JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

The Lunar Surface Innovation Consortium: Collaboratively Developing Lunar Surface Power Systems

Space Power Workshop

April 24, 2024

Lunar Surface Innovation
CONSORTIUM

Dr. Joseph P. Kozak

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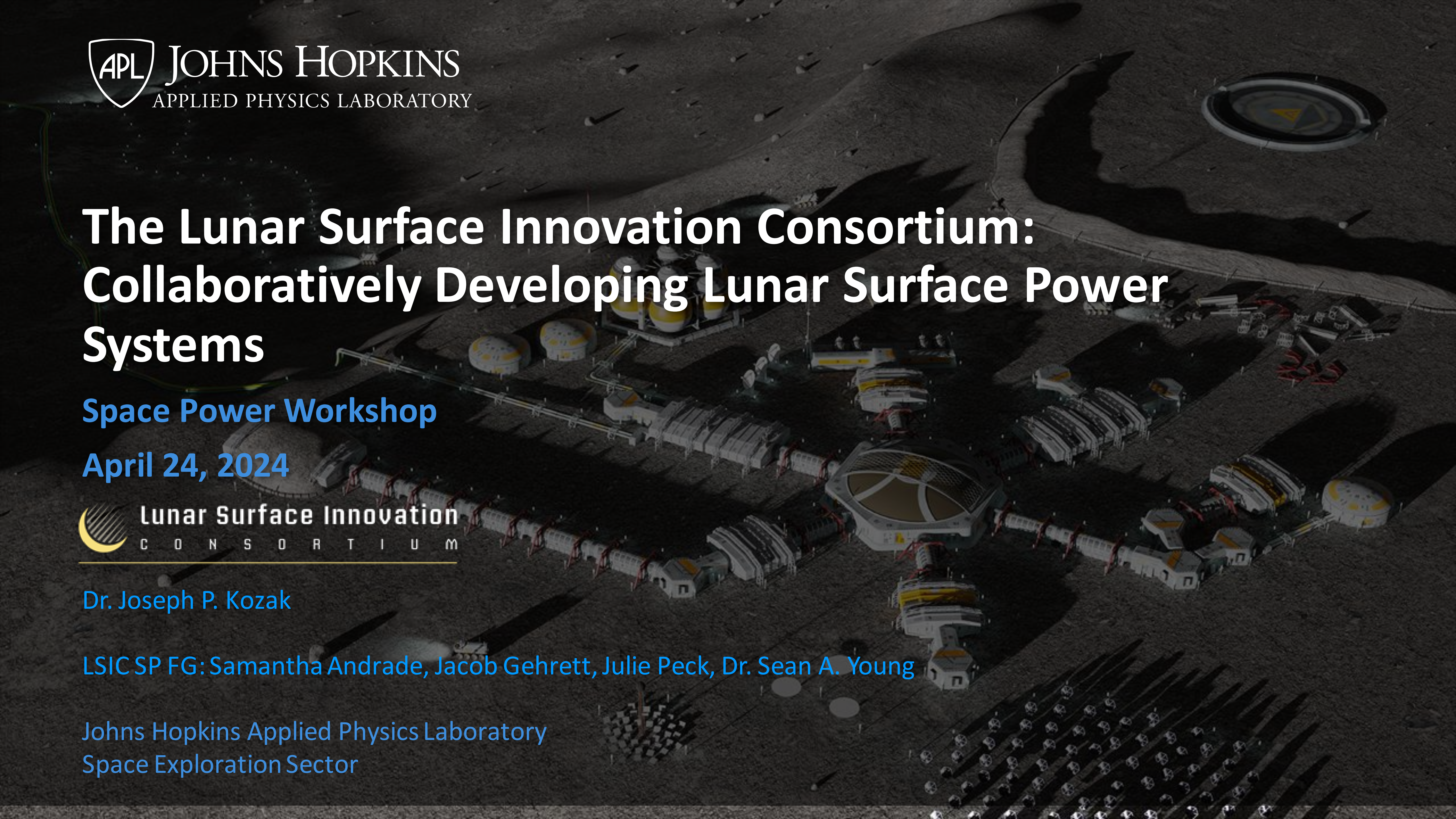
Johns Hopkins Applied Physics Laboratory
Space Exploration Sector



LSIC | Outline

- What is LSII/LSIC?
- Who are we?
- What does the Surface Power Focus Area do?
- How can you get involved?
- Summary

LSIC | Outline

- What is LSII/LSIC?
  - Mission and Objectives
  - Organization and Focus Areas
  - Partnerships
  - Scheduled Events
- Who are we?
- What does the Surface Power Focus Area do?
- How can you get involved?
- Summary

LSII | Mission

NASA's Lunar Surface Innovation Initiative (LSII) works across industry, academia, and government through in-house efforts and public-private partnerships to develop transformative capabilities for lunar surface exploration

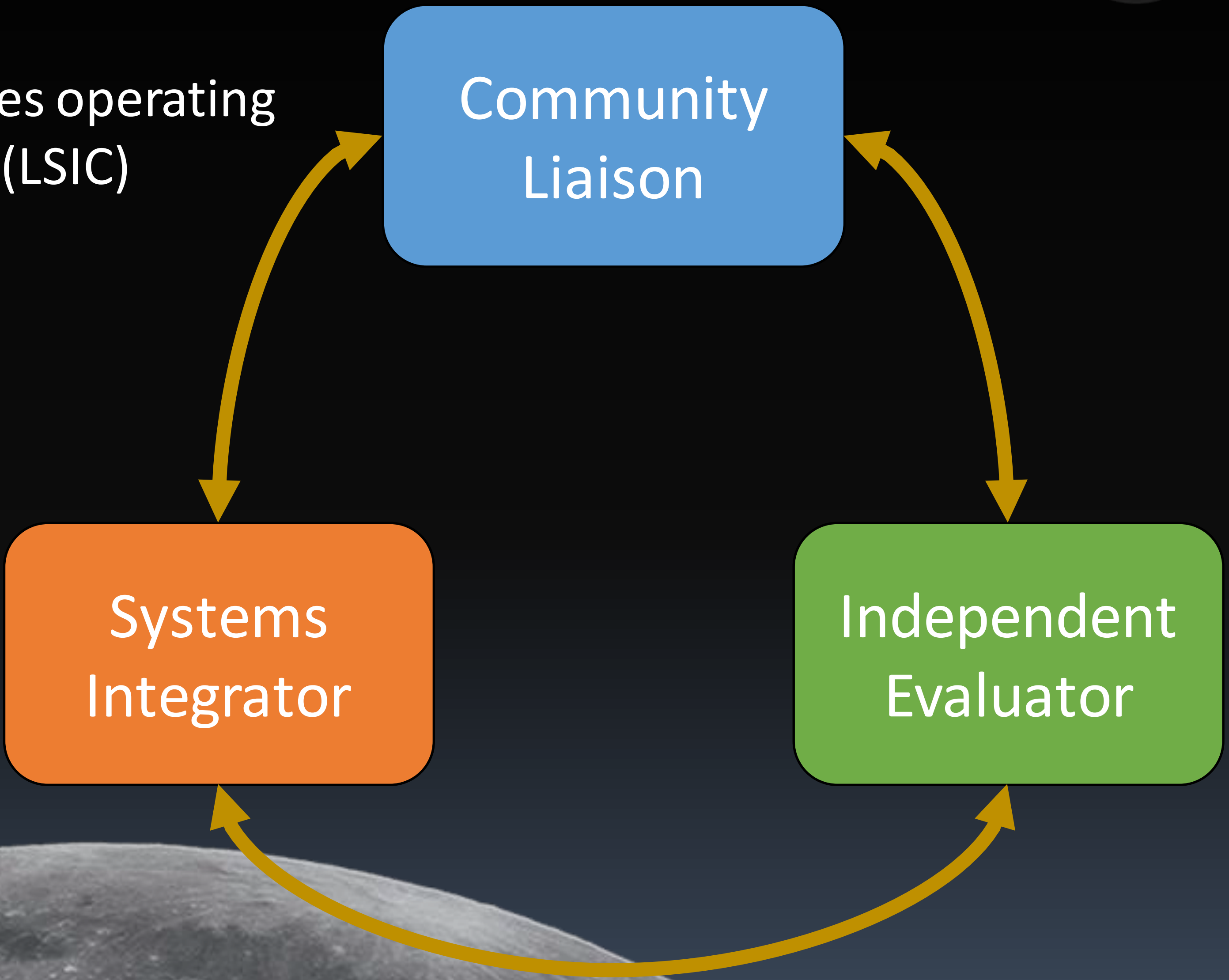
- LSII is a NASA Space Technology Mission Directorate (STMD) activity
- Formulating and integrating technology maturation activities across the TRL pipeline and Space Tech programs
- Leveraging innovative collaborations and partnerships to expedite technology development
- Utilizing early uncrewed lunar surface flight opportunities to inform key technology development

LSII | JHU/APL's Role

JHU APL is the LSII integrator, which includes operating the **Lunar Surface Innovation Consortium** (LSIC)

Extensive Community Involvement:

- LSII technical interchanges, 1:1 discussions, site visits
- LSIC thematic workshops, telecons
- Open community invitation for dialogues
  - What do you need to know next, and from whom?

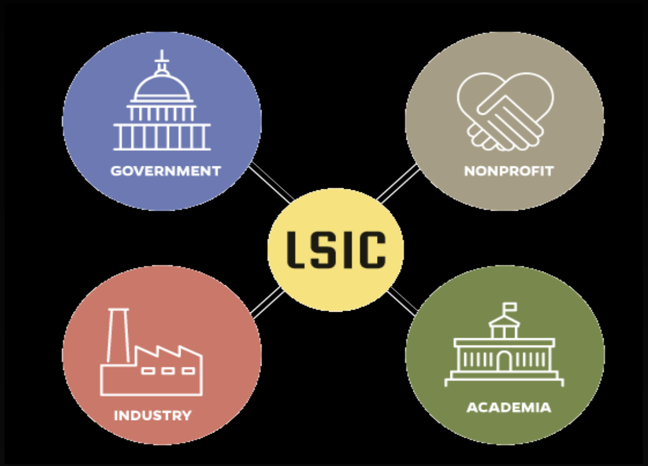


LSIC | Objectives

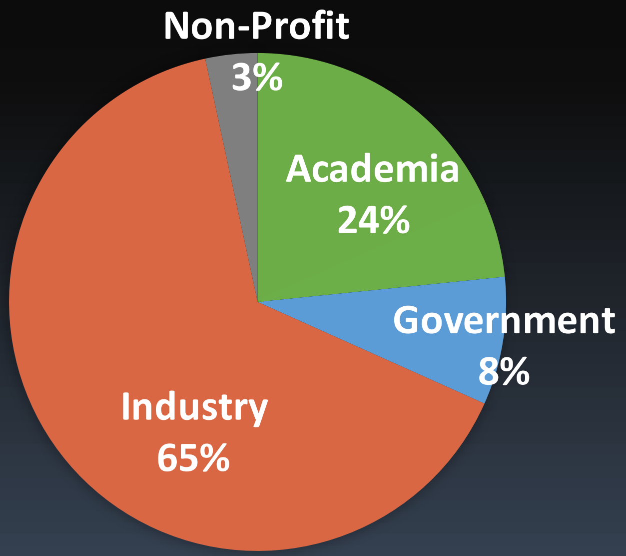
International alliance of universities, commercial companies, non-profit research institutions, NASA, and Other Government Agencies with a vested interest in the campaign to establish a sustained presence on the Moon.

Objectives

- Identify lunar surface technology needs and assess the readiness of relative systems and components
- Make recommendations for a cohesive, executable strategy for development and deployment of the technologies required for successful lunar surface exploration
- Provide a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results
- Foster growth of a diverse community and networking among members



INSTITUTIONAL BREAKDOWN



Bi-annual meetings, with monthly virtual Focus Area meetings for regular interaction.

LSII | Organization

NASA STMD

APL LSII Leadership

Foundational Technologies

Surface Power

In Situ Resource Utilization

Excavation and Construction

Crosscutting Capabilities:

- Extreme Environments
  - Dust Mitigation
  - Lunar Simulants
  - Extreme Access
  - Interoperability

Technical Areas:

- Water-ice Resource evaluation and Recovery
- O2 and Metal Extraction
- Value Network Mapping
- Interoperability and Maintenance by Design

Technical Areas:

- Infrastructure (e.g., landing and launch pads, habitats, roads)
- Technology (additive & autonomous construction, tools, manufacturing)
- In Situ Repair and Outfitting

Technical Areas:

- Materials and Surface Coatings
- Seals, Soft Goods, and Fabrics
- Communications
- Mobility
- Radiation Environment
- Thermal and Illumination Environment

LSIC | Participating Institutions

Some of the organizations that have been participating in LSIC activities:

- XISP Inc.
- Northrop Grumman
- Astrolab Venturi
- Colorado School of Mines
- Purdue University
- Astrobotic
- Lockheed Martin
- University of Houston
- Maxar
- Lockheed Martin
- Intuitive Machines
- Aegis Aerospace
- The Ohio State University
- Moog
- CPES Center for Power Electronics Systems
- SwRI Southwest Research Institute
- Bowie State University 1865
- Blue Origin For the Benefit of Earth
- Honeybee Robotics
- ASU Arizona State University
- BWXT BWX Technologies, Inc.

Newest enterprise: LOGIC

LOGIC Lunar Operating Guidelines for Infrastructure Consortium

LSIC | Outline

- What is LSII/LSIC?
- Who are we?
  - Meet the team
- What does the Surface Power Focus Area do?
- How can you get involved?
- Summary

LSIC | Surface Power Focus Area

The Surface Power (SP) Focus Area (FA) will address the technologies for generating, distributing, and storing power in the harsh lunar surface environment to arrive at power systems that enable sustained presence and exploration

Topics include:

- Fission Surface Power
- Solar Power
- Low-temperature Batteries
- Fuel Cells
- Wireless Transmission
- Long-distance Transmission
- Power Electronics
- Grid-scale Energy Storage

LSIC Lead

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NASA Point of Contact

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Principal Technologist for Power

LSIC | Surface Power Focus Area

The Surface Power (SP) Focus Area (FA) will address the technologies for generating, distributing, and storing power in the harsh lunar surface environment to arrive at power systems that enable sustained presence and exploration

Meetings: 4th Thursday of the Month
11:00 am – 12:00 pm ET

Surface Power Website:

Topics include:

- Fission Surface Power
- Solar Power
- Low-temperature Batteries
- Fuel Cells
- Wireless Transmission
- Long-distance Transmission
- Power Electronics
- Grid-scale Energy Storage

LSIC | Outline

- What is LSII/LSIC?
- Who are we?
- What does the Surface Power Focus Area do?
    - Technology Area Prioritization
    - Previous and Current Focus Area Activities
- How can you get involved?
- Summary

LSIC | STMD 2023 Baselined "Envisioned Future Priorities"

- Highest priority power EFP gap closures support commercially-financed, industrial-scale Lunar ISRU production in the early int the South Pole region
- Other gap closures support subsequent expansion toward construction and ISRU production at lower latitudes

A Mobile Fission Surface Power

B Reliable, Rad-Hard Power Conversion and Cable Transmission System

C Solar Power

Long Life, Grid-Scale Secondary Energy Storage

PSR Operations

D Wireless Power Transmission

Low Temperature Secondary Battery Modules

Radioisotope Energy Sources

Heliostats and Solar Reflectors

Superconducting Cable Transmission

Mars Forward

E CH_4/O_2 Primary Fuel Cell Power

2024 NASA STMD Technology Shortfalls:

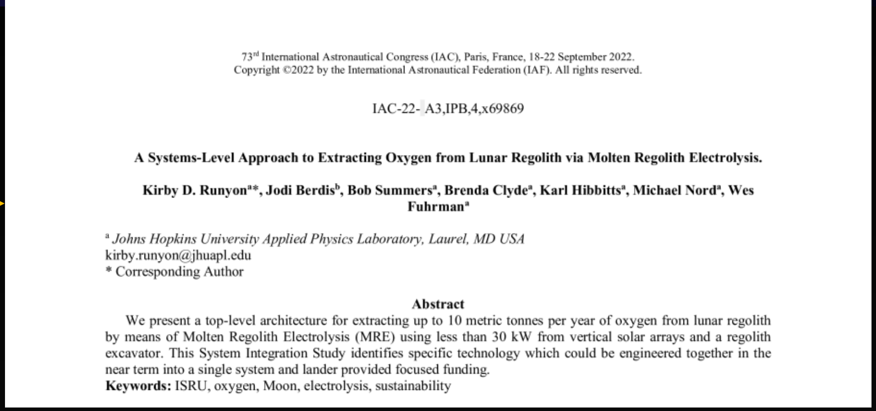
1. High Power Energy Generation on Moon and Mars Surfaces
2. Power for Non-Solar-Illuminated Small Systems
3. Energy Storage to Enable Robust and Long Duration Operations on Moon and Mars
4. Power Management Systems for Long Duration Lunar and Martian Missions
5. High Power, Long Distance Energy Transmission Across Distributed Surface Assets
6. Power and Data Transfer in Dusty Environments
7. Lunar Surface Power Generation from ISRU Derived Resources
8. Martian Surface Power Generation from ISRU Derived Resources

Activities depicted are not all funded or approved. This is a "notional future" developed to guide technology vision.

NASA TechPort Strategic Framework

LSIC | Previous Focus Area Activities

- Trade studies for various types of Lunar systems
  - Power System Focused
  - Integration with other Focus Areas (e.g., ISRU)



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A Systems-Level Approach to Extracting Oxygen from Lunar Regolith via Molten Regolith Electrolysis.

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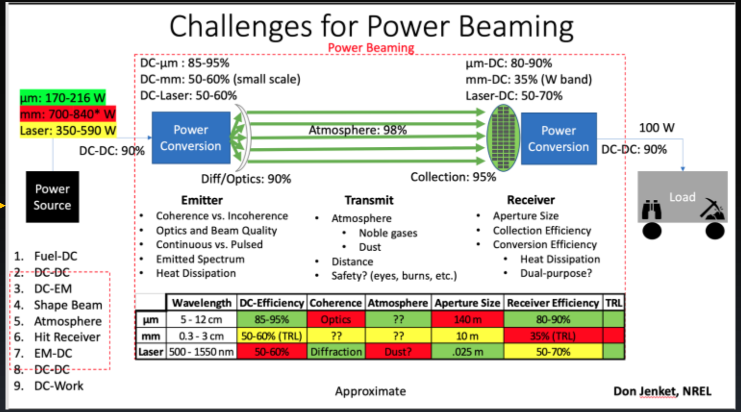
Abstract

We present a top-level architecture for extracting up to 10 metric tonnes per year of oxygen from lunar regolith by means of Molten Regolith Electrolysis (MRE) using less than 30 kW from vertical solar arrays and a regolith excavator. This System Integration Study identifies specific technology which could be engineered together in the near term into a single system and lander provided focused funding.

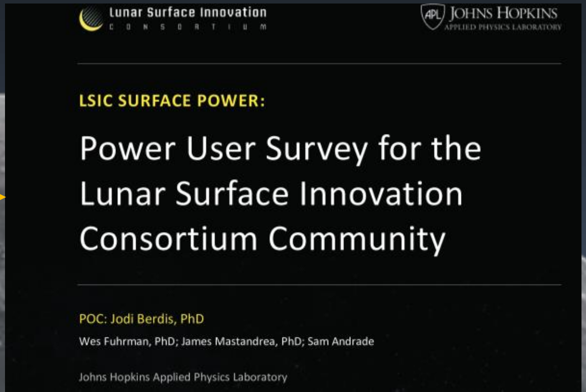
Keywords: ISRU, oxygen, Moon, electrolysis, sustainability

- Community Workshops
  - Power beaming
  - Low-temperature battery modules and survive-the-night capabilities
  - Power grid reliability



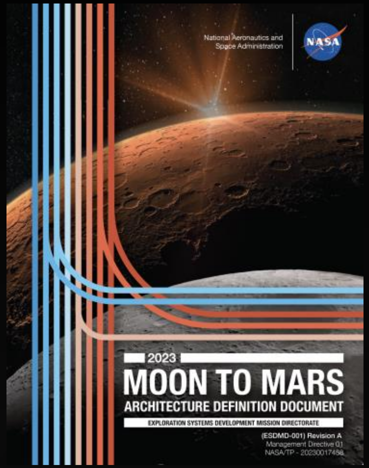
	Wavelength	DC-Efficiency	Coherence	Atmosphere	Aperture Size	Receiver Efficiency	TRL
µm	5 - 12 cm	85-95%	Optics	??	140 m	80-90%	
mm	0.3 - 3 cm	50-60% (TRL)	??	??	10 m	35% (TRL)	
Laser	500 - 1550 nm	50-60%	Diffraction	Dust?	.025 m	50-70%	

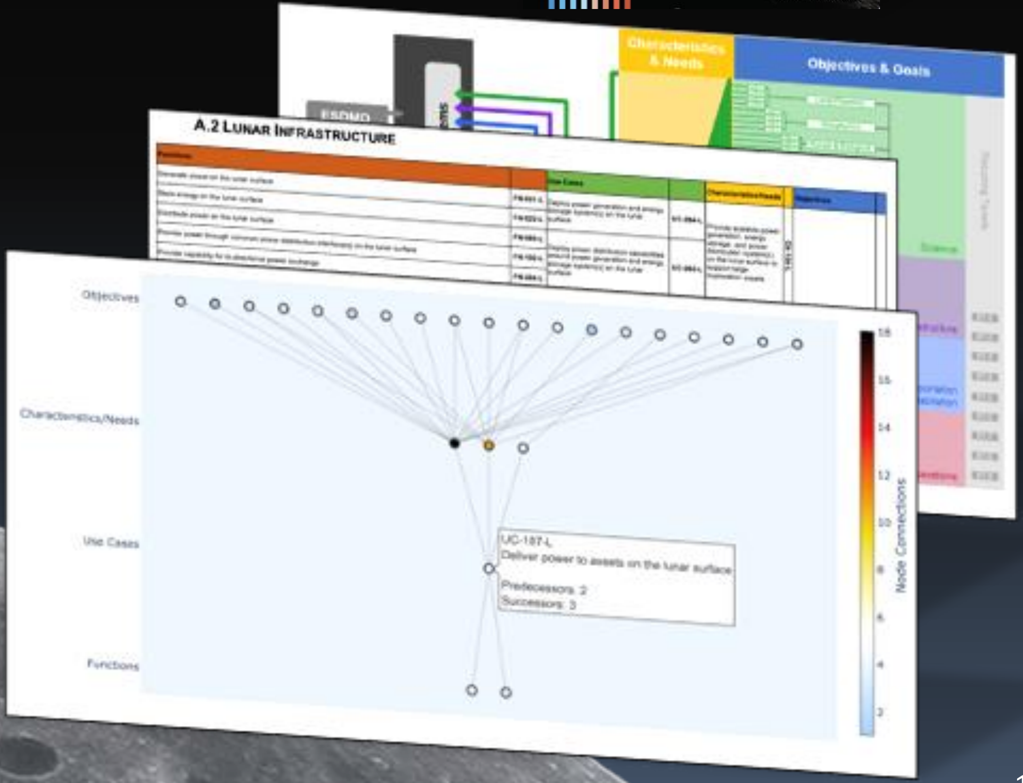
- Community Surveys
  - Power-user survey



LSIC | Moon-to-Mars Power Functions

- NASA's Moon to Mars Architecture encapsulates science, infrastructure, transportation, habitation, and operational objectives
  - Represents the most complete accounting of needs for systems on the Lunar surface
  - Identifies **functions** that Lunar surface power systems must perform to meet various **objectives**
- Current focus group activity:
  - Identify gaps, missing connections, incomplete, or insufficient descriptions in function → objective map
  - Identify candidate technology space to provide functions
  - Use these insights to inform trade studies





LSIC Surface Power Workshop (August 22, 2024)
- Community feedback on our initial assessment will be solicited!

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LSIC | How to get involved

Sign up to Participate

- Register at http://lsic.jhuapl.edu/
- Selecting a Focus Group will add you to that mailing list (moderate traffic)
- Can opt to only join LSIC Announcement list – monthly newsletter and major meeting announcements (low traffic)

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Summary

- Overview of Lunar Surface Innovation Initiative (LSII)
- Overview of Lunar Surface Innovation Consortium (LSIC)
- Technological Challenges for future Lunar Surface Power and SP-FA activities

Acknowledgements

- LSIC Surface Power Team:
  - Samantha Andrade, Jacob Gehrett, Julie Peck, Sean Young

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