

SSERVI Lunar Lab and Regolith Testbeds at NASA Ames Research Center J. Minafra¹, U. Wong¹, M. O'Connor¹, C. Walter², and K. Gibbs¹, NASA Solar System Exploration Research Virtual Institute (SSERVI)¹, NASA Ames Research Center, Moffett Field CA and United States Geological Survey (USGS)², Moffett Field, CA. (Contact: Kristina.gibbs@nasa.gov, joseph.minafra@nasa.gov)

Introduction: The Lunar Lab and Regolith Testbeds at NASA Ames, managed by SSERVI, are essential for advancing NASA's understanding of lunar operations and the impacts of dust exposure in a simulated lunar environment. The facility has recently expanded to feature three distinct lunar testbeds, along with a variety of lunar simulants.

1. The 4m x 4m testbed houses the world's largest collection of JSC-1A (~8 tons), designed to replicate the bulk chemistry of Apollo lunar samples.
2. The 19m x 4m testbed contains over 15 tons of LHS-1, a high-fidelity, mineral-based simulant representing the lunar highlands.
3. The 2m x 2m x 4m testbed features a deep bed of anorthosite, simulating the soil likely found at the lunar poles.

These testbeds serve multiple purposes for science and exploration research, providing excellent testing environments for upcoming phases of the Artemis Program.

Established following the 2009 Centennial Challenge Regolith Mining Competition, these testbeds have been utilized by a diverse range of researchers seeking high-fidelity environments for testing hardware designed for lunar missions. The 19m x 4m testbed was developed in collaboration with the NASA Intelligent Systems Division, which identified the need for visual testing environments for polar exploration.

NASA's first rover aimed at exploring the lunar south pole and mapping volatile distributions in permanently shadowed regions, extensively utilized these testbeds during navigation system development. Using the LHS-1 simulant, which closely approximates the albedo and bidirectional reflectance of polar regolith, along with a constellation of low-elevation sun simulators, the lab created a high-fidelity optical simulator for lunar terrain. Terrain geometry, including statistical hazard distributions like rocks and craters, was meticulously crafted, with a "dusting" process applied to mimic micrometeorite textures on the regolith surface. The objective was to replicate a diverse array of plausible "scenes" that a polar rover might encounter.

Prototype rover cameras imaged these scenes under polar lighting conditions to enhance image quality for operator navigation and stereo vision. Testing in this

environment addressed critical design and operational considerations, such as variability in photographic exposure, conditions for image stacking or HDR modes, expected 3D point cloud quality, performance of hazard detection and visual odometry algorithms, and optimal lighting placement. Additionally, engineering development unit (EDU) cameras were employed to gather data for requirement verification.

Furthermore, the USGS collaborated with SSERVI to construct the deep testbed for enhanced research capabilities. Previous work in the testbed has included terrain-relative navigation sensor development, aiding robotic maneuvering in dusty environments, and investigating ISRU identification and extraction techniques, including USGS drill testing for lunar subsurface exploration. Notably, the Lunar Surface Technology Research (LuSTR) initiative has also made significant contributions through its research efforts in these testbeds.

Additionally, several research activities are being conducted, including the NIRVSS (Near-Infrared Volatiles Spectrometer System), Lawrence Livermore National Laboratory (LLNL) demonstrating their Multistatic Ultra-Wideband Radar to the ISRU community, and the USGS Ground Penetrating Radar (GPR) experiments in the Deep Lunar Regolith. Emileigh brought out three GSSI GPR modules (900, 1600, and 2600 MHz) for testing, while Fleet Space is conducting seismic sensor testing in the testbed. Other initiatives include the Fleet's Real-time Geode and Seismic Payload and the Interplanetary Discovery Exploration research (SPIDER), along with the Atacama Rover Astrobiology Drilling Studies (ARADS/TRIDENT) drill.

Future applications may encompass ISRU testing for fuel, water, and other resource extraction, as well as exploring additive manufacturing techniques using regolith. The testbeds are accessible to the broader scientific and technological communities and can be customized for specific research needs. Previous users include the Artemis Program, Intelligent Robotics Group, USGS, NASA Ames' Intelligent Systems Division and Planetary Systems Branch, Universal Studios, and various international partners. For more information on availability and pricing, please visit <http://SSERVI.nasa.gov/testbed>

