HIGH FIDELITY LUNAR HIGHLANDS AND MARE REGOLITH SIMULANTS: ENABLING TOOLS FOR LUNAR SURFACE EXPLORATION AND ISRU DEVELOPMENT. D. T. Britt and K. M. Cannon
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Introduction: NASA's return to the Moon and the growth of the NewSpace industry has stimulated new interest in Lunar exploration and the utilization of Lunar resources (In-Situ Resource Utilization-ISRU). A large number of missions are slated to return to the Moon in the very near future. A key component in the development of new landers, new spacecraft hardware, and ISRU technology is their testing and verification in Lunar-like conditions. For ISRU it is particularly important to demonstrate function and performance with Lunar-like materials. Simulated space materials, or simulants, are an important tool for testing engineering hardware and mission operability and can also be used to address fundamental science and engineering questions [e.g., 1-3]. Here, we report on the service that the Exolith Laboratory of the Center for Lunar and Asteroid Surface Science (CLASS) offers in providing high fidelity, mineralogy-based simulants for the Lunar Highlands and Mare to the Lunar exploration community. These simulants have broad utility in scientific research, hardware development, and instrument/process testing.

Simulant design philosophy: Previous Lunar regolith simulants have been designed mostly based on their geotechnical properties, basaltic characteristics, and ease of mining, typically are quarried from a basalt flows. For the BP-1 simulant Apollo astronaut Jack Schmidt identified a silty deposit derived from the Black Point lava as having very similar physical properties to lunar soils. These deposits are tailings from gravel processing. The lava flow itself is fairly alkaline. BP-1 is a geotechnical simulant, in that its mineralogy and chemistry were not selected or modified to be similar to any known lunar samples. Because it is derived from basalt, the simulant is more similar to mare soils, but the plagioclase content is fairly high. The JSC-1 series is a low-Ti mare simulant made from volcanic ash mined from the San Francisco volcano field near Flagstaff, AZ. It contains a high glass fraction and is chemically similar to Apollo sample 14163. Details on all Lunar simulants can be found at the CLASS Planetary Simulant Data Base (https://sciences.ucf.edu/class/planetary-simulant-database/)

In contrast, at the Exolith Lab we design our asteroid and planetary simulants starting from the known mineralogy of the target bodies. Minerals are the basic building blocks of planetary materials, and simulants designed to replicate the mineralogy of a reference material will tend to compare well on many different metrics, because the secondary properties (spectra, strength, etc.) are a result of the specific combination of minerals present in the regolith. Through our work creating asteroid, Martian, and Lunar simulants we have built up a library of source minerals that can be quickly combined to prototype new simulants.

Methods: Our general steps for creating regolith simulants involve: (1) choosing the appropriate reference material and deriving a mineral recipe, (2) sourcing and preparing the constituent minerals, (3) grinding in a rock crusher to create a power-law size distribution of polymineralic grains. Additional steps may be needed for specific simulants, as described below. Details of all Exolith simulants can be found at https://sciences.ucf.edu/class/exolithlab/

Figure 1: LHS-1 Lunar Highlands Simulant

LHS-1 Lunar Highlands Simulants. The LHS-1 Lunar Highlands Simulant developed by the CLASS Exolith Lab is a high-fidelity, mineral-based simulant appropriate for a generic or average highlands location on the Moon. The simulant is not made of a single terrestrial lithology, but accurately captures the texture of Lunar Highlands regolith by combining both mineral and rock fragments (i.e., polymineralic grains) in accurate proportions. The particle size distribution is targeted to match that of typical Apollo soils.

LMS-1 Lunar Mare Simulants. The LMS-1 Lunar Mare Simulant developed by the CLASS Exolith Lab is a high-fidelity, mineral-based simulant appropriate for a generic or average mare location on the Moon. The simulant is not made of a single terrestrial lithology, but accurately captures the texture of lunar regolith by combining both mineral and rock fragments (i.e., polymineralic grains) in accurate proportions. The

particle size distribution of the simulant is targeted to match that of typical Apollo soils.

Figure 2: LMS-1 Lunar Mare Simulant

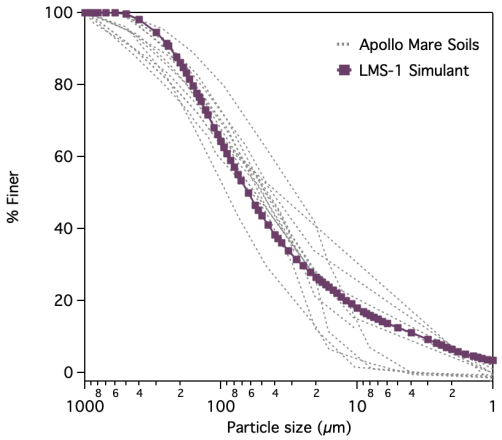

Figure 3: Particle size distribution for Apollo Mare Soils and LMS-1 Simulant.

Applications for ISRU. There is a growing need to develop and test ISRU hardware in highly realistic scenarios. This will involve using regolith simulants in environment chambers, and testing will benefit from the most realistic simulants available. We believe that LHS-1 and LMS-1 are some of the highest fidelity Lunar simulants ever produced, and will be useful for testing Lunar ISRU hardware and procedures.

Availability: These simulants, along with asteroid and Martian simulants, are currently available from the CLASS Exolith Lab at $25/kilo plus shipping. Users should contact the Exolith Lab for advice on their specific application

References: [1] Marshall J. P. et al. (2017) *Space Sci. Rev.*, *211*, 239-258. [2] Ash R. L. et al. (2016) *9th Sym. Space Resource Util.* [3] Böttger U. et al. (2012) *Planet. Space Sci.*, *60*, 356-362.