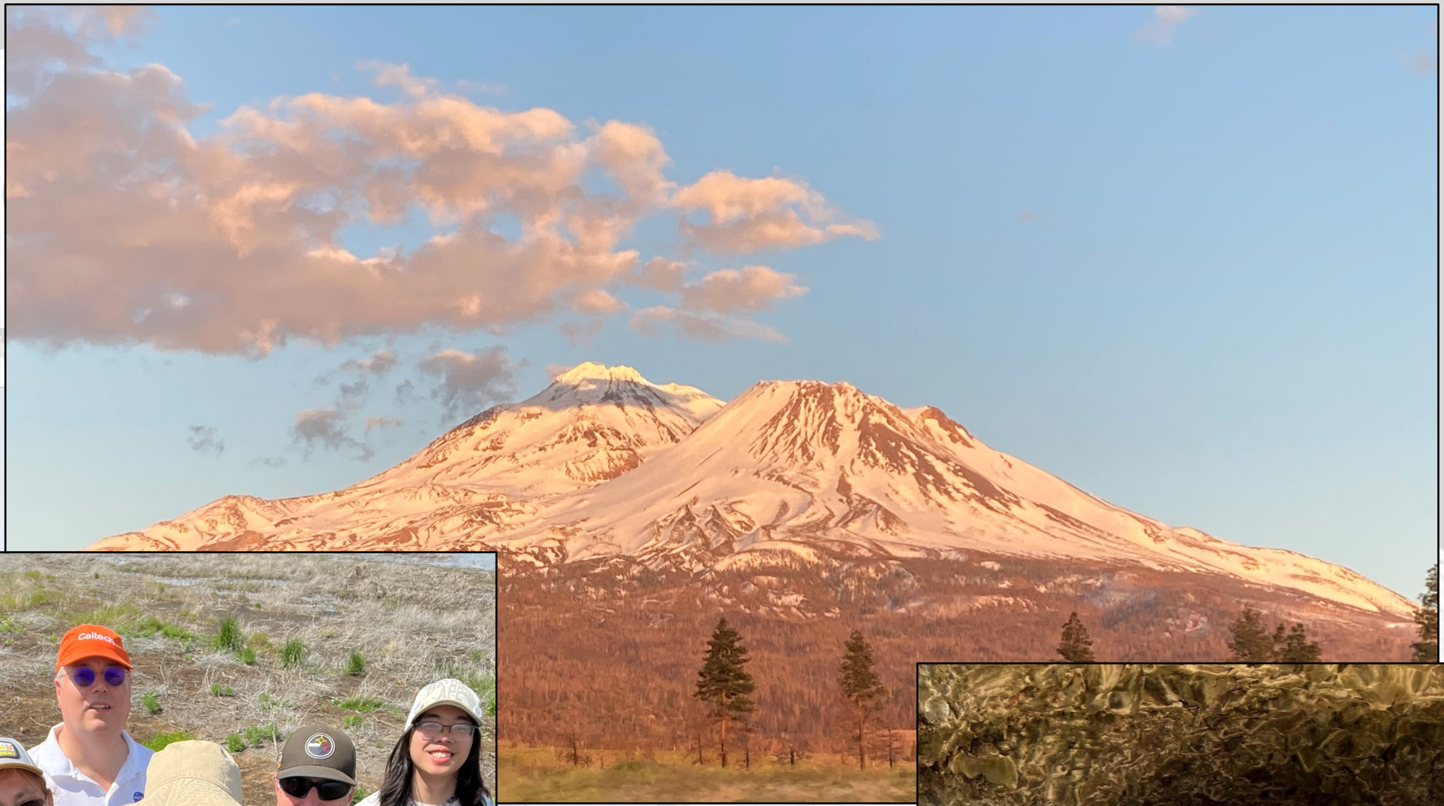

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Summary

- **SPARTA is a unique, high TRL (TRL 6) instrument with heritage from both terrestrial instruments and flown lunar science hardware (LISTER, TRL 9)**
- **Measurements cross-validate each other**
- **SPARTA team has developed and proposed unique mission concepts [Sollitt et al., 2024], open to collaboration and inclusion on other missions**
- **Developing astronaut-deployable version, investigating size scaling for different missions**

Image credit: LPI

Acknowledgements

SPARTA

- SPARTA development was supported by the NASA SMD PICASSO Program (PI Anderson) and the NASA STMD Flight Opportunities Program (PIs Anderson and Sollitt)
- J. Long-Fox supported by NASA Space Technology Graduate Research Opportunity (NSTGRO) Fellowship (NASA Cooperative Agreement 80NSSC23K1173) and the NASA Solar System Exploration Research Virtual Institute (SSERVI) Center for Lunar and Asteroid Surface Science (CLASS) (NASA Cooperative Agreement 80NSSSC19M0124, PI D. Britt)

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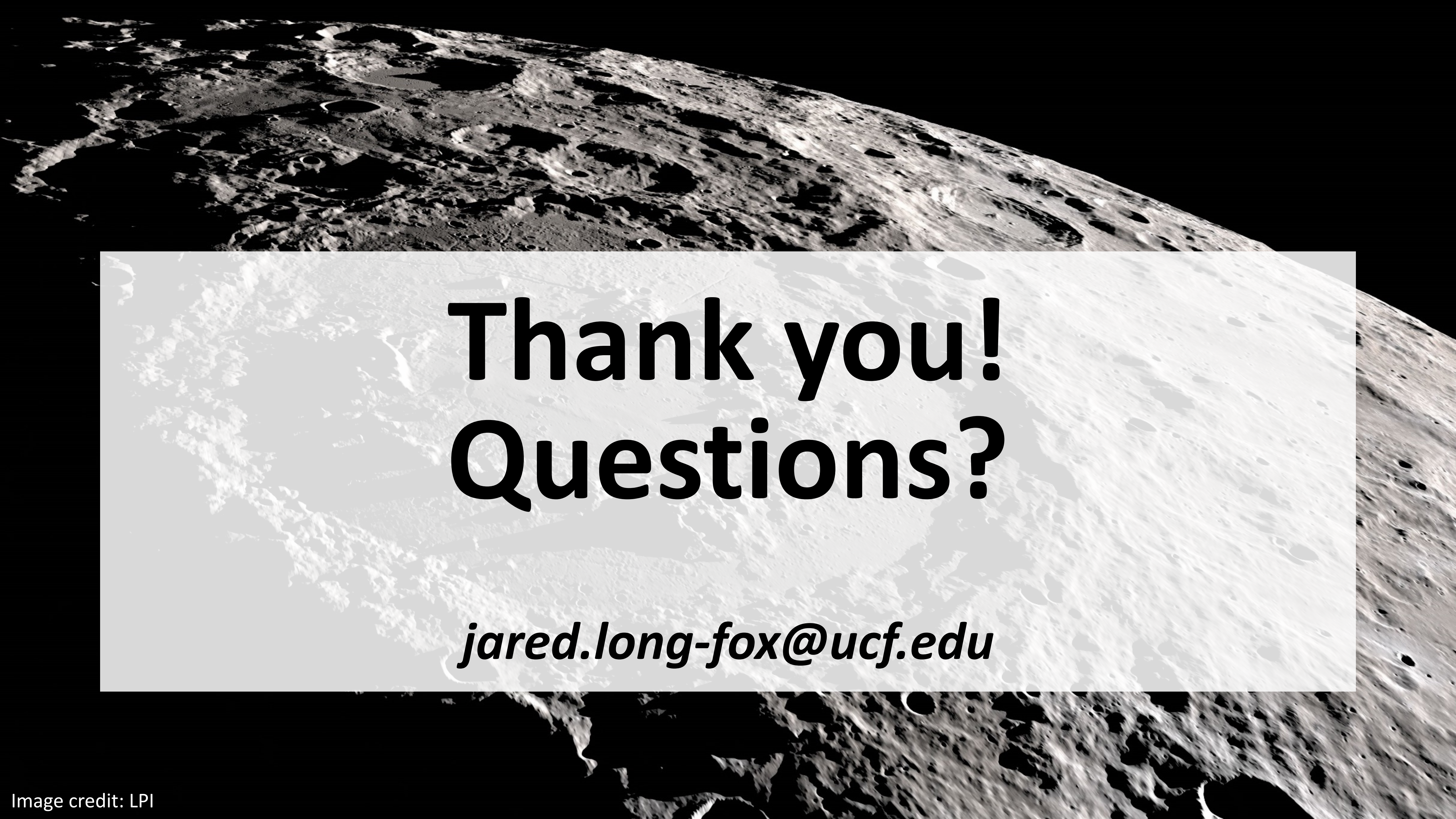

Thank you!
Questions?

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