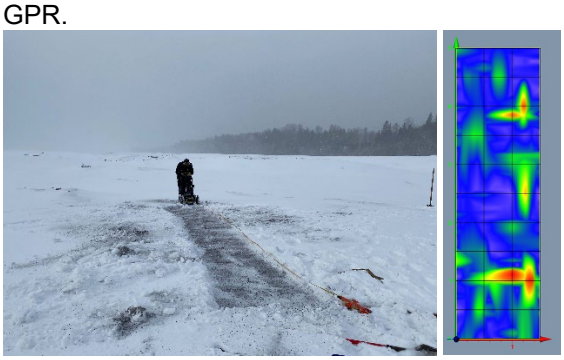
Thermal Cone Penetrometer and Ground Penetrating Radar Testing Progress for Determination of Lunar Regolith Geotechnical Properties and Volatile Characterization. P.J. van Susante[1] J. Allen[1], T.C. Eisele[1], T. Scarlett[1], and K.A. Zacny[2], [1]Michigan Technological University, 1400 Townsend Dr. Houghton, MI 49931, [2]Honeybee Robotics, 2408 Lincoln Avenue, Altadena, CA 91001. (Contact: pjvansus@mtu.edu)

Introduction: As part of the inaugural NASA Lunar Surface Technology Research (LuSTR) program [1] Michigan Technological University in collaboration with Honeybee Robotics was selected to develop a dynamic hot cone penetrometer (DHCP) in combination with ground penetrating radar (GPR) to characterize lunar geotechnical properties and the presence and quantity of volatiles. After 10 months of work, good progress has been made.

Test Hardware: The work has been divided into several tasks. The three main tasks worked on so far have been to 1) test several cone penetrometers, 2) test thermal heating of regolith and water/ice and, 3) test GPR in the field to detect ice and rocks. Several test setups and prototype hardware have been developed including a 1.05mx1.05mx1.22m regolith sandbox in which several custom instrumented cone penetrometer tests can be performed and compared with ASTM standard cone penetrometer testing, without affecting eachother while only having to prepare the compaction levels and ice content layering once to minimize variation in comparison tests due to preparation variability. For the heated cone we developed a testbed to measure the heat affected zone in regolith with a varying percentage of water or ice (zero-10 wt%). The data collected with 24-40 thermocouples at various locations/distances from the heater allowed us to measure the thermal profile and variation with different power levels for the heater. Phase changes and heat affected zone can be clearly seen in the data. A new testbed is being developed to measure similar response curves for cryogenically frozen volatiles. For the GPR we have created a field rover (HOPLITE) that can carry the GPR and the Percussive Hot Cone Penetrometer (PHCP) in the field test. This past summer and this winter we have tested the field rover as well as successfully buried ice and other targets in the basalt sands to be detected by the GPR.



Design Progress: An initial prototype for the PHCP is being designed. The percussive head and z-stage have been designed and are being finalized while the cone penetrometer concepts are being developed based on the geotechnical and thermal experiments and modeling performed to date.

Testing plan and deliverables: Testing will continue under lab and field conditions using cryogenically frozen regolith simulant and volatiles in the lab and two field sites. This coming summer, further field rover testing will be performed and next winter, a trench filled with different icy layers of regolith simulant to test the DHCP and GPR in a natural frozen basalt sand environment where we will create known underground ice and rock objects and ice layers to identify with GPR. Separate frozen icy regolith simulant test layers will be created in a large 40ft freezer container for testing the geotechnical property determination using the DHCP as function of ice content and percussive frequency and energy.

Conclusion & Future work: The project is progressing well despite some COVID challenges. We hope to fly the PHCP and GPR on a future CLPS mission.

References:

[1] NASA, https://www.nasa.gov/directorates/spacetech/lustr/US_Universities_to_Develop_Lunar_Tech_for_NASA (2021), last accessed 4/3/2021