Lunar Surface Innovation CONSORTIUM

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

Lunar Surface Innovation Consortium ISRU Focus Group Updates

Space Resources Roundtable
June 3-6, 2025, Golden, CO

Jodi Berdis, **Karl Hibbitts**, Anthony Coburger, Paul Burke, Michael Nord, Richard Miller

Lunar Surface Innovation Initiative (LSII)

LSII's role is to accelerate the STMD LIVE domain in achieving technologies for a sustained lunar presence. LSII works across industry, academia, and government to arrive at transformative capabilities for lunar surface applications.

Formulate and integrate technology maturation across TRL levels

Utilize surface flight opportunities to inform key technology development

Grow the Lunar Surface Innovation Consortium (LSIC) to foster innovation across sectors

Leverage innovative partnering and collaboration to expedite technology development

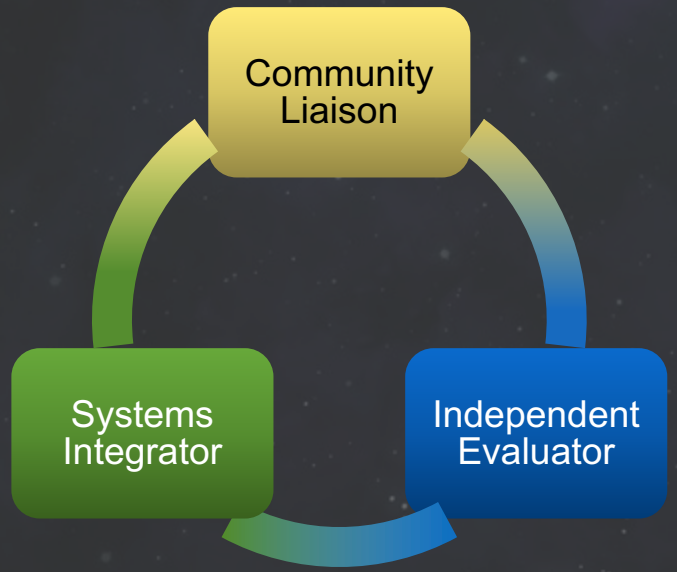
"LIVE, NASA Space Tech Surface Infrastructure and Exploration", AIAA ASCEND, August 2024, Niki Werkheiser, Director of Technology Maturation; LIVE Domain Lead, NASA STMD

Lunar Surface Innovation Initiative (LSII)

LSII SI

Lunar Surface Innovation Initiative Systems Integrator

LSII examines and supports technology development for an Enduring Lunar Presence and the Expansion of the Cislunar Ecosystem, aligned with NASA's Moon to Mars Objectives.



LSIC

Lunar Surface Innovation Consortium

Alliance of universities, commercial companies, non-profit research institutions, NASA, and other Government Agencies with a vested interest in the campaign to establish a sustained presence on the Moon.

Focus Areas

Crosscutting Capabilities

The Crosscutting Capabilities focus group provide expertise on topics that feed into the goals of the Foundational Technologies group and promote collaboration amongst internal and external stakeholders.

In Situ Resource Utilization

The ISRU focus group will advance technologies for the collection, processing, storing, and use of material found or manufactured on other astronomical objects.

Excavation & Construction

The Excavation & Construction focus group will assist NASA in evaluating technologies that enable affordable, robust, autonomous manufacturing and construction on the lunar surface.

Surface Power

The surface power focus group will provide specific recommendations to NASA for rapidly achieving appropriate-scale power-related technologies needed to enable sustained presence and exploration.

LSIC | ISRU Focus Area

The In Situ Resource Utilization (ISRU) Focus Area (FA) will advance technologies for the collection, processing, storing, and use of materials found or manufactured on the Moon. In addition to component technologies, the ISRU FA will examine the system-level challenges to achieving ISRU. Examples of topics to be explored include demonstrating systems for localizing water on the Moon and measuring its geophysical parameters, collecting and purifying water on the lunar surface, extracting oxygen and metals from lunar regolith, and the engineering / knowledge / integration challenges in achieving lunar ISRU at scale.

Meetings: 3rd Wednesday of the Month 11:00 am – 12:00 pm EST

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LSIC Co-Leads

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Paul Burke

NASA Points of Contact

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ISRU Systems Capability Lead

Dr. Julie Kleinhenz
Deputy ISRU Systems Capability Lead

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LSIC | ISRU Annual Goal and Priority Activities

ISRU 2025 Annual Goals

- Expand and foster the ISRU community by serving as an avenue for networking, collaborating, and learning (regarding ISRU and other FGs' technological development progress), as well as funding, career, and information dissemination opportunities.
- Identify, prioritize, and examine technical and knowledge gaps related to H_2O, O_2, and metals production and establish a clear path forward toward overcoming/closing those gaps.

ISRU Recent Highlights and Upcoming Activities

- September 2024 "O_2fR Pilot Plant Path Forward Workshop": We discussed evaluable pros and cons of various O_2fR technologies and strategies from a component and systems integration perspective.
  - Our ongoing Oxygen From Regolith (O_2fR) systems study aims to examine the interconnectedness of various subsystems surrounding an oxygen production system. The objective is to enhance community understanding of system-level concerns. We will report out on our progress, and we welcome any inputs from the community!
- July 2025: Testing, Interfacing, and Funding Workshop
  - O2fR Interfacing: Systems Interface Worksheet Updates and Path Forward
  - STeP-IT / LPG Testing: Success Stories and Lessons Learned from Similar Networks and Consortia
  - Non-Governmental Funding: Accessing Funding Resources and Opportunities from Non-Government Sources

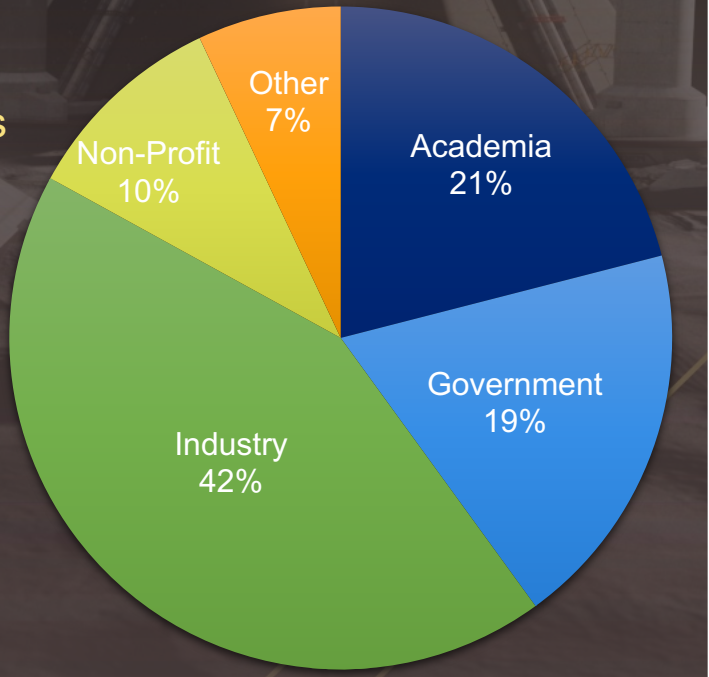
LSIC | O2fR Collaborative Systems Interface Virtual Workshop

Goal: promote system-level thinking

- Explored the interconnectedness of ISRU functions and providing a framework to help the ISRU community identify quantitative mismatches between upstream and downstream system parameters.
- Facilitated application of the O2fR Collaborative Systems Interface Workbook and considered the upstream and downstream interface conditions that impact ISRU system designers.

Registrants: 225

Attendees: 132



Key Takeaways

- Standardizing interfaces are crucial
- Designing modular ISRU systems is critical to enabling scalability
- ISRU community will benefit by sharing approaches of managing parameters
- Technology developers want mission requirements and better understanding of the end-users
- Terrestrial testbeds will be key to demonstrate ISRU processes in Moon-like environments
  - Subsystem-level testing would be most insightful and cost-effective
  - Digital twins and system simulations would also be useful

Community Feedback

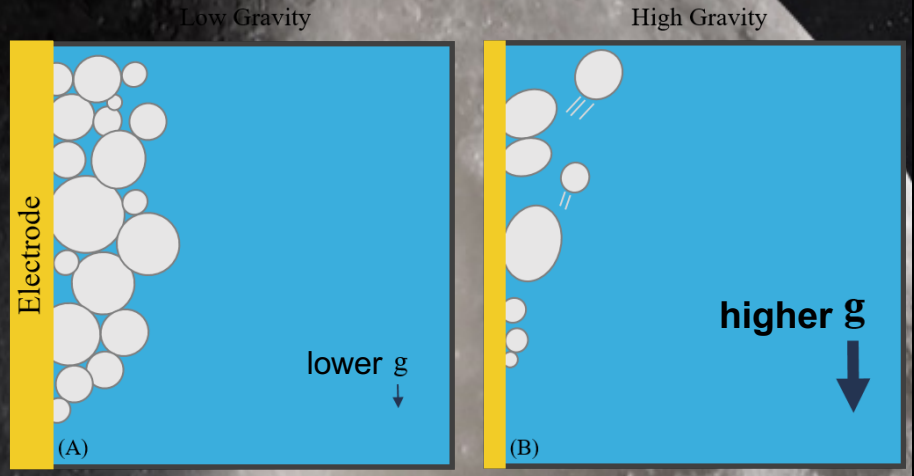
- Survey Response – LSIC ISRU FG asked the community how else we could help address system interfaces. The community's top response is standardization.
  - LOGIC aims to enable interoperability standards for ISRU, increased comms and advertisement of LOGIC may be needed to increase awareness
  - LSIC ISRU FG's aim remains characterizing parameters at system interfaces. LSIC ISRU FG may fill non-LOGIC related gaps

Workshop Materials: https://lsic.jhuapl.edu/Events/Agenda/index.php?id=571

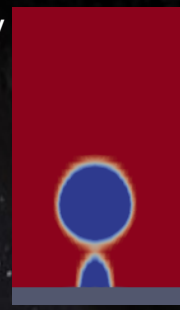
Modeling Water Electrolysis, MSE, and MRE across Gravity Levels

- Molten Regolith Electrolysis (MRE):
  - Case study relevant to other O2fR technologies
- Problem with Bubbles in Low-G:
  - Electrolysis could be stalled by lack of bubble motion
  - Bubble detachment scales nonlinearly with gravity
- CFD Modeling of Water Electrolysis, Molten Salt Electrolysis (MSE), and MRE:
  - Modeled at 1 g, Martian Gravity, and Lunar Gravity
  - Bubble volume and detachment rates scale nonlinearly with gravity
  - MRE is highly dependent upon electrode surface properties and electrolyte fluid properties
  - Water and MSE have similar behavior
  - Bubble do detach (albeit at slow rates) in Lunar gravity
- Variables Tested:
  - Types of Electrolysis (Water, MSE, MRE)
  - Gravitational Acceleration
  - Orientation of Electrode
  - Surface finish of electrode

MRE Horizontal Electrode (1 g)

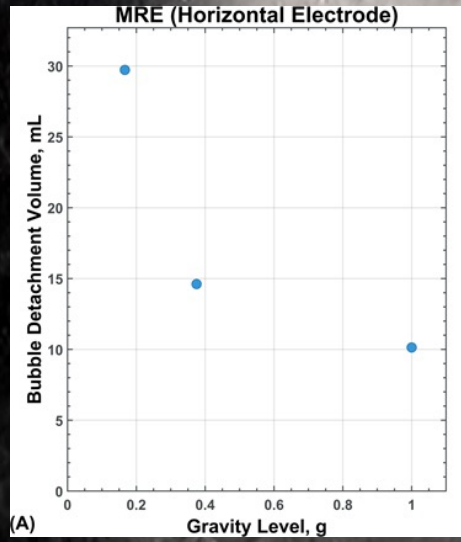


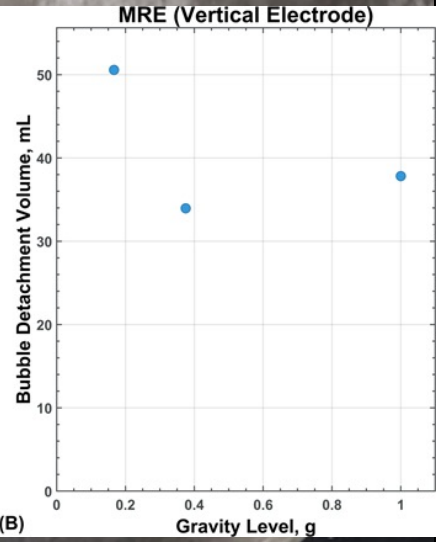
Decreased bubble detachment at lower gravity levels



Water Horizontal Electrode (Lunar g)

Water Vertical Electrode (Lunar g)





Burke et al., *in* Frontiers in Space Tech, 2024.
https://doi.org/10.3389/frspt.2024.1304579

LSIC Lunar Proving Grounds Efforts

1. What are the attributes of a facility(ies) that would be needed to demonstrate on Earth that a system of systems would work on the Moon?
2. **What sort of network or consortium could be put into place to help aid facility users and facility operators achieve this goal?**

Lunar proving grounds are desired and needed for developing technologies critical for sustained presence on the Moon.	**An LPG should focus on integration, validation, lifecycle testing, and humans-in-the-loop.**	**An LPG should have a pathway for international and small business access to facilities.**
Digital engineering tools (such as model-based system engineering approaches) can meet a sub-set of LPG elements.	**Deconflicted and coordinated existing facilities can serve many of the component-level testing prior to operational testing at an LPG.**	**An LPG should include interoperable infrastructure; LPG infrastructure must work with varied testing technologies, and enable testing of technology interoperability.**

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ISRU Testing, Interfacing, and Funding Workshop

Wednesday July 16th 2025 – Virtual

Objective

- Explore testing, interfacing, and funding opportunities for the ISRU community

Session Topics

- O_2 From Regolith: Systems Interface Worksheet updates and path forward
- Proving Grounds: Success stories and lessons learned from similar networks and consortia
- Non-Governmental Funding: Accessing funding resources and opportunities from non-government sources

Registration Opening Soon!

https://lsic.jhuapl.edu/Events/Agenda/index.php?id=624

Lunar Surface Innovation Consortium

SIGN UP!

LSIC welcomes participation from throughout the world, with the goal of connecting those interested in participating in humanity's future in space to one another!

https://lsic.jhuapl.edu

Products and Events

- Lunar Expertise for the Community
- Documents and Reports
- Notice board for employment and internship opportunities
- Facilities Directory
- News and Events Calendar
- Wiki Sites
- Community Whitepapers
- Simulant Reports
- Simulant and Data Buy Surveys
- Newsletters
- Specialized Workshops
- Annual Fall and Spring Meetings

…and more!

LSIC | ISRU Additional Upcoming Activities

- July 16, 2025: Testing, Interfacing, and Funding Workshop (advert on next slide)

- ASCEND 2025 Presence
  - Manuscript and oral presentation on O_2 Systems Integration
  - Workshop/Roundtable session on O_2 Systems Integration

- Various whitepaper development – including:
  - Excavation & Construction's Lunar Infrastructure Collaboration (LInC)
  - Networks of proving grounds
  - Resource knowledge gaps (such as He-3 and water ice)
  - System-level demos for O2fR technology

ISRU Community: How can we help you most?

Lunar Surface Innovation

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