

NASA Lunar Regolith Simulant Update. J. E. Gruener¹, R. N. Kovtun² and A. Slabic², ¹NASA Johnson Space Center (2101 E. NASA Parkway, XI4, Houston, TX, 77058, john.e.gruener@nasa.gov), ²Jacobs/NASA Johnson Space Center (2101 E. NASA Parkway, XI4-JETS, Houston, TX, 77058, rostislav.n.kovtun@nasa.gov, ane.slabic@nasa.gov)).

Introduction: The National Aeronautics and Space Administration (NASA) is collaborating with commercial and academic partners in the production of lunar regolith simulants. These simulants are being used by NASA, academia, and commercial companies to test systems and components intended to interact with the lunar surface as part of NASA's Artemis Program. NASA's role in these collaborations is to provide simulant specifications needed for NASA technology development, commercially acquire simulants, and to characterize the acquired commercial simulants and compare the simulants to lunar regolith data from the Apollo samples.

Continual Improvement of Lunar Simulants: In the late 1980s and early 1990s, NASA was tasked with planning a return to the Moon with humans, sometime in the early 21st century. Because of the small allocations of lunar sample that were available, and the need for larger amounts of material for the development and testing of exploration systems and components that would interact with the Moon's surface, lunar scientists developed lunar-like granular materials from terrestrial geologic feedstock that was like the samples brought from the Moon. These granular materials were termed 'lunar soil simulant'. The first lunar simulants concentrated on lunar mare materials and were named MLS-1 (Minnesota Lunar Simulant #1) [1] and JSC-1 (Johnson Space Center) [2]. These early lunar simulants consisted of particles of < 1 mm.

Since that time, many lunar simulants have continued to be produced at < 1 mm, even though the bulk regolith of the Moon is usually described as a pebble- or cobble-bearing silty sand [3, 4]. NASA is working to get larger particles included in currently produced general purpose lunar simulants. An example of this effort is recent work based on 25 Apollo 16 soil samples, that resulted in a lunar simulant particle size distribution (PSD) that includes particles up to 11 cm in size [5].

Lunar simulants produced today also include lunar highlands simulants. The first lunar highlands simulant produced in bulk resulted from a collaboration between NASA and the U.S. Geological Survey (USGS) and was called NU-LHT-2M (NASA-USGS Lunar Highlands Type). This simulant and others in the NU-LHT series were primarily produced from geologic materials from the Stillwater Complex in Montana [6].

These simulants also contained glass components created from the Stillwater feedstock. The latest evolution in the NU-LHT series is NUW-LHT-5M resulting from a collaboration between NASA and Washington Mills, a company in Niagara Falls, NY which is a major producer of fused materials [7]. NUW-LHT-5M consists of Stillwater anorthosite and norite, olivine, and glass manufactured by Washington Mills. The synthetic glass has a composition based on the average composition of Apollo 16 soil samples, and the glass component makes up 40% of the simulant.

This is an important step in improving lunar highlands simulants. Most commercially produced lunar highlands simulants use glass-bearing basaltic cinders that are roughly 50% glass [2] to provide a glass component. This typically results in a simulant glass component that is $\leq 15\%$. A recently proposed lunar soil classification system [8] shows a typical glass content of 20-45 %, based on analyses on 118 lunar soils [9].

Increasing the PSD of lunar simulants to include particle sizes >1 mm, and improving the glass component of all simulants, particularly highlands simulants are just two examples of how NASA is trying to continually improve the state-of-the-art of lunar regolith simulants. Lunar simulants play an important role in developing systems that will be used on the lunar surface in the 2020s.

NASA Lunar Regolith Simulant User's Guide, Rev. A: NASA is releasing a new lunar regolith simulant user's guide, updating the first NASA simulant guide published in 2010 [10]. The new guide will include sections on Lunar Regolith, Lunar Regolith Simulant, Selecting a Simulant; Figures of Merit, Working Safely with Lunar Simulants; and Preparing Lunar Simulants for Testing. It is intended that the User's Guide will be continually updated as new simulants are produced and characterized, and as new simulant preparation and testing procedures are developed. The User's Guide is being modeled on NASA's Cross-Program Design Specifications for Natural Environments (DSNE), currently in Revision I [11].

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