Lunar Surface Innovation CONSORTIUM

NASA

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

Lunar Surface Innovation Initiative/Consortium and Dust Mitigation Updates

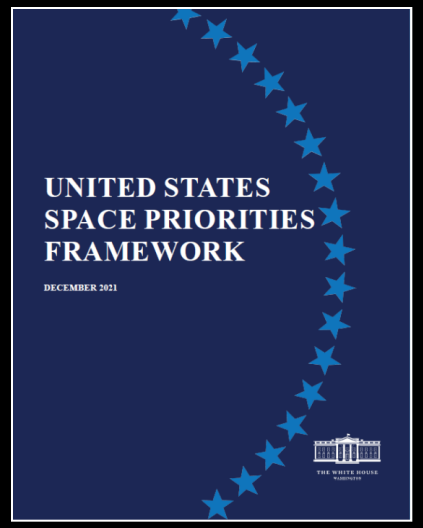
DAP 2023

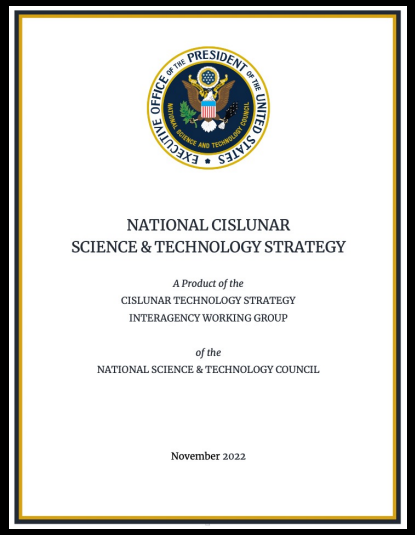
Jorge Núñez, Ph.D.
LSII Technical Area Lead for Dust Mitigation
Facilitator_DustMitigation@jhuapl.edu

Special Thanks:
Wes Fuhrman, Rachel Klima, Joshua Cahill, Brenda Clyde, Lindsey Tolis, Sarah Hasnain, Richard Miller, Stephen Izon, and Timothy Cole

Lunar Reconnaissance Orbiter Camera image (M1432398306LR; credit: NASA/GSFC/Arizona State University).

The Moon Is the Next Step in Exploration





"...the United States will lead the **return of humans to the Moon for long-term exploration and utilization**, followed by human missions to Mars and other destinations."

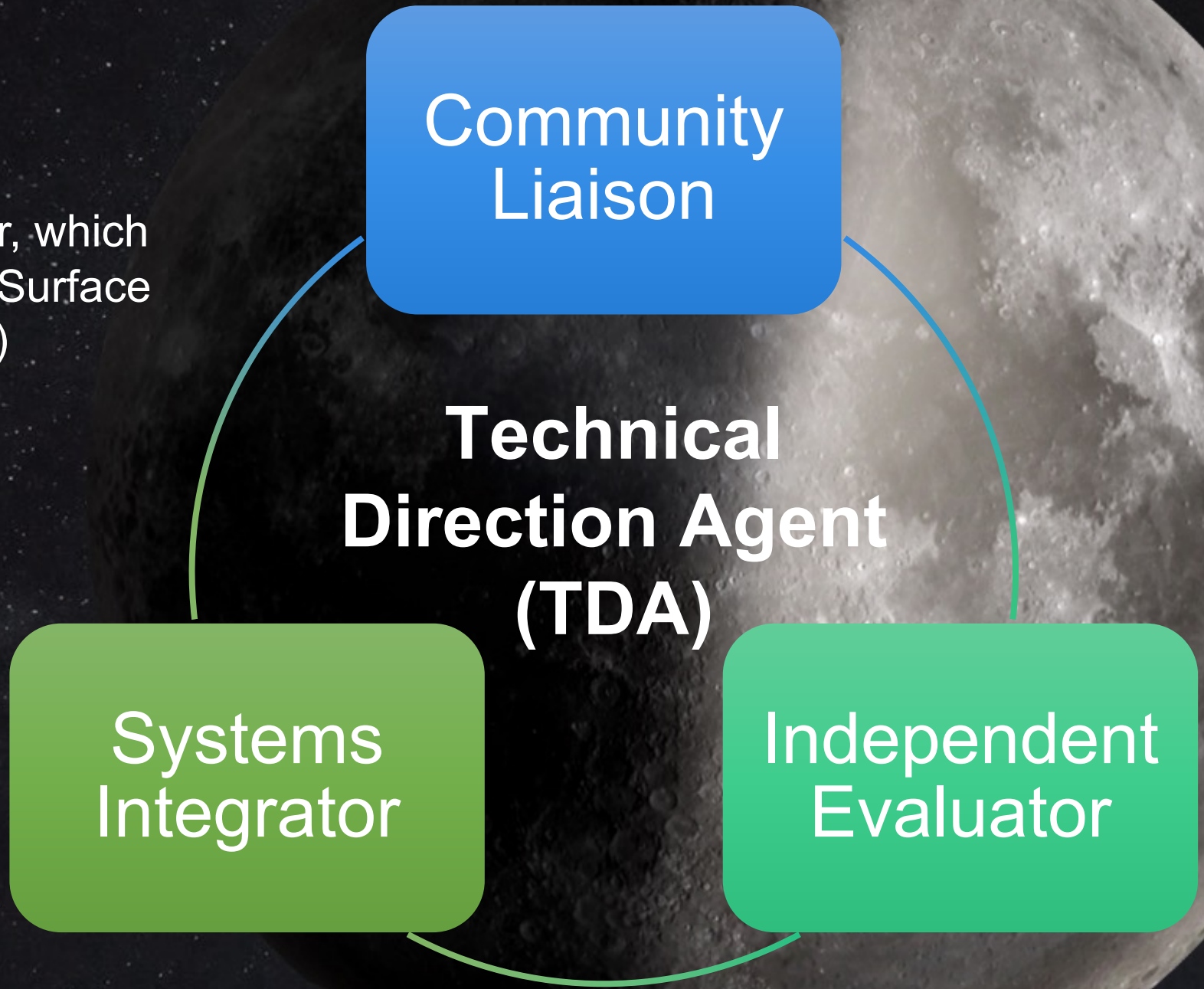
Lunar Surface Innovation Initiative (LSII)

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

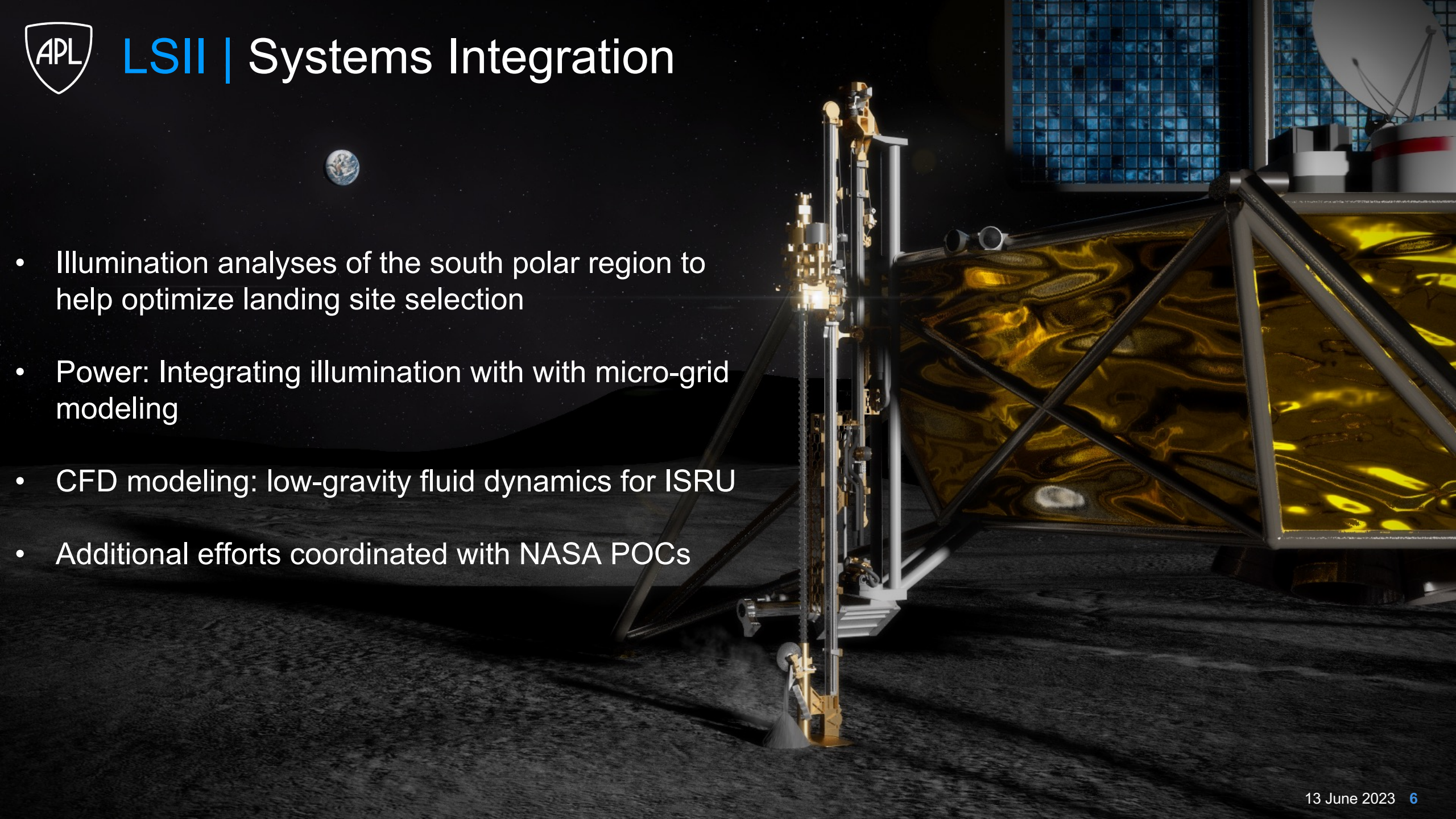
- LSII is a NASA Space Technology Mission Directorate activity
  - Formulating and integrating technology across the TRL pipeline
  - Leveraging innovative collaborations and partnerships to expedite technology development
  - Utilizing early uncrewed lunar surface flight opportunities to inform key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

LSII | APL's Role

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



LSII | Systems Integration



- Illumination analyses of the south polar region to help optimize landing site selection
- Power: Integrating illumination with with micro-grid modeling
- CFD modeling: low-gravity fluid dynamics for ISRU
- Additional efforts coordinated with NASA POCs

LSII | Independent Evaluator: Information Gathering

Extensive community involvement

- LSII technical interchanges, 1:1 discussions, site visits
- LSIC thematic workshops, telecons
- Deep bench of APL lunar expertise

To the broader community, there is an open invitation:

- What do you need to know next, and from whom?

APL is integrated with NASA Space Tech but steadfastly independent

LSII | Independent Evaluator: Select Take-Aways

Our return to the Moon tests more than technologies – it is stress-testing the sustained direction, funding, and execution across disparate stakeholders.

Some technology areas focus on point solutions which have infusion problems. Favor mission-oriented development priorities with tractable path to flight.

Digital engineering tools are underutilized. Leveraging industry capabilities takes advantage of extensive private investments.

STMD-Led CLPS missions offer potential for coordinated technology demonstrations with mission impact

Industry:

- Wants more rationale behind solicitations – work to define industry-relevant metrics
- Long-term commitment needed for big translational technology wins
- Engaged and participating, even in advance of a self-sustaining lunar economy

THE PATH TO AN ENDURING LUNAR PRESENCE

LSIC Community Draft White Paper

In the early 2030s, lunar infrastructure could support a science outpost and exploration proving grounds that can also bootstrap commercial activities.

The LSIC community is publishing a white paper to share their perspectives on key enabling actions that will help our nation and the world move together toward our shared use of the lunar surface.

LSIC

APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

LSII | The Path to an Enduring Lunar Presence

"In satisfying NASA's baseline Moon to Mars objectives, how do we ensure robust participation from industry that also enables a transition away from NASA as a sole customer?"

The Moon as a proving ground offers decades to:

- Develop exploration technologies and perform science
- Demonstrate commitment and unity of purpose
- Test and mature acquisition strategies

The Moon will show when we're ready for Mars, **and** when we're ready for an expansion of the cislunar ecosystem

LSII | The Path to an Enduring Lunar Presence

- Achieving an enduring presence on the lunar surface requires consistent intention and funding
- The global lunar community, including non-traditional players, are eager to work with NASA to achieve shared lunar goals
- Indicators of a long-term intention include interoperability and long-term use technologies such as dust mitigation
- Enabling access and accommodation lead to an enduring presence: re-use of infrastructure and systems extensible and interoperable within a larger architecture should permeate every lunar landing

LSII | The Path to an Enduring Lunar Presence

Taking your feedback now!
Final release at LSIC Fall Meeting

LSIC-Feedback@jhuapl.edu

LSIC.jhuapl.edu

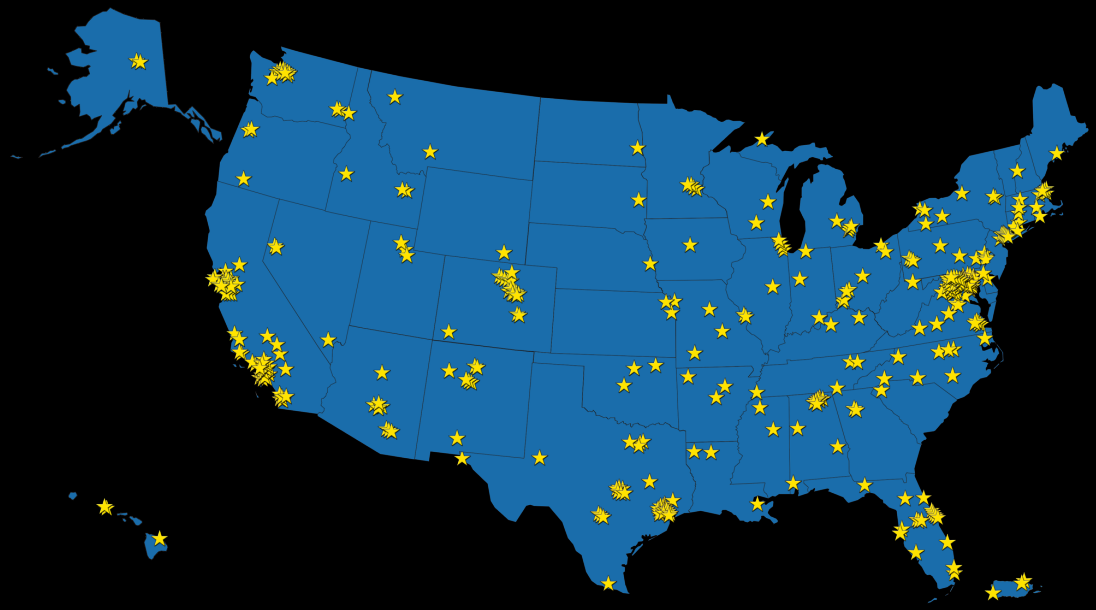
Lunar Surface Innovation Initiative (LSII)

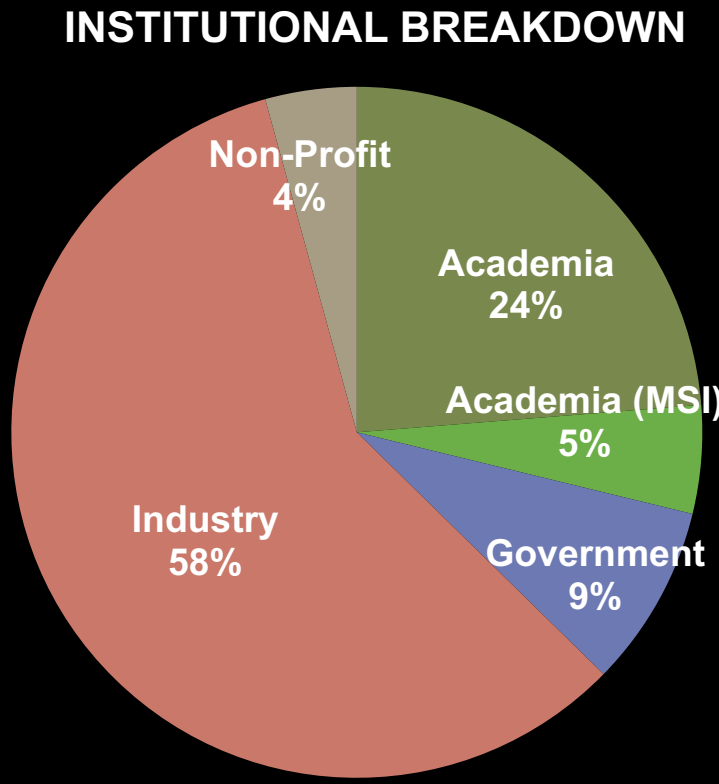
NASA's LSII works across industry, academia, and government through in-house efforts and public-private partnerships to develop transformative capabilities for lunar surface exploration

- LSII is a NASA Space Technology Mission Directorate 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
- Johns Hopkins Applied Physics Lab (APL) is the LSII integrator for NASA, including establishing the new Lunar Surface Innovation Consortium (LSIC)

The Lunar Surface Innovation Consortium (LSIC) provides a conduit for the community to discuss technical challenges and form partnerships

Lunar Surface Innovation Consortium (LSIC)





Objectives

- Foster growth of a diverse community and networking among members.
- Provide a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results.
- 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.

LSIC Spring Meeting 2023

Lunar Surface Innovation Consortium Spring Meeting

Monday, April 24, 2023 -Tuesday, April 25, 2023

Venue: Johns Hopkins Applied Physics Lab

FEATURED SPEAKERS

Pam Melroy
Deputy Administrator, NASA
read bio

Stefanie Tompkins
Director, DARPA
read bio

Matt Daniels
Assistant Director, White House OSTP
read bio

Kurt "Spuds" Vogel
Director of Space Architecture, NASA
read bio

James Reuter
Associate Administrator, NASA STMD
read bio

Walt Engelund
Deputy Associate Administrator for Programs, NASA STMD
read bio

EVENT DETAILS

Date: Monday, April 24, 2023 - Tuesday, April 25, 2023

Time: All times are Eastern.

Location: Johns Hopkins Applied Physics Lab

LIVESTREAM

Check back on April 24, 10:30 a.m.-12 p.m. EST, to view the public livestream of Spring Meeting's morning sessions.

https://lsic.jhuapl.edu/Events/Agenda/index.php?id=380

LSIC 2023 Spring Meeting | Major Takeaways

- ✓ **Community**
  - Record-breaking attendance:
    - **Online: 200+, In-Person: 300+**
- ✓ **International Lunar Year**
- ✓ **Moon to Mars Initiative**
  - **Moon as a proving ground offers stability**
  - **Importance and relevance to other NASA efforts**
- ✓ **Commercial Lunar Payload Services (CLPS)**
  - **Block buys of landers**
  - **Expansion of services**
- ✓ **Lunar Surface Technology Research (LuSTR) Program**
- ✓ **Whole Government Engagement in Maturing Cislunar Ecosystem and Policy**
  - **International engagement for lunar operations**
- ✓ **Commercial Sector Engagement**
  - **Desirable to refine business cases and/or value propositions for terrestrial expert organizations**
- ✓ **Interoperability**
  - **Critical; clear need to establish a lunar interoperability laboratory/facility for tech assessment**
  - **Marketplace for components that meet interoperable standards**
- ✓ **Lunar Environment Considerations**
  - **ECLIPSE: *Essential Compilation of Lunar Information in Preparation of Sustained Exploration* – Coming Sept 2023!**
  - **Dust mitigation and thermal management for component and next higher assemblies**
- ✓ **Autonomy**
  - **Needs further development, such as stakeholder-wide definition and frameworks that evaluate capability autonomy levels**

LSIC 2023 Spring Meeting | White Paper Feedback

LSIC Whitepaper

The Path to an Enduring Lunar Presence

Perspectives on key enabling actions that will help our nation and the world move together toward our shared use of the lunar surface.

Access White Paper:
https://lsic.jhuapl.edu/Resources/files/The%20Path%20to%20an%20Enduring%20Lunar%20Presence.pdf

Send feedback to: LSIC-Feedback@jhuapl.edu

NASA Moon to Mars Whitepapers

Architecture Concept Review

Systems Analysis of Architecture Drivers

Why NRHO: The Artemis Orbit

Why Artemis will Focus on the Lunar South Polar Region

Gateway: The Cislunar Springboard for International and Sustainable Human Deep Space Exploration

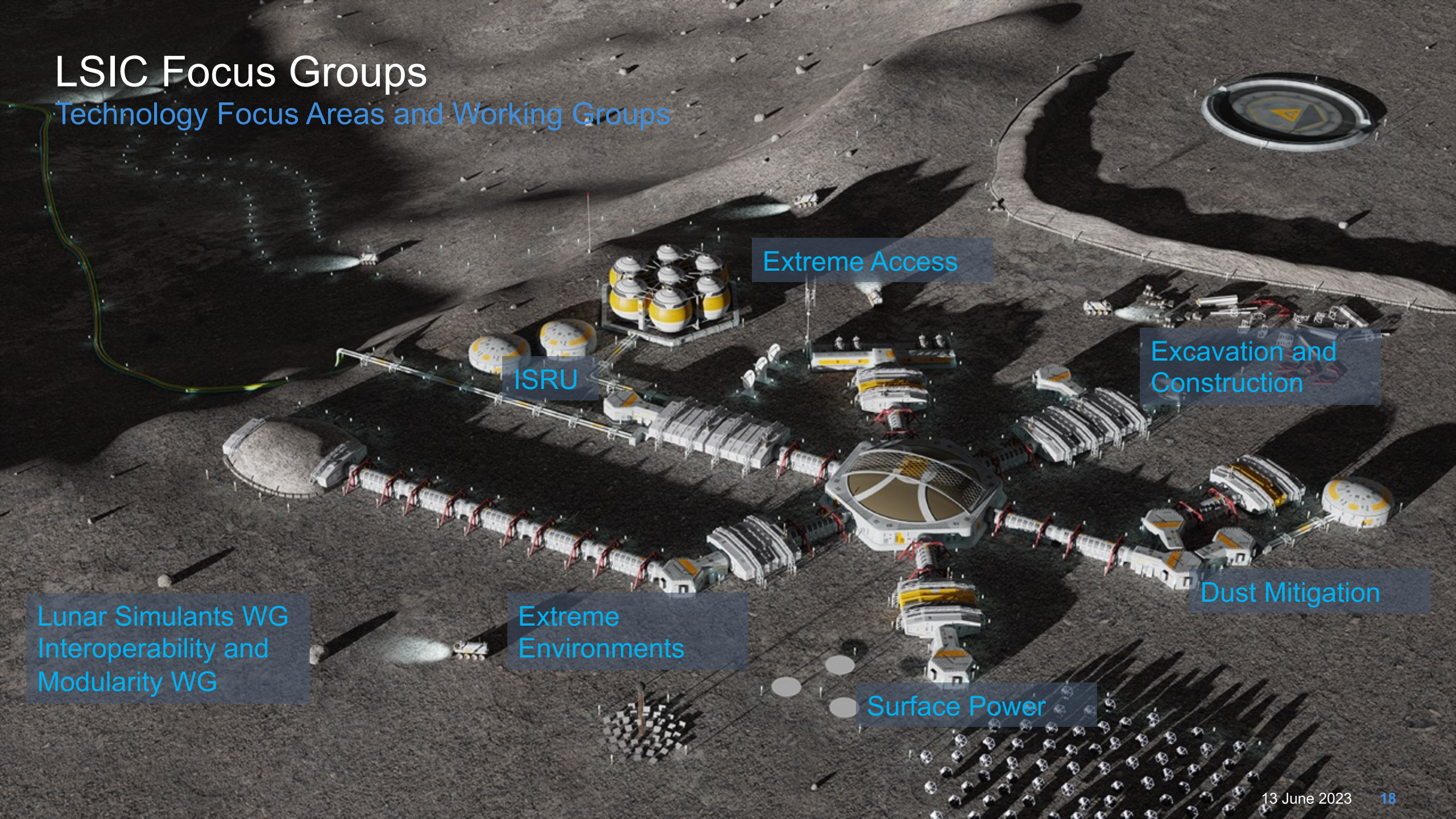
Mars-Forward Capabilities to be Tested at the Moon

Mars Transportation

Access White Papers:
https://www.nasa.gov/MoonToMarsArchitecture

LSIC Focus Groups

Technology Focus Areas and Working Groups



LSIC | Dust Mitigation Focus Group

Assess dust mitigation (DM) needs and evaluate current DM technologies, identifying gaps and harnessing the community to spur technology development. Work to adapt terrestrial technology for the space environment and mature environmental testing technologies.

Meetings: 3rd Thursday of the Month 12:00 – 1:00 pm ET

Mailing List: LSIC_DustMitigation@listserv.jhuapl.edu

Website: https://lsic.jhuapl.edu/Our-Work/Focus-Areas/index.php?fg=Dust-Mitigation

Dust Mitigation Wiki: https://lsic-wiki.jhuapl.edu/display/DM

Next LSIC Dust Mitigation Focus Group meeting on 06/15:

"2022 LSIC Simulants Assessment Report: Implications for Dust Mitigation"

- Dr. Karen Stockstill-Cahill, JHU/APL & LSIC Lunar Simulants Working Group Lead

Applied Physics Laboratory

Jorge Núñez

Lindsay Tolis

Sarah Hasnain

Rich Miller

Tim Cole

Stephen Izon

NASA

Kristen John
NASA Dust Mitigation Technical Integration Manager (TIM)

LSIC | Current Dust Mitigation Focus Group Work

Primary Objective

- Assess dust mitigation needs and current technologies, working to adapt terrestrial technology for the space environment and mature environmental testing technologies.

Highlights and Findings

- Identifying subgroup leads:
  - Standards and Interoperability (Dan Hawk)
  - Isolation Technologies (Ron Creel)
  - Interested in leading a Dust Mitigation Subgroup? Fill out our survey! https://forms.gle/AGpyJcNZBd6ihdaq7
- Bringing Dust Mitigation technology developers and system developers together (including ESDMD) is important for incorporating new dust mitigation technologies into systems/architectures in time.
  - Commercial providers are in good position to infuse new dust mitigation technologies into their systems
- High priority challenges and needs:
  - Establish a set of tolerances allowing systems to operate “dirty”
  - Acquire ground truth dust properties and plume/ejecta data from precursor missions to validate modeling tools and designs
  - Develop and standardize simulants and testing conditions to better capture real dust problems instead of approximations
  - Create pathways and mechanism for integrating dust tolerant/mitigation technologies into lunar systems and architecture
  - Perform technology demonstrations on CLPS landers to test in real-world conditions

Technical Areas:

- Standards & Interoperability
- Isolation Technologies
- Materials & Coatings
- Mechanisms & Connectors
- Modeling & Monitoring

Lunar Surface Innovation Consortium – All are welcome to join!

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

Upcoming Activities and Events

- Lunar Proving Grounds Workshop, June 12-13th
- Surface Power Reliability Workshop, July 26-27th
- Joint E&C / EA Autonomy Workshop, August 21, 2023
- 2023 LSIC Fall Meeting – Oct. 10-12th, 2023 (hybrid) & Transition to Industry Workshop
  - Hosted by Community College of Allegheny County, Pittsburgh, PA
- Dust Mitigation Workshop, Fall 2023
- 2024 LSIC Spring Meeting – Week of April 22nd, 2024
  - Johns Hopkins Applied Physics Laboratory, Kossiakoff Center, Laurel, MD

Sign up to Participate

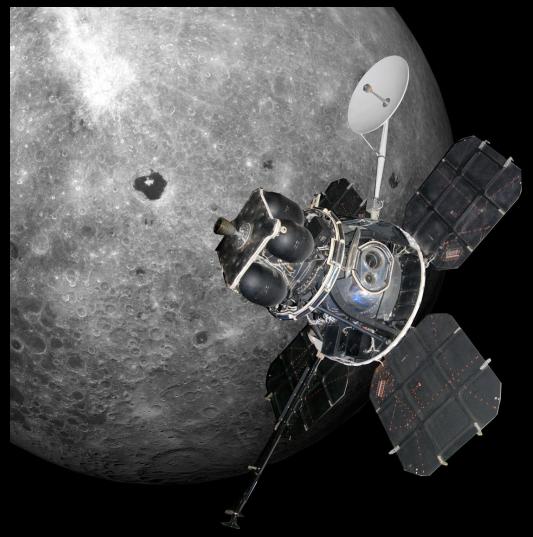
- Register at http://lsic.jhuapl.edu/
  - Adds you to LSIC Announcement list – monthly newsletter and major announcements (low traffic)
  - Sign-up to Receive LSIC and Dust Mitigation FG Updates


APL
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

ECLIPSE

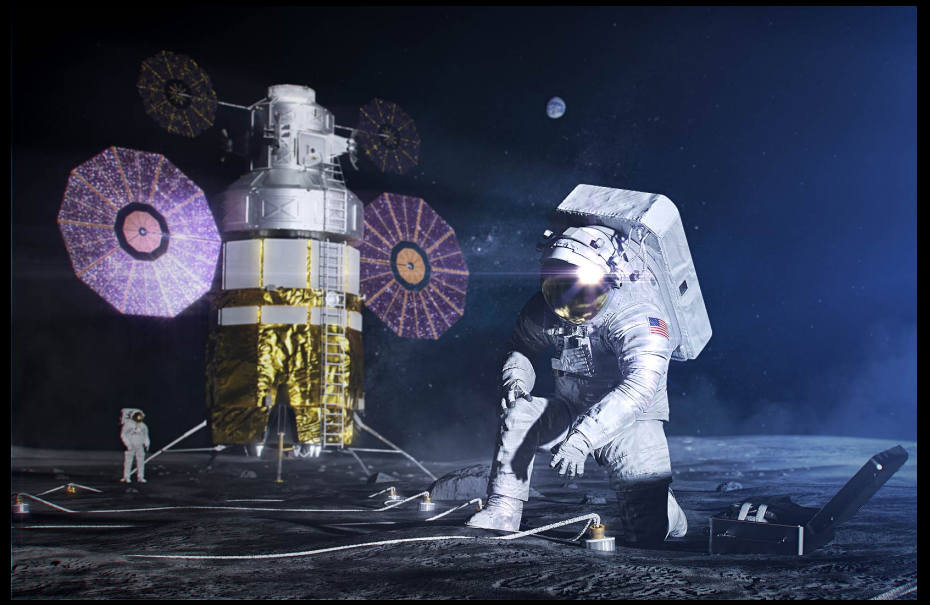
Essential Compilation of Lunar Information in Preparation of Sustained Exploration

Orbiting the Moon

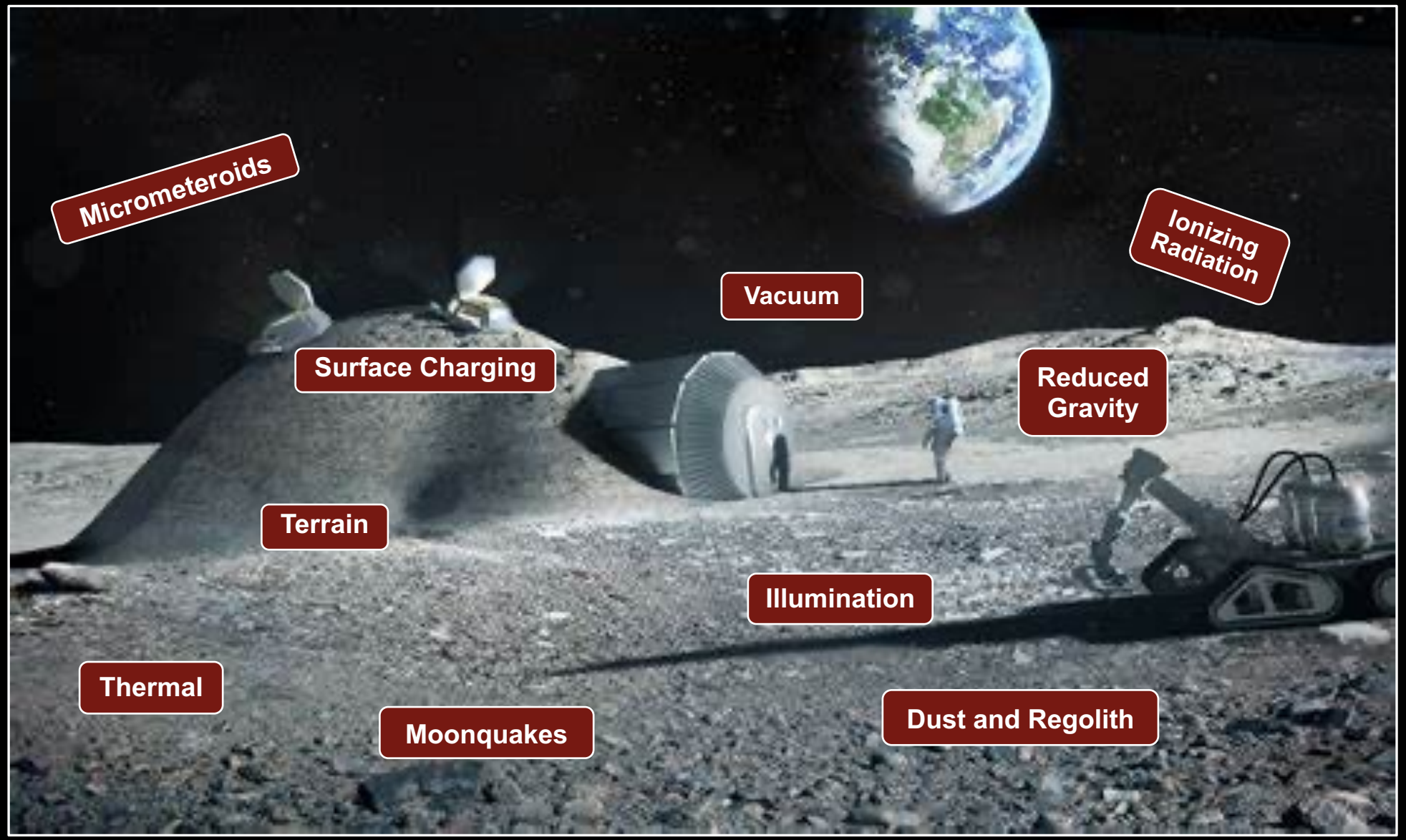


Getting to the Moon

Sustained Human Presence



Lunar Surface Environments



Goals of ECLIPSE

Astronaut David Scott on Slope of Hadley Delta During Apollo 15
Image Credit: NASA/JSC

- Provide an overview of the lunar surface environments that must be considered for proper **technology development**:
  - **Characteristics**
    - What and why?
  - **Challenges**
    - Risks to humans and hardware
    - Design input criticality
  - **Design Considerations**
    - Mitigation by careful engineering and qualification

LSIC | Fall Meeting, Nov 2nd-3rd 2022

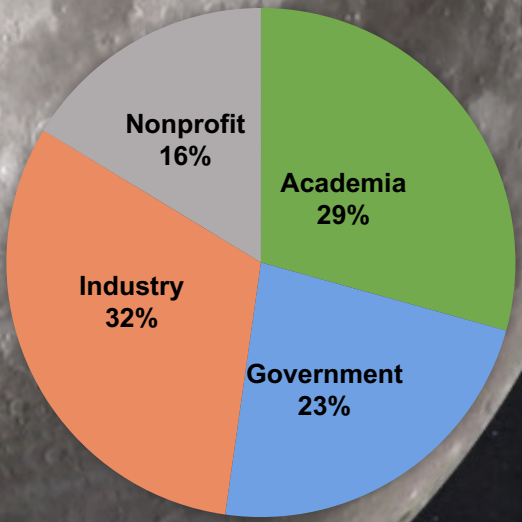
The Lunar Surface Innovation Consortium (LSIC) Fall Meeting, hosted by the University of Texas at El Paso (UTEP), provided a forum for NASA and the community to discuss technology development for establishing a sustained presence on the Moon, *specifically focusing on lunar excavation and construction*.

Over the course of two days, 443 individuals, representing >170 institutions attended. Nearly half (49%) of those who attended have not worked with NASA's Space Tech before.

Meeting Highlights:

- Congresswoman Veronica Escobar introduced the Keynote by NASA's Associate Administrator for Space Technology, Jim Reuter
- Former astronaut and current professor at UC Davis, Dr. Steve Robinson, shared a keynote about the Space Technology Research Institute (STRI) Habitats Optimized for Missions of Exploration (HOME)
- UTEP's Aerospace Center, shared their mission and success preparing students from UTEP (>80% Hispanic, majority first-gen) for high-paying jobs in the aerospace industry
- Technical talks and panels on topics including applying terrestrial lessons to lunar excavation, proving grounds, early infrastructure, lunar resources, and emerging technology and space law
- Tours of UTEP facilities, laboratories, and proving grounds, highlighted student's applied research with numerous opportunities for discussion between the students and attendees
- A breakout discussion group between student attendees and Space Tech leadership
- Local tours to visit 3-D printed barracks at Fort Bliss and testing facilities at White Sands

ATTENDEES



LSIC | Fall Meeting, Nov 2nd-3rd 2022

Key Findings:

- Continued understanding of what potential facilities and/or locations exist that can serve as lunar proving grounds will enable developers to mature their technology as effectively as possible on Earth, and will also help identify whether modifications to some of these facilities could help further fill gaps. For instance, large facilities such as White Sands or the Nevada Test Site may have the flexibility to customize areas for specific system-level field tests to prepare for deployment on the Moon. **Impact of dust was not considered equally across proposed proving grounds.**
- NASA's envisioned futures, coupled with discussions between NASA and the community, have provided a strong framework for understanding the challenges and needs for establishing infrastructure on the lunar surface. Continued integration of community feedback, as well as inclusion of the community in master planning will help incentivize private investment. **Industry, academia, and international partners are taking their cues from NASA.**
- NASA's Intellectual Property office models and contracting vehicles are creating constructive models for IP development other sectors are adopting. Cis-lunar technology development, in particular, is projected to have the strongest and highest sustained annual growth (8.6%) in the space sector over the next decade, with significant private investment beyond what NASA is investing. **Effort to increase confidence in this number will continue to build momentum on the commercial side.**

LSIC | Fall Meeting, Nov 2nd-3rd 2022

Key Findings:

- The community continues to seek to learn more about specific requirements from NASA. The Moon to Mars objectives provides a good starting point, but **the more this framework can be built out in a way that the community can understand concrete needs, the better**.
- Policy content was well-received at this event, compared to the previous LSIC Spring Meeting. Despite calls for a working group, given the inconsistent community appetite for this content **a well-constructed policy workshop may be more beneficial than a recurring meeting**. Consider partnering options.
- The community would like to have a better understanding of who (if anyone) might be a potential long-term customer, especially if there are other governmental needs beyond NASA and the Artemis program. **We need to work to better understand the hand-off following NASA's use of the Moon**. The Moon as a proving ground for more for decades is an idea well received by many within the LSIC community.
- Many technical gaps fall into the category of environmental, such as long-term night survival, radiation hardening, and prolonged dust and vacuum exposure, and logistical, such as standards, interoperability, and management of byproducts from activities (especially ISRU). **It is unclear if environmental complications are being effectively retired in the course of technology directed at other focus areas.**

LSIC | Lunar Proving Grounds Workshop: July 12-13

Summary:

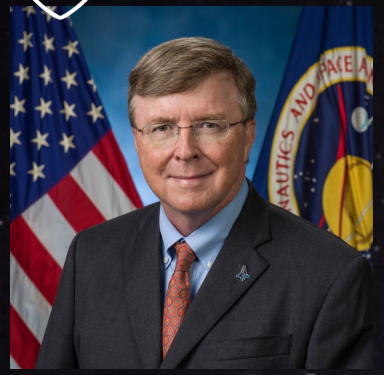
The topic of test facilities and Earth-based Lunar Proving Grounds has come up across all six Focus Areas of LSIC, and component- and instrument- level testing has been developed extensively at various facilities across the US. However, an integrated testing facility (or network of testing locations) where technology developers can verify and validate their technologies in conjunction with other dependent technologies at the larger system-level, specifically to ensure system readiness for flight and operation on the lunar surface, still requires development. Over the course of this two-day Lunar Proving Grounds (LPG) Workshop, we intend to dive into these topics and explore the requirements and characteristics that will be necessary for a unified LPG.

Save The Date sent out this month (April), registration to open in May with tentative agenda to follow.

Objectives:

1. Define a lunar proving ground, from the perspective of the technology developers.
2. Collect (not set) guidelines/needs from technology developer's perspective for a Lunar Proving Grounds.
3. Link community users with providers: identify the value chain, such as how to get access to facilities, etc.
4. Understand facility owners' capabilities and capacities, including the bottleneck of testing.

LSIC | Surface Power Reliability Workshop: July 26-27



John Scott (NASA)
Principal Technologist
Power & Energy Storage

Clay Smith (APL)
ISS Probabilistic Risk Assessment Creator

Blanca Lara (NASA)
NASA JSC EHP Lunar Power Lead

Jim Soeder (NASA, retired)
Senior Power Technologist (08-21)
Power Development Chief (87-08)

David McGlone (NAVSEA07)
Director
Submarine Safety Program

- 11:00AM – 3:30 PM ET via ZOOM
- How do we quantify and design for reliability?
- How should reliability be approached from the system/grid level and how should this affect the early-TRL development at the component level?
- Bring in Different Perspectives
  - ESDMD, STMD, Industry, Terrestrial Grids, Microgrids, DoD, and you!

Lunar Surface Innovation Consortium

NASA

APL Johns Hopkins Applied Physics Laboratory

The Access to Space Interface

A Searchable Interface Listing Spacecraft Hosts, Payloads, and Services that are Developing Technology for the Moon

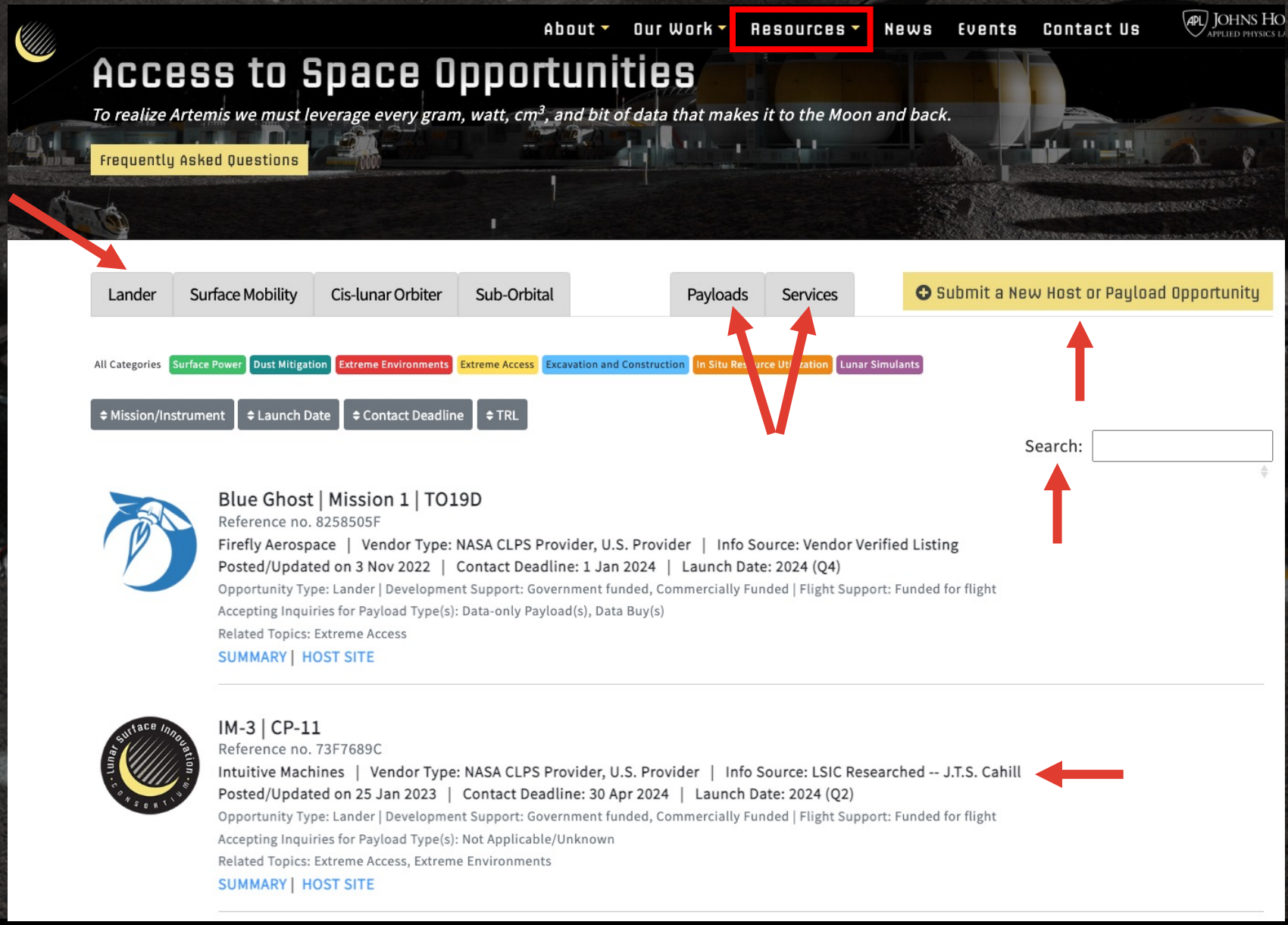
Josh Cahill (APL), Alysen Regiec (APL), and Rachel Klima (APL)

Leading Up To Its Creation

- LSIC has internally kicked around the idea of a clearinghouse, marketplace, or listing of upcoming pathways/rides to space and the Moon since near inception of the consortium.
- We began developing a small database that might be eventually used for such an interface with very basic information.
- However, the turning points came in 2022 during LEAG and CLPS Survive the Night conferences.
- At LEAG, a number of CLPS providers sat on a panel and multiple representatives pointedly socialized that they had (X) kgs left on landers readying for flight and were looking for customer payloads that may fit.
- Then at CLPS Survive the Night, multiple session panels discussed at some length the need for some sort of initial marketplace that may spur along a cislunar ecosystem.

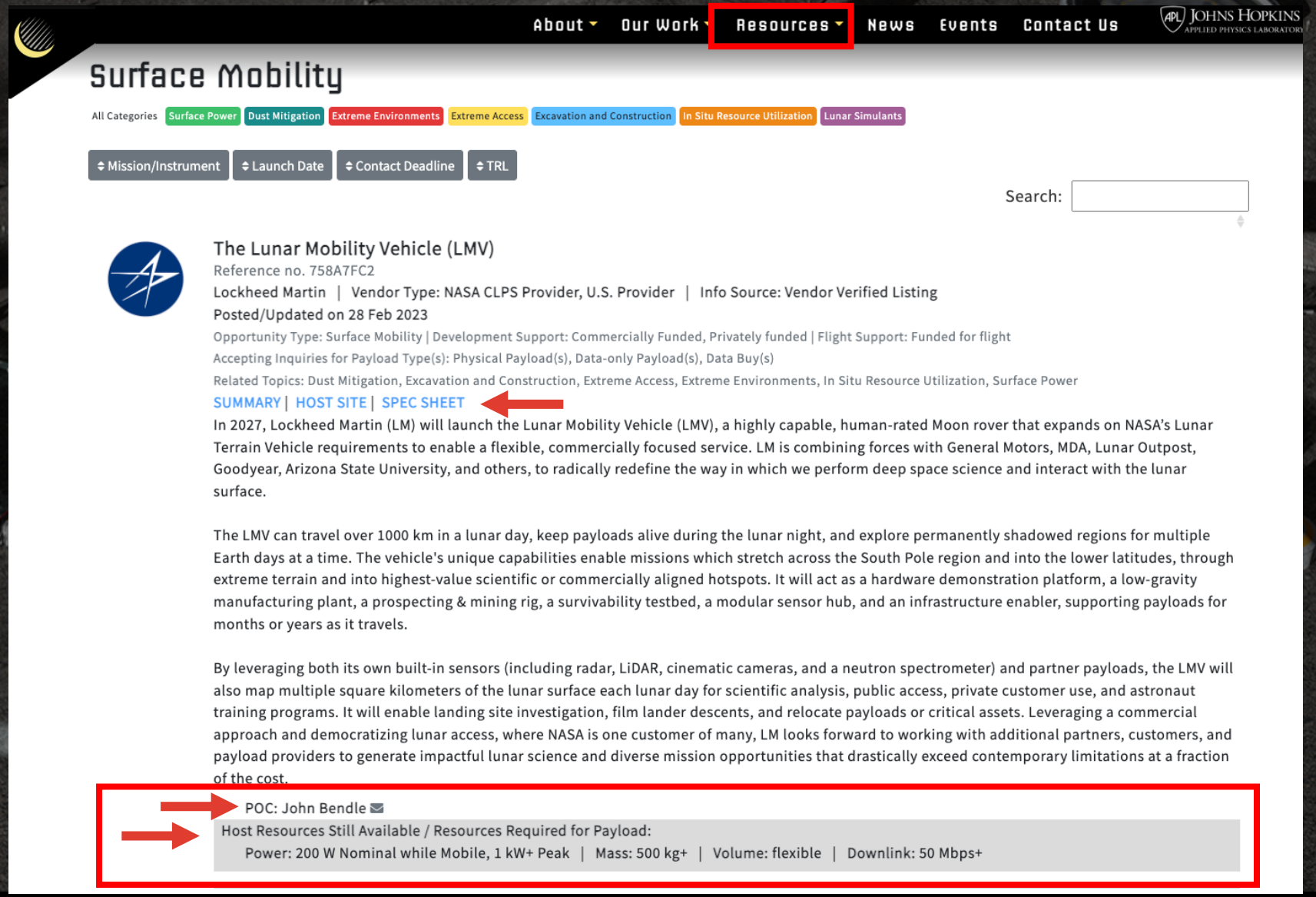
The Access to Space Interface

- The interface is organized by host, including (STMD is supporting lunar tech development on several platforms)
- Host vendors may submit listings looking for riders
- Payloads and services vendors may make listings looking for rides. (**CLPS Requested*)
- LSIC will research basic details of unlisted opportunities



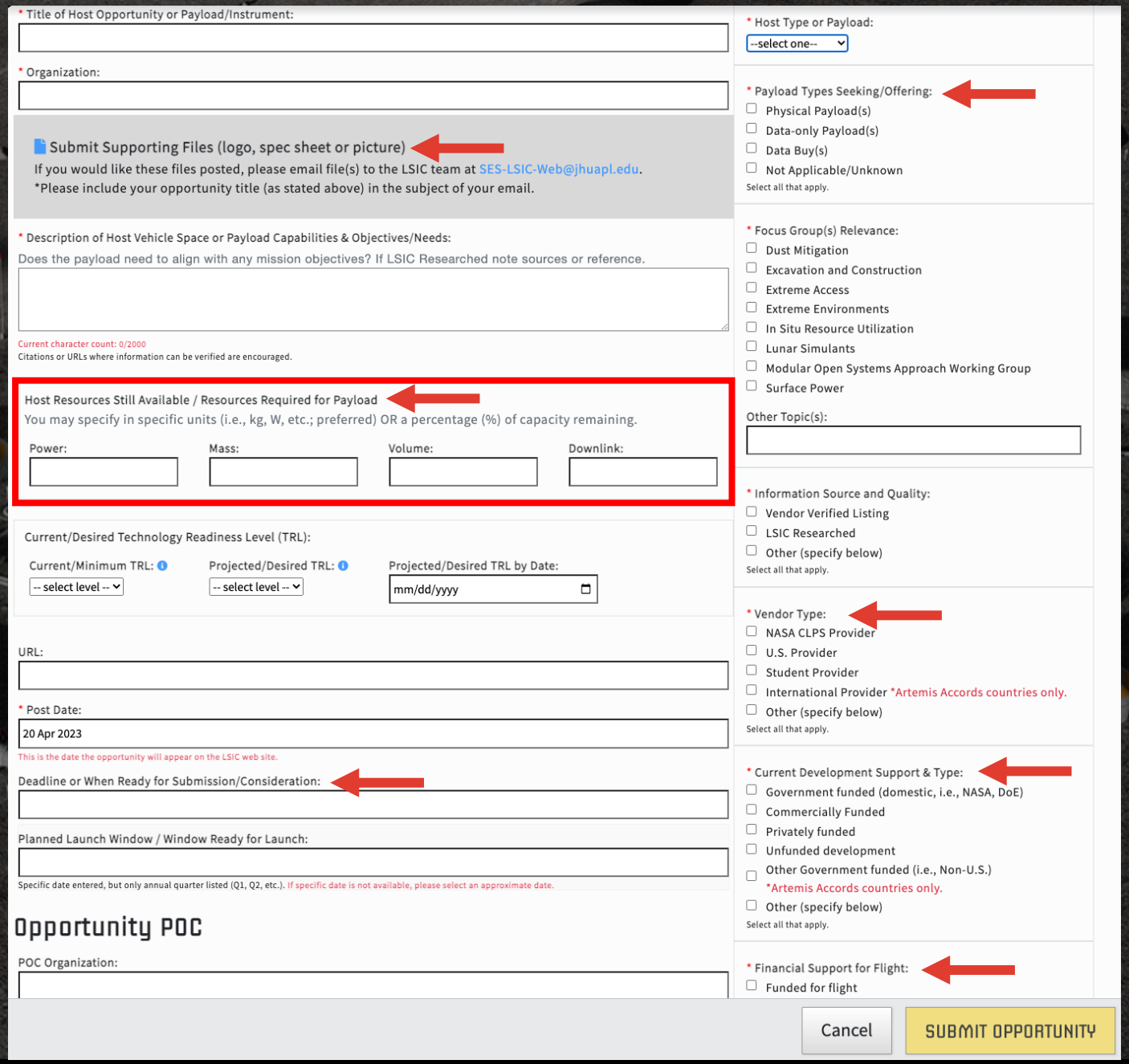
The Interface

- Basic identifier in case vendor wants to:
  - Update
  - Replace a listing
  - Or more than one listing for a single manifest
- Summary description may be expanded for basic additional info
- Designated POC
- Resource Needs and/or Availability



Keep It Simple

- Host and payload information is listed and focuses upon the basics to find opportunities:
  - Timing
  - Residual (not total) resources (e.g., mass, power, data)
  - Mission destination summary
  - Payload capability
  - Readiness (TRL)
- Type of payload(s) provided or searching for (*data only payloads & data buys too)
- Source, quality, and credibility
- Financial Support
  - Development financial support (i.e., (un)funded and from where)
  - Flight financial support too
  - *Artemis Accords vendors also



What Does It Provide Community and LSIC

- In the best case scenario, it is a centralized place …
  - for the community to keep track of host **AND** payload provider technology developments set on a path to the Moon
  - for providers to be seen and advertise
  - for hosts to continue to find customers even when physical manifest is static (e.g., data only payloads, data-buys)
  - A place for student host and payloads to be seen
- Closer to real-time (within a month or so of becoming public) information that is straightforward and succinct
- Information LSII/LSIC may utilize to advise NASA