Lunar Surface Innovation Consortium

Extreme Environments Focus Group

Thanks for joining!
Our meeting will begin at 3:05 pm EDT

Website: http://lsic.jhuapl.edu/Focus-Areas/Extreme-Environments.php
Task 1 Sign-up: https://forms.gle/ZunmGRFb4W9gDCrH8
Listserv: LSIC_ExtremeEnvironments@listserv.jhuapl.edu
Facilitator: Facilitator_ExtremeEnvironments@jhuapl.edu

Lunar Surface Innovation
CONSORTIUM

Extreme Environments Focus Group July Telecon

July 14, 2020

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Planetary Spectroscopy Section Supervisor
Johns Hopkins Applied Physics Laboratory

Facilitator_ExtremeEnvironments@jhuapl.edu

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Today’s Agenda

- NASA FG Point of Contact Introduction (Mark Hilburger) ← Rescheduled to August
- Task 1 Overview and Status (Ben Greenhagen)
- Task 1 Subgroup Updates
  - Thermal Environment (Ahsan Choudhuri)
  - Illumination Environment (Craig Peterson)
  - Communication Environment (Marshall Eubanks)
  - Radiation Environment (Lawrence Heilbronn)
  - Vacuum Environment (Stephen Indyk)
- Task 1 Next Steps (Ben Greenhagen)
- Year 1 Goal Discussion

Extreme Environments FG

The role of the focus group is to: (1) Connect academic institutions, non-profits, industry, and NASA to help technology development and build collaborations. (2) Identify critical challenges for sustainable operations on the lunar surface. (3) Enable and facilitate all categories of members.

- What are the lunar extreme environments?
- What are the technology needs to enable survival and operations in the extreme environments?
- Which technologies already exist? How can they be improved?
- Which technologies need to be developed? Is there a pathway to development?
- How can NASA STMD best help you develop your technologies?

Task 1:
Environment Definition

Task 2:
Technology Needs, Capabilities, and Gaps

Task 3:
Facility Needs and Access

Focus Group Roles (Updated)

- FG Facilitator:
  - Manage focus group and ensure clear communication. Organize focus group to maintain alignment with NASA STMD expectations, LSII Leadership, and LSIC Executive Committee.
- FG Member
  - Participate in meetings and tasks. Share your knowledge!
- Task (Subgroup) Lead:
  - Lead peers in short-duration, product-focused activities that advance focus group objectives and develop consensus.
- Task (Subgroup) Supporter:
  - Participate in all task (subgroup) discussions. Agree to help produce products.
- Task (Subgroup) Participant:
  - Participate in task (subgroup) discussions. Agree to review products.

You can hold multiple FG roles!

Task 1 Overview

Goal: Define lunar extreme environments relevant to enabling systems to survive and operate throughout the full range of lunar surface conditions

- *Capture primary environment characteristics and variability on the Moon.*
- *Identify environmental challenges to technology development.*
- *Include all environment categories intrinsic to survival and operation.*

- Kickoff Product: Quad chart presented at a FG monthly telecon (*July 14 or later*). Signals the start of the task.
- Review Product: Short presentation that defines the environment category based on the work of the subgroup. Guides ~15 minute discussion at a FG monthly telecon (*August 10 or later*).
- Archive Product: Revised version of the Review Product and 1-2 pages of text for the focus group wiki.

Planned Task 1 Subgroups

- *Thermal Environment (daytime, nighttime, polar, etc.)*
- *Illumination Environment (nominal diurnal, permanent shadow, near-continuous light)*
- *Communication Environment (nearside, farside, subsurface, etc.)*
- *Solar Wind / Plasma Environment (nearside, farside, polar, etc.)*
- *Radiation Environment (surface, subsurface, etc.)*
- *Vacuum Environment (outgassing, sublimation, electrostatic, etc.)*
- *Surface Interactions (dust, regolith toxicity, rocks, etc.)*
- *Subsurface Interaction (rock/ice stratigraphy, constrained environments, etc.)*
- *Other External Hazards (seismicity, micrometeorites, CMEs, etc.)*

The ability to survive and operate in extreme environments underlies the all aspects of LSII and many specific topics cross-cut with other LSIC focus groups

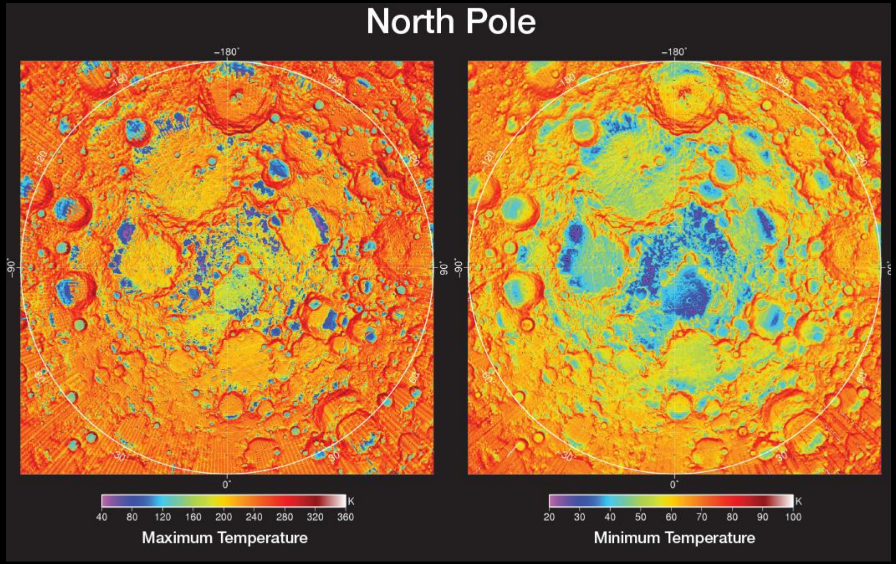
Task 1 Subgroups Leads

- *Thermal Environment (Ahsan Chouchuri)*
- *Illumination Environment (Craig Peterson)*
- *Communication Environment (Marshall Eubanks)*
- *Radiation Environment (Lawrence Heilbronn)*
- *Vacuum Environment (Stephen Indyk)*

Thermal Environment

- *Lead: Ahsan Choudhuri, The University of Texas at El Paso, ahsan@utep.edu*
  - *Associate Vice President for Aerospace Center; Founding Director, NASA MIRO Center for Space Exploration & Technology Research*
  - *Research Interests: Propulsion, Hypersonics, Robotic Landers, Small Spacecraft, and Lunar Surface Operations*
- *Supporters:*
  - *Marshall Eubanks; Space Initiatives Inc*
  - *Ben Greenhagen; Johns Hopkins Applied Physics Laboratory*
  - *CraigPeterson; Trans Astronautica Corporation*
  - *Matt Siegler, Planetary Science Institute*
  - *Kris Zacny, Honeybeer Robotics*
- *Participants:*
  - *Daoru Han, Missouri University of Science and Technology*
  - *Angeliki Kapoglou, European Space Agency*
  - *Michael J Poston, Southwest Research Institute*
  - *Tracie Prater, NASA*
  - *KT Ramesh, Johns Hopkins Applied Physics Laboratory*
  - *Melissa Roth; Off Planet Research*
  - *Howard Runge, Runge Tech*
  - *Doug Stanley, National Institute of Aerospace*
  - *Paul van Susante, Missouri University of Science and Technology*

Thermal Environment



Temperature Variation
Lunar Reconnaissance Orbiter
nasa.gov

- *Primary Characteristics*
  - *Wide Temperature Range: 400 K-40 K*
  - *Heat flux (incident solar flux 0 - 1414 W/m^2; planetary IR flux 0 – 1314 W/m^2; and albedo 0.076 - 0.297)*

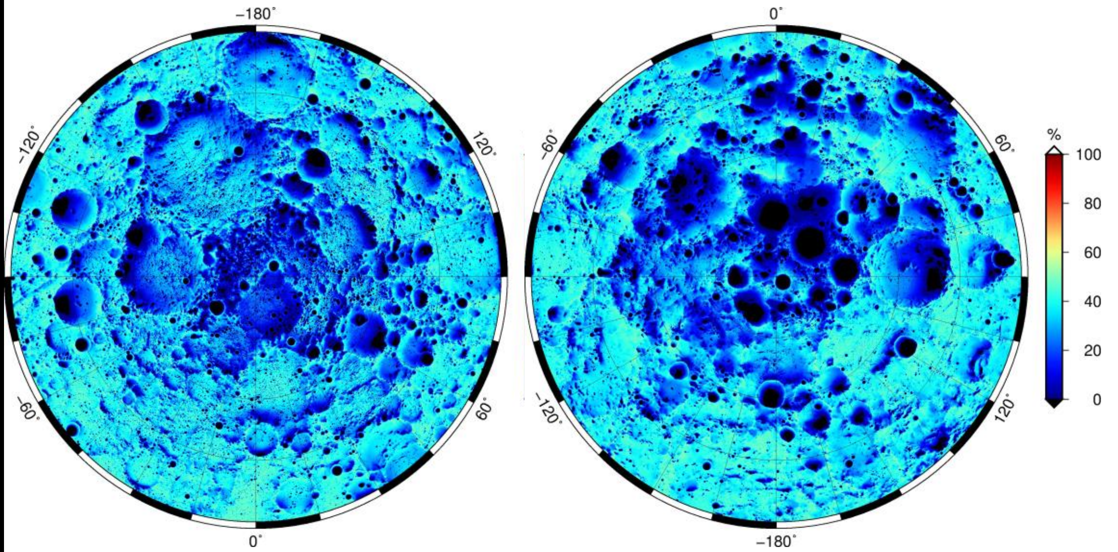
- *Environmental Variability*
  - *Equator: 140 K – 400 K; 94 K (average minimum) – 392 K (average maximum); mean 215 K.*
  - *Polar (poleward of 85°): 50 K (average minimum) – 202 K (average maximum); mean 104 K; minimum 25 K in the floor of the Moon's Hermite Crater.*
  - *Thermophysical properties*

- *Challenge to Technology Development*
  - *Low temperature: electronic performance in extreme cold environments*
  - *Brittle phase transitions of metals with abrupt changes in properties, the effects of combined low temperature and radiation*
  - *Thermal cycling: thermal performance and fatigue for 40 K- 400 K thermal cycling in every month*

Illumination Environment

- *Lead: Craig Peterson, TransAstronautica Corp. craig@transastracorp.com*
  - *Systems Engineer for TransAstra supporting NIAC Phase 2 Lunar Polar Mining Outpost Study*
  - *Previously JPL performing mission architecture/design, systems engineering, technology evaluation, etc*
- *Supporters:*
  - Eubanks, Marshall; tme@space-initiatives.com
  - Siegler, Matt; matthew.a.siegler@gmail.com
  - Zacny, Kris; kazacny@honeybeerobotics.com
- *Participants:*
  - Greenhagen, Ben; benjamin.greenhagen@jhuapl.edu
  - Han, Daoru; handao@mst.edu
  - Kapoglou, Angeliki; kapoglou.angeliki@gmail.com
  - Meyer, Heather; Heather.Meyer@jhuapl.edu
  - Stanley, Doug; Stanley@nianet.org
  - van Susante, Paul; pjvansus@mtu.edu

Illumination Environment



Modeled solar illumination from LRO LOLA

- *Primary Characteristics*
  - For most of the lunar surface there is 13.5 days of constant illumination and 13.5 days of no illumination other than Earthshine (limited to near side).
    - Earthshine is considerably brighter than moonshine and could allow for some operations during night periods on the near side
    - Insufficient for solar power though.
    - Causes extreme temperature variations (127 degrees Celsius to minus 173 C)
  - *There are also permanently shadowed regions (PSR) near the poles maintaining even colder temperatures (minus 253 to minus 163 C)*
  - *Also mostly (up to 90%) illuminated regions (MIR) at >100 C*

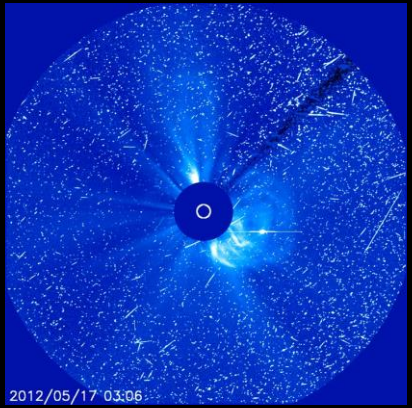
- *Environmental Variability*
  - *Illumination varies over the course of the lunar day due to incidence angle (cosine) effects.*
  - *Some minor variability due to terrain*
  - *EXCEPT at THE LUNAR POLES*
  - *At the poles illumination can vary widely over the space of just a few kilometers.*
  - *Illumination at the poles can also vary over a few hundreds of meters elevation change.*

- *Challenge to Technology Development*
  - *Survival during the long night*
    - *Sleep mode during nights?*
  - *Radiation effects from unfiltered sunlight and solar events (CME)*
  - *Temperature cycling on mechanical systems*
    - *Material thermal expansion/contraction*
  - *Obtaining power in the lunar PSRs*
  - *Staying cool in the lunar MIRs*

Radiation Environment

- *Lead: Lawrence Heilbronn, University of Tennessee, Lheilbro@utk.edu*
  - *Professor, Nuclear Engineering Department*
  - *Member of the National Council on Radiation Protection and Measurements*
- *Supporters:*
  - *Hugh Barnaby (Arizona State University)*
  - *John Schaf (MOOG Inc Space and Defense Group)*
- *Participants:*
  - *Bonnie Dunbar (Texas A&M University); Connor Geiman (University of Washington), Ben Greenhagen (JHUAPL); Susan Ip-Jewel (AvatarMEDIC, LLC; Mars Academy USA, LLC); Angeliki Kapoglou (European Space Agency); Heather Meyer (JHUAPL); Michaela Musilova (International MoonBase Alliance); Michael Poston (Southwest Research Institute); Leonardo Regoli (JHUAPL); Melissa Roth (Off Planet Research, LLC)*

Radiation Environment



SOHO coronagraph of a SEP event (left), habitat that incorporates regolith for shielding (right)

- *Primary Characteristics*
  - *Galactic Cosmic Rays (GCR)*
  - *Solar Energetic Particles (SEP)*
  - *Albedo from GCR and SEP interactions in lunar regolith*
  - *Man-made sources used for power (radioisotope power systems, fission surface power systems)*

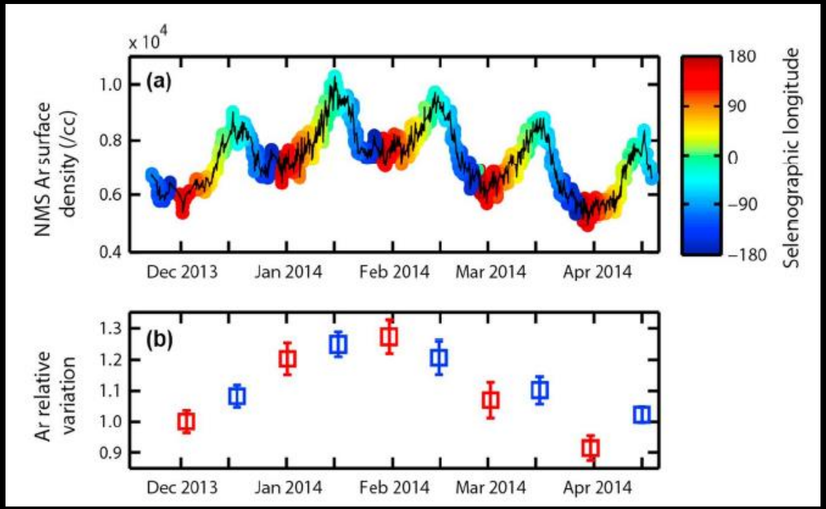
- *Environmental Variability*
  - *GCR always present, but intensity varies with solar cycle*
  - *SEP events can last up to several days*
  - *SEP energies and intensity vary from event to event*
  - *Incident radiation and dose depends on location on Moon (near a crater wall, on a flat, open location) and amount of habitat shielding*

- *Challenge to Technology Development*
  - *Uncertainty in radiation transport model predictions of fluence and dose in shielded environments*
  - *Prediction of SEP occurrence, duration and intensity*
  - *Uncertainty of risks to humans and electronics from the high-energy, heavy-ion components of space radiation*

Vacuum Environment

- *Lead: Stephen Indyk, Honeybee Robotics, sjindyk@honeybeerobotics.com*
  - *Background in mechanism development for planetary environments, including lunar structures*
  - *8 years of experience in Mars rover operations*
- *Supporters:*
  - *Donald Barker, University of Houston*
  - *Marshall Eubanks, Space Initiatives Inc.*
  - *Matt Siegler, Planetary Science Institute*
  - *Kris Zacny, Honeybee Robotics*
- *Participants:*
  - *Ahsan Choudhuri (University of Texas at El Paso); Bonnie Dunbar (Texas A&M University); Ben Greenhagen (Johns Hopkins Applied Physics Lab); Daoru Han (Missouri S&T); Angeliki Kapoglou (ESA); Michael Poston (Southwest Research Institute); Melissa Roth (Off Planet Research); Paul van Susante (Michigan Tech)*

Vacuum Environment



LADEE NMS Instrument Argon Variability, Benna et. Al 2015

- *Primary Characteristics*
  - *Correctly characterized as a vacuum*
    - *Surface pressure at night: 3e-10 Pa*
    - Composition due to solar wind of He, Ne, H_2, Ar
    - Abundance at surface 2 x 10^5 particles/cm^3
  - *Diurnal temperature range:*
    - *Equator : 120 C to -130 C (400 K to -140 K)*
    - *Poles: Hermite Crater floor -250 C (25 K)*

- *Environmental Variability*
  - *Day to night variance*
  - *~ 1% more solar energy as farside is closer to the sun at noon than nearside*
  - *Volatiles released at lunar surface at solar terminator*

- *Challenge to Technology Development*
  - *Thermal considerations: conduction and radiation, no convection*
  - *Friction*
  - *Welding*
  - *Electrostatics at high vacuum behave differently (Dust)*
  - *Limited lubrication options*

Subgroups Without Leads

Desirable to identify leads for these subgroups ASAP

- *Solar Wind / Plasma Environment (nearside, farside, polar, etc.)*
- *Other External Hazards (seismicity, micrometeorites, CMEs, etc.)*

Solar Wind / Plasma Environment

- *Lead: <OPEN>*

- *Supporters:*
  - *Donald Barker, University of Houston*
  - *Marshall Eubanks, Space Initiatives Inc.*
  - *John Schaf, MOOG Inc Space and Defense Group*

- *Participants:*
  - *Ben Alterman (Southwest Research Institute); Ben Greenhagen (JHUAPL); Daoru Han (Missouri S&T); Lawrence Heilbronn (University of Tennessee); Angeliki Kapoglou (ESA); Michael Poston (Southwest Research Institute); Leonardo Regoli (JHUAPL); Melissa Roth (Off Planet Research, LLC)*

Other External Hazards

- *Lead: <OPEN>*

- *Supporters:*
  - *Bonnie Dunbar, Texas A&M University*
  - *Lawrence Heilbronn, University of Tennessee*
  - *Melissa Roth, Off Planet Research, LLC*
  - *Christopher Wohl, NASA LRC*

- *Participants:*
  - *Conner Geiman (University of Washington); Ben Greenhagen (JHUAPL); Angeliki Kapoglou (ESA); KT Ramesh (JHU), Valerie Wiesner (NASA GRC)*

Subgroups Without Leads

Desirable to identify leads for these subgroups ASAP

- *Solar Wind / Plasma Environment (nearside, farside, polar, etc.)*
- *Other External Hazards (seismicity, micrometeorites, CMEs, etc.)*

These categories need to be refined to focus on intrinsic aspects of the lunar surface environment and avoid topics primarily covered in other focus groups

- *Surface Interactions (dust, regolith toxicity, rocks, etc.)*
- *Subsurface Interaction (rock/ice stratigraphy, constrained environments, etc.)*

Subgroup sign-up: https://forms.gle/ZunmGRFb4W9gDCrH8

Task 1 Next Steps

- Before our next meeting (next four weeks)
  - Identify task leads for "solar wind / plasma environments" and "other external hazards" categories
  - Send thoughts or comments regarding "surface interactions" and "subsurface interactions" to listserv or FG Facilitator
  - Increase diverse pool of supporters and participants for all subgroups
  - Subgroup leads / facilitator meeting to refine products and plans
  - Leads begin holding subgroup discussions

- At our next meeting (August 11th at 3:05 pm)
  - Updates from subgroup leads
  - New subgroup leads will present environment quad chart
  - Review product discussions (if available)
  - Discussion towards refining "surface interactions" and "subsurface interactions" categories

- After our next meeting (late August / early September)
  - Subgroups continue working towards review and archive products
  - Refine plans for follow-on tasks (technologies and facilities)

Year 1 Focus Group Goal

- We will collaboratively decide on a 1-year goal for us to work on as a group
  - Actionable and impactful
  - Specifically relevant to our focus area
  - Doable within 1 year
  - Uses capabilities of focus group members
  - Can be accomplished with existing resources
  - Inspired by current issues
  - Beneficial broadly to all stakeholders

- Example: Provide reference for a lunar environment users guide for technology development
  - Product that outlines gaps in capabilities introduced by extreme environments on the Moon. Define the parameter space and associated challenges of environmental factors that are relevant to technology developers for their use case. Describe what facilities exist for testing and demonstration, how to access them, and what facilities are needed at each phase of development.

Discussion

- Please use the raise hand feature (preferred)
- You can also comment in chat

- What environmental information do you need to proceed with your development?
- What ancillary technologies are preventing you from advancing your target technology?
- Do you have access to the facilities that you need?
- What opportunities do you need to mature your technology?

- General: What kinds of focus groups activities would be most productive?
- General: How do you see our focus group interacting with the other focus groups?

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