Electromagnetic Reflection Characterization of Simulated Lunar Ice Using Ground Penetrating Radar

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Introduction: With the discovery of lunar ice residing within the permanently shaded regions on the moon, there is an opportunity to pre-characterize the icy material for the preparation of lunar surface missions using the geophysics of ground penetrating radar (GPR) and rover technology. A series of field testing surveys have been conducted at designated testing sites to quantify GPR data under simulated conditions by burying ice during winter conditions. The goal is to create an accurate data set of ice reflection signatures in a basaltic sand material and lunar simulant to be used as preparation for future space missions to the moon under the NASA Artemis Project.

Methodolgy: Ground Penetrating Radar (GPR) is a geophysical tool that emits electromagnetic radiowaves into the subsurface to measure reflection coefficients at contrasting material boundaries. GPR is economical, accurate, and small-scale making it an excellent instrument to be used in conjunction with rover technology in search of ice on the moon.

Depending on the weather conditions in the environment and other controllable variables, we can perform GPR surveys with ice to collect approximate reflection data. The collected data can then help us understand and refine the relevant variables as we continue to introduce more complex simulated lunar conditions during our research progression.

We are interested in visualizing the first meter of depth within the lunar regolith. For our purposes, we are using a range of GPR antenna frequencies of 50, 100, 500, and 1000 MHz for analysis. It has been found that 500 and 1000 MHz antennas provide the best resolution at our target depth.

Buried targets consist of solid ice blocks, a volume of ice cubes, dry ice blocks, solid ice blocks surrounded by dry ice blocks, a basalt rock, excavated and refilled basalt sands, excavated and refilled basalt sands mixed with snow, undisturbed material.

Testing Sites: The criteria for suitable testing sites include minimizing outside factors, NEPA permitting for minor excavation and ease of access for the rover prototype. The stamp sands near Gay, Michigan along the shoreline of Lake Superior fit this criteria as our current primary field testing site. The stamp sands are a collection of silt, sand and gravel sized basaltic waste rock that was emplaced by copper miners during the late 1800s and early 1900s (Figure 1).

Figure 1: Stamp Sand field site near Gay, MI.

This summer, we will be performing further field testing at the Keweenaw Research Center (KRC), a 900 acre test facility at MTU, where more in-depth and complex GPR testing will take place. The KRC will serve as a controlled environment for advanced testing. This includes constructing a multisectional trench filled with lunar regolith simulant with varying compositions of ice and material in each section which can then be scanned using a rover and GPR.

Data Collection and Analysis: GPR Survey format is performed via line and grid surveys using a manuverable cart (Figure 2) that can quickly collect data along most terrain surfaces. The cart is capable of housing two different radar antennas that can be used simultaneously via the SPIDAR® module from Sensors and Software.

Figure 2: NOGGIN® 500 MHz GPR antenna attached to Sensors and Software SmartCart

Preliminary testing began with using lower frequency GPR antenna frequencies to allow for deeper depth penetration to assess the testing validity of the subsurface and locate suitable testing locations that is free of anomalous material and has a deeper than 1m water table. Further supplementary tests focused on collecting reflection signatures of ice and small basaltic cobbles using 500 and 1000 MHz antennas. Object reflections were done through minor excavating and burial of testing material at known depths. These tests also aided in calibrating the subsurface velocity which is used to improve reflection signature accuracy and data integrity.

After the data is collected, the raw data must then be processed using Ekko_Project4 software by Sensors and Software that allows us to adjust the gain, apply background subtraction, and dewow the signals as well as applying certain filters if needed. Detected objects will depict an inverted hyperbola on a depth vs position vs time plot (Figure 3).

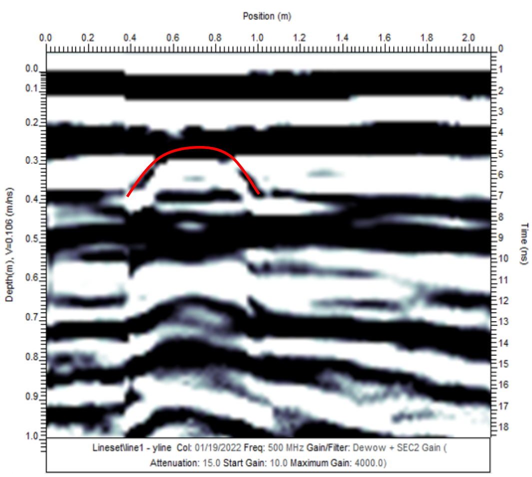

Figure 3: Processed radargram depicting the reflection signature (red line) of an ice block at a depth of 0.3 meters.

The processed data can then be further analyzed through other programs such as Voxler® for visualization/presentation purposes. It also allows us to more clearly see the detected objects and spot any anomalous bodies (Figure 4).

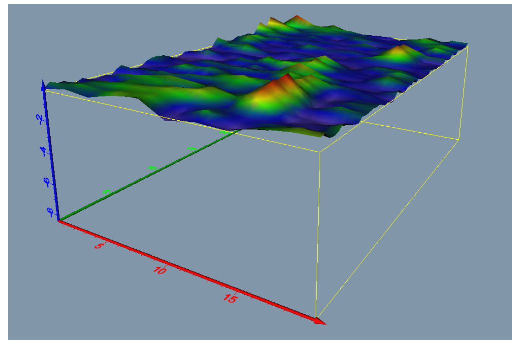

Figure 4: GPR reflection data using Voxler program by Golden Software®.

Future research goals: As we further refine ice signature reflection data, we will be increasing the complexity behind each field survey in conjunction with rover technology. Future GPR tests will focus on further simulating material through lunar simulants, understanding the role of temperature by performing tests in a freezer container, and by fluctuating the proportions of ice to basaltic material. These advanced tests will help further approximate lunar conditions and GPR reflection behavior as we achieve our research goals.