Thermal Cone Penetrometer and Ground Penetrating Radar Testing Progress for Determination of Lunar Regolith Geotechnical Properties and Volatile Characterization

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Approach

Concept:

Combine Ground Penetrating Radar (GPR) with a percussive cone penetrometer with heaters and thermal sensors to determine spatial distribution of ice and other volatiles in the subsurface, as well as determine geotechnical properties of the regolith.

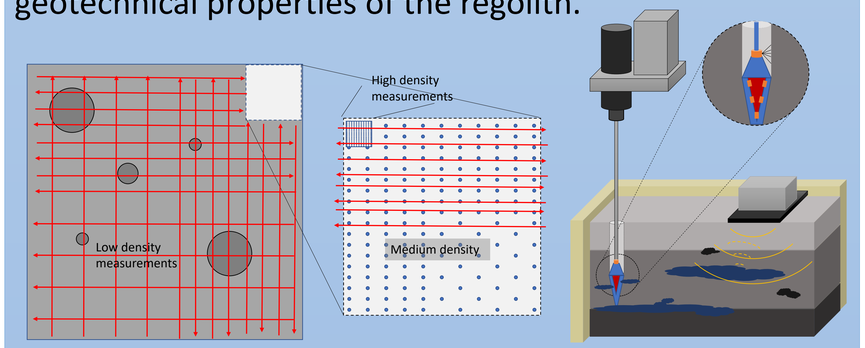


Figure 1: Percussive Hot Cone Penetrometer during insertion into regolith, determining geotechnical properties going down and detecting volatiles by stopping and heating every 10 cm down to 1m depth. GPR detects layers and continuity between cone penetrometer locations. Spacing between measurements can vary from dense to medium to low spatial density.

Development Objective

Planned accomplishments: develop, build and test a percussive heated cone penetrometer (PHCP) to TRL-5/6 in combination with GPR to determine the type, concentration and vertical and lateral variation of volatiles in the lunar regolith by using thermal profiles and cycling. A dataset of thermal release profiles of cryogenically frozen regolith infused with volatiles will be a major objective. A dataset of geotechnical cone penetrometer data as it varies with relative density, and granular or cemented ice content is being put together as well as a dataset of GPR data at 500 MHz and 1000 MHz to detect ice and rocks in basalt sand and lunar simulant.

The project has five parallel development stages: 1) test setups, 2) geotechnical data and penetrometer, 3) thermal volatile data and heater and sensors, 4) GPR data, and 5) integrated PHCP design and TRIDENT z-stage integration

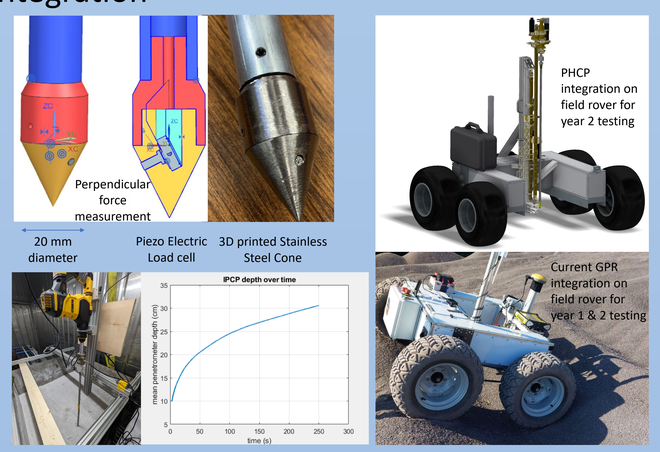
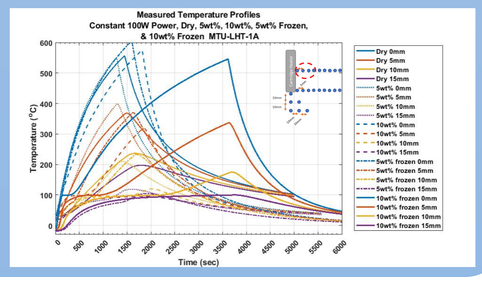


Figure 2: Cone penetrometer instrumented for Geotech measurements (top left), vibratory cone penetrometer test setup and graph (bottom left), artist impression of the full PHCP with TRIDENT z-stage (top right) and field rover with GPR during field test (bottom right)

The thermal design starts with determining the heat affected zone and data gathering from thermo-couples under various wt% water / ice and heating at various power levels.

Figure 3: One example of the thermal datasets collected. 24 thermocouples, 3 power levels and 5 water/ice/dry combinations



Ground Penetrating radar testing was performed in summer and academic year 21-22 at the stamp sands in Gay, MI where 1000's of acres of leftover crushed basalt can be found and were various targets were buried. A solid ice block, ice-cubes, dry-ice slabs, a mix of water ice and dry-ice, basalt rock, disturbed ground and undisturbed ground were measured with a 500 MHz GPR from Sensors and Software, both in line and grid patterns. 12 field tests were performed to characterize the site overall and to gather specific target data. Positioning accuracy is extremely important for accurate data interpretation.

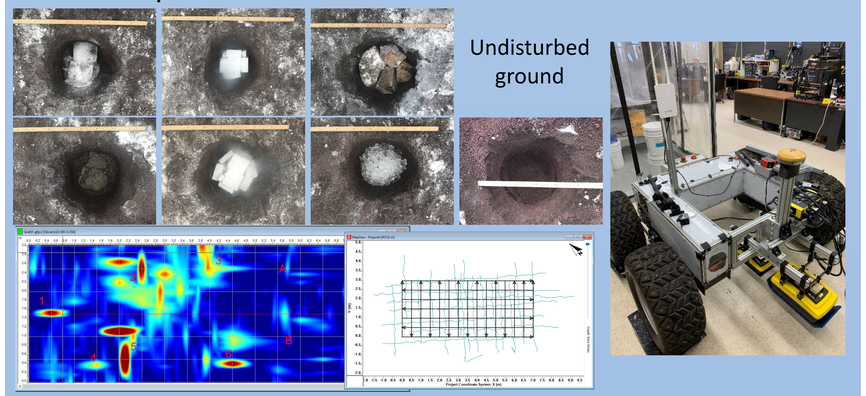


Figure 4: A picture of the 8 buried targets (top left) and the grid results (bottom left and bottom center showing inaccuracies in data interpretation. The field rover with the 500 MHz and 1000 MHz GPR installed as well as the GPS and SPIDAR module.

In year two of this project, the PHCP will be further developed and final field testing, including GPR, will occur in winter 2022/23 in a trench filled with lunar simulant and various ice concentrations. Honeybee Robotics will then test the PHCP in their tall DTVAC.

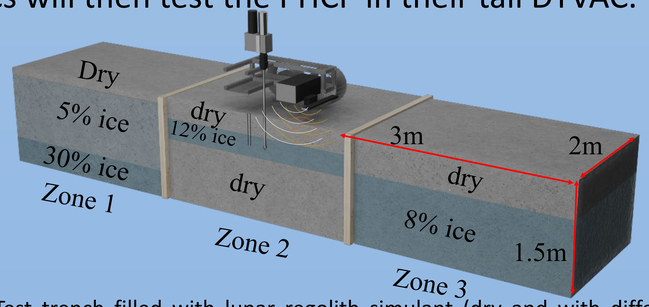


Figure 5: Test trench filled with lunar regolith simulant (dry and with different ice content). The trench is divided into three zones with varying layers.

This work is supported by an Lunar Surface Technology Research (LuSTR) grant from NASA's Space Technology Research Grants Program Grant # 80NSSC21K0769