



Lunar Surface Innovation

C O N S O R T I U M

Extreme Environments Focus Group June Meeting

June 8, 2021

Dr. Benjamin Greenhagen
Planetary Spectroscopy Section Supervisor
Johns Hopkins Applied Physics Laboratory

Facilitator_ExtremeEnvironments@jhuapl.edu



Today's Agenda

- LSIC Updates (2 min – Greenhagen)
- Surface Environment Activity – Survey and Final Steps (5 min – Greenhagen)
- Surface Environment Activity – Subgroup Rankings Discussion (15 min – Greenhagen, Subgroup Leads)
- Featured Presentation (25 min – Moorhead)
 - “The Primary Meteoroid Flux at the Moon and the Lunar South Pole”
- Open floor (time permitting)

LSIC Updates

LSIC Spring Meeting was May 11-12

- Presentations are now archived online
 - <http://lsic.jhuapl.edu/News-and-Events/Agenda/index.php?id=124>

Vertical Solar Array Technologies (VSAT) Meeting was May 27

- Joint meeting with Surface Power, Dust Mitigation, and Extreme Environments
- Presentations are now archived online (Surface Power page)
 - <http://lsic.jhuapl.edu/Focus-Areas/Surface-Power.php>

Upcoming LSIC Workshops (<http://lsic.jhuapl.edu/News-and-Events/>)

- Power Beaming Workshop (7/22-7/23/21)
- Commercial Lunar Payload Services Workshop (TBD Fall 2021)
- TBD Joint Focus Group Workshop(s) (starting Fall 2021)

Surface Environment Activity

Topic: Identifying and Classifying Specific Lunar Surface Environments

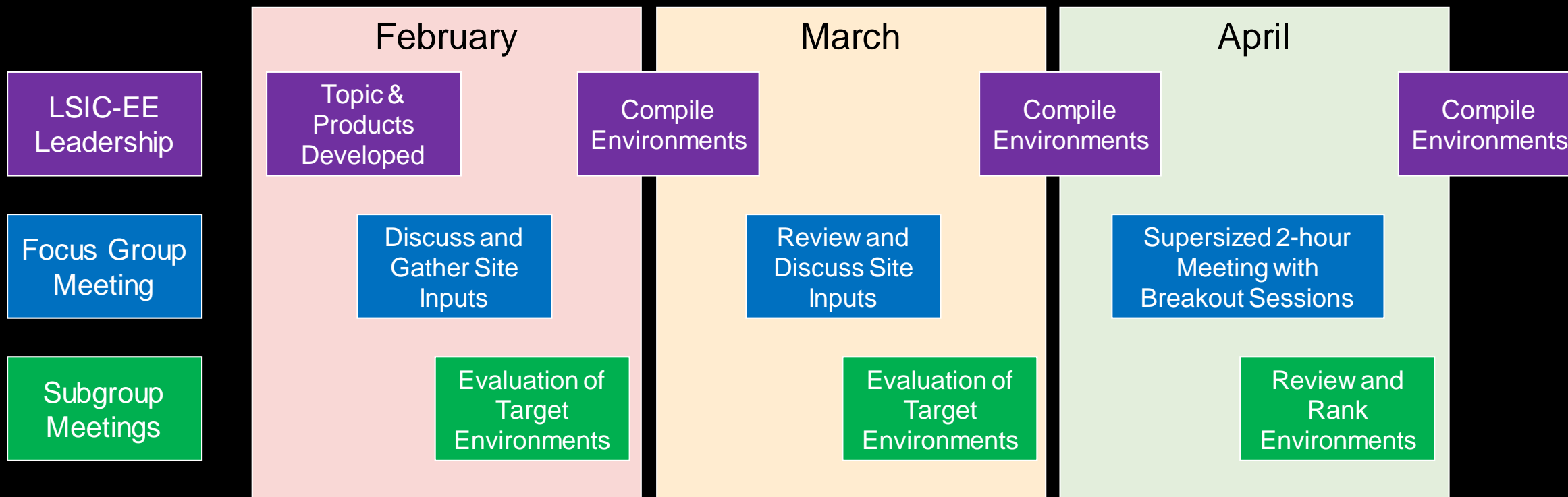
- “Breaking Down the Lunar Environment Monolith”
- How do different environments stress technologies in different ways

Polar Environments	Environmental Variations
Permanently Shadowed Regions (PSRs)	<ul style="list-style-type: none"> • PSRs with significant reflected illumination • PSRs without significant reflected illumination • PSRs with volatiles in the near-surface regolith • PSRs with desiccated near-surface regolith
Areas of High Illumination (>55% Illumination)	<ul style="list-style-type: none"> • Naturally high illumination • Mobility-enabled high illumination
Mixed Polar Environments	<ul style="list-style-type: none"> • Illuminated terrain with rover-accessible macro cold traps (10s to 100s+ meter PSRs) • Illuminated terrain with rover-accessible micro cold traps (1 - 10 meter PSRs) • Occasionally illuminated terrain with subsurface volatile stability • Polar pits or lava tubes (hypothetical)

Non-Polar Environments	Environmental Variations
Apollo-style Environments	<ul style="list-style-type: none"> • Maria • Highlands
Topographic Margins	<ul style="list-style-type: none"> • Crater features (rims, peaks, floor fractures) • Volcanic features (vents, domes, riles)
Lunar Pits & Lava Tubes	<ul style="list-style-type: none"> • Mare basalt features • Impact melt features
Surface Anomalies	<ul style="list-style-type: none"> • Irregular Mare Patches • Regolith Texture Anomalies (High/Low Dust, Pyroclastic, etc.) • Magnetic Anomalies

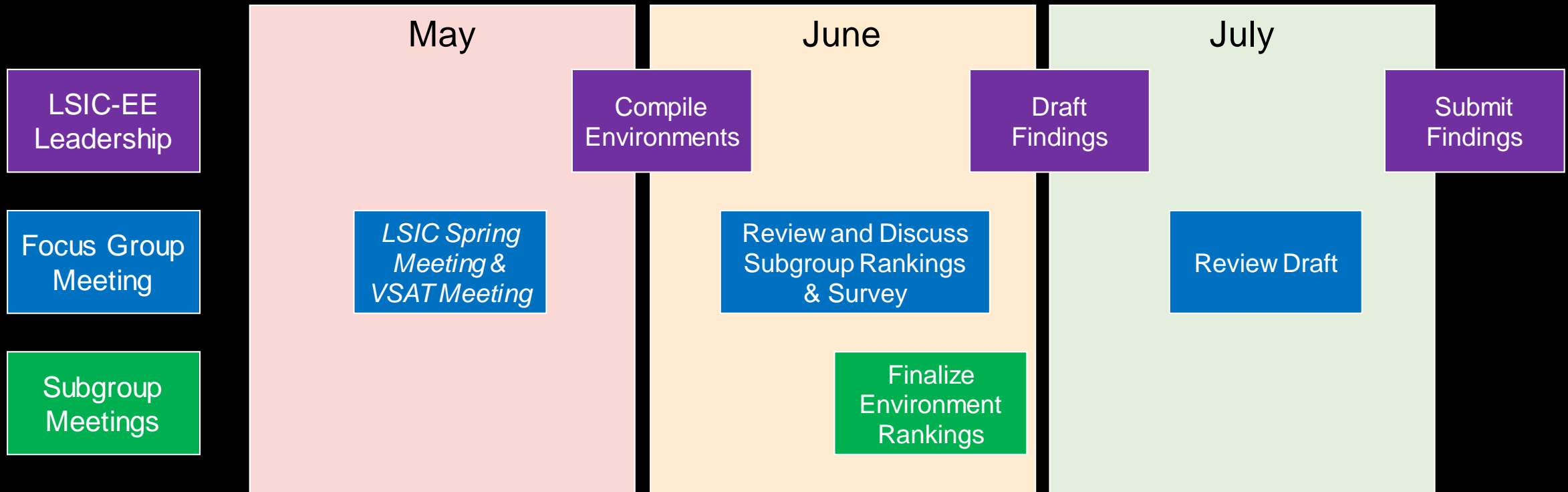
Surface Environment Activity

Activities to Complete Before the LSIC Spring Meeting



Surface Environment Activity

Activities to Complete After the LSIC Spring Meeting



New Activity Home on Confluence

Extreme Environments Home - E: X

Isic-wiki.jhuapl.edu/display/EE/Extreme+Environments+Home

LSIC Spaces People Create

Extreme Environments

Pages

Blog

SPACE SHORTCUTS

- Meeting notes
- File lists

PAGE TREE

- Understanding Specific Lunar Sur
 - APL Internal Page
 - EE Monthly Meeting
 - Extreme Environments Subgroup
 - File lists
 - LSIC-EE Conversations
 - Meeting notes
 - Who's Who in LSIC-EE

Dashboard

Extreme Environments Home

Created by Andrea Harman, last modified by Benjamin Greenhagen 12 minutes ago

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: @ Benjamin Greenhagen

Facilitator Email: Facilitator@ExtremeEnvironments@jhuapl.edu

Listserv Address: Listserv Address: LSIC_EXTREMEENVIRONMENTS@LISTSERV.JHUAPL.EDU

Focus Group Monthly Meetings: Second Tuesday at 3:05 p.m. ET

Surface Environment Activity: Understanding 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.

- Welcome to LSIC-EE Confluence!
- LSIC-EE Open Discussion
- Task 1 - Defining the Environment
 - Oct. 6 Brainstorming
 - Nov 10 2020 Meeting Discussions
 - Jan 12 2021 Meeting Discussions
 - Feb 9 2021 Meeting Discussions
 - Mar 9 2021 Meeting Discussions
 - June 8 2021 Meeting Discussions

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

Subgroups Information & Subgroups Meeting Schedule

Subgroup	Meeting Time	Subgroup Lead	Institution of Subgroup Lead
Radiation Environment	4th Wed.at 2 pm ET	Lawrence Heilbronn	University of Tennessee Knoxville
Regolith/ Surface Interface	4th Tues. at 11 am 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	3rd Tues. at 5 pm ET	Ahsan Choudhuri	University of Texas El Paso
Vacuum / Exosphere Environment	4th Thurs. at 12 pm ET	Stephen Indyk	Honeybee Robotics
External Hazards	TBA	(Position open)	-

Recent space activity

- Benjamin Greenhagen
 - June 2021 Topic #2 - The Primary

Space contributors

- Benjamin Greenhagen (a minute ago)
- Stephen Indyk (24 minutes ago)

Past Meetings

- 13 April 2021
- 9 March 2021

<https://Isic-wiki.jhuapl.edu/display/EE>

Surface Environment Activity

Survey

- Vote for the environment(s) you think we should prioritize for our next FG workshop(s) or working meeting(s)
- <https://forms.gle/QiKzFjLvLnXhdGgN8>
- Vote early and vote often (please try to respond by the end of this week)!

Review Draft Findings

- *Findings will be on Confluence*
- *Brief discussion at July Focus Group Meeting, July 13th*

Subgroup Environment Rankings

Summary of all Subgroups (<https://lsic-wiki.jhuapl.edu/pages/viewpage.action?pageId=13340355>)

Specific Environment	Radiation	Regolith / Surface	Space Weather / Plasma	Thermal & Illumination	Vacuum / Exosphere
P1. Permanently Shadowed Regions	5 (Tier 2)	1 (Tier 1)	4 (Tier 2)	1 (Both)	1
P2. Areas of High Illumination	4 (Tier 2)	6 (Tier 3)	6 (Tier 3)	3 (T) & 7 (I)	6
P3. Mixed Polar Environments	2 (Tier 1)	2 (Tier 1)	1 (Tier 1)	2 (T) & 3 (I)	1
NP1. Apollo-Style	1 (Tier 1)	7 (Tier 3)	7 (Tier 3)	5 (Both)	7
NP2. Topographic Margins	3 (Tier 1)	5 (Tier 2)	3 (Tier 2)	6 (T) & 4 (I)	3
NP3. Lunar Pits / Lava Tubes	6 (Tier 3)	4 (Tier 2)	5 (Tier 3)	4 (T) & 2 (I)	4
NP4. Surface Anomalies	7 (Tier 3)	3 (Tier 2)	2 (Tier 1)	7 (T) & 5 (I)	5

Subgroup Environment Rankings

Radiation Environment Subgroup (<https://lsic-wiki.jhuapl.edu/display/EE/RadEnv+lunar+surface+environments+ranking>)

Specific Environment	Radiation	Notes
NP1. Apollo-Style	1 (Tier 1)	highest GCR flux, shelter needed for SEP event, largest source of background/interference for instruments
P3. Mixed Polar Environments	2 (Tier 1)	highly variable rad environment due to variable local shielding, regolith composition affects albedo neutron spectrum
NP2. Topographic Margins	3 (Tier 1)	local variations in rad environment due to variations in shielding provided by topographical features (crater walls, etc.)
P2. Areas of High Illumination	4 (Tier 2)	highest GCR dose of polar sites, but less uncertainty in predicted dose
P1. Permanently Shadowed Regions	5 (Tier 2)	same comment as P3, but variability and associated uncertainty less than P3
NP3. Lunar Pits / Lava Tubes	6 (Tier 3)	Shielding inside lava tubes is very thick, very low doses. Interesting to look at dose inside near entrance, though.
NP4. Surface Anomalies	7 (Tier 3)	Magnetic field strengths too low to affect ionizing radiation environment

Subgroup Environment Rankings

Regolith / Surface Interface Subgroup (<https://lsic-wiki.jhuapl.edu/display/EE/RSI%3A+Landing+Sites+Rankings>)

Specific Environment	Regolith / Surface	Notes
P1. Permanently Shadowed Regions	1 (Tier 1)	Extreme conditions w/ potential volatile reactions and physical differences. Temperatures may exceed expected thermal performance of suit materials.
P3. Mixed Polar Environments	2 (Tier 1)	Need to transition between extremes. Potential interaction with volatiles.
NP4. Surface Anomalies	3 (Tier 2)	Many unknowns, especially for properties.
NP3. Lunar Pits / Lava Tubes	4 (Tier 2)	Many unknowns, but likely very different compared to surface regolith. While water ice may not be stable in the tube entrances at lower latitudes, sulfur may be. The expected sharp boulders may pose hazardous for spacesuits.
NP2. Topographic Margins	5 (Tier 2)	Challenges for navigation but fewer unknowns.
P2. Areas of High Illumination	6 (Tier 3)	Less characterized but longer days to maintain properties and less frequent ESD than NP1.
NP1. Apollo-Style	7 (Tier 3)	Fairly well characterized.

Subgroup Environment Rankings

Space Weather / Plasma Subgroup (<https://lsic-wiki.jhuapl.edu/display/EE/SWPE%3A+Surface+Environment+Rankings>)

Specific Environment	Space Weather / Plasma	Notes
P3. Mixed Polar Environments	1 (Tier 1)	Large uncertainties; potential for transient environments.
NP4. Surface Anomalies	2 (Tier 1)	Big uncertainty & variable; not very well understood
NP2. Topographic Margins	3 (Tier 2)	Potential gradients expected across adjacent surfaces / regions (large dV -> risk of ESD)
P1. Permanently Shadowed Regions	4 (Tier 2)	Technically very challenging but generally better understood
NP3. Lunar Pits / Lava Tubes	5 (Tier 3)	Unlikely to be much charging in tubes; pits may fit elsewhere
P2. Areas of High Illumination	6 (Tier 3)	High photocurrent; comparatively well-studied
NP1. Apollo-Style	7 (Tier 3)	Large absolute charging expected (e.g. kV night side during magnetotail passage); comparatively well known, however. Similar comments regarding terminator

Subgroup Environment Rankings

Thermal & Illumination Subgroup (<https://lsic-wiki.jhuapl.edu/display/EE/Lunar+Surface+Environment+Ranking>)

Specific Environment	Thermal	Illumination	Notes
P1. Permanently Shadowed Regions	1	1	
P3. Mixed Polar Environments	2	3	
P2. Areas of High Illumination	3	7	
NP3. Lunar Pits / Lava Tubes	4	2	Radiator Design/Heat Rejection Challenges
NP1. Apollo-Style	5	5	
NP2. Topographic Margins	6	4	
NP4. Surface Anomalies	7	5	

Subgroup Environment Rankings

Vacuum / Exosphere Subgroup (<https://lsic-wiki.jhuapl.edu/display/EE/VEE+Lunar+Surface+Environment+Ranking>)

Specific Environment	Vacuum / Exosphere	Notes
P1. Permanently Shadowed Regions	1	Many unknowns with PSR environment.
P3. Mixed Polar Environments	1	Difficult to deal with technology challenges for a transient environment. Many unknowns with PSR environment. Exploring Mixed Polar Environments has to encounter two difficult environmental condition sets.
NP2. Topographic Margins	3	Transitions have more and more complex requirements.
NP3. Lunar Pits / Lava Tubes	4	May provide complex atmospheric conditions due to exploration interactions. Will out-gassing material from exploratory system become trapped in this space and affect any instrument measurements?
NP4. Surface Anomalies	5	Complex, but likely similar vacuum environment conditions to what is currently understood.
P2. Areas of High Illumination	6	Better understood conditions, most likely fewer surfaces with out-gassing properties.
NP1. Apollo-Style	7	Studied and best understood environment of this environment set.

Subgroup Environment Rankings

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Featured Presentation

- The Primary Meteoroid Flux at the Moon and the Lunar South Pole
 - Althea Moorhead, NASA Meteoroid Environment Office, MSFC



JOHNS HOPKINS
APPLIED PHYSICS LABORATORY