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NETS 2022

NUCLEAR and EMERGING TECHNOLOGIES for SPACE



Modular Open Systems Approach (MOSA) for a Robust Commercial Lunar Ecosystem

- Applying DoD Lessons Learned to Lunar Spaceflight

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NASA

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY



Pre-NASA:

- US Army's Deputy Chief Scientist for Robotics
- Liaison between R&D lab and Robotics PM offices
- Managed the ROS-M Program
- Established the Modular Autonomy & Robotics Software (MARS) Program
- Supported DoD adoption of Robotics IOP and ROS
- Supporting author for the TARDEC 30-year strategy and the Army's Robotics & Autonomous Systems Strategy

NASA:

- PM for GRC's PILS flight project
- PM for 11 GCD power projects

WHY MOSA?

Open System: Maximizes accessibility, reduces barriers to entry, prevents vendor lock

Modularity: Speeds innovation, fosters design re-use, enables incremental development & growth

Therefore, using a MOSA to develop an architecture:

- **Synergizes** "modularity" and "open systems" to produce better products with lower development cost and risk
  - Saves consumer money and increases developer profit margin
- **Ensures interoperability** among commercial, government, and int'l partners
  - Eases system integration
  - Allows incremental upgrades
  - Reduces spares & service cost
  - Fosters design re-use













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MOSAS IN GOVERNMENT USE

MOSAs have been implemented by Government agencies (in some instances, now mandated by 10 US Code § 2446a)

- History: Early Iraq & Afghanistan
  - IEDs were killing warfighters and civilians
  - Robotics became front-line in the fight against IEDs
- Two options:
  1) Rush robotics to field
  2) People die
- Option 1 was chosen













THE RESULT

- Robots were fielded with no interoperability, no MOSA
- Completely unsustainable, but <u>emergency necessitated</u> it
  - Most fielded systems were divested (lost investment)
- Sustainment and future growth required a MOSA
  - Government asked industry to develop the MOSA
  - Robotics IOP was born
  - VICTORY architecture was established
  - Later ROS-M followed the lead of the worldwide ROS community
- DoD's MOSA-based architectures now highly successful and popular

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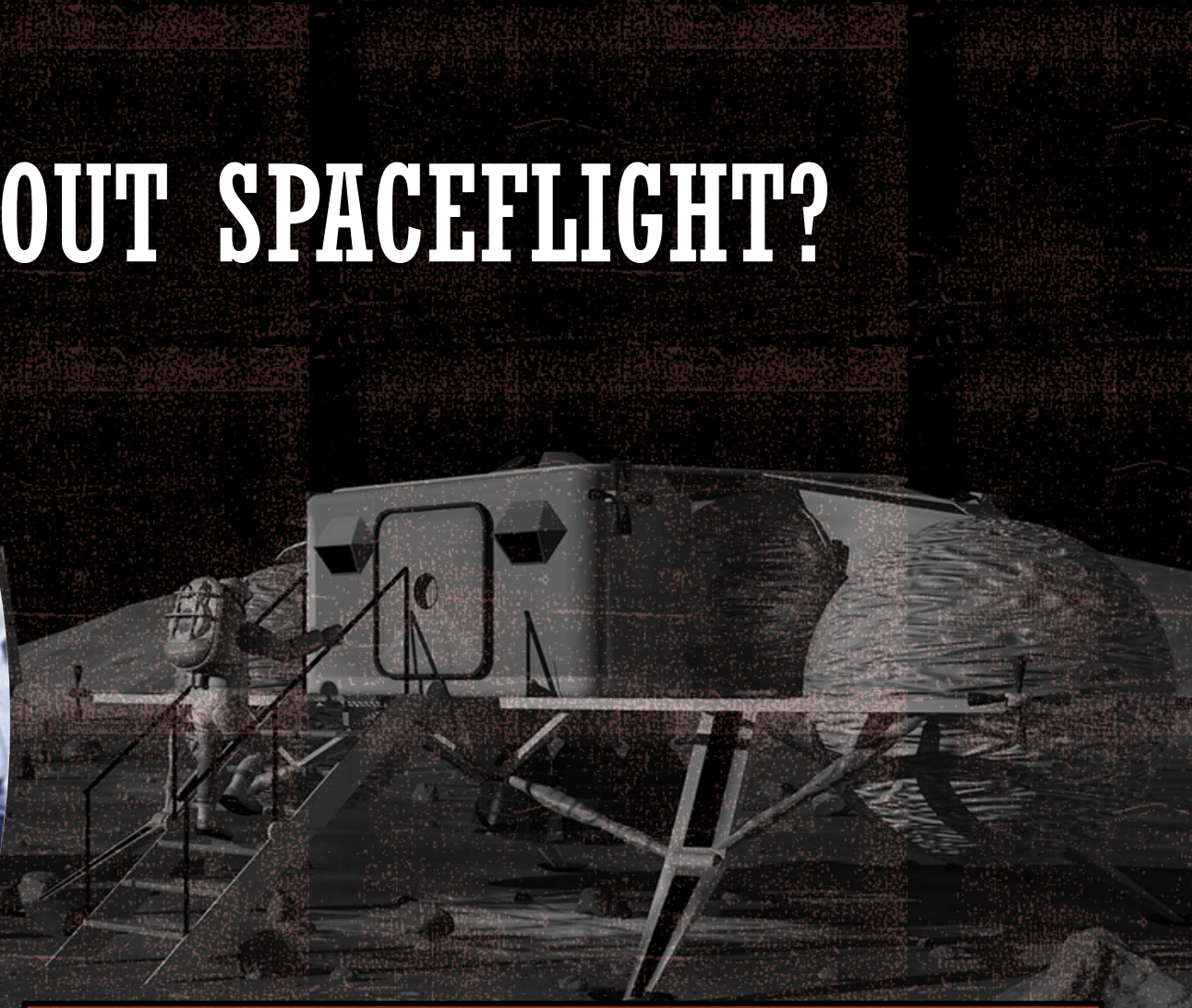
SO… WHAT ABOUT SPACEFLIGHT?



"Boots on ground by 2025"

This is "emergency speed"

Therefore, no MOSA for 2025



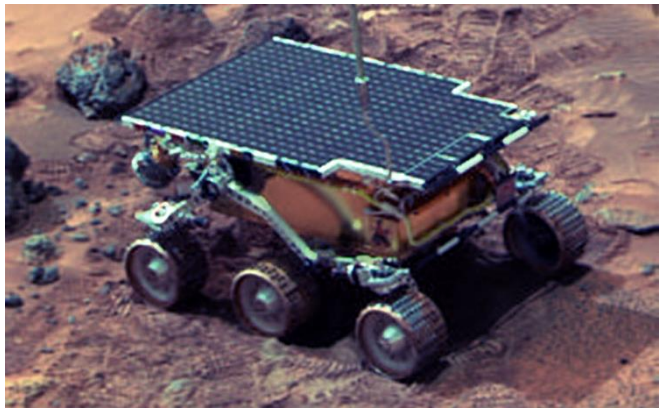
However… Surface habitat, lunar terrain vehicles, power, ISRU, etc. are **not emergency speed** and MOSAs should be implemented

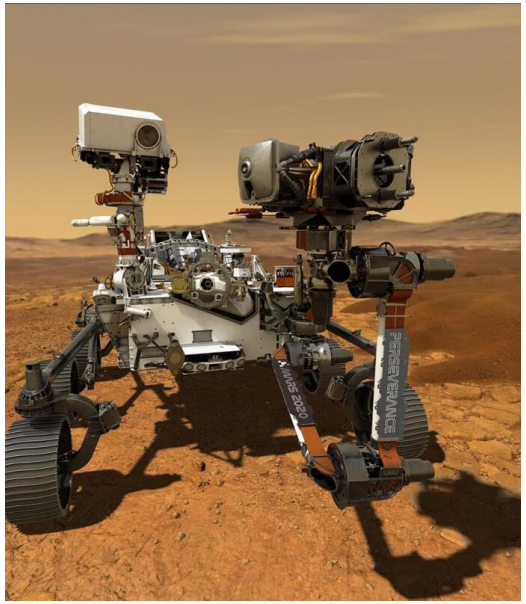
WHY NOW?

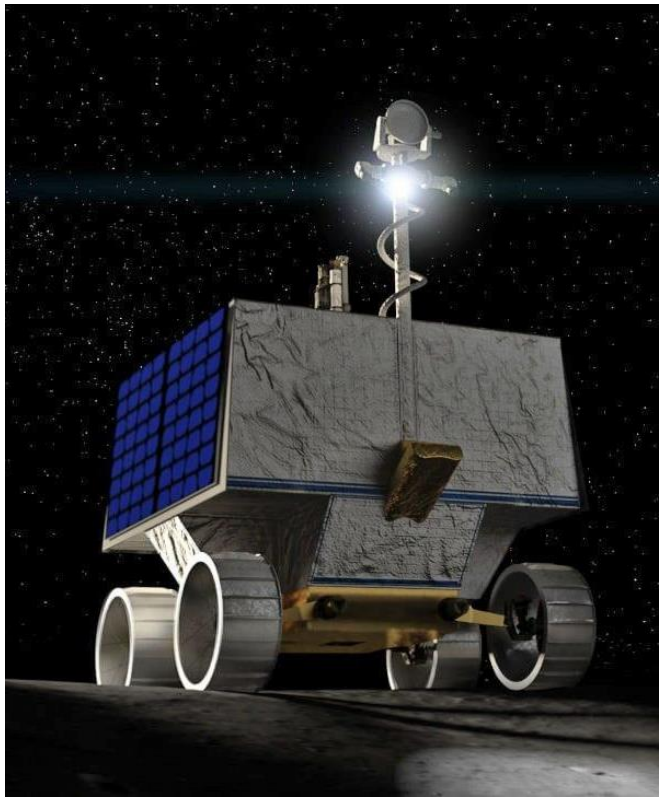
- Spaceflight robotics (rovers) historically are highly specialized for a mission
- "Going to the Moon to stay" requires a complete robotics portfolio to:
  - Perform myriad tasks
  - Work collaboratively with peers (current and future)
  - Act redundantly
  - Recover immobile and damaged robots for repair
  - Seamlessly swap out parts as appropriate
  - Allow incremental upgrades
  - Reduce development time and spares
  - Ease teaming among industry

The lunar ISRU campaign will be **the most robotics-dependent operation undertaken by humanity** to date











THE MOST ROBOTICS-DEPENDENT CAMPAIGN UNDERTAKEN BY HUMANITY

- 0% chance of sending humans to the Moon solely to mine, deliver, and process regolith
- For the first time in human history, we need not rely on manual labor
- The technology exists, but requires diverse partnerships enabled by a MOSA-driven architecture

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FROM HERE TO THERE

1) Establish the basics first – Lunar surface power grid, communications, etc. are nearly ready for formal adoption of basic MOSA-driven architectures

2) Learning from these first architectures, begin Government-influenced industry development of a robotics MOSA

- Must be **modular**, **upgradeable**, and **affordable for commercial partners to design, build, and sustain**

3) Architectures define the interfaces between components and allow as many parts as possible to be independently developed, tested, and built

GENERAL MOSA ADOPTION PRINCIPLES

Adopt – Where possible, adopt an existing open architecture

Adapt – If needed, adapt existing architectures

Author – Only when necessary, author a new architecture


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Lunar Surface Innovation Initiative
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CONSORTIUM

Lunar Surface Innovation Initiative (LSII)

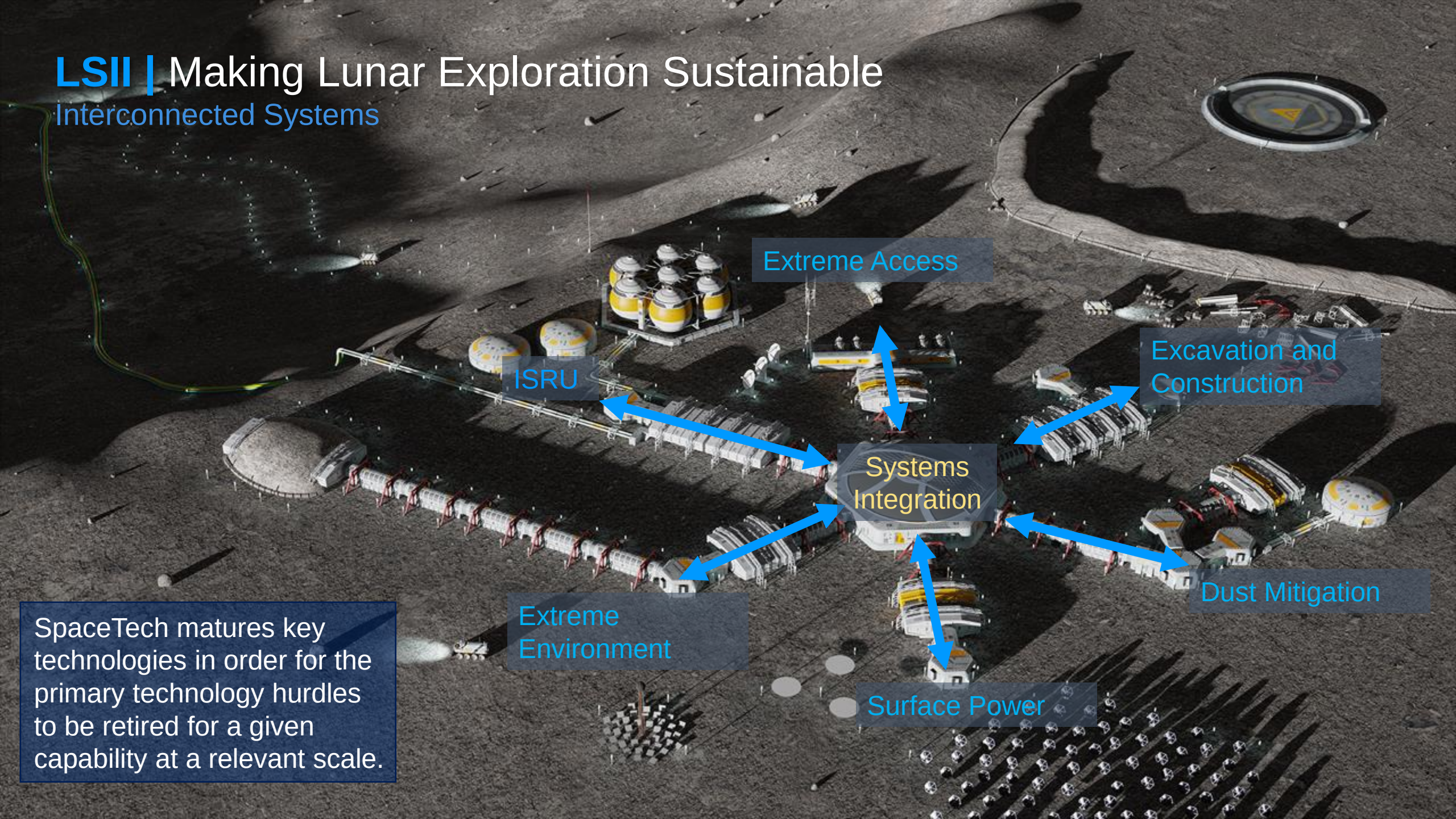
- LSII is a NASA Space Technology Mission Directorate activity to develop technology that enables a sustained human presence on the lunar surface
- Formulating and integrating expedited technology maturation activities across the TRL pipeline by leveraging innovative collaborations and partnerships
- 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)



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 | Making Lunar Exploration Sustainable

Interconnected Systems



SpaceTech matures key technologies in order for the primary technology hurdles to be retired for a given capability at a relevant scale.

LSII | APL is the LSII Integrator for NASA

Technical Direction Agent (TDA)

- **Systems Integration**
  - APL provides an **independent analysis of NASA's architecture**, assists NASA in balancing of technical performance and programmatic needs that satisfy NASA's lunar campaign. We synthesize available technologies from NASA, industry and academia that best enables a sustainable lunar presence
  - Technologies are split into six capability areas:



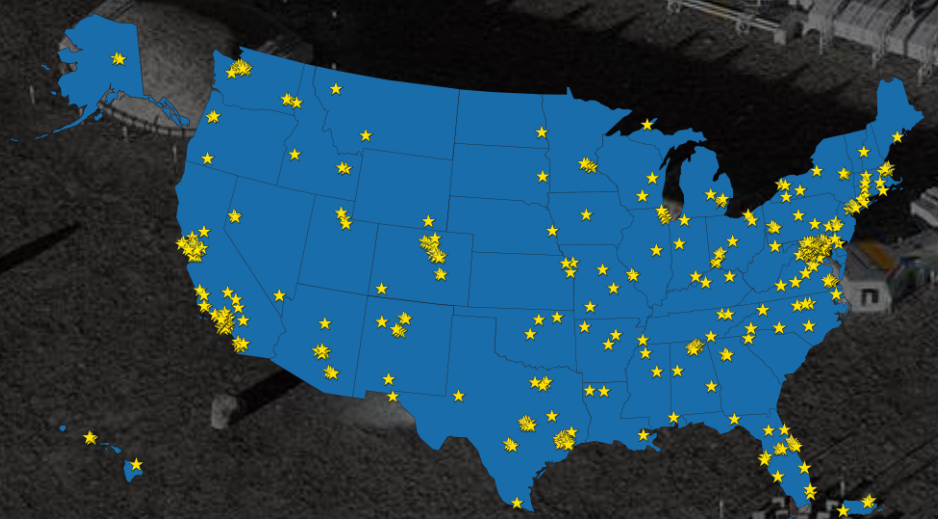
LSII | Lunar Surface Innovation Consortium

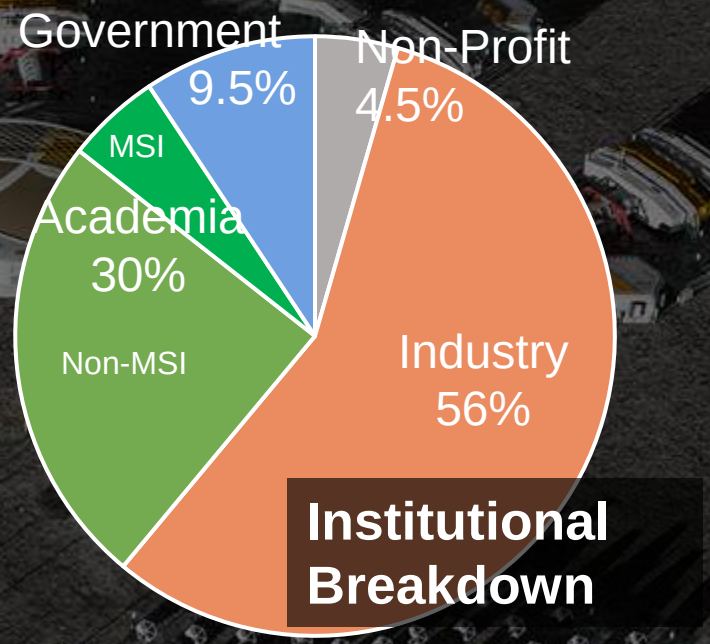
- LSIC Goals
  - The Consortium is a nationwide alliance of academia, industry, non-profits, and government agencies with a vested interest in establishing a sustained presence on the Moon
  - LSIC seeks to cultivate innovation by fostering growth of a diverse community and networking among members. Key goal is to enable collaborative relationships, build community and develop talent, and compilation of member input and report outcomes and recommendations



LSII | Lunar Surface Innovation Consortium

- LSIC Goals (cont.)
  - Communications include biannual face to face meeting, as well as monthly thematic focus group meetings. LSIC currently has over **1700 members from more than 600 institutions**





LSII | Lunar Interoperability

- Modular Open System Approach (MOSA) WG
  - Ensuring lunar interoperability to support a robust and sustainable lunar presence
  - Leveraging the lessons learned from the other communities
    - MOSA from DoD
    - *Adopt Adapt Author*
  - Established to be an LSIC wide group that cuts across of 6 focus groups.
  - Topical areas
    - Standards, modularity, architectures, maintenance, repairability



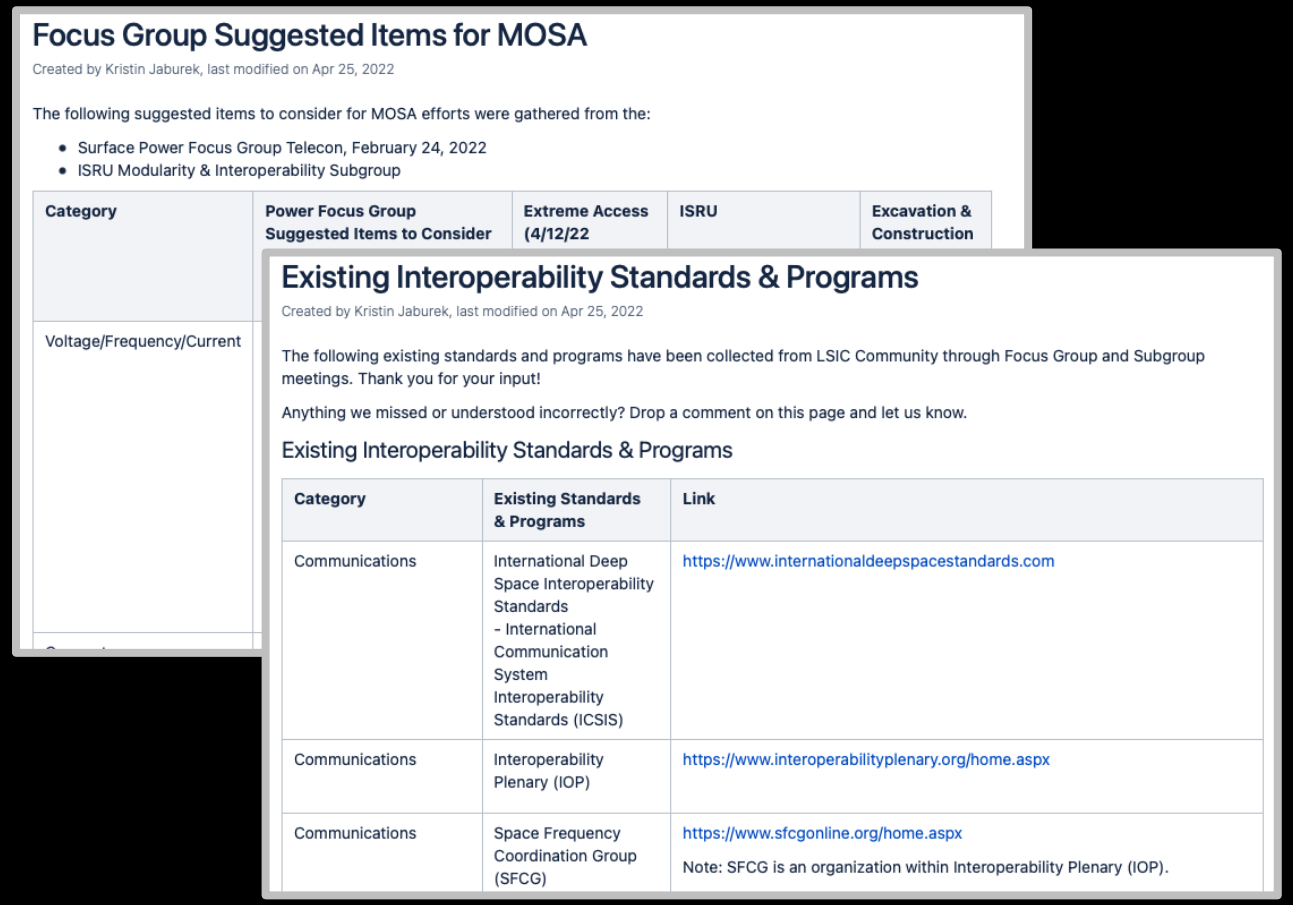
LSII | Lunar Interoperability

- CY 2022 LSIC MOSA WG Tasks
  - Document what technologies could benefit from standards, modularity, and open architectures
  - Compile existing interoperability efforts
  - Identify critical interfaces that would benefit from standardization
  - Hosting community discussions on lunar interoperability



LSII | Lunar Interoperability

- CY 2022 LSIC MOSA WG Task Progress



Focus Group Suggested Items for MOSA

Created by Kristin Jaburek, last modified on Apr 25, 2022

The following suggested items to consider for MOSA efforts were gathered from the:

- Surface Power Focus Group Telecon, February 24, 2022
- ISRU Modularity & Interoperability Subgroup

Category	Power Focus Group Suggested Items to Consider	Extreme Access (4/12/22	ISRU	Excavation & Construction
Voltage/Frequency/Current				

Existing Interoperability Standards & Programs

Created by Kristin Jaburek, last modified on Apr 25, 2022

The following existing standards and programs have been collected from LSIC Community through Focus Group and Subgroup meetings. Thank you for your input!

Anything we missed or understood incorrectly? Drop a comment on this page and let us know.

Existing Interoperability Standards & Programs

Category	Existing Standards & Programs	Link
Communications	International Deep Space Interoperability Standards - International Communication System Interoperability Standards (ICSIS)	https://www.internationaldeepspacestandards.com
Communications	Interoperability Plenary (IOP)	https://www.interoperabilityplenary.org/home.aspx
Communications	Space Frequency Coordination Group (SFCG)	https://www.sfcgonline.org/home.aspx Note: SFCG is an organization within Interoperability Plenary (IOP).

Community Brainstorming System Examples

- robotics and landers,
- power,
- software,
- system architectures,
- hardware,
- connectors,
- communications,
- units of measurement,
- sensors,
- safety equipment,
- human-machine interfaces,
- repairability and maintenance,
- disposal,
- ISRU equipment,
- construction equipment,
- human operation
- labelling

LSII | Lunar Interoperability

- Next Steps
  - Prioritize the systems and interfaces that need MOSAs
  - Organize community recommendations on those systems and interfaces.
  - Document the community findings and provided recommendations to NASA STMD leadership



LSIC | Join the Conversations

- **All are welcome to participate**
- **Influence important lunar technology and interoperability discussions**

- 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)
- Focus group meeting notes and recordings available on the website
- Internal LSIC site (Confluence) allows asynchronous participation and networking, including community bulletin board



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