LUNAR REGOLITH TERRAIN FIELD AT NASA MARSHALL SPACE FLIGHT CENTER. J. M. Lorenzo[1], M. P. Zanetti[2], P. M. Bremner[2], D. A. Patterson[1], G. Tsoflias[3], S. Karunatillake[1], H. F. Haviland[2], R. C. Weber[2]. [1]Dept. Geology and Geophysics, Louisiana State University, Cnr. Tower and S. Campus Drives, Baton Rouge, LA 70803, gllore@lsu.edu; [2]NASA Marshall Space Flight Center, 320 Sparkman Drive, Huntsville, AL 35820, michael.r.zanetti@nasa.gov. [3]University of Kansas, Geology, Ritchie Hall, room #354B, Lawrence, KS 66045-7613, tsoflias@ku.edu.

Introduction: The Lunar Regolith Terrain (LRT) field is an outdoor planetary analog environment facility located on base at Marshall Space Flight Center, Huntsville, Alabama, U.S.A. The field contains 500 tons of lunar regolith simulant confined within a 125 ft x 125 ft (38 m x 38 m) area with a depth range between ~5 in - ~4 ft (~13 cm – 1.2m) that can be modified to suit user needs (Figure 1). Lunar regolith simulant is of

Figure 1. Panoramic view of Lunar Regolith Terrain Field looking with its farthest corner pointing toward the southeast.

JSC-1A [1] feedstock material (volcanic cinder sand sourced from Meriam Crater, Flagstaff, AZ) with representative geotechnical, geochemical, and optical properties of lunar mare basalt. The LRTF provides an

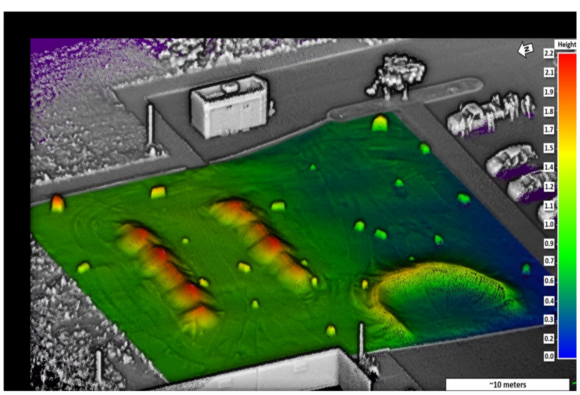

Figure 2. A dynamic LiDAR imagery map of the topography, color-coded for elevation, currently available for the Lunar Regolith Terrain Field (Figure 1).

accessible planetary analog surface environment for surface mobility testing, autonomous roving operations, developing advanced navigation techniques and operations development.

The northern 30 % of the field contains buried fiducials comprising large sheets of aluminum, steel and PVC

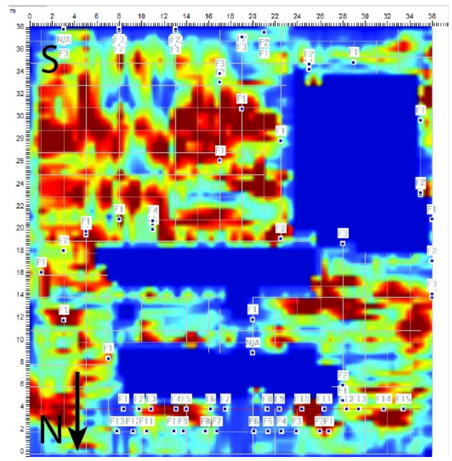

Figure 3. Slice of three-dimensional gridded GPR data volume at a depth near the base of the simulant fill. Orientation of this image corresponds. Hotter, reddish, colors represent higher radar amplitude. Solid rectangular blue (low amplitude) are either landscaped portions of the Lunar Regolith Terrain (Figures 1 and 2) or movable boulders that were not surveyed. North is oriented toward the bottom of this image.

pipes of various dimensions to allow for possible ground penetrating radar and shallow seismic instrument calibration studies. Approximately 50% can be developed into subterranean or deep crater simulation environments. Open air placement can allow future outdoor flight- based testing

Ground-Penetrating Radar Surveys: We collected suitable ground-penetrating radar (GPR) data down to the base of the simulant cover using bistatic antennae with a nominal frequency of 1 GHz. Whereas a 2-m x 2-m grid proved initially suitable for a complete survey of the field (Figure 3), ready detection of the buried fiducials along the northernmost strip of the field required a grid of 1 m x 1 m (Figure 4).

We estimated the averaged GPR velocities at 0.18 m/ns by two means. We interactively matched hyperbolic reflection events from (1) a commonmidpoint or wide-angle reflection and refraction data set and (2) a diffraction event from above the center of a buried culvert (Figure 5).

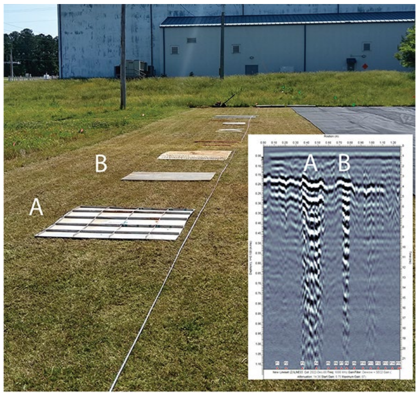

Figure 4. Buried sheets of metal, steel pipes and plastic sheets of different sizes and shapes lie at the northernmost portion of the field (Figures 1 and 2). Currently, the fiducials lie beneath a geofabric (mm thick) and the simulant layer. Radargrams (inset) collected across the current field can readily located the buried fiducials when using a 1-m x 1-m spaced survey grid.

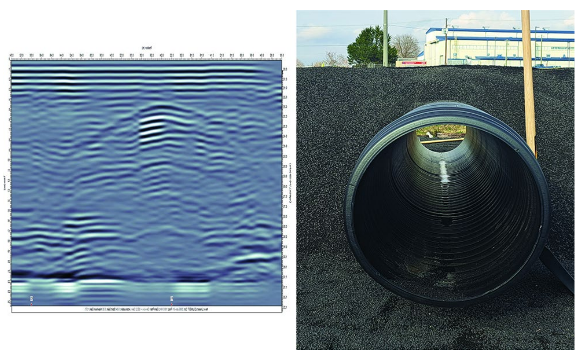

Figure 5. Redistribution of the simulant with a shovel allowed quick burial of plastic, corrugated, culvert (RIGHT). The GPR section is 2.2 m wide and the diameter of the culver is 60 cm. Travel time to the apex of the diffraction is 2.2 ns.

Seismic Surveys: We used a weighted buried aluminum block to generate horizontal shear wave waves (SH). Shear waves are advantageous over traditional compressional waves (P) because in the same material they travel more slowly and, for the same frequency allow greater resolution. In addition, they are expected to be less sensitive to fluids. SH surveys require only a single-component sensor but are capable of detecting Love (surface waves), reflected and transmitted/refracted waves.

In our test case (Figure 6) we measured horizontal SH velocities as low as 50 – 60 m/s in the regolith, confirmed by modeling diving wave arrivals and the interpretation of dispersion (frequency-phase velocity) plots. However, either high attenuation or insufficient coupling in the loose simulant kept frequency content below 200 Hz.

Future work will involve additional P-wave survey data collection and analyses, extraction of P and SH attenuation parameters to calibrate shallow geophysical lunar missions.

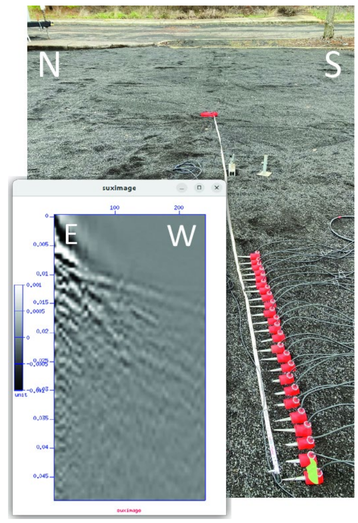

Figure 6. High-frequency conventional geophones (100 Hz corner frequency) lying horizontally to capture horizontal-component seismograms (inset). Opposite-polarity horizontal blows on a vertical plate are used to generate two data sets at each shotpoint location These data are differenced to remove unwanted converted P-waves. Geophones lie oriented E-to-W. Seismic data (inset) source-to-geophone offsets (X axis) range between 5 cm to 2.35 m. The total time (vertical axis) is 50 ms, estimated from the initiation of the seismic blow.

Acknowledgments: Ground-penetrating radar data and seismic data shown herein are available at https://github.com/gllore/LPSC_2023_LunarRegolithTerrainField. JML thanks the Ernest & Alice Neal Professorship in Geology & Geophysics and the Department of Geology and Geophysics at LSU for field support.

References: Summers, A. W., and Zanetti M. R. (2022) Lunar Surface Innovation Consortium, El Paso TX. [2] Gustafson, R. J., and White, B.C. (2009), *SAE* .https://doi.org/10.4271/2009-01-2336.