SPARTA TOOLKIT: OVERVIEW OF RECENT TERRESTRIAL TESTING. R. C. Anderson[1], D. Buczkowski[2], K Chin[1], J.M. Dohm[3], J. Long-Fox[4], L. Sollitt[5], D. Y. Wyrick[6], K. Zacny[7], [1]NASA/Jet Propulsion Laboratory/California Institute of Technology, [2]JHU/Applied Physics Laboratory, [3]Exploration Institute, [4]University of Central Florida, [5]NASA/Ames Research Center, [6]Southwest Research Institute, [7]Honeybee Robotics, Robert.c.anderson@jpl.nasa.gov

Introduction: In-depth characterization of the subsurface properties of in situ planetary regolith is a high priority for future planetary missions. SPARTA is a highly versatile, miniature, multitool instrument **(Fig. 1**; also see [1,2—this conference]) that can robotically deploy a cone penetrometer/vane shear geomechanical tool that incorporates a dielectric probe and thermal conductivity measurements at depth (<1m) into planetary surfaces.

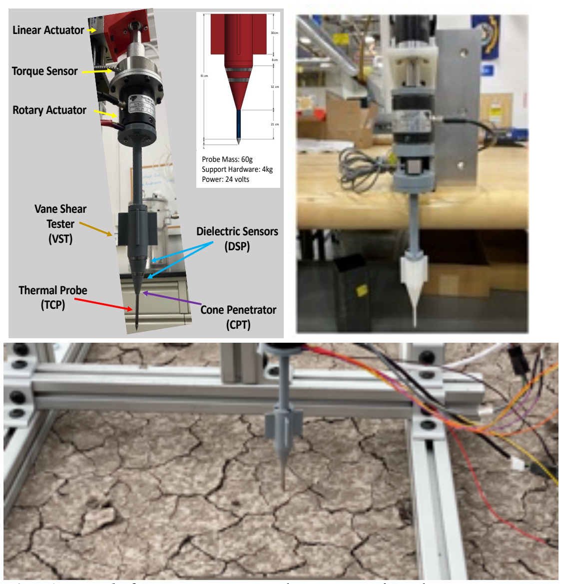

Fig. 1 *Top left*: Components that comprise the SPARTA toolkit. *Top right*: First SPARTA breadboard. *Bottom*: SPARTA operating in its first field test.

The SPARTA toolkit consists of four components (**Fig. 1**): a cone penetration test (CPT), a vane shear test (VST), a dielectric spectroscopy probe (DSP), and a thermal conductivity probe (TCP). Physical measurements conducted by SPARTA are soil shear strength, penetration resistance, temperature, thermal conductivity, and the potential presence of water/ice. The CPT and VST test mechanical properties (e.g., shear strength) by resistance to penetration into the regolith and rotation until failure. Mechanical properties are deduced from the calibrated voltages (and therefore forces) used to penetrate and break the regolith. The DSP uses an alternating voltage to turn a section of regolith into a circuit. The phase shift and subsequent amplitude of the received current will depend on the chemical properties, including water/ice content. The TCP heats the regolith at its tip and measures the changing temperature along the length of the probe as a function of time to determine thermal conductivity. SPARTA provides NASA with a new capability to collect a suite of in situ subsurface measurements of the geomechanical, thermal, electrical, and chemical properties of dry or icy regolith.

SPARTA Testing to Date: The purpose of SPARTA testing is to demonstrate the operation of the different components. Our testing has focused on three areas: laboratory, field, and Zero-G environmental (gravity, temperature, pressure).

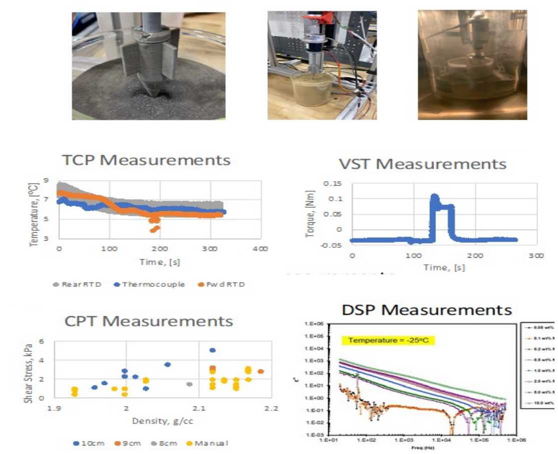

Fig. 2. Results from early SPARTA laboratory testing under terrestrial environmental conditions using MMS & JSC-1a.

Laboratory: The early laboratory tests of SPARTA focused primarily on component-level tests under terrestrial environmental conditions. Each component was individually tested using Mars Mojave Simulants (MMS-Mars) and JSC-1a (Lunar) simulants. **Fig. 2** is an example of one of the MMS runs.

Field Testing Site 1: The initial field tests of SPARTA were held at the northern margin of Black Lava Point, Gray Mountain, AZ. Field data was

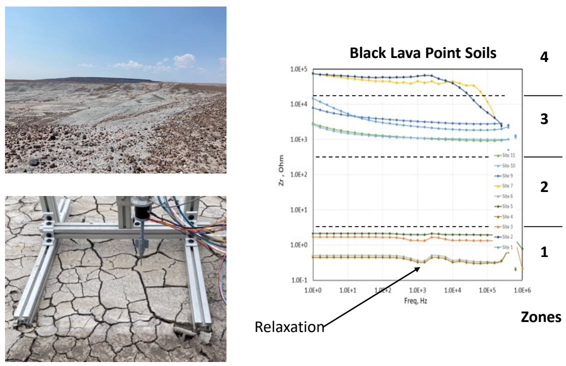

Fig. 3. Black Lava Field soils: converting phase angle to impedance provides an excellent determination of water. If the curve is in: Zone 1—low impedance indicative of high-water content (saturated, >10%); Zone 2 -- impedance indicative of moderate water content (5-10%); Zone 3 – high impedance indicative of low water content (1-5%); and Zone 4 – very high impedance indicative of very dry (<1%). The curve on the bottom has a dip around 1000 Hz indicating a relaxation state demonstrating that some chemical/ion in the system is gaining a charge.

collected for the CPT, TCP, and DSP. No VST data were collected due to software/hardware interface issues. **Fig. 3** are DSP results from the Black Lava Point field site.

***Field site #2*:** SPARTA was recently employed in the GEODES 2022 Field Test (SSERVI) at Medicine Lake, CA. The SPARTA PICASSO Mars breadboard (Year 2) was tested to a maximum of 250N on both the linear stage and the rotation actuator (**Fig. 4**). **Fig. 4** illustrates the first time all four components of SPARTA were tested in situ simultaneously.

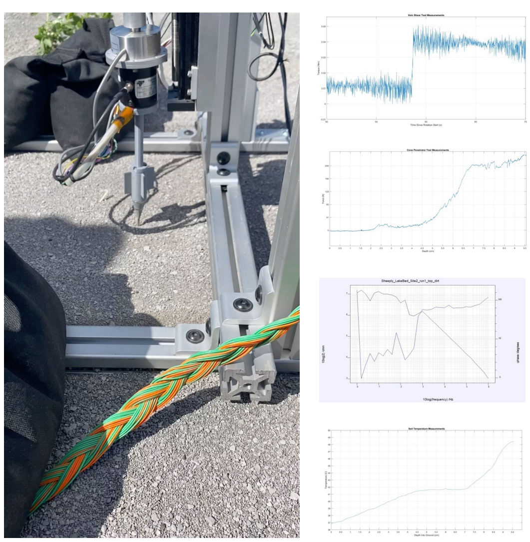

Fig. 4. Data were collected from a section of the lake bed that had been drained, and thus considered representative of ancient lake deposits on Mars (e.g., Gale Crater).

Gravity Testing: One of the additional avenues for testing SPARTA was provided by the Nasa Armstrong Flight-Opportunities Program. Funds were provided for testing under 12 martian, 13 lunar, and 35 zero-gravity conditions on the Zero-G aircraft (**Fig. 5**). For these tests, DSP and CPT data were acquired through 60 parabolas. We were able to accomplish two-thirds of our initial objectives: acquiring excellent component data during multiple gravities for both the DSP and CPT. Due to a mechanical failure of the VST once in Florida, we were unable to correct it before the flight and thus removed it from the payload. Results from **Fig. 5** clearly show that gravity has a direct effect on the movement of volatiles for fine-grained materials (MMS).

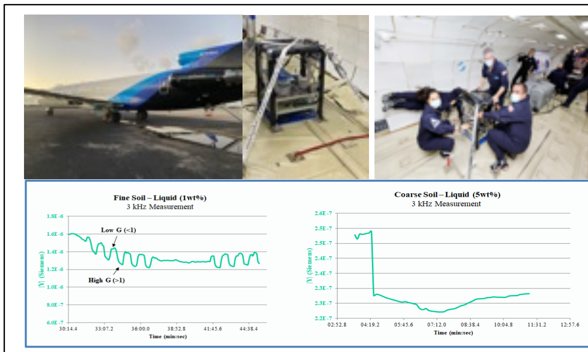

Fig. 5. Examples of two DSP runs for fine- and coarse-grained MMS samples under varying gravities. Left graph illustrates the effect that gravity has on water movement (1% water) in fine-grained samples. Low-gravity results are interpreted to be greater mobility of water and or soil (TBD). Right graph contains coarse-grained simulant (5% water—near saturation) illustrating stable water conditions during both high to zero-gravity environments.

Conclusions: Testing to date indicate that the SPARTA breadboard toolkit is fully functional. Upcoming SPARTA gravity testing includes a Blue Origin mission (planned for the Summer of 2023). Further probe testing is underway to assure maximum design. The fabrication of the final brassboard probe (TRL 6) will be completed by the end of 6/2023. In this presentation, we will detail the results of SPARTA testing.

References: [1] Wyrick, D.Y. et al. (2023), LPSC 2023. [2] Sollitt, L.S. et al. (2023) LPSC 2023.