

Planetary Advisory Committee

June 21, 2023



Greg Schmidt, SSERVI Director

SSERVI has been jointly funded by NASA's **Science** and **Human Exploration** Directorates (now SMD and ESDMD) since its inception in 2008 as the NASA Lunar Science Institute (NLSI) for targeted **lunar science** and **support of human exploration**.

- SSERVI bridges the two directorates with a focus on **Exploration science— science *enabling* human exploration or science *enabled by* human exploration**.
- NASA HQ can leverage active partnerships between Institute and foreign agencies/institutions for **Mission development support and research opportunities**.
- **Cooperative Agreement Notices (CANs) set the science/exploration guidelines** to which the teams propose.
 - NASA HQ provides input on both CAN focus and team selections.
 - **CANs issued every 2.5 to 3 years** allow overlap between Teams and provides continuity of the Institute's core research to NASA's changing strategic goals.
- In 2013, NASA HQ broadened research topics to include NEAs, Martian moons in response to Administration direction.
- SSERVI Senior Review held in 2022, strong support for SSERVI structure and activities....
- SSERVI responded to Artemis with increased focus on lunar exploration research in CAN-4.



- **Currently 13 US teams**, funded in 2019 and 2023, each with 5-year cooperative agreements
 - 1200+ publications since institute became SSERVI in 2013
 - 250+ funded researchers and students
- **11 international partners** with major focus on lunar science and missions; more in development
- **Solar System Treks Project (SSTP)** – visualization tool originally created during Constellation program, enabling science, missions and outreach.
 - SSERVI assumed management at request of NASA HQ in 2013.
- **Central Office**
 - Leadership and overall institute direction
 - Planning and management of domestic teams and international partnerships
 - Community development and support through a wide variety of activities



SSERVI is committed to mentoring the next generation of space enthusiasts and leaders in innovation through partnerships with schools, educators, and students.



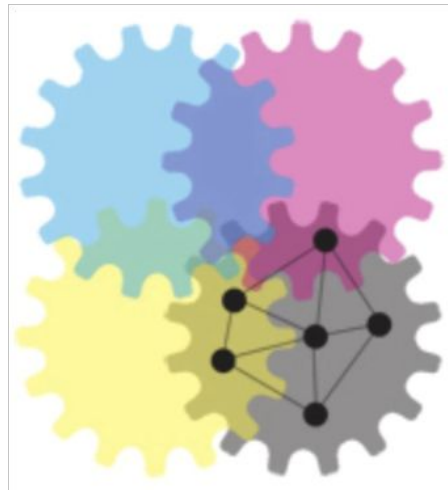
The Freebots team Freedom Middle School in Stone Mountain, GA received top awards at the Georgia Symposium on Space Innovations for their poster titled 'The Radiation Transformation: Decreasing Barriers to Long Term Space Travel.'

Key Institute goals include Equity, Diversity, Inclusion, and Accessibility (EDIA) and training the next generation.

1. Conduct groundbreaking cross-disciplinary research between the science and exploration communities



2. Integrate enabling scientific and technical analyses into NASA's human exploration and science enterprises



3. Connect the research community using innovative technological approaches for collaboration and information dissemination across geographic boundaries



4. Train and develop a diverse next generation of explorers



5. Win the hearts and minds of the public through global outreach and engagement

CAN-3 Teams *(funded October 2019)*

• **Center for Lunar and Asteroid Surface Science (CLASS)**, Prof. Daniel Britt, University of Central Florida, Orlando, FL



• **Interdisciplinary Consortium for Evaluating Volatile Origins (ICE FIVE-O)**, Dr. Jeffrey Gillis Davis, Washington University, St. Louis, MO



• **Remote, In Situ, and Synchrotron Studies for Science and Exploration 2 (RISE2)**, Prof. Timothy Glotch, Stony Brook University, Stony Brook, NY



• **Resource Exploration and Science of OUR Cosmic Environment (RESOURCE)**, Dr. Jennifer L. Heldmann, NASA Ames Research Center, Moffett Field, CA



• **Institute for Modeling Plasma, Atmospheres and Cosmic Dust (IMPACT)**, Prof. Mihaly Horanyi, University of Colorado, Boulder, CO



• **Lunar Environment And Dynamics for Exploration Research (LEADER)**, Dr. Rosemary Killen, NASA Goddard Space Flight Center, Greenbelt, MD



• **Center for Lunar Science and Exploration (CLSE)**, Dr. David A. Kring, Lunar and Planetary Institute, Houston, TX



• **Geophysical Exploration Of Dynamics and Evolution of Solar System (GEODES)**, Dr. Nicholas Schmerr, University of Maryland, College Park, MD

CAN-4 Teams (to be onboarded Summer 2023)

- **Lunar Structure, Composition, and Processes for Exploration (LunaSCOPE)**, led by Alexander Evans at Brown University in Providence, Rhode Island. The team will investigate the evolution, fate, and consequences of the lunar magma ocean, as well as the origin, abundance, distribution, and isotopic composition of volatiles.



- **Center for Lunar Origin and Evolution (CLOE)**, led by Bill Bottke of Southwest Research Institute's Solar System Science and Exploration Division, which is located in Boulder, Colorado. The team will investigate important questions related to the understanding of solar system origin and the conditions of Earth-Moon formation.



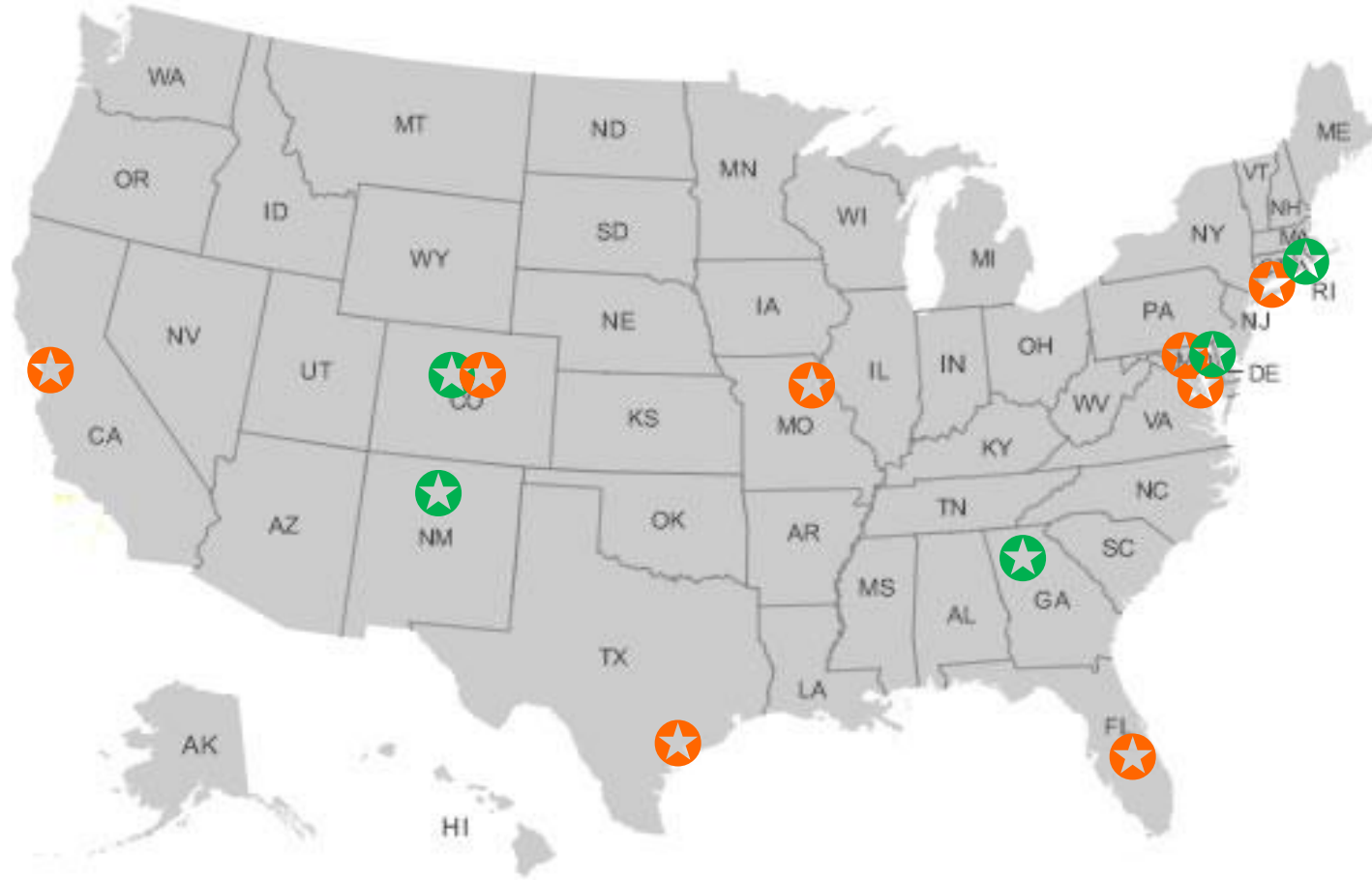
- **Research Activities Supporting Science and Lunar Exploration (RASSLE)**, led by Dana Hurley at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. The team will lay the science foundation for the future of lunar exploration in the fields of the evolution of volatiles in lunar polar regions, solar system chronology, and cryogenic sample handling.




- **Center for Lunar Environment and Volatile Exploration Research (CLEVER)**, led by Thomas Orlando at the Georgia Institute of Technology in Atlanta. The team will characterize the lunar environment and volatile inventories required for near-term sustained human exploration of the Moon.



- **Center for Advanced Sample Analysis of Astromaterials from the Moon and Beyond (CASA Moon)**, led by Charles (Chip) Shearer at the University of New Mexico in Albuquerque. The team will decipher the origin, evolution, and chronology of the ancient lunar crust through lunar sample analysis.



CAN-3 PI: 

CAN-4 PI: 

Ancient Lunar Atmosphere

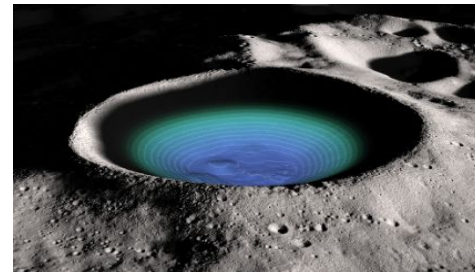
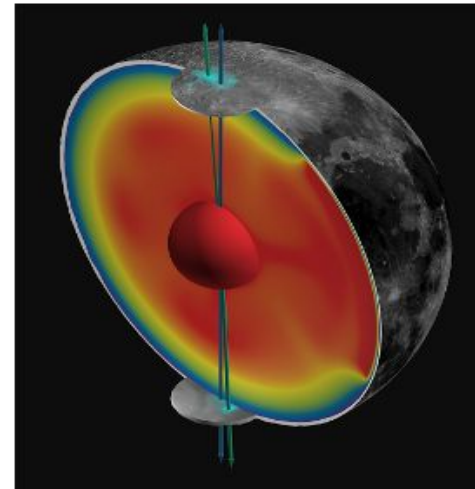
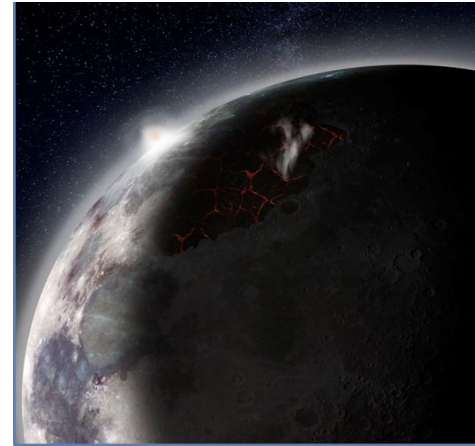
Analyses of Apollo samples (Needham & Kring, EPSL 2017) indicated that magmas that breached the lunar surface and flowed for hundreds of kilometers, carried gas components, such as carbon monoxide, the ingredients for water, sulfur, and other volatile species. New calculations show those gases accumulated around the Moon to form a transient atmosphere. The atmosphere was thickest during the peak in volcanic activity about 3.5 billion years ago and, when created, would have persisted for about 70 million years before being lost. A portion of the volatiles may have been trapped from the atmosphere into cold, permanently shadowed regions near the lunar poles and, thus, may provide a source of air and fuel for astronauts conducting lunar surface operations and missions beyond the Moon.

Lunar Polar Wander

SSERVI researchers (Siegler et al.) studied maps of lunar polar hydrogen from NASA satellite data to discover the Moon tilted away from its original axis by about five degrees roughly three billion years ago. Water ice can exist on in areas of permanent shadow, but when exposed to direct sunlight it evaporates into space. A shift of the lunar spin axis enabled sunlight to creep into areas that were once shadowed. Ice that survived this shift effectively “paints” a path along which the axis moved. This is the first physical evidence that the Moon underwent a dramatic change in orientation and implies that much of the polar ice on the Moon is billions of years old. This research can inform us as to where the volatiles currently exist on the poles of the Moon, and may open the door to further discoveries on the interior evolution of the Moon, as well as the origin of water on the Moon and early Earth.

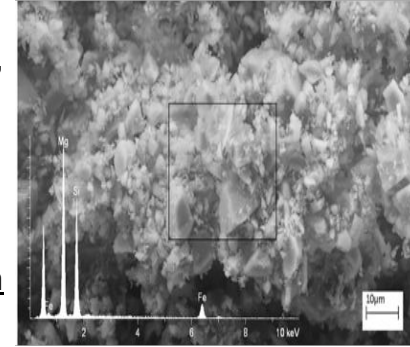
Identifying and Accessing Volatiles

SSERVI research is enabling NASA's ability to identify (RESOURCE maps), locate (Bussey's sun/shadow maps), and access volatiles (CLSE slope maps), as well as how to collect, preserve and process volatile samples (REVEALS' Lunar Volatile Extraction and Purification Pod (LVEPP)). Researchers have produced new geologic resource prospecting maps for a portion of the Schrödinger basin peak ring and adjacent basin floor (2024 CLPS mission targets).



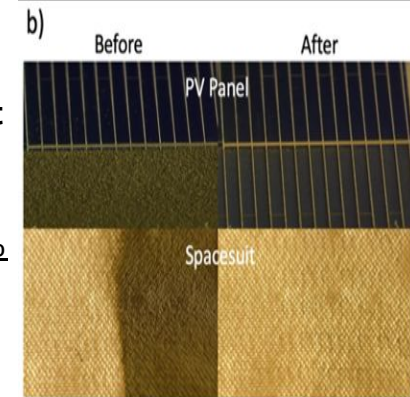
Dust Toxicity Research

RISE2 Team (PI Glotch) is studying lunar dust samples brought back by astronauts to investigate **reactive species in lunar regolith**, including silicon dioxide (50%), iron oxide and calcium oxide (45%), and other oxides (5%). Researchers discovered certain minerals that are known to quickly react with human cells and generate toxic hydroxyl radicals that have previously been linked to lung cancers. Results revealed that inhaled particles may generate toxic hydroxyl radicals for up to 5-6 days in lung fluid. Models indicate that olivine in the human lungs can induce detrimental health effects similar to asbestos exposure. The work indicates that the lunar surface may be even worse for human health than we thought, as inhaled lunar dust can settle in the human lungs for years and could induce long-term potential health effects like that of silicosis.



E-beam Dust Mitigation Technology

SSERVI IMPACT team (PI Munsat) is developing an **electron beam technology to remove lunar dust** from sensitive surfaces such as spacesuits. Charged dust is ejected from the surface as a result of strong electric repulsive forces. Varying the e-beam incident angle optimized cleaning efficiency by 10-20%. The multiple e-beam demonstration resulted in most of the insulating samples showing 80-90% cleanliness after only 2-3 mins.



Exolith Lab Regolith Development

SSERVI's CLASS team (PI Britt) is **developing new regolith simulants** and agglutinates using Lunar simulants. Over 11 types of Lunar, Martian, and asteroid simulants are available for agency or community procurement, including Lunar Highland (LHS-1) and Mare (LHM-1) simulants. For more info visit <https://exolithsimulants.com/>

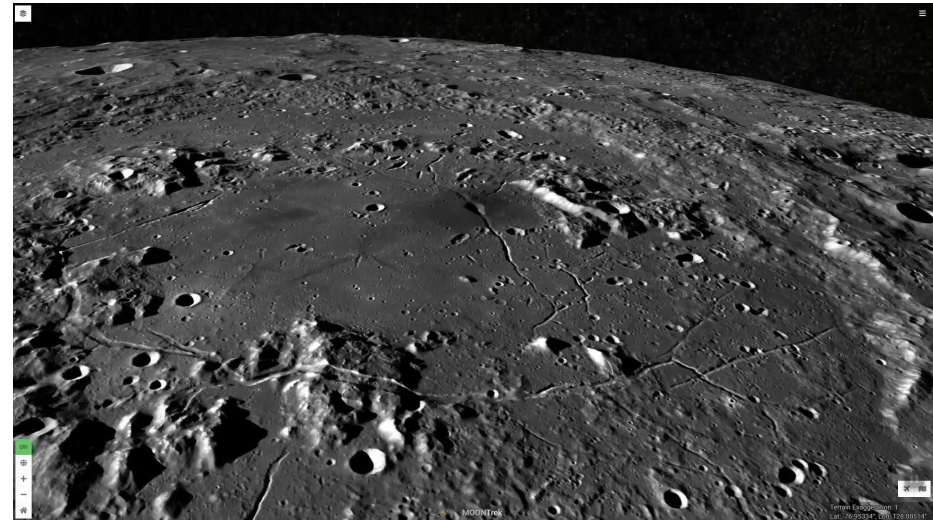


New Space Materials: Neutron shielding, electrostatic charge dissipation, and dust mitigation

REVEALS Team (PI Orlando) is designing **optimized shielding** for Lunar neutrons by distributing boron in polyethylene (HDPE) composites. Developed spray-on coatings for static charge dissipation and dust mitigation for space suits, and other EVA applications. Results show a significant decrease in effective radiation dose, improving shielding technology by 4x to 30x over Al and 1.5x to 2x over HDPE.

The NASA Solar System Treks Project is an integrated suite of data visualization and analysis tools supporting mission planning, lunar/planetary science, and public engagement using advanced analysis tools, high resolution geospatial data, and digital elevation models.

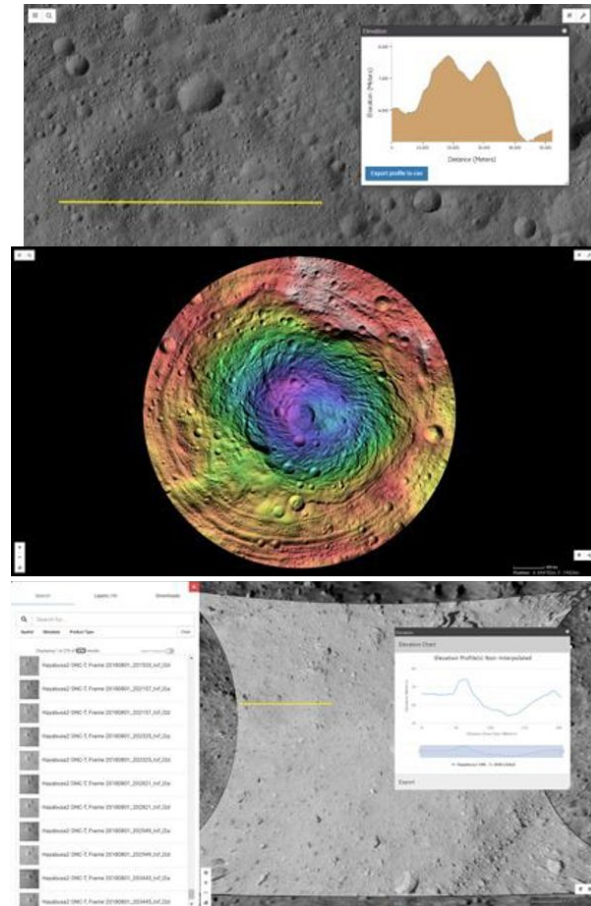
- Initially developed to support Constellation Program site selection and analysis – 2008
- Moon Trek Released – 2017; replaced LMMP
- HQ and various missions have commissioned a variety of new portals for a growing number of planetary bodies that have been added to the Treks suite, **facilitating comparative planetology**.
- 2D & 3D Interactive Visualization (overlays, sharing, flyovers, 3D printing, custom VR experiences)
- Wide range of analysis tools take advantage of Machine Learning (ML) and Artificial Intelligence (AI)
- All Solar System Treks are available as resources for NASA Science Activation partners and to the greater outreach and education community.
- The online web portal requires no downloads; **anyone with internet access** can view images and other digital products.



Mission Support for NASA and its International Partners

SSTP portals have been commissioned by missions to facilitate dissemination and visualization of mission data as well as for outreach and planning in advance of the return of mission data.

- Dawn – Vesta Trek and Ceres Trek
- Cassini – Titan Trek and Icy Moon Treks
- OSIRIS-REx – Bennu Trek
- Hyabusa2 – Ryugu Trek
- BepiColombo – Mercury Trek
- Europa Clipper – Europa Trek
- MMX – Phobos Trek (in development)
- COLMENA – Moon Trek lunar surface analyses
- Artemis, VIPER, Endurance – Traverse planning, data dissemination, ballistic dust hazard analysis
- Lunar Trailblazer – Data dissemination and visualization
- Curiosity and Perseverance – Line of sight communications analysis/planning
- CLPS – Landing site analysis



A network of 11 International teams leverage government, academia, and industry to advance science and engineering technologies on a no-exchange-of-funds basis.

TIMELINE OF INTERNATIONAL PARTNERSHIPS



Additionally, researchers from the following countries have contacted SSERVI to start new proposals for partnership:

- Taiwan
- Namibia
- India
- Mexico
- Norway

Numerous achievements since inception of international program including establishment of pan-European lunar science consortium and annual ELS

The 11th European Lunar Symposium (ELS) will be held under the umbrella of the European nodes of SSERVI on June 27-29, 2023 at the Palazzo della Salute in Padua, Italy.

This conference brings together the European scientific community involved in lunar science and exploration and the international experts engaged in lunar missions.

The conference will consist of both oral presentations and posters with particular emphasis on lunar science and technology for future exploration missions, lunar in-situ resource utilization (ISRU), and results from mission studies preparing for future human exploration on the lunar surface.



Last Year's Impact: The 2022 European Lunar Symposium produced 73 recorded presentations with nearly 5,000 live views and over 800 on-demand playback views.

NASA EXPLORATION SCIENCE FORUM

JULY 18-20, 2023

UNIVERSITY OF MARYLAND
COLLEGE PARK



The 2023 NASA Exploration Science Forum (NESF) will be held, in-person and virtually, at The Hotel, University of Maryland in College Park Maryland, from July 18 - 20, 2023. NESF is SSERVI's biggest annual event, held since 2008.

- **A Hybrid Event for All**
 - We are excited to welcome audiences and presenters in-person and virtually for a hybrid meeting experience enabling rich science discovery, discussions, and networking opportunities.
- **Networking Everywhere**
 - People are at the heart of SSERVI and our Forum, so we're making sure that all attendees have opportunities to network with each other.
- **The Science**
 - Hear about the latest science discoveries, share your ideas, and help accelerate our mission.
- **For the Next Generation**
 - Students present their work to peers and distinguished scientists, connect with possible mentors for career advancement, or compete in student poster competitions.

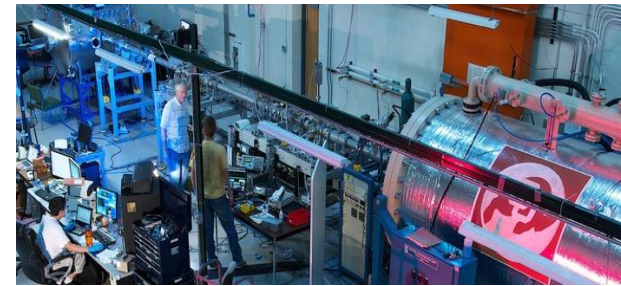
Last Year's Impact: *The 2022 NESF produced 144 recorded presentations with over 3,500 live views*

Lunar Lab & Regolith testbed (NASA ARC)

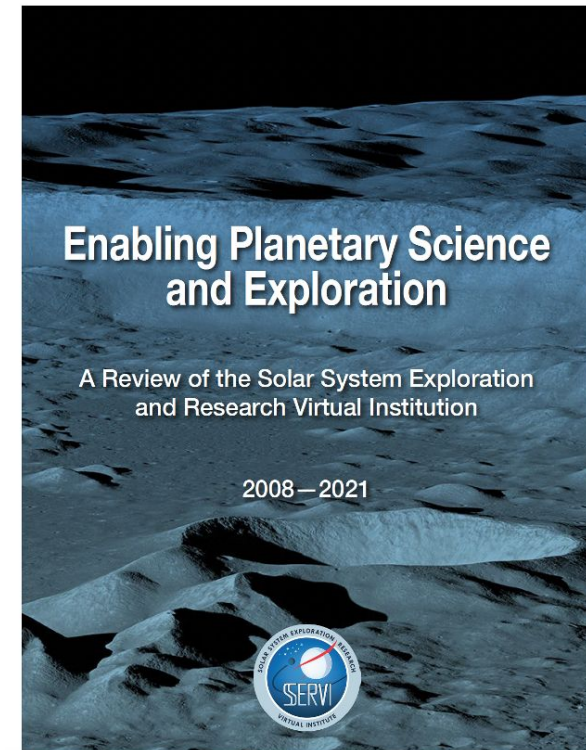
- SSERVI-managed testbed at NASA Ames contains 8 tons of JSC-1A **lunar regolith** and 22 tons of **Anorthosite simulant** available to SSERVI teams and other NASA partners.

Dust Accelerator Lab (U. Colorado)

- Currently the only setup in the world capable of generating hypervelocity dust particles ($\gg 100$ km/s). The 3 MV linear electrostatic dust accelerator is used for **impact studies and instrument calibration** for space applications.
- Exolith **Regolith Simulant Manufacturing Lab** (U. Central Florida)
 - Provides simulant for important exploration and science tests
 - Largest supplier in world; shipped >2418 Kg to 352 unique customers
- **PLANETAS Lab** at NASA Ames (field portable instrumentation available to the community).
- Ultra High Vacuum **Ice and Gas Target Chambers** (U. Colorado)
- **Radiation Facility** (NASA GSFC)
- **Ultra-Violet Spectrometry** Laboratory Facility (PSI)
- **Microgravity** Drop Tower (U. Central Florida)
- **Vibrational Spectroscopy** Lab (Stonybrook U., NY)
- **Physical Properties** Lab (U. Central Florida)



- A Review of virtual institutes was recommended by previous planetary decadal midterm
- Independent committee was chartered by PSD to comprehensively review SSERVI (from its inception as NLSI)
- Key leaders:
 - HQ oversight: A. Nahm
 - Chairs: C. Evans (JSC) and C. Shearer (UNM)
- Committee report available at
- <https://www.lpi.usra.edu/NASA-academies-resources/sservi-report-300-dpi-01072022.pdf>
- Key recommendations:
 - SSERVI should continue, with support from both science and exploration
 - Lunar focus for CAN-4
- Additional input from recently-released planetary decadal report in line with senior review recommendations



SSERVI continues working with key stakeholders—including NASA’s Mission Directorates, research teams, and international partners—to advance the goals of Artemis and enable a new era of human exploration of the Moon.

“The SSERVI Senior Review Panel (SSRP) recommends that SSERVI should continue to be supported in a predictable manner by both SMD and HEOMD(ESDMD)”

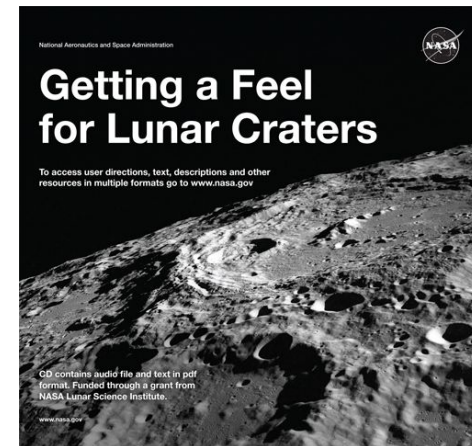
“Research at the junction of [science and human exploration research] is critical for enabling a successful human exploration campaign to the Moon. The SSRP concluded that SSERVI brings high value to the planetary science and exploration communities as a large, cross-disciplinary institute.”

“The SSERVI style of research complements the more targeted ROSES Research and Analysis (R&A) program in the planetary sciences. The review panel found that SSERVI is well positioned to both bridge and amplify NASA science and human exploration research, and funding from both NASA directorates should continue.”

“SSERVI focus should be directed on the Earth’s Moon for the next cycle of node selections, and the current SSERVI nodes should align their work to include a focus on the Moon.”

“... rebuild and replenish the sample science community over the coming decade. Consider sample training, collection, documentation, preservation, curation, measurements, and science with integration among nodes in future focus themes and CANs.”

- SSERVI has a strong track record and continued interest in supporting new commercial lunar efforts.
Major history back to NLSI days including strong support of **GLXP** and potential associated commercial lunar science program.
Lunar Science for Landed Missions had major commercial participation.
- Commercial partnerships have been instrumental in the development the **Lunar Regolith Testbed** and production of SSERVI's **Books for the Blind**.
- Provided Interface for CLPS leadership at SSERVI Executive Council Meetings.



SSERVI is deeply committed to taking steps to enable positive change in equity, diversity, inclusion, and accessibility (EDIA):

- While EDIA projects have been a part of SSERVI for a long time, it has been a major focus of the Institute since 2020.
- CAN 4 included EDIA requirements for the first time.
 - Other Institute Objectives (OIO) included a Team Inclusion Plan, Community EDIA Plan, and Code-of-Conduct.
- SSERVI EDIA Focus Group was established in mid 2020 and has become one of the most active Focus Groups in the institute, with many members from the SSERVI PIs and non-SSERVI community.
- SSERVI researchers active writers/cosigners of EDIA white papers for Planetary Science Decadal Survey.
- Commitment to accessibility has permeated SSERVI practices.
 - E.g., tactile books for the blind have made extraordinary progress in explaining eclipses, lunar morphology and other topics to the visually impaired.



Equity, Diversity, and Inclusion Focus Group Artwork.



Diversity is
being invited
to the party

Inclusion is
being invited
to dance

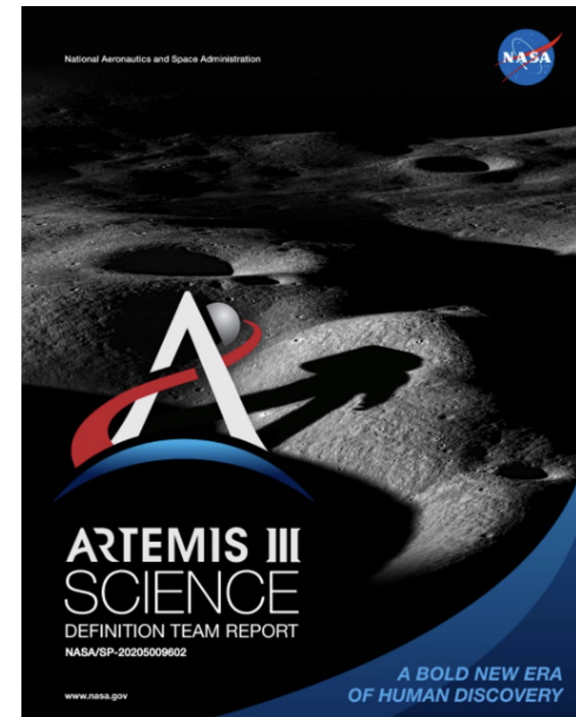
Equity is
getting to the
party

Social Justice
is welcome

- Students and young professionals
 - Support of students since beginning through LunGradCon, Next Generation Lunar Scientists and Engineers (NGLSE), and many others.
- Travel Support
 - SSERVI provides student travel support to major scientific meetings.
- Internships
 - SSERVI internships provide hands-on research and professional development opportunities.
 - NASA Postdoctoral Program (NPP) with postdocs shared between teams to facilitate inter-team collaborations.
- Training
 - SSERVI provides Laboratory and Field Research training opportunities.
- Public engagement
 - A wide range of supported activities ranging from “Books for the Blind,” to eclipses, K-12 engagement, and beyond.



- Years of support to community organizations
 - LEAG – ExComm member for 14 years, joint workshops, student support
 - LSIC – on LSIC ExComm, LSIC director attends SSERVI EC, charter participant in all workshops
 - Former SBAG Executive/Steering Committee Member
- Broad virtual support of science and exploration communities
 - SSERVI was able to provide immediate support to planetary and exploration communities in the pandemic
 - Nearly 20 Lunar Surface Science Workshops, Phobos/Deimos, lunar landing sites and many others
- NASA Exploration Science Forum – only meeting focused on bridging exploration/science, core SSERVI meeting
- International partnerships – currently 11 with several in development
 - Created cross-European consortium with annual European Lunar Symposium meeting since 2012
- Four annual awards widely recognized in community
- Focus groups open to entire community
 - Wide range of topics including lunar volatiles, IDEA, Analogs, and DAP
 - Plans to use FG to address exploration goals; valuable input from community



SSERVI contributions to the Science Definition Team Report (PI Heldmann SDT member) are informing Artemis utilization objectives.

Q&A

