Lunar Surface Innovation CONSORTIUM

JOHNS HOPKINS APPLIED PHYSICS LABORATORY

Lunar Surface Innovation Consortium ISRU Focus Group Updates

Space Resources Roundtable

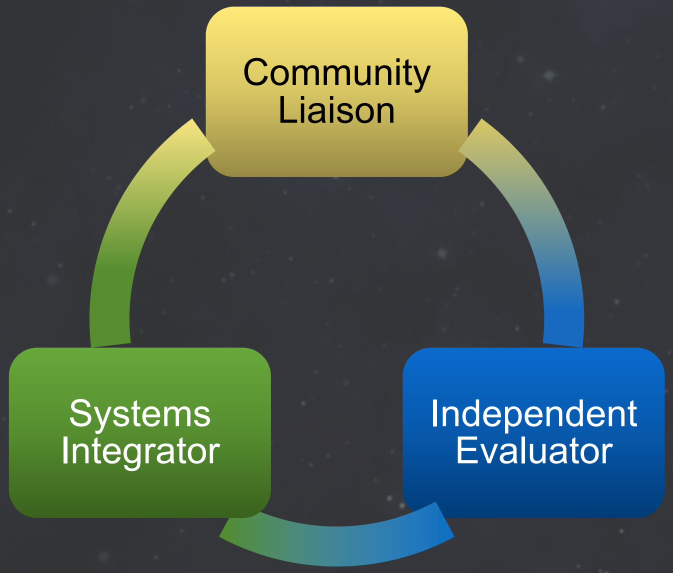
June 4-7, 2024, Golden, CO

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

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

Lunar Infrastructure Foundational Technologies

Crosscutting Capabilities

The Crosscutting Capabilities focus group will provide expertise on an array of topics which 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 material 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 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 | ISRU Annual Goal and Priority Activities

ISRU 2024 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 O2 and metals production and establish a clear path forward toward overcoming/closing those gaps.

ISRU Wants You To Know

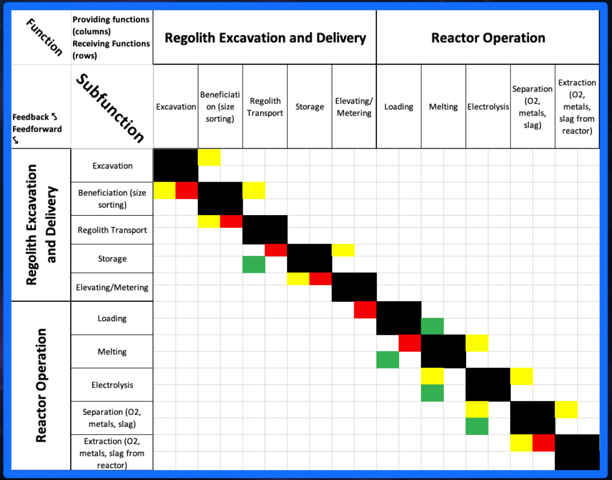
- Many of our Monthly telecons will start including more "working" time, with driven discussions and polling to encourage participation and conversation.
- We look forward to a dedicated Networking Telecon in June!

ISRU Recent Highlights and Upcoming Activities

- Our own Paul Burke published on MRE O_2 Bubble Modeling: https://doi.org/10.3389/frspt.2024.1304579
- Planned workshop: September 2024 "O2fR Pilot Plant Path Forward": We'll discuss evaluable pros and cons of various O2fR technologies and strategies from a component and systems integration perspective.
- Our Oxygen From Regolith (O2fR) 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 look forward to reporting out on our progress, and we welcome any inputs from the community!

SRR Planned Roundtable Discussion: LSIC Oxygen From Regolith (O_2fR) Systems Engineering Framework

- Design Structure Matrix
  - Uncovers dependencies between subsystems
  - Identifies physical parameters passing through interfaces



- Interface Worksheet
  - Organizes subsystem interfaces and interfacing physical parameters
  - Tracks expected values of physical parameters at interfaces to identify mismatches

UPSTREAM SUBSYSTEM → SUBSYSTEM

Provider	Interfacing Quantity	Provider Expectation	Receiver Expectation	Interfacing Quantity	Receiver
Regolith Processing & Handling	Regolith Processing Rate	### kg/day	### kg/day	Regolith Processing Rate	ISRU Reactor
Power	Power	### kW_th	### kW_th	Power	ISRU Reactor

SUBSYSTEM → DOWNSTREAM SUBSYSTEM

Provider	Interfacing Quantity	Provider Expectation	Receiver Expectation	Interfacing Quantity	Receiver
ISRU Reactor	O2 Production Rate	### kg/hr	### kg/hr	O2 Production Rate	O2 Storage
ISRU Reactor	Max ISRU System Operating Temperature	#### K	#### K	Max ISRU System Operating Temp.	O2 Storage
			#### K		Liquefaction
			#### K		Regolith Processing and Handling

LSIC Lunar Proving Grounds Workshop
July 12-13, 2023 (Hybrid)

Overarching Goal: 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?

- **~300 individuals (100 in-person)** from NASA/Academia/Commercial/Non-profits

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.

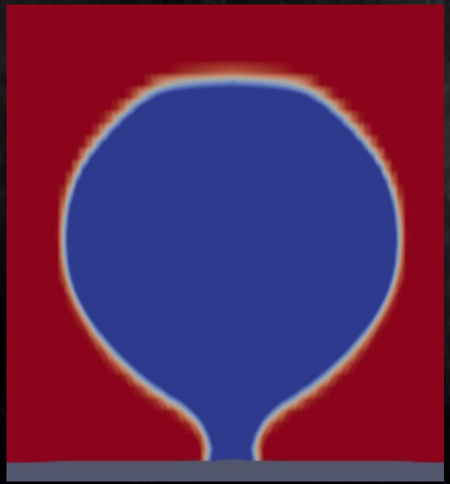
An LPG should include interoperable infrastructure; LPG infrastructure must work with varied testing technologies, and enable testing of technology interoperability.

Potential follow-on to LPG workshop/meeting is under review

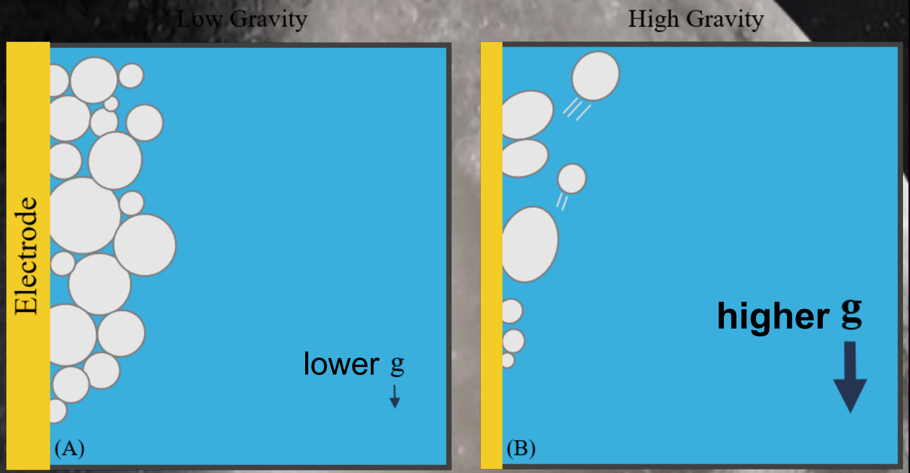
Modeling Water Electrolysis, MSE, and MRE across Gravity Levels

- Molten Regolith Electrolysis (MRE):
  - In-situ production of oxygen
  - In-situ production of metal alloys
- Problem with Bubbles in Low-G:
  - Electrolysis could be stalled due to decreased bubble detachment (decreased buoyancy)
  - 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

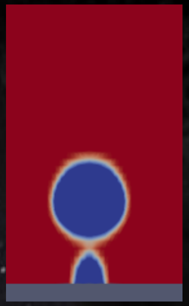
Burke et al., *in* Frontiers in Space Tech, 2024. https://doi.org/10.3389/frspt.2024.1304579



MRE Horizontal Electrode (1 g)

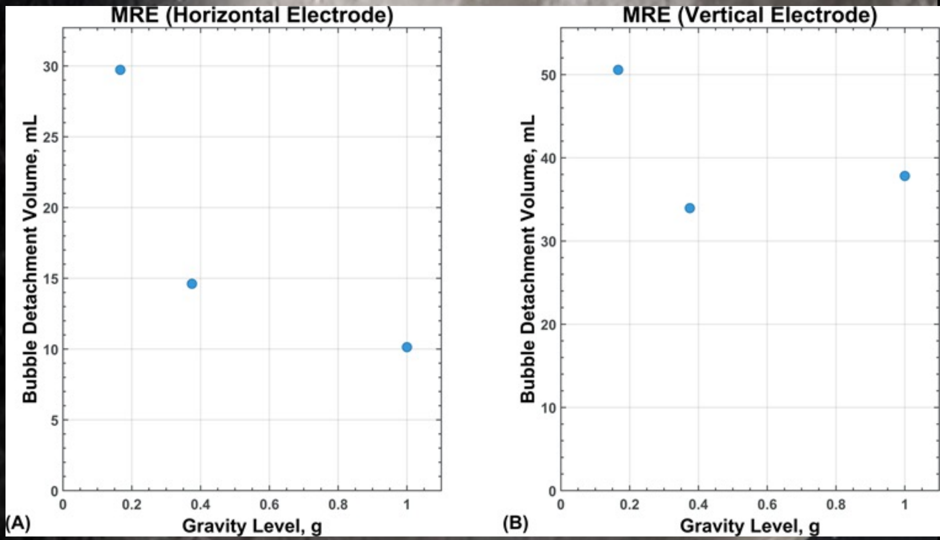


Decreased bubble detachment at lower gravity levels



Water Horizontal Electrode (Lunar g)

Water Vertical Electrode (Lunar g)



LSII | Water Prospecting: Finding the Water

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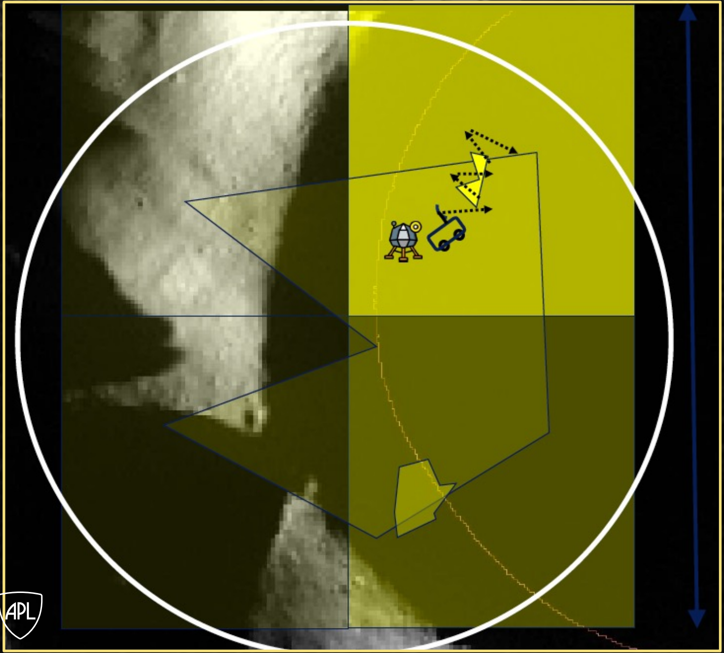
What do we need to know?

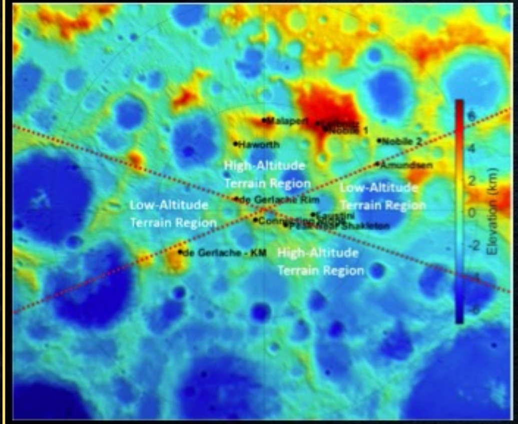
1. Location and abundance in the subsurface
2. Location and abundance on the surface
3. Physical state
4. Composition/contaminants
5. Modeling

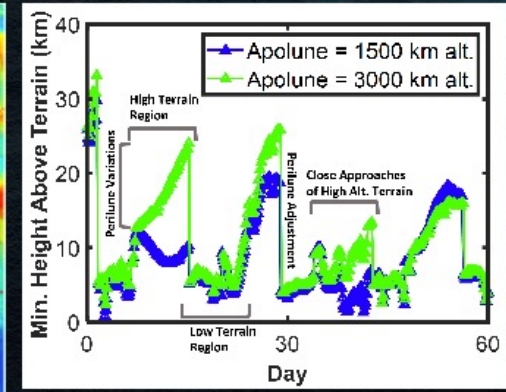


Orbital high resolution recon with Neutron Spectroscopy

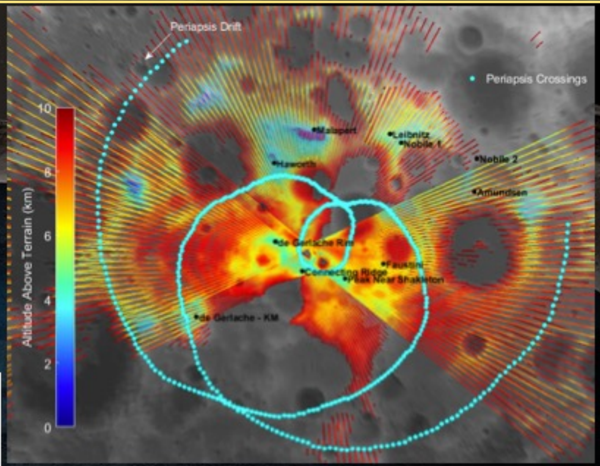
Constraining the areas of interest in PSRs

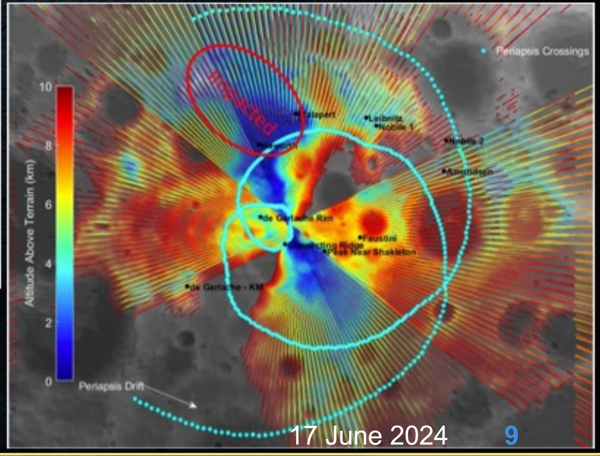
Active periapsis control has the potential to achieve orbits as good as 5 km and no worse than 10 km above PSR locations of interest.





Shannon et al., 2022





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!

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