



Lunar Surface Innovation
C O N S O R T I U M

Lunar Surface Innovation Extreme Environments

Presentation to Space Environments Virtual Seminar

Approved for Public Release [20220011131]



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August 2, 2022

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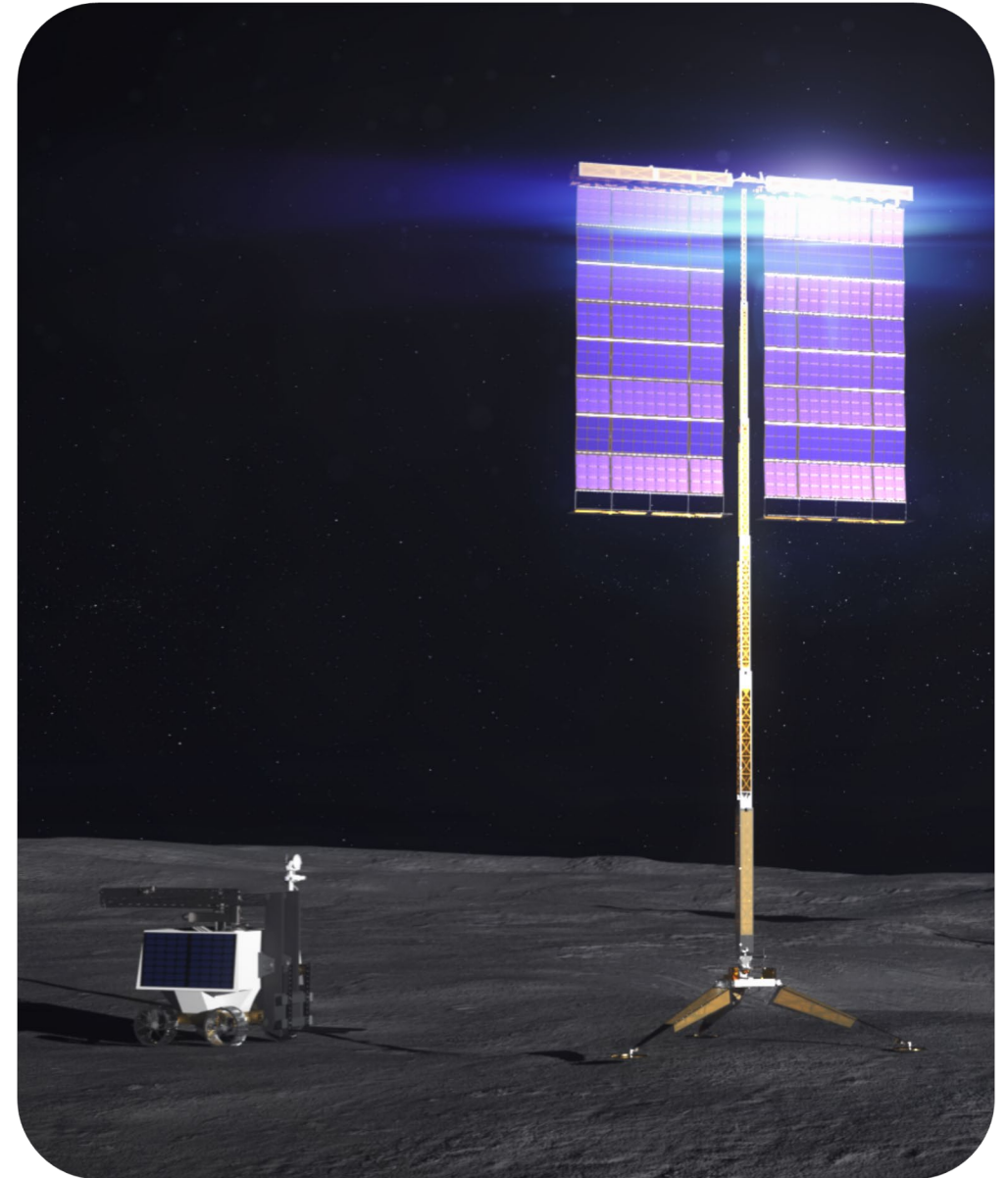


JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Agenda



- Introduction
- Overview of STMD/LSII/LSIC
- Overview of EE focus group
- Objectives and accomplishments



Introductions and Objective



Introductions

- Dr. Benjamin Greenhagen (benjamin.greenhagen@jhuapl.edu)
 - LSIC Extreme Environments Focus Area Lead
 - Strategic Integrator for Planetary Science , JHU APL
- Dr. Jamie Porter (jamie.porter@jhuapl.edu)
 - LSIC Extreme Environments Facilitator
 - Assistant Group Supervisor Space Environmental Effects Engineering, JHU APL
- Kevin Somervill (kevin.m.somervill@nasa.gov)
 - STMD Lunar Surface Innovation Initiative (LSII)
 - Technical Integration Manager for Extreme Environments

Objective

- Introduce LSIC and specifically the Extreme Environments focus group

Extreme Environments

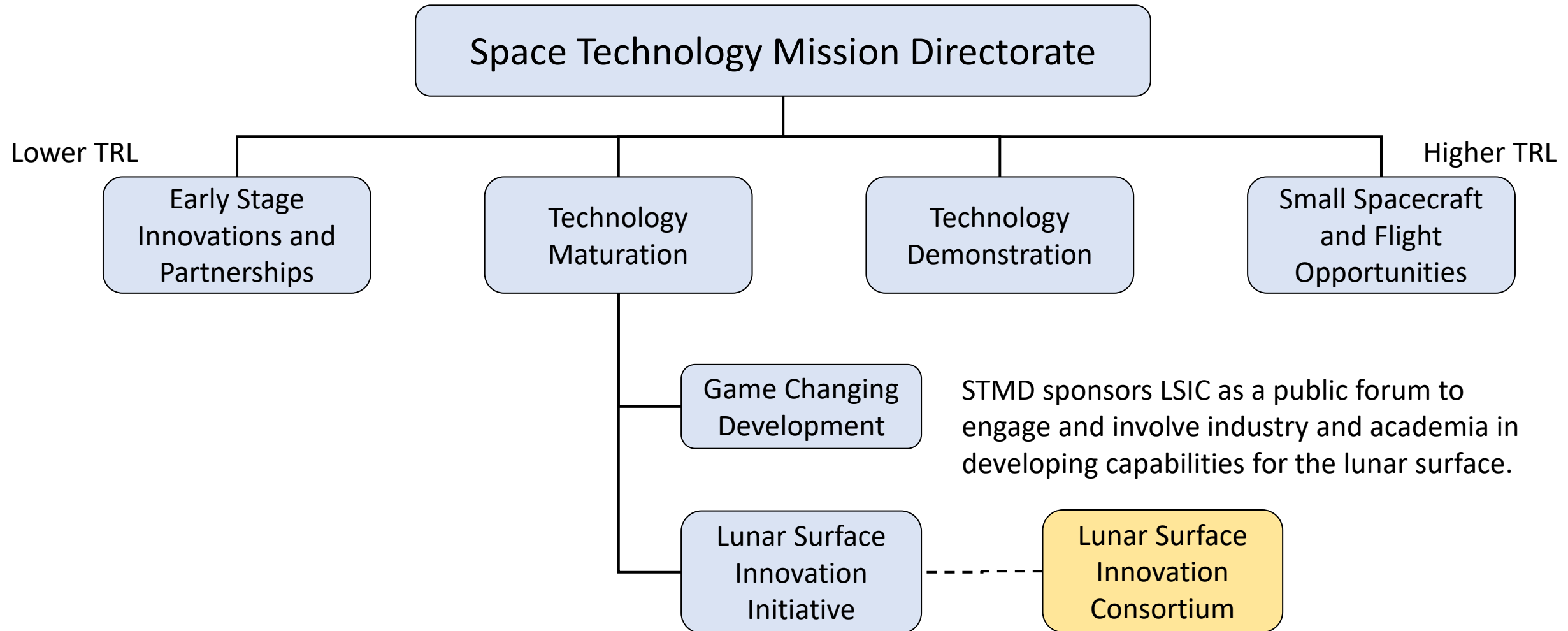
The LSIC Extreme Environments (LSIC-EE) focus area will progress technologies enabling the survival and operation of systems through the full range of lunar surface and subsurface conditions. These technologies will enable landers, rovers, manipulators, and other systems to operate through extreme conditions such as rapid temperature changes and permanently shadowed regions. Addition examples of extreme environments include exogenic factors (e.g. illumination, communications, radiation, plasma, micro-meteorites) and endogenic factors (e.g., dust, surface toxicity, regolith, rocks).

APL Staff
Contact all staff

- Benjamin Greenhagen
EE FOCUS AREA LEAD
- Jamie Porter
FOCUS GROUP FACILITATOR
- Karen Stockstill-Cahill
SUBGROUP COORDINATOR
- Alice Cocoros

<https://lsic.jhuapl.edu/Focus-Areas/index.php?fg=Extreme-Environments>

Organizational Structure



STMD matures technology from concept through infusion

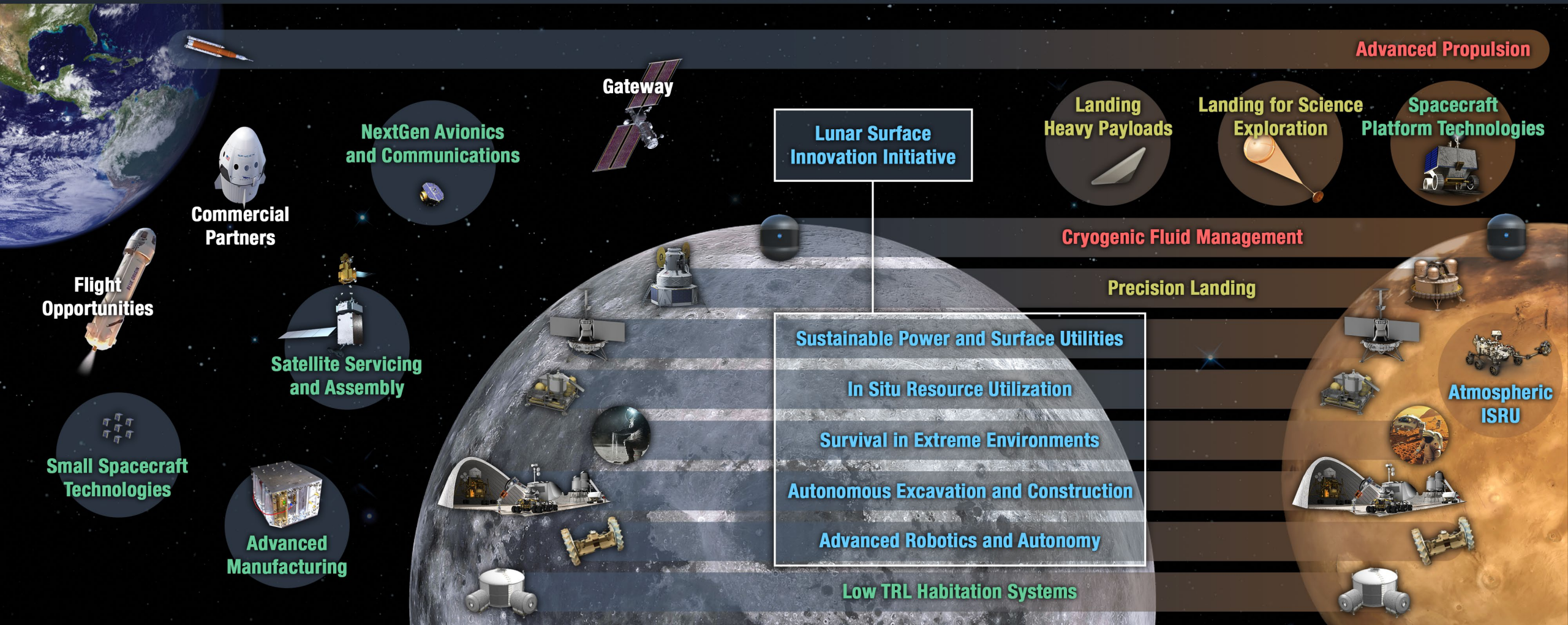
Ensuring American Global Leadership in Space Technology

**Rapid, Safe, and Efficient
Space Transportation**

**Expanded Access to Diverse
Surface Destinations**

**Sustainable Living and Working
Farther from Earth**

**Transformative Missions
and Discoveries**



Technology Drives Exploration

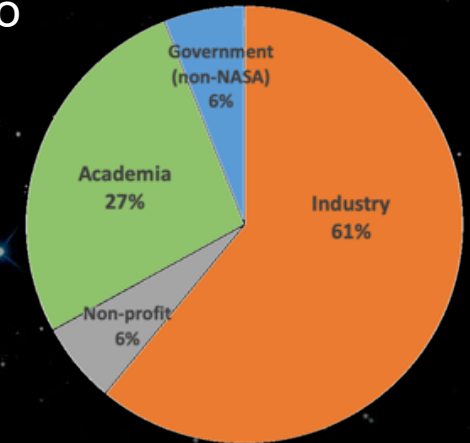
The Lunar Surface Innovation Initiative (LSII)



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

- Formulate and integrate technology maturation activities across the TRL pipeline and Space Technology programs
- Leverage innovative partnering and procurement approaches to expedite technology development
- Utilize early uncrewed lunar surface flight opportunities to inform key technology development
- Establish the Lunar Surface Innovation Consortium (LSIC) comprised of academia, industry, non-profits and other government agencies

LSII Representation: Engaged 600 organizations across 50 states, DC and Puerto Rico





Lunar Surface Innovation Consortium (LSIC)



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

LSIC Objectives include:

- Identifying lunar surface technology needs and assessing the readiness of relative systems and components
- Making recommendations for a cohesive, executable strategy for development and deployment of the technologies required for successful lunar surface exploration
- Providing a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results.

Focus Groups (FG) are the primary means for consistent interaction with the LSIC Community. This includes:

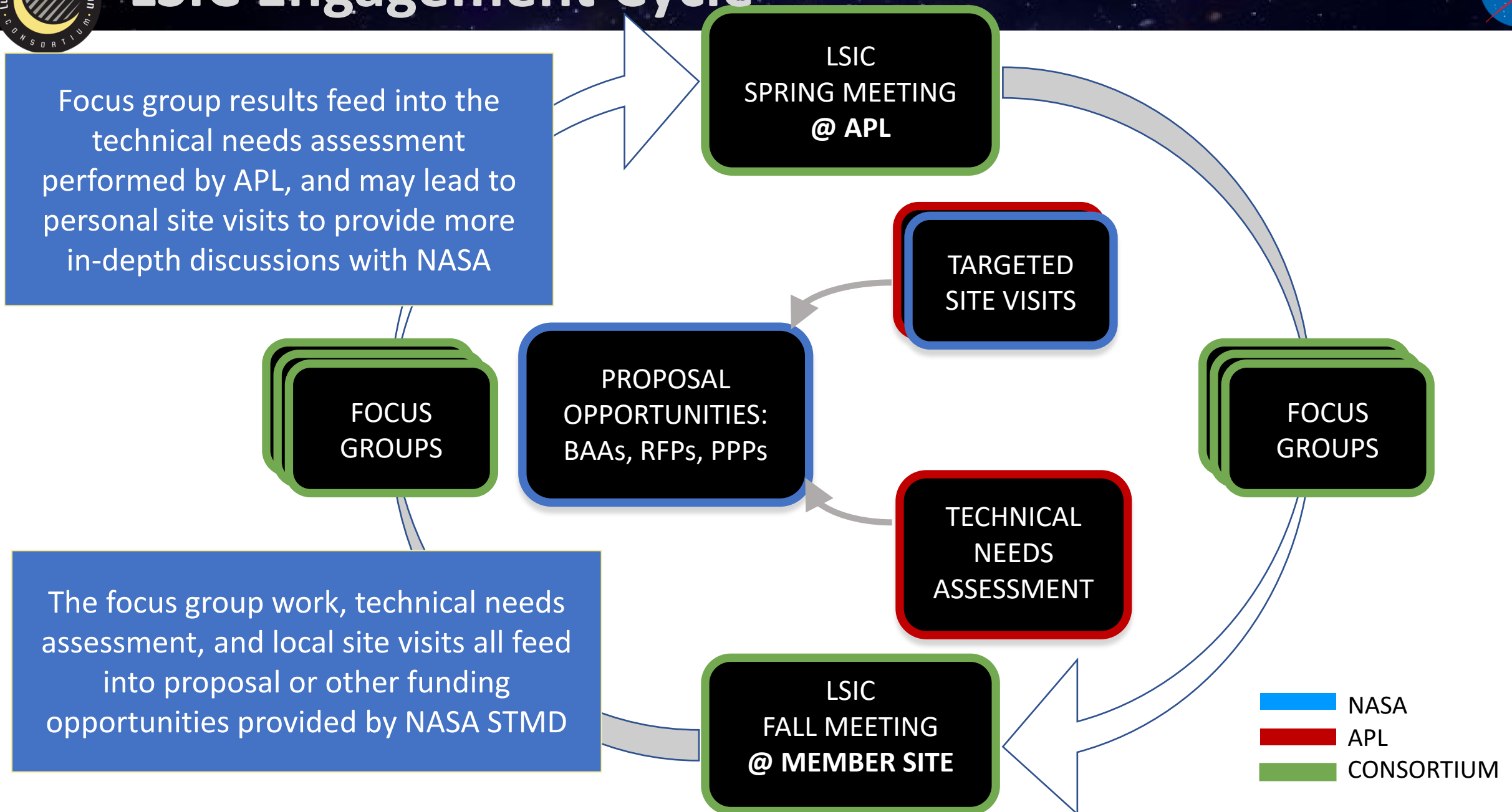
- Establishing collaborative relationships among members via virtual monthly forums, quarterly virtual workshops, and LSIC member site visits
- Building community and developing talent
- Compiling member input and reporting outcomes and recommendations



If interested in further information, please visit lsic.jhuapl.edu



LSIC Engagement Cycle



Focus Areas





Extreme Environment Focus Group



Vision

To build a community specializing in extreme lunar environments, provide and maintain community recommendations and guides to encourage technology testing in relevant environments, and evaluate specific priority surface environments for technology, observation/simulation, and testing/maturation capabilities and gaps.

Monthly Focus Meeting: Second Tuesday at 3:05 PM ET

Mailing List: LSIC_EXTREMEENVIRONMENTS@LISTSERV.JHUAPL.EDU

Website: <https://lsic.jhuapl.edu/Focus-Areas/Extreme-Environments.php>

Benjamin Greenhagen
EE Focus Area Lead



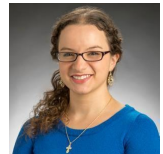
Jamie Porter
Focus Group Facilitator



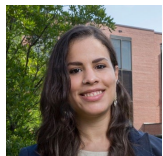
Karen Stockstill-Cahill
Subgroup Coordinator



Alice Cocoros
Cross Group Coordinator



Samalis Santini De Leon
EE Systems Engineering



Milena Graziano
EE Materials Engineering



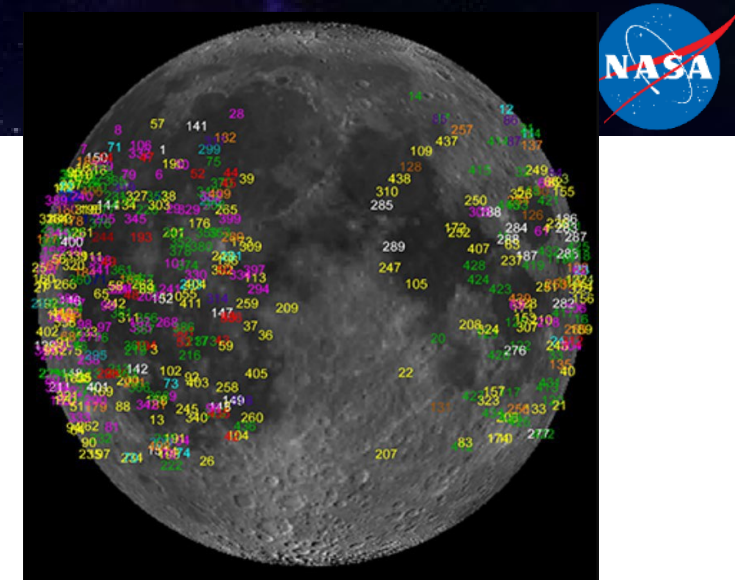
Kevin Somervill
*Technical Integration
Manager for EE*



	Radiation Environment Subgroup Lead: Dr. Lawrence Heilbronn, University of Tennessee, Knoxville	Galactic Cosmic Rays (GCR); Solar Energetic Particles (SEP); Albedo from GCR and SEP interactions in lunar regolith
	Regolith/Surface Interface Subgroup Lead: Melissa Roth, Off Planet Research	Volatiles; Grain Surface Chemistry; glass vs. mineral; endogenic vs. exogenic; Adhesiveness; Abrasiveness
	Space Weather / Plasma Environment Subgroup Lead: Justin Likar, JHU Applied Physics Laboratory	Variability between “nominal” and “extreme” environments; range of characteristic timescales; surface and near-surface plasma (magnetotail lobes, plasma sheet, solar wind); human generated
	Thermal & Illumination Environment Subgroup Lead: André Bénard, Michigan State University	Wide Temperature Range (40 K to 400 K); Heat flux (incident solar flux 0 - 1414 W/m²; planetary IR flux 0 – 1314 W/m²; and albedo 0.076 - 0.297)
	Vacuum / Exosphere Environment Subgroup Lead: Stephen Indyk, Honeybee Robotics	Surface pressure (at night) 3e-10 Pa; composition due to solar wind (He, Ne, H₂, Ar), abundance at surface, 2e5 particles/cm³

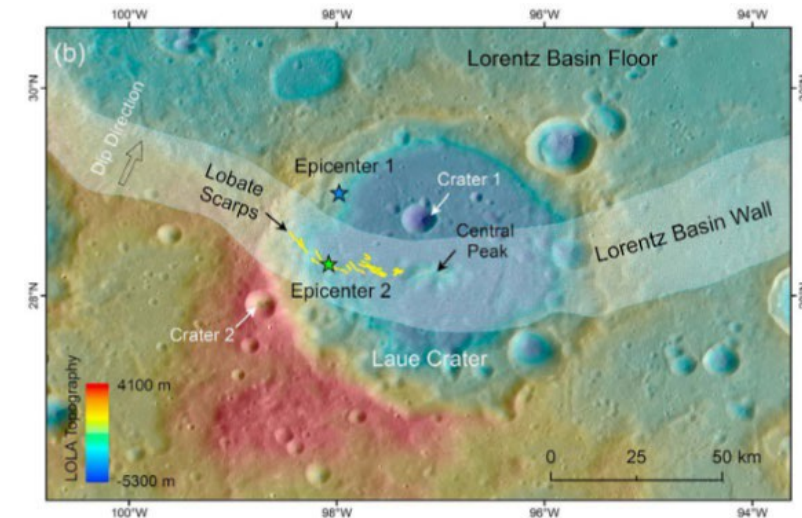
New! External Hazards Subgroup

- Covers all remaining hazards that can pose critical risks to lunar surface exploration systems, including:
 - Seismology
 - Lunar tectonism, moonquakes, microseisms, lunar rockfalls, avalanches
 - Mechanisms, internal structure evolution, frequency, measurement, modeling, seismic hazard mapping
 - Impactors
 - Particles, dust, asteroids, comets, meteoroids
 - Landing site (hypocenters), average speed, flux, mass/size, impact rate, threat, monitoring



Meteoroid Environment Office (MEO)
Impact Candidates 2005-2020

<https://www.nasa.gov/offices/meo/home/index.html>



Laue Crater

Kumar et al, Geophysical Research Letters 46, pp. 7972-7981



Year-1 Effort (2020-2021)



Building a Community:

- Monthly meetings featuring a variety of styles (discussions, guest speakers, etc.)
- Used community input to define subgroups based around aspects of the lunar environment; established subgroups with independent meeting schedules
- Encouraging the use of our wiki collaboration tool, Confluence, to the maximum extent possible
 - <https://lsic-wiki.jhuapl.edu/display/EE/>

Evaluating Specific Lunar Surface Environments

- Inclusive, multi-month series of meetings at focus group and subgroup levels
- Topic: Identifying and Characterizing Specific Lunar Environments
 - *In year 1, subgroups focused on collecting and organizing resources and determining the topic and scope of their community guidance document*
 - Specific lunar environments included in this study cover all planned and anticipated landing site locations for both human and robotic missions
 - Each subgroup has a dedicated space on Confluence to share information & resources, engage in discussions, and contribute to subgroup documents

Polar Environments

Permanently Shadowed Regions (PSRs)

Areas of High Illumination (>55% Illumination)

Mixed Polar Environments

Non-Polar Environments

Apollo-style Environments

Topographic Margins

Lunar Pits & Lava Tubes

Surface Anomalies

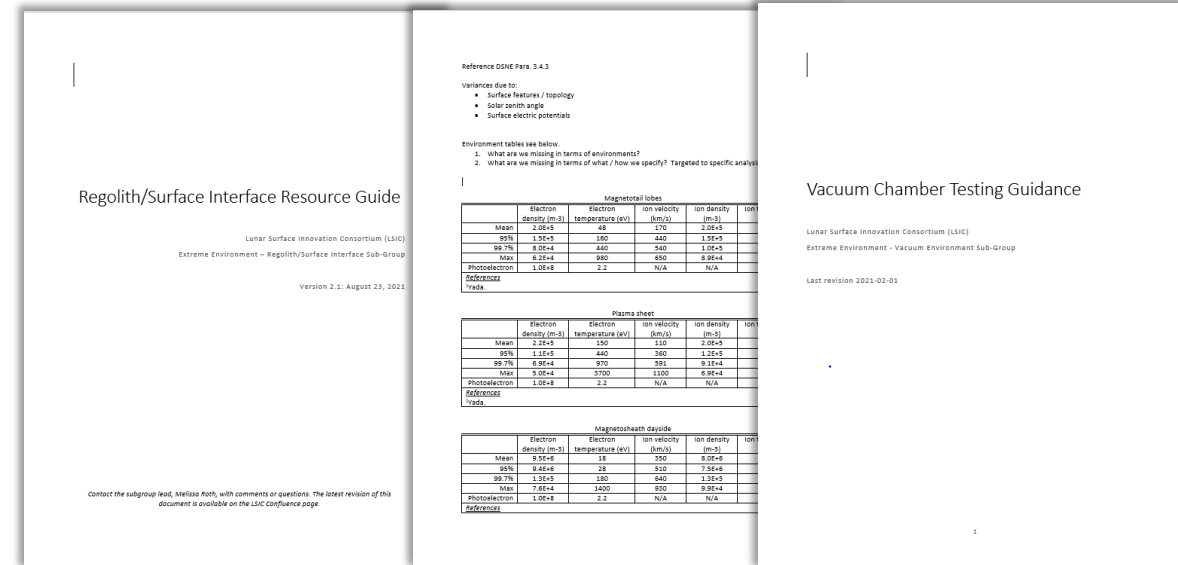
Goal 1

- Evaluate capabilities and gaps related to technology, observation / simulation, and testing / maturation for one or more prioritized lunar surface environments in a public white paper
 - Subgroups supported multi-month effort to discuss/explore technology/software/data gaps
 - Conducting crosstalks, workshops, etc. to discuss and document concerns for our path forward



Goal 2

- Publish a technology maturation guide relevant to one (or more) LSIC-EE subgroups.
 - Regolith, plasma, and vacuum/test subgroups are compiling resource guides to help the community at large



2022-2023 Extreme Environment Draft Goals

Goal 1

- Support all LSIC community hardware design and maturation by providing environmental effects guidelines and best practices through crosstalks, workshops, references, etc.

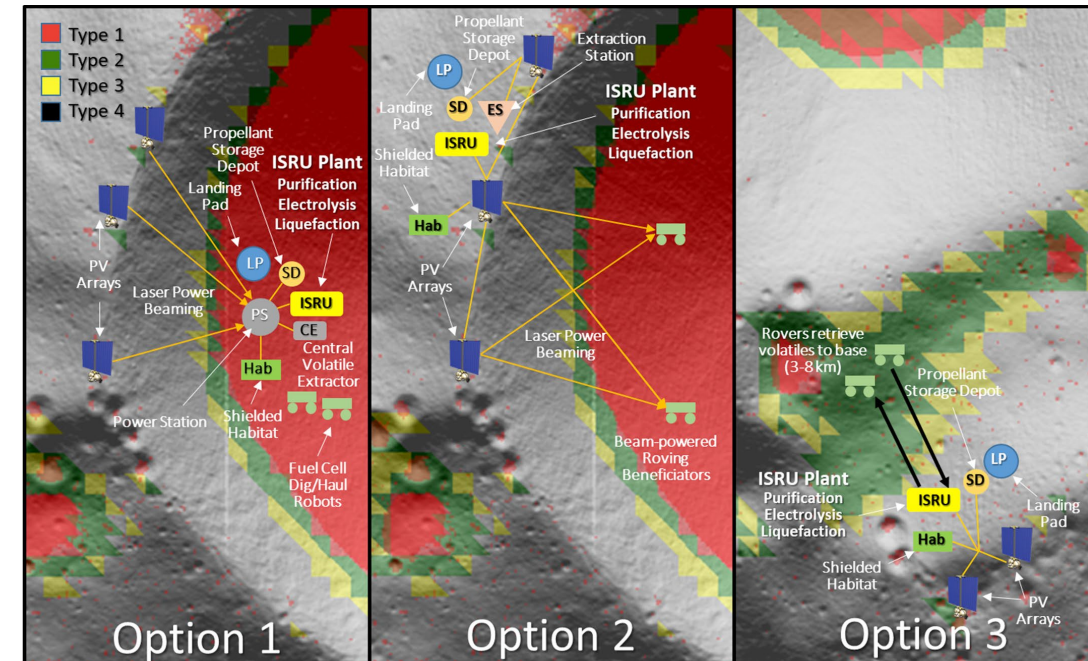
Goal 2

- Publish resource guides relevant to one (or more) LSIC-EE subgroups.

Designing for the Extremes Workshop

- Discuss specific access challenges and how environmental effects affect the design of hardware needed to implement an architecture as defined in the RLSO2 study
- Identify data needed to set design requirements and determine whether that data has already been collected, or what additional data is needed
- Discuss ways to test to these requirements

<https://lsic.jhuapl.edu/Events/Agenda/index.php?id=232>



Rad-Hard Power Electronics [Dec. 7, 2021]

- Key takeaways
 - NASA has identified the need for power electronics systems that are 99% reliable in the lunar surface environment for a minimum of ten (10) years
 - EE focus group work is critical to defining target lunar environments, device test methodology and pass/fail criteria development, and the identification and support of test facilities for device qualification

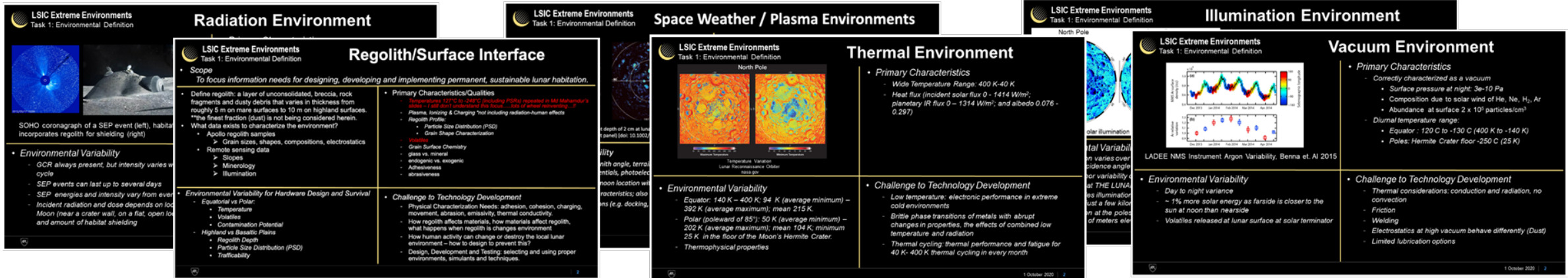
Plasma Interactions with Lunar Regolith/Dust [Mar. 15, 2022]

- Key takeaways:
 - Evident need for fundamental physics, modelling, and experimental work in dust, plasma, regolith, and space system interactions / interconnections
 - Knowledge gaps include plasma-related dust accumulation rates, lunar day and night plasma events, and triboelectric charging

Radiation, Regolith, and E&C [July 18, 2022]

- Key takeaways:
 - While there are good indications of how regolith can be used as regolith shielding, there are still SKGs that should be investigated during early missions to help with modeling and future planning.
 - Questions raised around sensitivity of certain variables relative to ensuring a uniform and robust structure for sintering and 3D printing processes – in particular, the nonuniformity in terms of both composition and particle size distribution

- Need for further discussion and representative testing guidance for system operations in lunar regolith
- Accurate and acceptable determination of charging risks (with quantified uncertainties) demands developments in analytical modeling and ground testing methods / capabilities
- Ground-based testing facilities, modeling tools and expertise exist to help understand the risks from the ionizing radiation environment on future lunar missions
- Everyone would benefit from shared testing knowledge and the establishment of testing standards and common practices in simulated lunar vacuum environment
- TRL for CFM MLIs needs to be improved from level 4 by testing various cryogenic liquids for lunar gateway or Cis-Lunar Space and other orbits





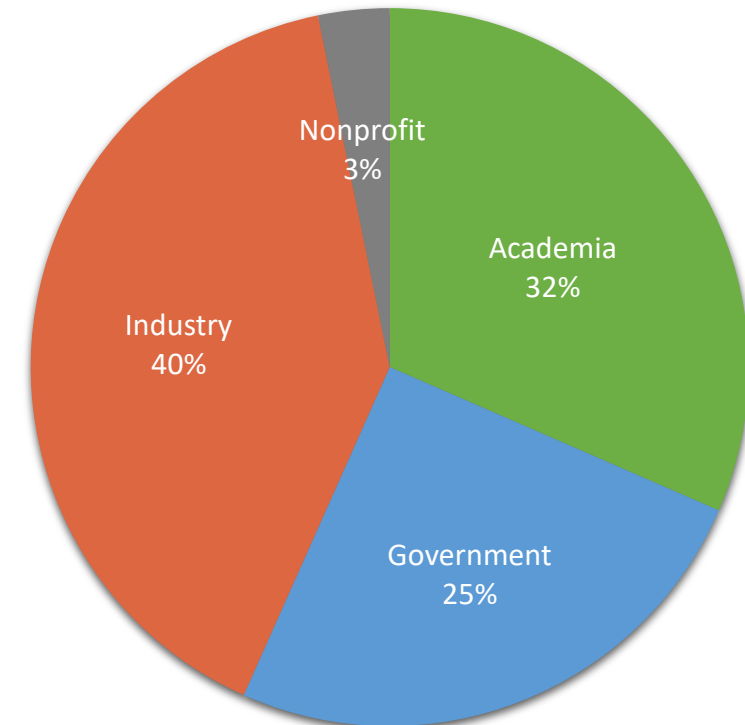
Designing for the Extremes Workshop – Aug. 5



- Workshop on the many challenges associated with regolith excavation and transport
 - Many environmental factors contribute to the engineering and testing of necessary hardware to successfully access and maneuver these sites
 - Environmental effects need to be explored for technology and data development
 - This workshop will provide an opportunity to discuss these risks and technologies needed to address them
- This interactive workshop will consist of:
 - An overview of the Robotics Lunar Surface Operations 2 (RLSO2) study
 - Environmental Effects panel with Q&A
 - Panel with Q&A on technology needed to access these sites, and breakout sessions
- Workshop goals:
 - Discuss specific access challenges and how environmental effects affect the design of hardware needed to implement an architecture as defined in the RLSO2 study
 - Identify data needed to set design requirements and determine whether that data has already been collected, or what additional data is needed
 - Discuss ways to test to these requirements

Registered Participants: 871

Average Monthly Meeting Attendance: 100



LSIC Spaces People Create

Pages / Extreme Environments Home

Created by Andrea Haman, last modified by Jamie Porter on Apr 05, 2022

Extreme Environments

The Extreme Environments focus area will progress technologies enabling the survival and operation of systems through the full range of lunar surface and subsurface conditions that drive engineering requirements. These technologies will enable landers, rovers, manipulators, and other systems to operate through extreme conditions such as rapid temperature changes and permanently shadowed regions. Additional examples of extreme environments include exogenic factors (e.g., illumination, communications, radiation, plasma, micro-meteorites) and endogenic factors (e.g., dust, surface toxicity, regolith, rocks). An important expected output is the generation of an Extreme Environments User's Guide.

Extreme Environments Members: Who's Who in LSIC-EE

Facilitator: Jamie Porter
Facilitator Email: Facilitator@ExtremeEnvironments@jhuapl.edu
Listserve Address: LSIC_EXTREMEENVIRONMENTS@LISTSERV.JHUAPL.EDU
Focus Group Monthly Meetings: Second Tuesday at 3:05 p.m. ET
<https://jhuapl.zoomgov.com/j/1613825581?pwd=U09kaFVSRGtGSnNjc2NoE0pGWWJZz09>
 Meeting ID: 161 382 5581
 Password: 761924

Surface Environment Activity: Specific Lunar Surface Environments and Technical Challenges

Extreme Environments Conversations

To create a new conversation, just hit the "create" button while on the LSIC-EE Conversations page to keep everything in the same place.

- April 20 2022 EE MOSA Brainstorming Questions
- August 10 2021 Meeting Discussions
- July 13 2021 Meeting Discussions
- June 8 2021 Meeting Discussions
- Mar 9 2021 Meeting Discussions
- Feb 9 2021 Meeting Discussions
- Jan 12 2021 Meeting Discussions
- Nov 10 2020 Meeting Discussions
- Oct. 6 Brainstorming
- Task 1 - Defining the Environment
- LSIC-EE Open Discussion
- Welcome to LSIC-EE Confluence!

The Extreme Environments Focus Group Meets Monthly on 2nd Tuesday at 3:05pm ET

Subgroups Information & Subgroups Meeting Schedule
 (Please see subgroup page for connection information.)

Subgroup	Meeting Time	Subgroup Lead	Institution of Subgroup Lead
Radiation Environment	3rd Wed at 2 pm ET	Lawrence Heilbrunn	University of Tennessee Knoxville
Regolith/ Surface Interface	4th Fri. at 3 pm ET	Melissa Roth	Off Planet Research
Space Weather / Plasma Environment	4th Mon. at 2 pm ET*	Justin Likar	JHU Applied Physics Laboratory
Thermal & Illumination Environment	4th Fri. at 2 pm ET	Ahsan Choudhuri	University of Texas El Paso
Vacuum / Exosphere Environment	4th Thurs. at 12 pm ET *3rd Th for Nov. & Dec. 2021	Stephen Indyk	Honeybee Robotics
External Meetings	TBA	(@ExtEnvMeetings)	

APL Internal Page

LSIC Spaces People Create

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Who's Who in LSIC-EE

Created by Benjamin Greenhagen, last modified by Igor Alarado on Mar 10, 2022

Make sure that you stay on the radar of all of NASA and the rest of the community! Fill out the table below for your institution; don't be shy! Please don't delete other entries.

Other Focus Groups:

- Who's Who in DM
- Who's Who in Extreme Access (EA)
- Who's Who in E&C
- Who's Who in ISRU
- Who's Who in SP

Who Are You? (Individual or Institution)	What Do You Do?	What Do You Want Others to Know About You?	Other Comments
Randall Kirschman, PhD.	Consulting on electronic devices and hardware, particularly for extreme temperatures.	I have been involved with R&D for cryogenic electronics for a long time.	I am interested in contribution to exo-cryo-capable.
Ben Greenhagen, LSIC-EE FG Facilitator	As the LSIC-EE Facilitator, I help to form a collaborative alliance of NASA, industry, academia, non-profits and government in areas relevant to Extreme Environments. My research interests focus on thermal emission spectroscopy from airless bodies. I love flight missions and am the Deputy PI of the LRO Diviner Lunar Radiometer, a Co-I of Lunar Flashlight, a Co-I of L-CRIS, and a Co-I of the BepiColombo MERTIS. I also run a laboratory spectroscopy facility, the Simulated Airless Body Emission Laboratory.		I'm here to help build this community! I build bridges not just between NASA but also between community are looking for opportunities to be in this community, let me know!
Kevin Somerville NASA POC	As the NASA POC, I help to communicate and coordinate between the LSIC forum and NASA. While my background is in the development of electronics for space applications, I'm keenly interested in how NASA can help to develop commercial capabilities and further academic and industrial research.	I can help to connect you with people and organization in NASA.	
Honeybee Robotics	Honeybee focuses on developing space mining robots for exploration and ISRU. We develop sampling and sample handling systems for all extra-planets.	We work with NASA, Industry and Academia to develop new technologies and missions. It's more fun to explore together!	To the Moon!



Technology Drives Exploration