TOWARD AN ARRAY-BASED PASSIVE SEISMIC EXPERIMENT AT THE LUNAR SOUTH POLE FOR WATER ICE PROSPECTING AND GEOTECHNICAL CHARACTERISATION OF THE REGOLITH

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Introduction: The safety of critical lunar infrastructure depends on the geotechnical and seismic state of the shallow lunar subsurface, and future development of a human presence on the Moon's surface will require detailed mapping of subsurface resources, in particular water ice.

Apollo mission seismometers showed that tidal forces can generate large lunar seismic events at relatively shallow depth, with moment magnitude greater than five [1]. Despite the overall lower seismicity of the Moon, the seismic risk due amplification of seismic surface waves in low-velocity, porous lunar regolith and impact breccia is potentially significant. Earthquake hazard assessments for the Moon will have to consider the potential catastrophic effects of critical infrastructure failure. However, the seismic characteristics of these near surface layers is unknown, and the behavior of lunar regolith during seismic events is under-constrained.

Identification of water ice deposits are crucial for future habitation missions, but these deposits may be obscured by barren regolith. Water ice deposits in craters on the moon can form due to several mechanisms, including impacts of water-rich comets [2] or from the condensation of volcanic vapors [3]. These ice deposits may have specific seismic properties that are distinctly different from the lunar regolith - they may possess anomalously high seismic velocities compared to the barren regolith.

In this presentation we show progress towards our goal of deploying a passive seismic array near the Moon's south pole to answer these questions.

SPIDER experiment: Fleet Space Technologies is sending a 3-component seismometer, named SPIDER, to the Nobile crater as part of the Moon to Mars Demonstrator program funded by the Australian Space Agency [4]. One of the goals of the experiment is to show that compact seismometers can record seismic noise and impulsive signals from micrometeorite impacts that can in turn be used to determine the seismic velocity of the shallow lunar regolith, using well known approaches for subsurface mapping and characterisation from the engineering and resources industries on Earth. The results of this experiment pave the way towards array-based experiments to directly image the lunar regolith to potentially reveal water ice deposits in the shallow regolith.

Lunar regolith properties: Preliminary work on our collaboration with the Space Resources Program at the Colorado School of Mines to determine the seismic properties of different types of lunar ice deposits will also be presented. This involves making lunar regolith simulant with different concentrations and distributions of water ice crystal and making ultrasonic measurements of P- and S-wave velocities at different confining pressures representative of different depths in the lunar regolith. Determining differences in seismic wave speeds between barren and icy regolith is crucial to test the applicability of passive seismic array-based methods for imaging the regolith to illuminate water ice deposits. Early results indicate that regolith containing as little as 1% water ice dispersed as crystals has a detectable seismic velocity increase.

Finally, we will show our work in combining the laboratory measurements with high-resolution finite element modeling of lunar regolith containing ice deposits of different concentrations and depths being impacted by micrometeorite impacts, to test our hypothesis of using array-based passive seismic imaging to scan the regolith for water ice. The results of the laboratory experiments and the finite element modeling will aid in the array design required to successfully determine the presence or lack of water ice deposits near the lunar south pole.

ARTEMIS 3 experiment: The SPIDER seismic experiment, along with our laboratory measurements and numerical modeling, will validate our proposal to deploy a line of seismometers proximal to the Human Landing System (HLS) in an approximate 2D array configuration spanning approximately 100 m radially outward. The array would collect both passive environmental ambient-noise seismic data (from tidal effects, crustal stresses, and micrometeorite activity), and active source data from Artemis activities. The outcomes from the experiment would be a 2D cross section of the seismic velocities of the lunar regolith down to at least 30 m depth, which in turn will provide geotechnical characterisation of the regolith and reveal potential water ice deposits, which would appear as high velocity zones based on laboratory measurements.

References:

[1] McFadden, et. al., Encyclopedia of the solar system, 2006.
[2] Svetsov and Shuvalov, Planetary and Space Science 117, 2015.
[3] Basilevsky et. al., Solar System Research 46, 2012.
[4] https://tinyurl.com/3nxue2tz