



Lunar Surface Innovation

C O N S O R T I U M

Extreme Access Focus Group Telecon

March 11, 2021

We'll start around 3:03

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Today's Agenda

- Upcoming Meetings/Opportunities
- LSIC Updates
- Feedback on last week's Lunar Mapping for Precision Landing workshop
- Presentation on state of the art in position, navigation, and timing (PNT) for the Moon
- Pick times for subgroup meetings
 - Lunar O & M facility subgroup (previously known as sheds/Wadis)
 - PNT
- Annual Goal – vote for an environment/location
- Open floor and Discussion

Upcoming Meetings

- Focus Group Telecons (2nd Thursday each month, 3-4 pm EST)
 - March 11, 2021
 - April 8, 2021
- Lunar and Planetary Science Workshop March 15-19
 - Register at https://www.hou.usra.edu/meeting_portal/registration/index.cfm?mtg=lpssc2021
- LSIC Spring Meeting Tuesday May 11- Wednesday May 12
 - More details coming in April

Extreme Environments – Mar 21

Current Activity: Identifying and Classifying Specific Lunar Surface Environments

- Purpose and Products

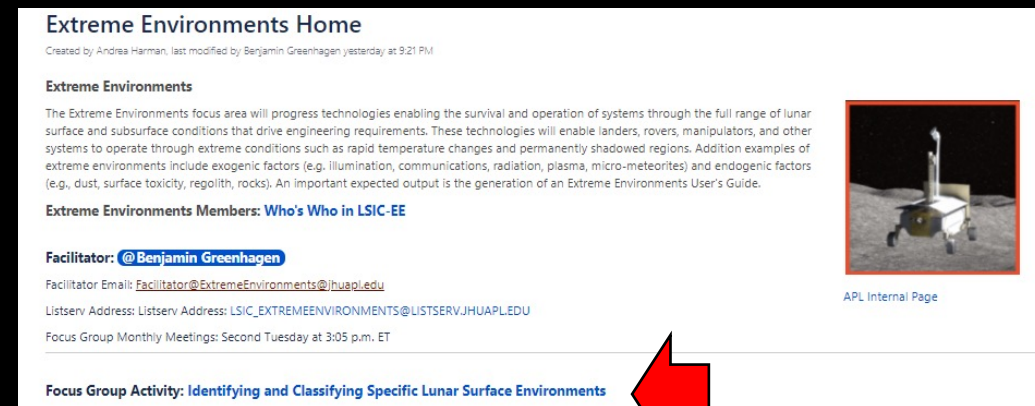
- “Breaking Down the Lunar Environment Monolith”
- How do different environments stress technologies in different ways
- How do specific lunar environment differ from descriptions of the general lunar environment?
- Product #1: Preliminary environmental assessments for each type, archived on Confluence
- Product #2: “Final” list of environments ranked by subgroups according to difficulty

- Identified 3 Polar and 4 Non-Polar Environment Types (including 19 variants)

- Activity is on Confluence: <https://lsic-wiki.jhuapl.edu/display/EE/Identifying+and+Classifying+Specific+Lunar+Surface+Environments>

- LSIC-EE Subgroups Meetings in Late March to Evaluate Environments

- Radiation, Regolith & Surface Interface, Space Weather & Plasma, Thermal & Illumination, Vacuum & Exosphere
- Schedules on Confluence




Extreme Environments Home
Created by Andrea Harman, last modified by Benjamin Greenhagen yesterday at 9:21 PM

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

Focus Group Activity: Identifying and Classifying Specific Lunar Surface Environments



APL Internal Page

Extreme Environments – Mar 21

LSIC-EE “Supersized” Working Meeting on April 13th, 2:30-4:30 ET

- 2:30 - Introduction, Scope, and Products (5 min)
- 2:35 - Review of Environment Drivers (5 min lightning talks)
- 3:00 - Transition to Breakout Zooms (5 min)
- 3:05 - Breakout Sessions (55 min)
 - Polar Specific Environments
 - Non-Polar Specific Environments
- 4:00 - Transition to Plenary Zoom (5 min)
- 4:05 - Brief Recaps / Burning Questions (10 min)
- 4:15 - Next Steps and Discussion (15 min)

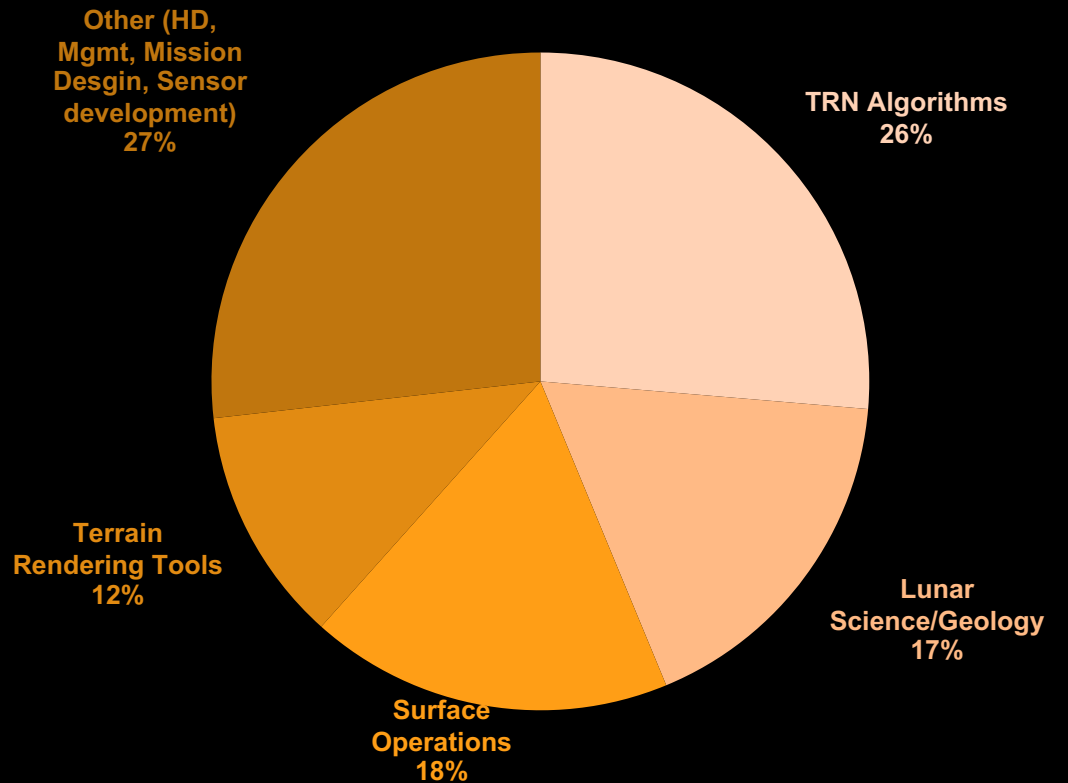
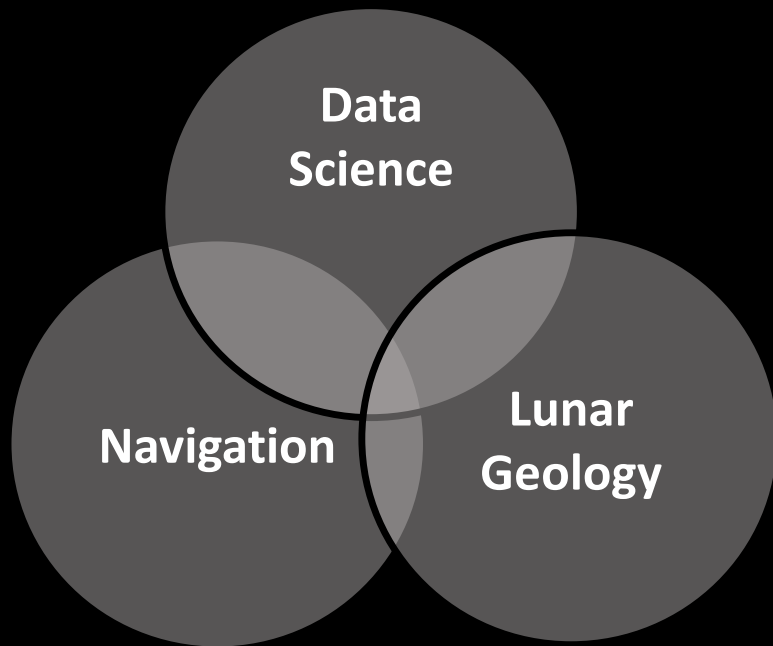
Follow-up Activities Kickoff After the LSIC Spring Meeting

- Prioritize Specific Lunar Environments (and down select to a few to focus on initially)
- Identify Capabilities and Gaps related to Observation (Knowledge) & Simulation (Prediction), Technology Capabilities, and Experimental Testing & Technology Maturation (including Facilities)

Workshop on Lunar Mapping for Precision Landing

- March 2-4, 2021
 - 12-4 ET each day
 - <http://lsic.jhuapl.edu/Events/Agenda/index.php?id=120>
- Goal: Bring together lunar geologists, data scientists, navigation engineers
- Objective: Develop a mutual understanding of map requirements to achieve lunar TRN solutions and provide better insight into the map data and map building processes
- Purpose was to get input from the community to help NASA catalog existing tools, methods and approaches for building DEMS, accurate rendering of the surface, verification and validation (V&V) of TRN systems

Workshop Attendees

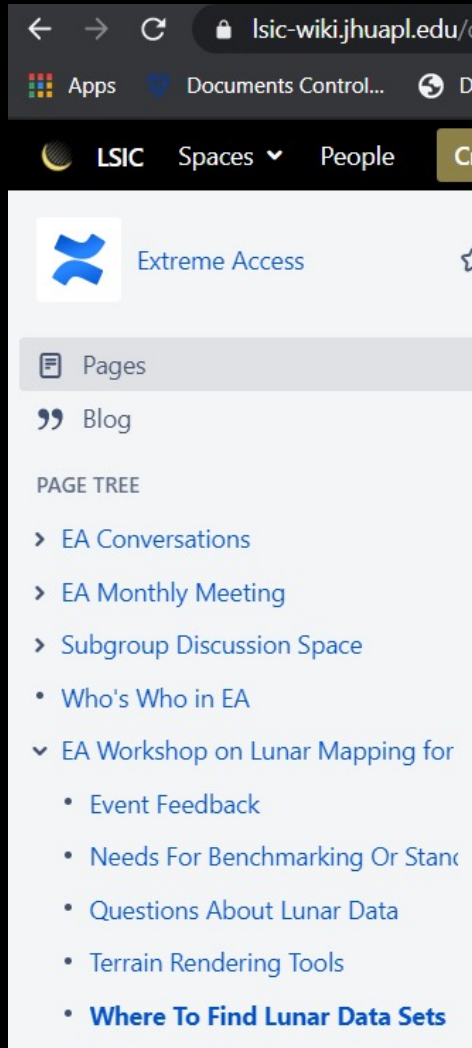




Questions/comments from workshop

- How can we prepare for (and take advantage of) a future when there are commercial sources of map data (e.g., from CLPS vendors) and not just space agencies?
- How can we support future missions to subsurface voids?
- Can CLPS lander data be used to Validate Maps?
- want to see good justification for the requirements; asking for too much (more than needed) can have ripple effects and be significantly harder to achieve
- Others?

Lunar mapping discussion space



The screenshot shows a web browser window with the address bar displaying 'Isic-wiki.jhuapl.edu/'. The browser's address bar includes navigation icons (back, forward, refresh) and a lock icon. Below the address bar, there are icons for 'Apps', 'Documents Control...', and 'D'. The main content area shows a navigation menu for 'Extreme Access' with the following items:

- Extreme Access
- Pages
- Blog
- PAGE TREE
 - > EA Conversations
 - > EA Monthly Meeting
 - > Subgroup Discussion Space
 - Who's Who in EA
 - ▼ EA Workshop on Lunar Mapping for
 - Event Feedback
 - Needs For Benchmarking Or Stanc
 - Questions About Lunar Data
 - Terrain Rendering Tools
 - **Where To Find Lunar Data Sets**

- Current Funding Opportunities:

- 2021 Early Career Faculty appendix: NOI February 24, proposals due March 24, 2021
- MUREP Space Technology Artemis Research (M-STAR) Implementation Funding proposals due May 10, 2021
<https://nspires.nasaprs.com/external/solicitations/summary.do?sollid=%7b417DB666-0D23-6D49-8BF4-F4EAF4B0AF5D%7d&path=&method=init>
- Watts on the Moon Centennial Challenge
 - <https://www.herox.com/WattsOnTheMoon>
 - Phase 1 Registration and Submission Deadline: 25 March 2021
- Break the Ice Lunar Challenge
 - <https://breaktheicechallenge.com/>
 - Registration and System Architecture Submission Deadline: 18 June 2021

- Thinking ahead:

Lunar Surface Technology Research (LuSTR) – awards just announced. Next deadline to submit is December 31, 2021

https://www.nasa.gov/strg/new_nasa_lunar_tech_funding_opportunity_for_us_universities

Information on additional funding opportunities at

- <http://lsic.jhuapl.edu/Resources/Funding-Opportunities.php>



Lunar Surface Innovation

C O N S O R T I U M

Position, Navigation, and Timing in Extreme Lunar Environments

March 11, 2021

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JHU Applied Physics Laboratory

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How many of you work in or are interested in position, navigation, and timing (PNT)? Raise your hand if you are, and, if you are inclined, add details in the chat.

What are you hoping to learn about lunar surface PNT today? Please type a response in the chat window (or unmute your microphone and give us a verbal response)

Overview

- Extreme access definition
- Lunar surface navigation challenges
- Sensor options
- Where are we now with autonomous lunar robots? Moon Ranger tech demo
- Current research and development activities



Extreme Access - Definition

- “Extreme access” refers to *autonomous* robotic missions in environments such as
 - Lava tubes
 - Skylights
 - Permanently shadowed regions (PSRs)
 - Far side of the Moon
- Technologies for entry, descent, and landing are part of the discussion, but this group is not directly concerned with navigation of orbiting spacecraft

Lunar surface navigation challenges

- Much of the technology we rely upon for navigation on earth is not available on the Moon
 - GPS
 - LIDAR
 - Magnetic compasses
- Lunar dust obscures sensors
- Some regions
 - never see the light of day (permanently shadowed regions)
 - don't have a view of the sky (lava tubes)
 - don't have a line of sight to earth (making teleoperation impossible)
 - have low sun elevation and sudden transitions from light to darkness
 - shadows at the poles present additional visual navigation challenges

Navigation sensor options

- Currently available
 - Visual
 - Cameras
 - Sun compass
 - Star tracker
 - Inertial measurement unit
 - Wheel encoders
- Under development
 - GPS receiver for earth-orbiting GPS signals (LuGRE mission scheduled to fly in 2023)
- “Pie in the sky” (likely going to happen, but probably not for a few more years)
 - Lunar GPS constellation
 - LIDAR for lunar rovers

Where are we now?

Teleoperated



VIPER – scheduled for 2023 mission to lunar south pole

Autonomous



Moon Ranger – tech demo scheduled for 2022 mission to lunar south pole

- Moon Ranger is using a suite of sensor systems working together
 - IMUs
 - Wheel encoders
 - Cameras
 - Lasers for light striping in shadowed areas
- Some sensors are usable only in certain environments or at certain times.
- When navigating from a light region to a shadowed one, the robot will switch to a different sensor suite

- TERRAIN MAPPING AND POSE ESTIMATION FOR POLAR SHADOWED REGIONS OF THE MOON <https://www.hou.usra.edu/meetings/isairas2020fullpapers/pdf/5070.pdf>
- <https://www.ri.cmu.edu/project/moon-ranger/>

Current R & D

Navigation options for GPS-denied locales

- “Dead reckoning” (rover adds up its measured rate of movement over time to figure out how far it has moved)
 - Inertial measurement unit (IMU)
 - Wheel encoders
- Absolute positioning (not how far rover traveled, but where it is relative to some pre-defined coordinate system)
 - Star tracker - <https://lsic-wiki.jhuapl.edu/display/EA/Star+trackers+for+surface+navigation>
 - Could be used to provide an absolute position estimate to rovers operating in the dark that have a view of the sky
 - Sun compass <https://lsic-wiki.jhuapl.edu/pages/viewpage.action?pageId=11338308>
 - Used on Apollo 15 mission as a backup navigation method
 - Also used for navigation and antenna pointing on Mars missions
 - Provides an absolute position estimate to rovers with a view of the sun
 - Beacons (<https://lsic-wiki.jhuapl.edu/display/EA/Beacons>)
 - Beacon systems are commonly used on earth for navigation by mining robots and autonomous robots inside warehouses
- Terrain relative navigation – we have created Confluence pages, hoping to add content soon

Current R & D

GPS (<https://lsic-wiki.jhuapl.edu/display/EA/GPS>)

- GPS from earth-orbiting satellites
 - Lunar GNSS receiver experiment (LuGRE) – slated for deployment to Mare Crisium basin in 2023
- Using one, two, or just a few satellites for GPS
 - APL and JPL have both published research on this. See the GPS page in Confluence for a complete list of references
- Full-fledged GPS constellation proposals

Questions?

Subgroup formation

Lunar O & M meeting time

- Vote for a time for the Lunar O & M subgroup to meet. Use the annotation tool to put a checkmark or other mark on your chosen time or type your vote in the chat
 - 1st Thursday of the month at 3 pm (type OM 1 in the chat)
 - 3rd Thursday of the month at 3 pm (type OM 3 in the chat)
 - 4th Thursday of the month at 3 pm (type OM 4 in the chat)
 - Other (write in the chat) (type OM and your proposed time in the chat)

PNT subgroup meeting times

- Vote for a time for the PNT subgroup to meet. Use the annotation tool to put a checkmark or other mark on your chosen time or type your vote in the chat
 - 1st Thursday of the month at 3 pm (type PNT 1 in the chat)
 - 3rd Thursday of the month at 3 pm (type PNT 3 in the chat)
 - 4th Thursday of the month at 3 pm (type PNT 4 in the chat)
 - Other (write in the chat) (type PNT and your proposed time in the chat)

LSIC EA Annual Goal

- Vote for which extreme access area you would like us to focus on first (type your vote in the chat):
 - lunar south pole
 - PSRs
 - lunar pits
 - Lava tubes
 - Far side of the moon
 - Other area not listed
- For 1-2 areas of interest we will identify mission/system architecture elements needed to provide access (e.g., mobility challenges, comms, PNT, etc), including identifying specific technology needs and gaps, prioritizing development timelines, and providing a general roadmap and recommendations for needed technology, testing, and demonstrations.



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Contact information

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Surface Power	LSIC_Power@listserv.jhuapl.edu	Wes Fuhrman
Extreme Environments	LSIC_ExtremeEnvironment@listserv.jhuapl.edu	Ben Greenhagen
Extreme Access	LSIC_ExtremeAccess@listserv.jhuapl.edu	Angela Stickle
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