Michigan Technological Universities' Lunar Highland Simulant MTU-LHT-1A . P.J. van Susante[1], and C.L. Carey[2] 1 Michigan Technological University, Dept. of Mechanical Engineering – Engineering Mechanics, 1400 Townsend Drive, Houghton, MI 49931, pjvansus@mtu.edu, 2 Michigan Technological University, Dept. of Mechanical Engineering – Engineering Mechanics, 1400 Townsend Drive, Houghton, MI 49931, clcarey@mtu.edu

Introduction: The lunar environment imposes challenges to engineering: near vacuum environment, micro gravity, and unique material environment. For designs to be verified, they need to be tested in a relevant environment meaning simulating as much of the lunar environment as is feasible. In the Planetary Surface Technology Development Lab, research is being conducted for space applications. Many lunar regolith simulants exist for testing, but are prohibitively expensive in large quantities. The scale of testing planned demanded that lunar simulant be produced in house. This paper aims to introduce the lunar simulant MTU-LHT-1A and discuss a selection of resulting material properties with respect to lunar sample reference.

Materials: MTU-LHT-1A is composed of crushed black scoria basalt and two varieties of calcium feldspar sourced from Greenland: greenspar 250 and greenspar 90. Each component is shipped in large 1000-1200 kg super bags which are known to self sort in transit, so the bags are distributed into buckets using a variation on quartering defined by ASTM C702/C702M-18 [1] partially shown in figure 1.

Figure 1: Intial step in separation process

The black scoria is too coarse and requires crushing to reduce the particle range to desired values. A roller rock crusher was used and particles were screened to less than 1000 µm. Greenspar 250 and 90 were known to be less than 250 µm and 90 µm respectively.

Methods: The testing used to evaluate the materials targeted on particle size distribution, as the minerology was well known from source. The specific test methods used were dry sieving, wet sieving, and hydrometer testing [2].

The mixture of materials used to create was designed using the particle size distributions collected from the black scoria and greenspars. A design was created by taking the weighted sum of inputs to represent each possible mixture. The best mixture was determined iteratively seeking the minimum square difference to lunar mean [3]. This solution was altered slightly to account for measurable quanities. The final designed distribution can be seen in figure 2.

Preliminary Results: Characterization of the simulant is underway, so only initial results are available. Figure 2 shows the measured test result of the final mixture in the form of a dry and wet sieve. These results show the reliability of the design methodology and adherence to lunar samples.

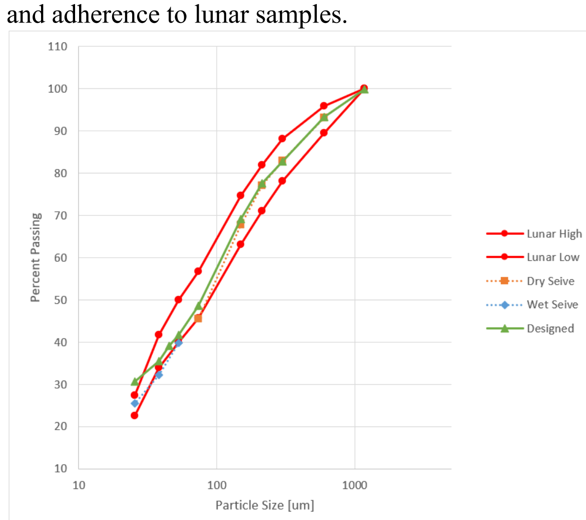

Figure 2: Comparison of measured results to lunar reference and designed distribution

Many tests are underway as the simulant's properties will need to be geotechnically characterized for reference in the reseach that is conducted with it. The specific gravity will be explored with pychnometer testing, the shear strength, cohesion and friction angle will be tested with a triaxial test, and a scale for relative bulk density will be determined with standard testing.

Supported Projects: MTU-LHT-1A is being used in Planetary Surface Technological Development Lab for many projects, allowing better understanding of mechanical behaviors in lunar regolith. These projects include exploration of friction and wear, the flow of regolith. The regolith is also used for testing of small lunar vehicles in a 14 ft x 6 ft area shown in figure 3, in MTU's dusty thermal vacuum chamber as well as in several test setups in the 40ft freezer container for icy lunar regolith simulant testing.

Figure 3: Simulant "sandbox" used for vechicle testing

Looking ahead, the PSTDL will be adding additional components to MTU-LHT-1A. Ice particles and other volitles will be added for in depth thermal profile analysis and olivene will be added to more accurately account for mineral hardness in wear testing. In summer 2022 approximately 100,000 lb of MTU-LHT-1A will be manufactured and partially mixed with ice to create icy layers for a test trench for Ground penetrating radar and thermal cone penetrometer testing.

References: [1] ASTM Standard C702/C720M-18 (2018) *Standard Practice for Reducing Sample of aggregate to Testing Size*. [2] R. Burt, (2009) *Soil Survey Field and Laboratory Methods Manual,* 40-62. [3] G. H. Heiken, et al. (1991) *Lunar Sourcebook a user's guide to the moon*.