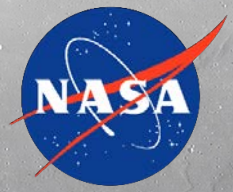
Astromaterials Research and Exploration Science
Johnson Space Center

National Aeronautics and
Space Administration



Simulant
Development
Lab

NASA JSC's SDL and Artemis Testing

presented by Hannah O'Brien, Amentum at NASA JSC

Simulant Development Lab (SDL) at JSC

- The **SDL** is a **multifunction collaborative lab space** that supports the **development**, **curation**, **analysis**, **testing**, and **distribution** of **planetary simulants** (Lunar, Martian, Asteroidal) and granular materials.
- The SDL provides a dynamic working space where **science** (*characterization of physical simulant properties*) and **engineering** (*tools, gloves and suit materials, dust mitigation, robotic prototypes*) **experiments can be conducted using testbeds of simulants**.
- The lab currently houses over ***35 metric tons of simulant material***.
- Additionally, the SDL is furnished with a wide scope of **equipment and tools** used to **process simulants** (*including bulk simulant and feedstock materials such as rocks*) along with a key selection of **analytical instruments** which are used to **characterize** these materials.

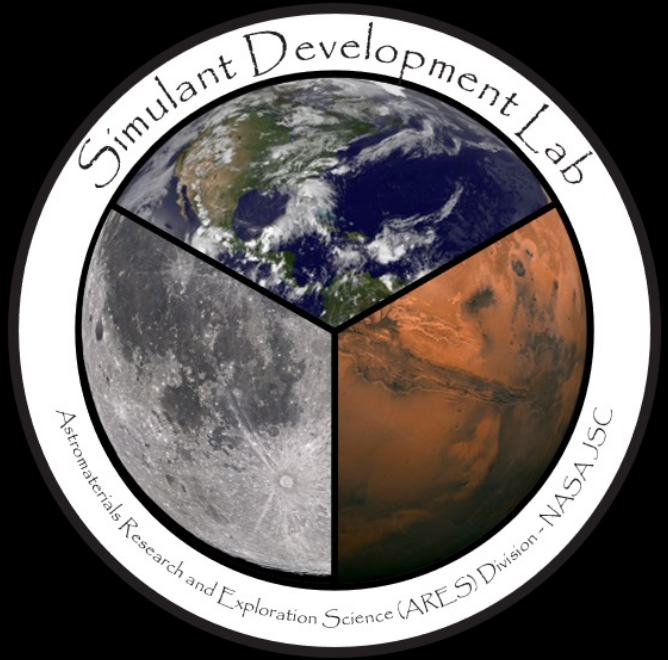
SDL Team

Anastasia Ford
Surface Science and Technology Specialist and SDL Civil Servant Lead

Hannah O'Brien
Lunar Geoscientist and Contract Lab Manager

Ross Kovtun
Lunar Geotechnical Scientist and lab co-lead

Sarah Simpson
Mars Research Scientist and lab support staff



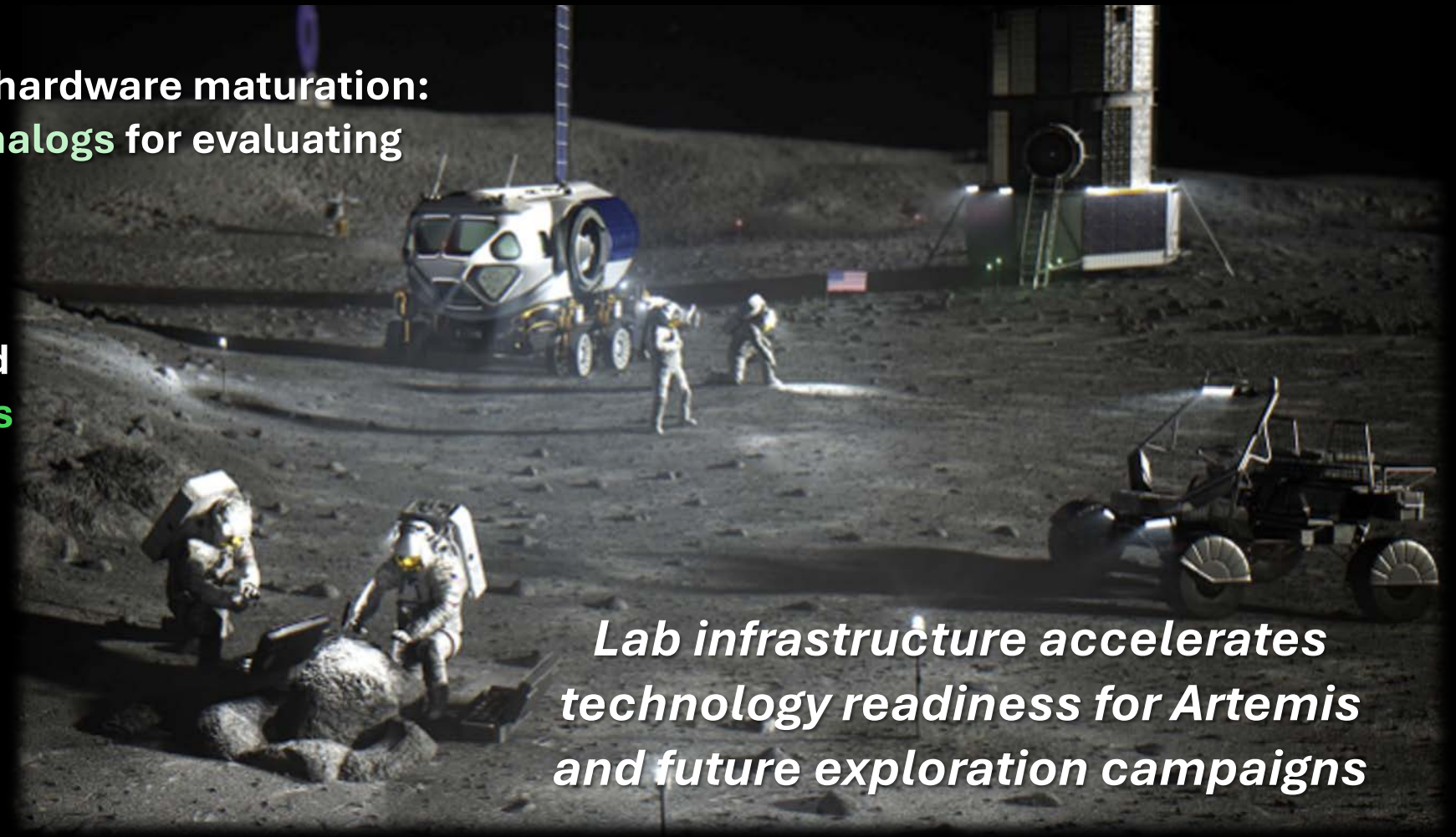
Doug Archer
Mars Research Scientist and lab support staff

Artemis Testing

The SDL provides controlled and repeatable ambient testing environments that replicate the physical and compositional properties of lunar regolith

Enables and supports Artemis hardware maturation: providing safe, Earth-based analogs for evaluating systems

must withstand regolith dust interactions, physical wear and abrasion, and operational loads



Lab infrastructure accelerates technology readiness for Artemis and future exploration campaigns

Lunar Simulant Review

- Lunar regolith simulants are *geologically complex*
  - Constituents are rarely found in-situ concomitantly on Earth
    - Lunar regolith has both a crystalline and glass component (agglutinates and impact melt) with no direct terrestrial analog

- Manufacturing of higher fidelity simulant is difficult
  - Properties that are routinely focused on: particle size distribution (PSD), particle geometry, mineralogy, chemistry, bulk density
  - Properties not routinely investigated: optical, thermal, electrical, geotechnical, etc.

- There is not one 'best' lunar simulant currently available, and there is not one simulant that will satisfy the needs of all projects
  - *Simulant fidelity should be tied to project TRL*
  - Project details critical for selection of relevant simulant

Methods and Capabilities: Materials Processing

The SDL's processing capabilities allow precise control of: simulant particle size, distribution, and compositional characteristics.

Material Processing Equipment:

- Gilson BO-350S 7ft^3 Stainless Steel Interior Bench Oven (for thermal conditioning and drying of simulants prior to vacuum chamber testing)
- Gilson LC-37 Bico Badger Jaw Crusher
- Pavestone JAC12CE Rock Crusher, Gilson LC-53 Bico Pulverizer
- Gilson LCA-91 Dust Enclosure Bench, Gilson LC-91 1 Tier Jar Mill
- Gilson SS-15D Gilson 8in Sieve Shaker
- Gilson 8in Vibratory Sieve Shaker
- Readco Kurimoto RK Labmaster Mixer
- Gilson Mechanical Soil Compactor

Methods and Capabilities: Analytical Instruments

Analytical tools in the facility support physical properties evaluation aligned with engineering performance needs.

Analytical Instruments in the lab include:

- **Microtrac Sync Wet/Dry Multi Laser Diffraction Particle Size Analyzer (Range: 0.01 – 2,000 microns),**
- **Keyence VHX-7000 Series Digital Microscope,**
- **Bartington MS2B Dual Frequency Sensor + MS3 Meter (Magnetic Susceptibility),**
- **Gilson Standard Pneumatic Direct Shear Machine**

The lab also houses a variety of sieves, tumblers, a shear vane, two cone penetrometers, a density drive tube, and a density sand cone for physical, geotechnical, and mechanical analysis of simulants.

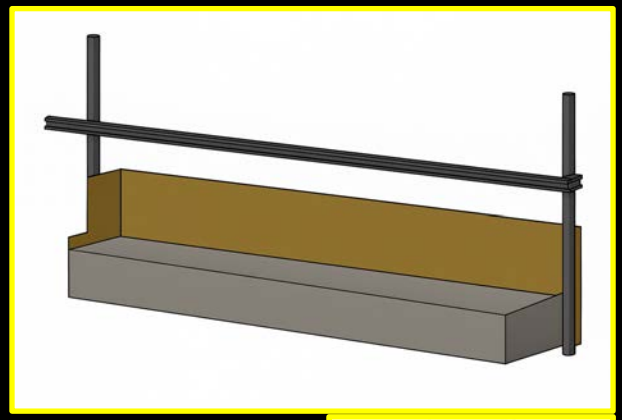
Integrated Testing

SDL enables integrated testing across a wide range of exploration hardware and mission scenarios

- Testbeds support mechanical, thermal, electrical, and operational evaluations of components and systems designed for lunar surface deployment
- adaptable processing and workflows
- modifiable testing gloveboxes and testbeds
- supports repeatable test campaigns for engineering verification and validation, contributing to *improved fidelity* in technology maturation pathways

Exploration Lab Manager Pedro Sanchez operates a single leg penetrometer that supports the LASSIE-M project in a densified lunar simulant test bed.

LASSIE-M is a joint NASA & university research project that evaluates the capabilities and effectiveness of legged robots for planetary surface exploration



Custom built simulant test bed for analysis of push/pull/drag forces in a densified container of simulant

Integrated Testing Applications: Dust Mitigation

The SDL supports Artemis activities including dust-mitigation testing for a variety of systems and hardware

Non-exhaustive list includes test flight hardware, electrostatic shields, suit materials, life support systems, electrical connectors, etc.

We work closely with the engineers leading these projects and provide SME level support on their test plans, in lab testing support, and post testing analysis

HULC (Handheld Universal Lunar Camera) dust mitigation testing

Hardware subsystem simulant testing

Integrated Testing Applications: Geology Tools Testing

The SDL provides testing space and support for Artemis tools testing and development teams to conduct evaluations

Lunar Scientist Hannah O'Brien scoops lunar simulant material out of densified lunar simulant testing bin, using a scoop from the government reference design geology toolset.

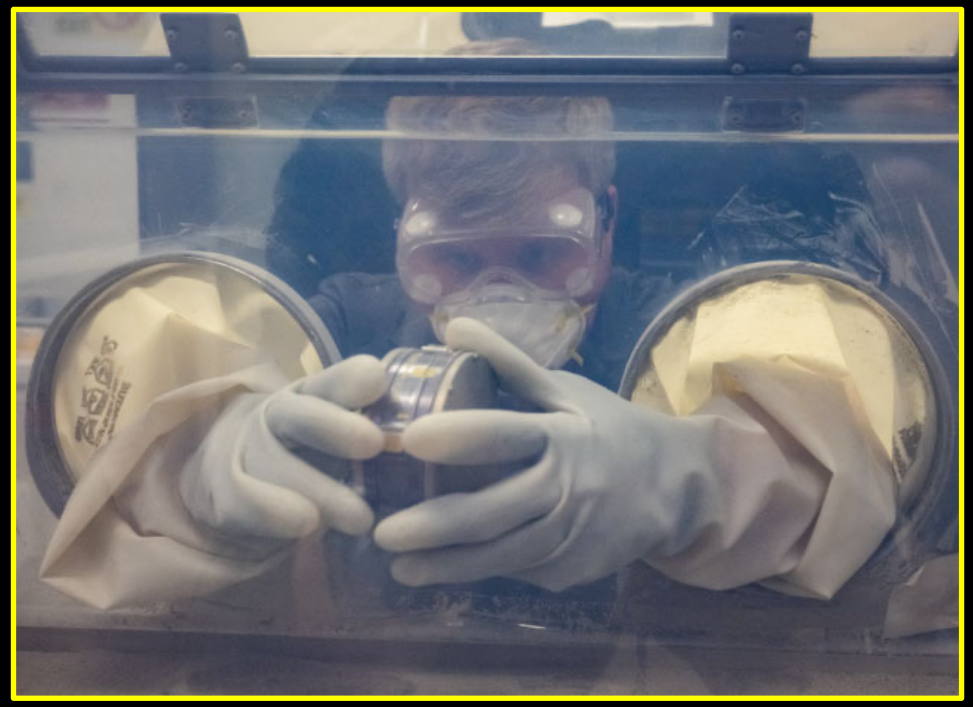
Tools Engineer Yisha Ng hammers a Drive Tube into a densified lunar simulant testing bin, collecting a core sample of simulant material. (tools used: Hammer, Extension Handle, Drive Tube from government reference design tool kit).

Integrated Testing Applications: Hardware Performance Evaluations

Pre-test

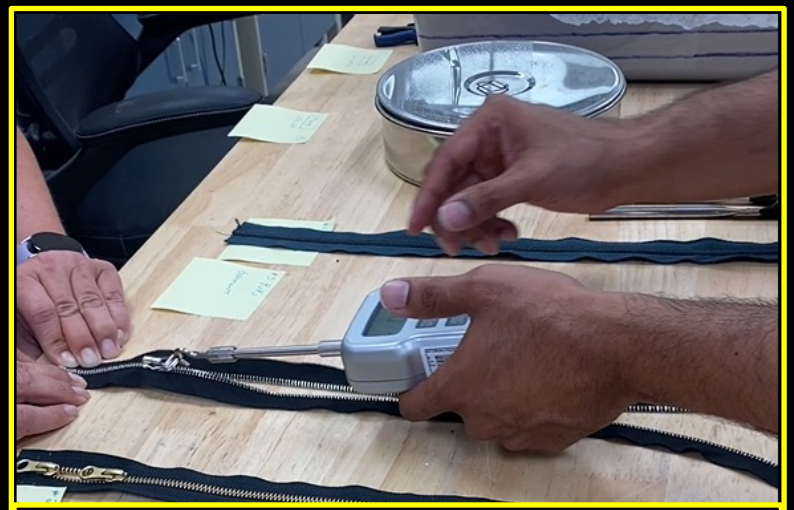
Electrical Connectors tested for abrasion and wear after exposure to lunar regolith simulant

Post-test



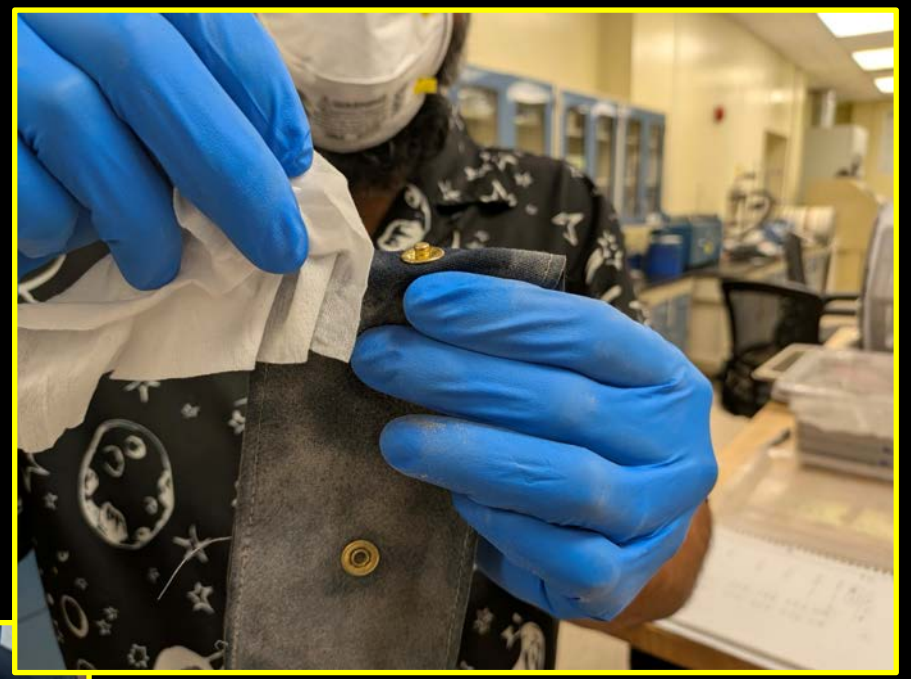
Test Engineer James O'Hara examines an astronaut glove wrist connector seal in a dusty lunar simulant environment in a glovebox in the SDL.

Integrated Testing Applications: Softgoods Abrasion and Puncture Resistance



Measuring actuation forces of zippers pre and post-application of lunar simulant.

The SDL was utilized to evaluate the performance of mechanical fasteners (zippers and snap fasteners) when exposed to lunar simulant application

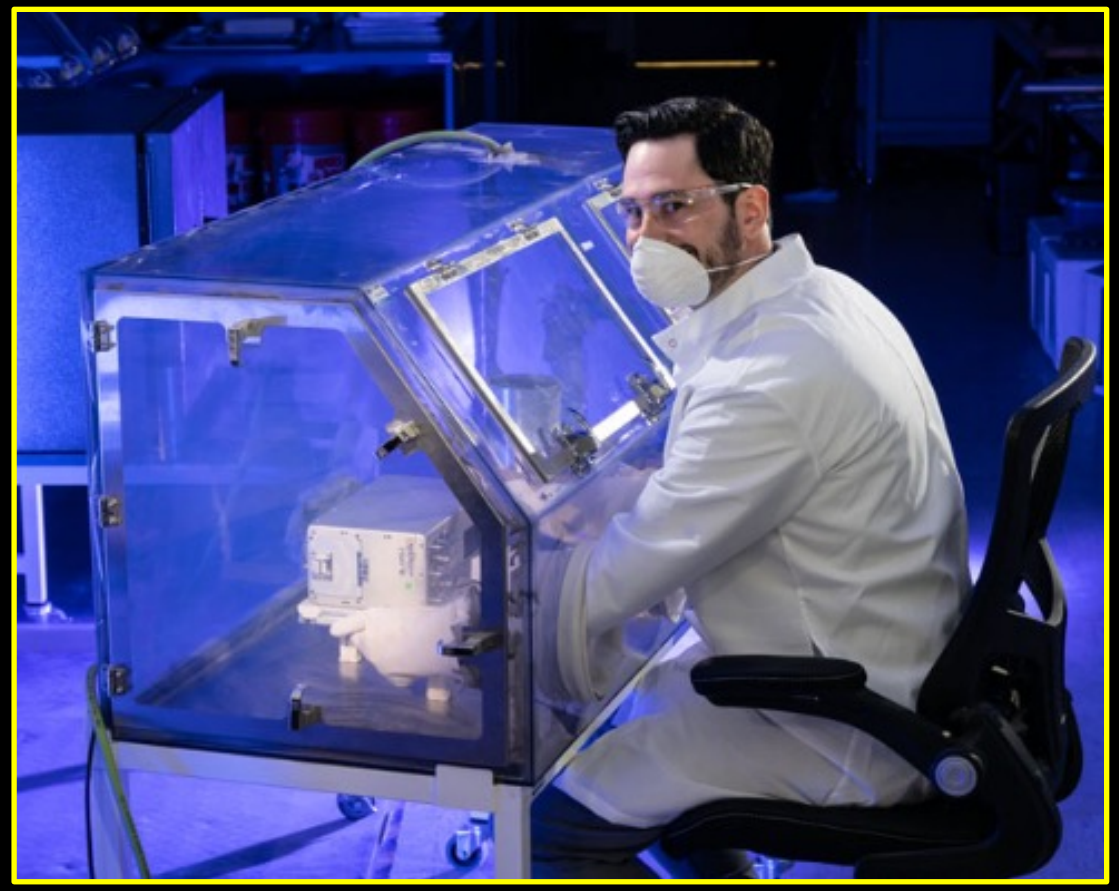


HLS Softgoods Project Engineer Ashdin Medhora performs a functional evaluation of the effect of cleaning a garment snap fastener coupon with available HLS in-flight cleaning wipes after direct exposure to lunar simulant.

"Dunk Test"
Zipper is fully immersed in simulant

Dust Application w/ Zipper Open

Integrated Testing Applications: Electronics Resiliency Testing



Test Engineer Jason Miller operates an Anomaly Gas Analyzer (AGA) to discover how aerosolized lunar simulant affects the internal sensors and electronics. Lunar simulant is aerosolized via a TOPAS dust disperser within the glove box.

Integrated Testing Applications: Astronaut/Crew Training

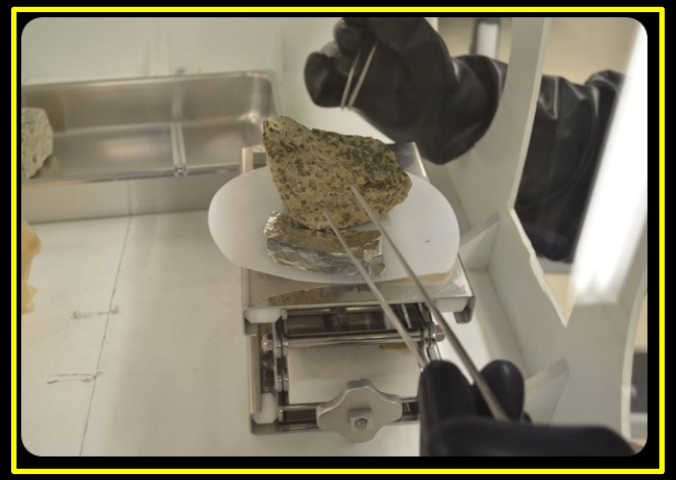
The SDL provides crew training tools such as (but not limited to):

- representative simulant samples for lunar sample collection and handling training
- test bins and barrels for suited testing and training

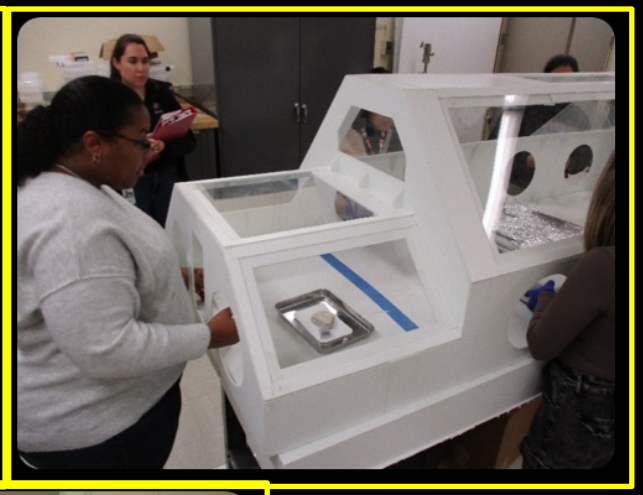
Astronaut Nicole Mann in the xEMU suit testing a drive tube from the Government Reference Design tool kit into a densified barrel of lunar simulant in the ARGOS facility at JSC.

Sample Return Mission Planning and Training

SDL supports Artemis sample return mission planning and training by providing representative simulant samples for curation procedure development and practice



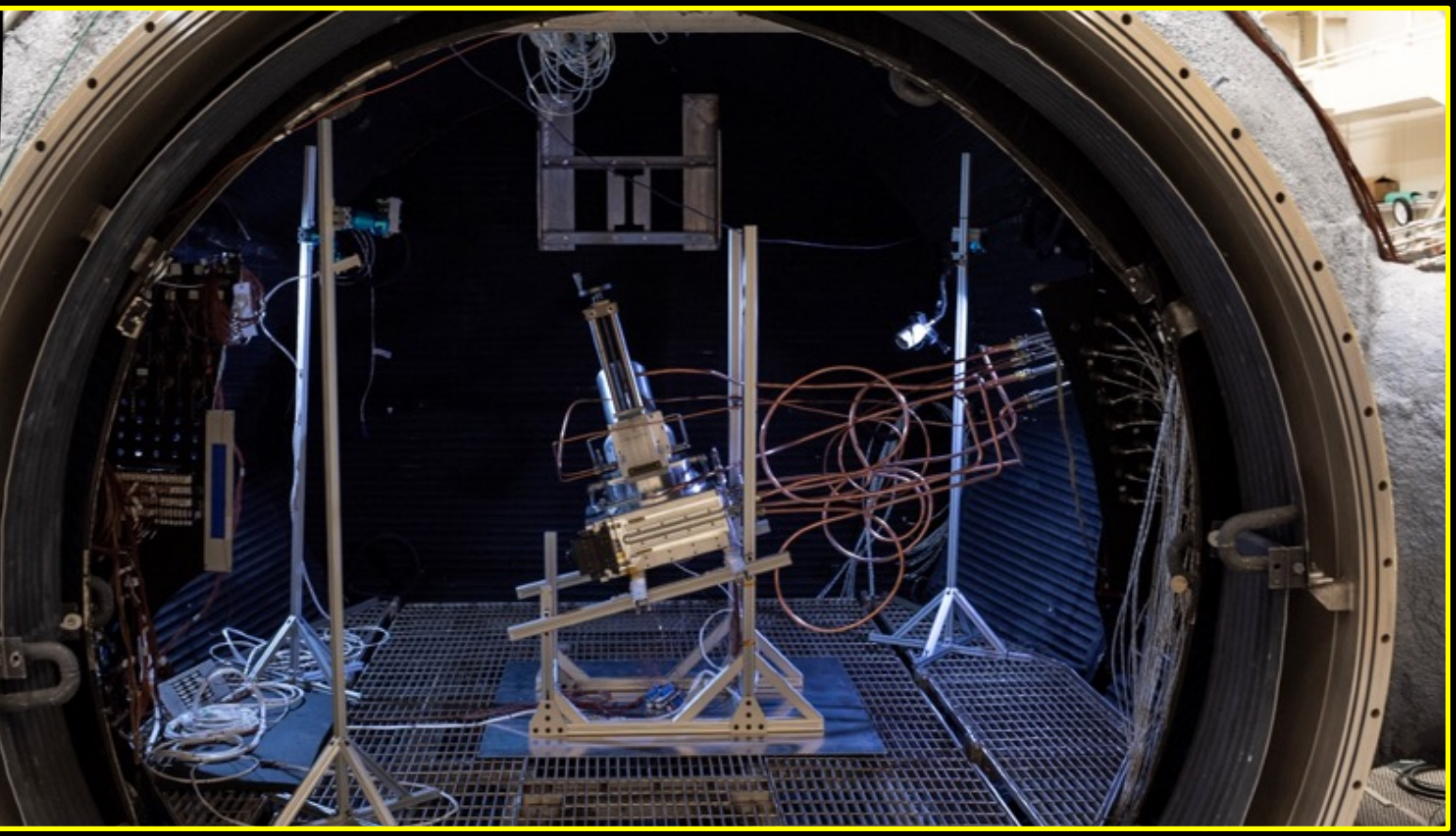
Lunar simulant samples being examined, processed, and measured as part of procedural development and testing for Preliminary Examination (PE)



Artemis PE Processors developing and testing procedures for initial sample return

ISRU Tech Development Support

The SDL supports various ISRU technology development tests through providing simulants and simulant expertise, to teams and projects such as CaRD

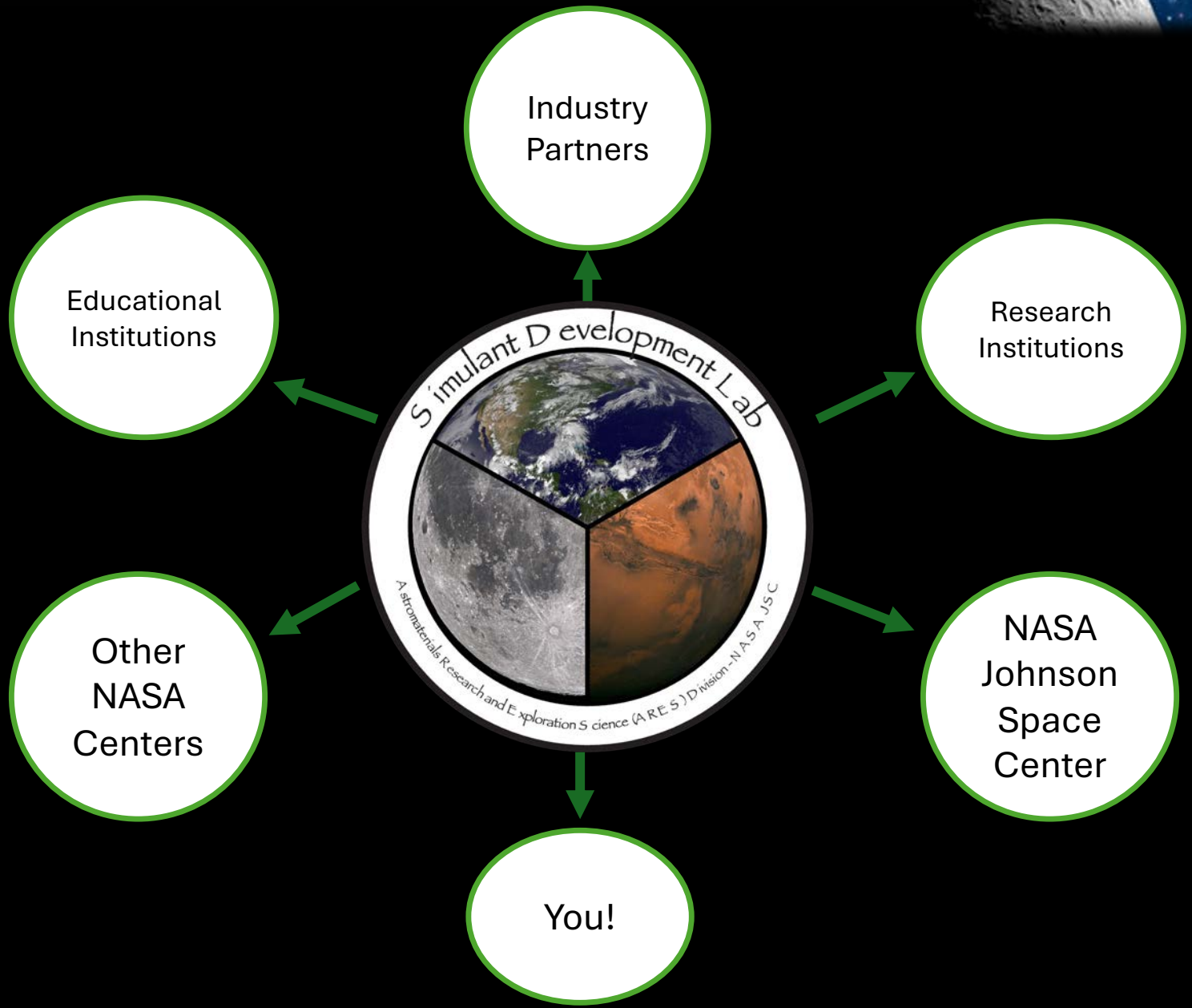


CaRD reactor in 15ft vacuum chamber

NASA's Carbothermal Reduction Demonstration (CaRD) team successfully extracted oxygen from simulated lunar soil within a vacuum chamber using a high-powered laser and a carbothermal reactor to melt the soil.

preparing the regolith simulant for oxygen extraction

Simulant Development Lab (SDL) at JSC



Simulant Advisory Committee

The Simulant Advisory Committee (SAC) is an Agency-wide team of simulant experts technology developers can obtain advice from on the simulant types to use during testing

SAC is steered by Jennifer Edmunson (MSFC) and meetings led by Hannah O'Brien (JSC)

The SAC is funded under the Regolith Simulant Analysis Project, under the Live domain of the Space Technology Mission Directorate.

Membership:

Jennifer Edmunson (MSFC) is the Project Manager

Hannah O'Brien (JSC)

Ross Kovtun (JSC)

Anastasia Ford (JSC)

Beverly Kemmerer (KSC)

Heather Oravec (GRC)

Doug Rickman (MSFC)

Sarah Simpson (JSC)

Doug Archer (JSC)

Anna Martin (APL)

Simulant User's Guide and Simulant Database

Additional Tools for Simulant Knowledge and Expertise:

Lunar Simulant User's Guide:
https://ntrs.nasa.gov/citations/20240011783

Lunar Regolith Simulant User's Guide provides the lunar exploration community with an explanation of what lunar simulants are and how they are made, how simulants compare to real lunar samples, how to safely use lunar simulants, and what is needed in preparing lunar simulant material for engineering or operational testing.

Simulant User's Database (hosted by SSERVI, managed by NASA)
https://sservi.nasa.gov/simulants/

The Simulant Database was set up not only as an information source, but to function as a comparative tool between simulants, as well as a platform where simulant users and producers could provide feedback that would further strengthen the information made available. We encourage you to check it out!

Questions?

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