Lunar Surface Innovation
CONSORTIUM

Extreme Access Focus Group Telecon

August 12, 2021

We'll start around 3:03

Dr. Angela Stickle
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JHU Applied Physics Laboratory

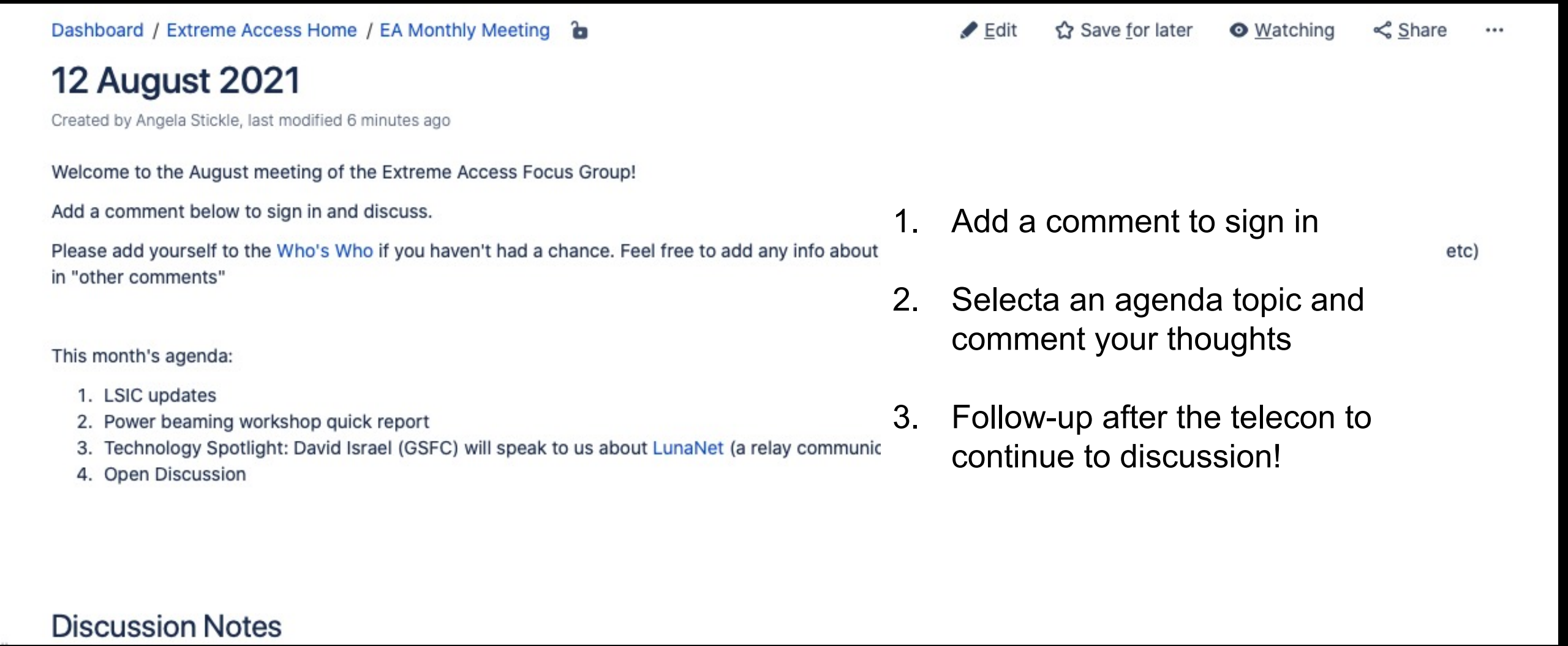
Facilitator_ExtremeAccess@jhuapl.edu

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Today's Agenda

- Introductions
- LSIC Focus Group Updates
  - Power Beaming Workshop Quick Summary
  - Upcoming MOSA discussions
- Upcoming Meetings/Opportunities
- Technology Spotlight
- Open floor and Discussion

Join the Discussion on Confluence



1. Add a comment to sign in
2. Selecta an agenda topic and comment your thoughts
3. Follow-up after the telecon to continue to discussion!

Confluence is an important resource to provide asynchronous discussion opportunities and a record of conversations

Introduction: Malcolm Gilmore

- Extreme Access CIRCUIT Intern for 2021-2022

Power Beaming Workshop Quick-Look

July 22,/23 2021

Dr. Wesley T. Fuhrman
Johns Hopkins Applied Physics Laboratory
Space Exploration Sector

Wesley.Fuhrman@jhuapl.edu

LSIC | Why the Power Beaming Workshop

- Community-requested, sponsor-approved
- Recent and pending solicitations
- Partners and outside stakeholders with additional expertise

LSIC Power Beaming for the Lunar Surface workshop

- Webinar had steady ~120-130 participants day 1, ~100 on day 2
  - Survey Results:
    - Understanding: Mean 3.5 -> 4.5 Median 3 -> 5
    - Diversity: Mean 4.4, Median 4
    - Inclusion: Mean 4.5, Median 5

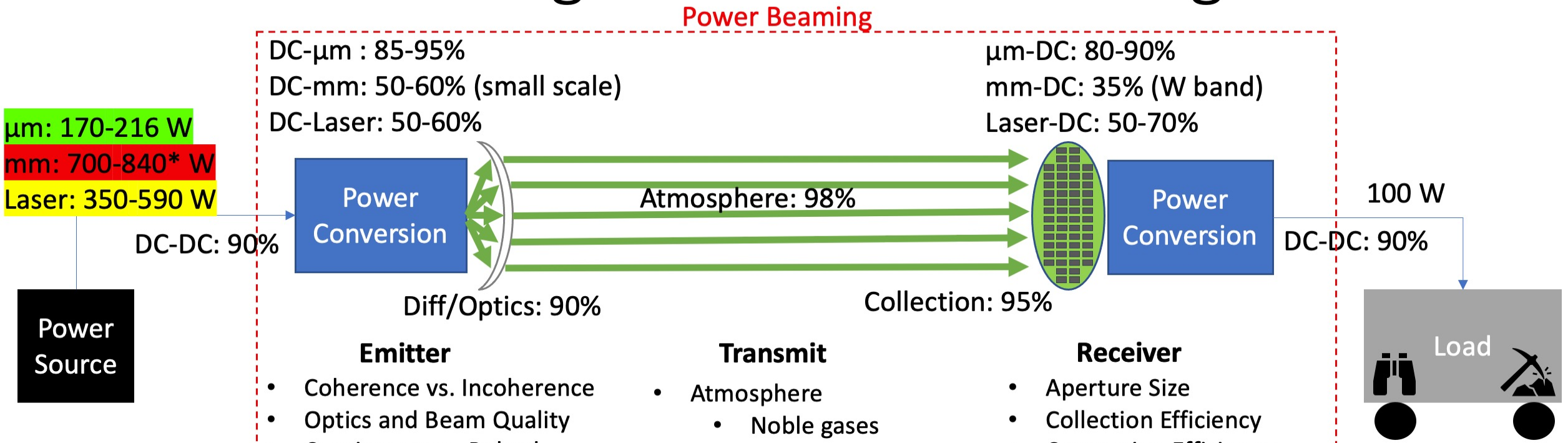
- Invited talks by Paul Jaffe and Geoff Landis especially well-received
  - DoD partners have appropriate tech for our use case (Paul Jaffe)
  - No deal-breakers for power beaming on the lunar surface (Geoff Landis)

- 40+ participated through the breakouts both days
  - Strong conversation 1+ hour into networking session
  - Networking session had more video use and audience participation than breakouts.

LSIC Power Beaming for the Lunar Surface workshop

- General consensus is that power beaming is a pragmatic solution for H2O prospecting and deep PSR exploration. Marginal cost of extending range is trivially small for laser PB. Could also be used to connect regions with complementary illumination.
- Current PB hardware is not space-qualified but could be rapidly advanced
- Power Beaming Figure of Merit currently under consideration for WoTM is not ideal, especially for laser power beaming
- PB reduces complexity compared to cabled-power for exploration
- Thermal management complicates design of high-power systems,

Challenges for Power Beaming



Emitter

- Coherence vs. Incoherence
- Optics and Beam Quality
- Continuous vs. Pulsed
- Emitted Spectrum
- Heat Dissipation

Transmit

- Atmosphere
  - Noble gases
  - Dust
- Distance
- Safety? (eyes, burns, etc.)

Receiver

- Aperture Size
- Collection Efficiency
- Conversion Efficiency
  - Heat Dissipation
  - Dual-purpose?

	Wavelength	DC-Efficiency	Coherence	Atmosphere	Aperture Size	Receiver Efficiency	TRL
µm	5 - 12 cm	85-95%	Optics	??	140 m	80-90%	
mm	0.3 - 3 cm	50-60% (TRL)	??	??	10 m	35% (TRL)	
Laser	500 - 1550 nm	50-60%	Diffraction	Dust?	.025 m	50-70%	

1. Fuel-DC
2. ~~DC-DC~~
3. DC-EM
4. Shape Beam
5. Atmosphere
6. Hit Receiver
7. EM-DC
8. ~~DC-DC~~
9. DC-Work

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Matt DeMinico

MOSA discussion intro

E&C Workshop on August 20th , 2021

- ***Save the date : August 20th, 2 PM - 4:30 PM, Eastern***
- An extended monthly meeting in lieu of regular meeting.
- Workshop Theme: **High-TRL Technologies for initial infrastructure development and LLP**
- Tentative Agenda:
  - NASA E&C Roadmap.
  - Break-out sessions:
    - High-TRL technology for initial infrastructure development
    - Power needs for E&C
  - Panel discussion on Landing and Launch Pads (LLP)

Your participation will help shape these activities.

Save the Date! LSIC 2021 Fall Meeting

- November 3-4, 2021
- Hybrid Meeting, in-person events taking place at Bowie State University (Bowie, MD)
- Please fill out this short survey to assist with planning:
  - https://forms.gle/DpdnJM5LPiXwcste7

Upcoming Meetings

- Focus Group Telecons (2nd Thursday each month, 3-4 pm EST)
  - August 12, 2021
  - September 9, 2021

- Lunar Surface Science Workshop
  - Fundamental and Applied Lunar Surface Research in Physical Sciences (August 18-19, 2021)
  - Free, but registration is required, deadline Aug. 13
  - https://www.hou.usra.edu/meetings/lunarsurface2020/

This physical sciences workshop will focus on:

- Lunar dust and its properties, behavior, and mitigation
- Life support and thermal management
- Materials flammability and habitat fire safety
- Extraction of water-ice from regolith research, including separation, purification, electrolysis, and liquefaction
- Lunar environment and its effects on materials
- Lunar research in extraction, processing, and handling
- Lunar research for advanced manufacturing
- Fundamental physics research on the lunar surface

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  - July 8, 2021
  - August 12, 2021

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- LSIC Excavation and Construction (short) workshop, August 20 2:30-4:30 pm
  - **https://lsic-wiki.jhuapl.edu/x/coMiAQ**
  - NASA E&C Roadmap
  - Lunar Simulants
  - Requirements/Design/Construction of launch/landing pads

Other Notes of Interest

- **Subgroup Meetings – notes on Confluence**
  - PNT subgroup meeting, 19 August 3 pm ET
  - Communications subgroup kickoff, July 21
  - TRN subgroup kickoff, August 4
  - Mobility Subgroup, TBD
  - Service Sheds, TBD

- Current Funding Opportunities:
  - LuSTR due September 17, 2021

    https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=838616/solicitationId=%7BFC8AA32D-180F-9B49-AE48-7C30FCD68E9B%7D/viewSolicitationDocument=1/ST-REDDI-2021%20Appendix%20B5%20-%20LuSTR%202021.pdf

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

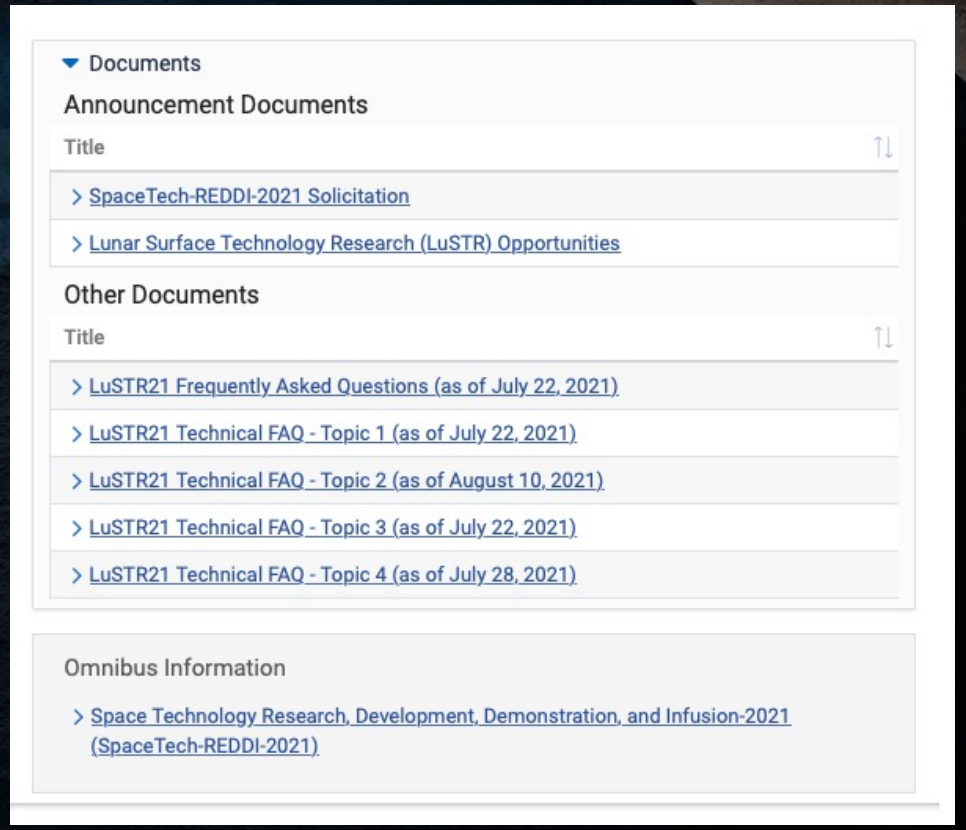
LuSTR Solicitation Released!

STMD Lunar Surface Technology Research Opportunities

- NOIs due August 20, 2021
- Proposals Due: September 17, 2021
- **LuSTR is focused on the development of early- to mid-TRL (2-4) lunar surface technologies of high priority to NASA's Mission Directorates**

- **Eligibility:** Accredited U.S. universities are eligible to submit proposals; teaming and collaboration are permitted
  - At least 60% of the proposed budget must go to accredited U.S. universities
  - The university submitting the proposal may partner with other universities and colleges. Partnering with industry and/or non-profit entities is encouraged

- Award Amount: $1M to $2M total per award
- Maximum of two years



LuSTR 2021 topics

- This LuSTR Appendix solicits efforts that can be integrated into Artemis' sequence of missions that start with the near-term development of enabling infrastructure and lay the foundation for a sustained human and robotic presence.

- *Topic 1 – Autonomous Systems for Excavation and Site Preparation*
  - The objective of this topic is to develop and demonstrate autonomous surface construction technologies, specifically those for excavation and site preparation, required to enable a sustained human presence on the lunar surface

- *Topic 2 – Lunar Regolith Mineral Beneficiation*
  - The goal of this topic is to enable greater efficiency and ultimately reduce waste during the physical separation and concentration of lunar surface minerals of importance to In- Situ Resource Utilization (ISRU) and Manufacturing and Construction processes.

- *Topic 3 – Cold-Temperature Analog Integrated Circuits*
  - The goal of this topic is to develop analog integrated circuits and analog-to-digital electronics, fabricated using standard foundry processes that will function under the extreme low temperatures of the lunar night and shadowed regions.

- *Topic 4 – Novel Heat Transfer Fluids*
  - The goal of this topic is to develop and/or characterize novel heat transfer fluids that may provide significant mass and performance improvements in thermal control systems for lunar surface applications.

Resources

Created by Angela Stickle, last modified less than a minute ago

More Coming Soon!

Lunar Reconnaissance Orbiter Resources

https://lunar.gsfc.nasa.gov/resources.html - A summary of resources and data provided by the LRO project, including links to maps/data and tools

http://imbrium.mit.edu/. - The Lunar Orbiter Laser Altimeter (LOLA) Data Node, the main stop for LOLA data products and DEMs

https://pgda.gsfc.nasa.gov/products/78 - High resolution LOLA maps for the lunar south pole

https://pds-geosciences.wustl.edu/missions/lro/ - LRO Planetary Data System data repository site for all instruments

Lunar strategy and reports

The SCEM report: https://www.nap.edu/catalog/11954/the-scientific-context-for-exploration-of-the-moon (if you don't have one, make a NAS account for free pdf download)

The Lunar Exploration Roadmap: https://solarsystem.nasa.gov/studies/182/the-lunar-exploration-roadmap-exploring-the-moon-in-the-21st-century-themes-goals-objectives-investig/

and https://www.globalspaceexploration.org/?p=1049

Artemis Plan: https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf

Artemis Science Definition Plan: https://www.nasa.gov/sites/default/files/atoms/files/artemis-iii-science-definition-report-12042020c.pdf

Lunar Data Access and Tools

Accessing Lunar Data Sets. - Descriptions of the main lunar data sets for DEMs and images, and their properties/uncertainties (based on info collected during the Workshop for Lunar Mapping and Precision Landing)

Data Manipulation Tools – Tools to generate DEMs/DTMs

Accessing Data Sets

Created by Angela Stickle, last modified by Michelle Zosky on Aug 10, 2021

LRO Lunar Quickmap

The Lunar Quickmap tool is an online resource for evaluating the surface of the Moon. The user interface consists of a map viewer, which lets you choose specific views of the Moon, and a series of side-panel options that allow users to customize what they're seeing and to query data.

Data Access:

https://quickmap.lroc.asu.edu/

LOLA Digital Elevation Models

Instrument Summary: Lunar Orbiter Laser Altimeter, one of 7 payload instruments on LRO. Objectives are to measure lunar surface topography and to establish a global lunar geodetic coordinate system.

Types of measurements:

- Topography
- Slopes - 25 m baselines
- Surface roughness - 5 m baseline
- 1064 nm albedo at zero phase

Data Summary:

- All the LOLA data are on the NASA Planetary Data System (PDS; http://imbrium.mit.edu)
- The LOLA DEMs (Gridded Data Records, GDRs) are made in:
  - cylindrical projection
    - global, from 4ppd to 128ppd (~240, 480, 1900, 7500 m/pix)
    - global but tiled, from 256ppd to 512 ppd (60, 120 m/pix)
  - polar stereographic projection (both poles)
    - 45°-90° at 100/200/400 m/pix
    - 60°-90° at 120/240 m/pix
    - 75°-90° at 30/60/120/240 m/pix
    - 80°-90° at 20/40/80 m/pix
    - 85°-90° at 10/20/40 m/pix
    - 87.5°-90° at 5/10/20 m/pix
- Data gaps in the DEMs are interpolated, but associated count maps (LDECs) can be used to mask the interpolated values
- The count maps can also be used to assess the effective resolution of LOLA locally

DEMs Uncertainty:

- Typical height / slope RMS uncertainties are 0.3-0.5 m / 1.5-2.5°
  - Interpolation and slope error are spatially correlated with gap

Data Access:

- Global LOLA+Kaguya DEM: https://pgda.gsfc.nasa.gov/products/54 or tinyurl.com/sldem2015
  - High-resolution lunar topography
  - Global maps & map tiles for regional images
- New LOLA DEMs of South Pole Sites: https://pgda.gsfc.nasa.gov/
  - Sites 1, 4, 7, 11
  - Reduced orbital errors, new track geolocation uncertainty is ~10-20 cm horizontally and ~2-4 cm vertically
  - LDEM height and slope uncertainties have a median RMS Z error ~0.30-0.50 m and a median RMS slope error ~1.5-2.5 deg
- Lunar Orbital Data Explorer: http://ode.rsl.wustl.edu/moon (Click on "LOLA RDR Query")
- LOLA Topography products:
  - 5mpp https://pgda.gsfc.nasa.gov/products/78
  - Regional products: http://imbrium.mit.edu/BROWSE/LOLA_GDR/POLAR/SOUTH_POLE/
  - LOLA global roughness maps at various scales: http://imbrium.mit.edu/BROWSE/EXTRAS/FRACTAL/
- LOLA roughness maps and studies:
  - https://www.sciencedirect.com/science/article/pii/S0019103513001929
  - https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GL087782
  - https://www.hou.usra.edu/meetings/lpsc2015/pdf/2218.pd

https://lsic-wiki.jhuapl.edu/x/1IAXAQ

Data Manipulation Tools

Created by Michelle Zosky, last modified on Aug 10, 2021

Ames Stereo Pipeline

Summary:

- A suite of command-line tools for creating terrain models from orbital or aerial images
- Tools that help manipulate terrain data
- Parallelizable (runs on desktops and supercomputers)
- Open Source (Apache 2.0), but binaries available for linux and macOS

Access:

- Developed in the open on GitHub: https://github.com/NeoGeographyToolkit/StereoPipeline

SOCET SET/GXP

Socet GXP™:

- BAE Systems' new photogrammetric solution. version 3.2 released 2009
- image analysis, photogrammetry, remote sensing, video exploitation, cartography, feature extraction, 3D visualization and manual editing
- GXP™ has established close ties with the Community Sensor Model (CSM) working group, government agencies, ...

Community Sensor Model (CSM):

- CSM is simply a standardized application programming interface (API) developed by the U.S. Air Force and the National Geospatial Intelligence Agency and now supported by the CSM Working Group
- paper: Laura et al., 2019, Planetary Sensor Models Interoperability Using the Community Sensor Model Specification: https://doi.org/10.1029/2019EA000713

Access:

- All code on GitHUB:
  - Called usgscsm
  - SPICE library - ALE
  - CSM API wrapped for Python - swigcsm
  - usgscsm helper test suite - knoten
- Support in GXP, initial support in NASA Ames Stereo-Pipeline (ASP) and USGS ISIS
  - Plans to integrate across: GXP/ASP/ISIS
- Should work in other CSM- capable apps like ENVI, Erdas, ArcGIS Pro, OSSIM,...

Instrument & Link	Production ready
MRO HiRISE	sub-pixel; in testing for production
MRO CTX	nearly sub-pixel; still in research
MEX HRSC	sub-pixel; in testing for production
LROC NAC	sub-pixel; in testing for production
Kaguya TC	barely sub-pixel; in testing
Messenger MDIS NAC	sub-pixel; in testing for production
Cassini ISS NAC	sub-pixel; in testing for production
Cassini ISS WAC	sub-pixel; in testing for production

https://lsic-wiki.jhuapl.edu/x/Q4MiAQ

LSIC Extreme Access Year 2 Goals

Vision: Build a community specializing in technology required to access, navigate, and explore surface and subsurface areas on the Moon. Identify areas of interest in technology development, evaluate readiness, and provide a resource for members to gain & share information, network, and discuss technology needs for lunar exploration.

Year 2 Goals:

Identify mission/system elements needed to provide access in challenging lunar environments, including identifying specific technology needs and gaps, prioritizing development timelines, and providing a general roadmap and recommendations for needed technology, testing, and demonstrations.

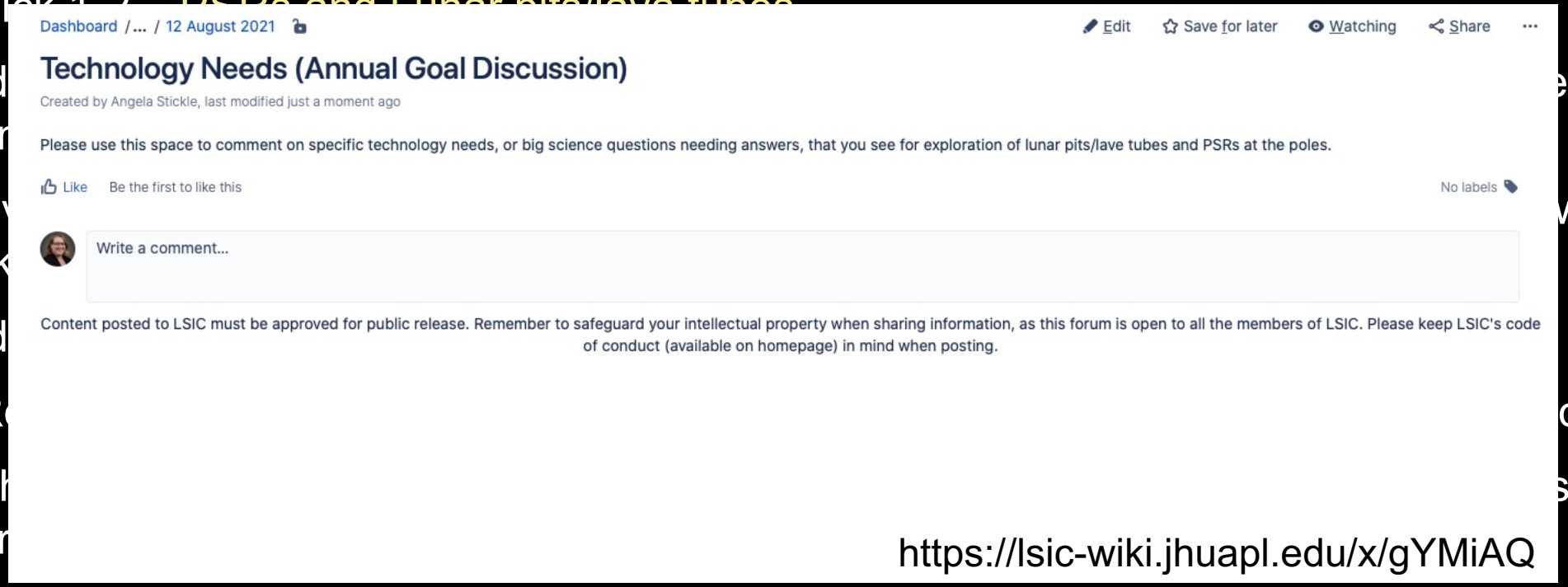
- *PSRs and lunar pits/lava tubes were chosen as high priority environments*
- *We will work with the EE group to identify environment requirements and challenges*
- *Conduct at least 1 technical interchange meeting*

Build a community and develop collaborative relationships among members

- Inclusive monthly telecons with member technology spotlights
- Provide networking opportunities at large LSIC meetings, mentoring through LSIC channels
- Community-led subgroups for in depth discussions and networking

We are now on Step-3/4!

- ✅ Identify areas and/or environments of interest
- ✅ Pi… PSRs and Lunar pits/lave tubes
3. Id… e the
er…
4. Ev… will
lik…
5. Id…
6. R… os
7. Th… s
gr…
8. Write a report of some sort



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Technology Spotlight

David Israel (GSFC): LunaNet

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Communications

- Confluence is our record of discussions and a good repository
  - Confluence is free to you and available to all registered LSIC members
  - We will be using Confluence to document discussions and provide resources to LSIC members. All focus groups have a separate page so it's a good collaboration space.
  - To request an account, please email Andrea Harman: ams573@alumni.psu.edu

- Technology Spotlights/Lightning Talks at monthly telecons
  - Anyone can volunteer to give a lightning talk (10-20 mins)
  - Email Angela or Sarah, or comment on Confluence, to sign up!

- Updates to the webpage - http://lsic.jhuapl.edu/Focus-Areas/Extreme-Access.php
  - Notes, slides, recordings from telecons posted here

Follow the Code of Conduct for all Focus Group communications

Contact information

LSIC Director: Rachel Klima, SES-LSIC-Director@jhuapl.edu
http://lsic.jhuapl.edu

Focus Group Area	Listserv address	Facilitator
In-Situ Resource Utilization	LSIC_ISRU@listserv.jhuapl.edu	Karl Hibbitts
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
Excavation and Construction	LSIC_ExcavationConstruction@listserv.jhuapl.edu	Athonu Chatterjee
Dust Mitigation	LSIC_DustMitigation@listserv.jhuapl.edu	Jorge Núñez

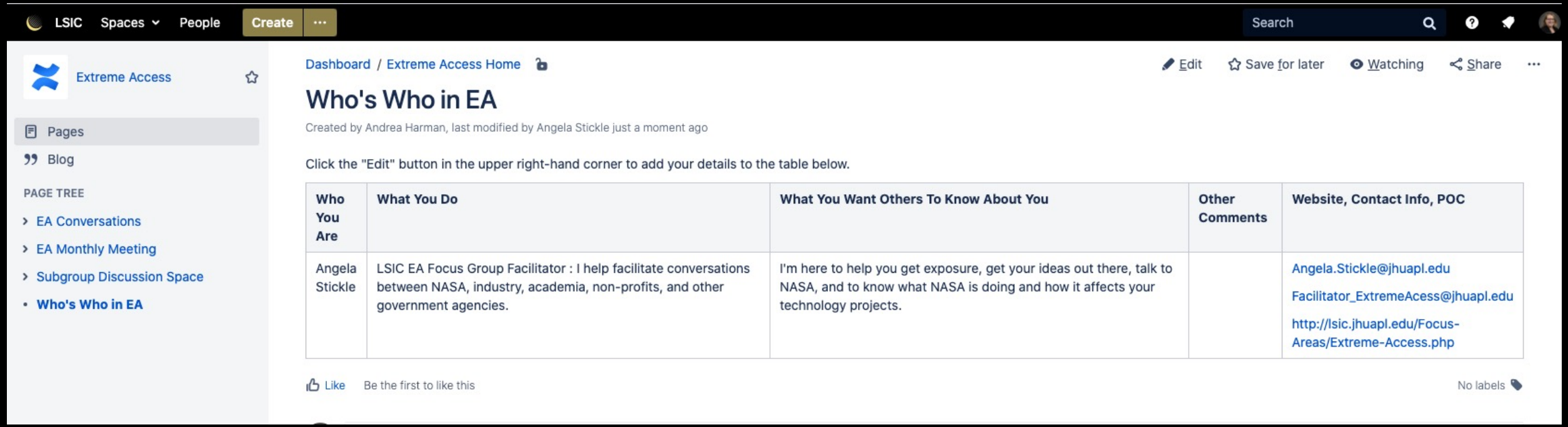
LSIC Meeting Cadence

- **Bi-Annual Meetings** (Spring and Fall)
  - May 11-12 Spring Meeting (accepting Abstracts now)
- **Monthly Focus Group Meetings**
  - 2nd Tuesday of the Month 3:00-4:00 pm – Extreme Environment
  - 2nd Thursday of the Month 3:00-4:00 pm – Extreme Access
  - 3rd Wednesday of the Month 3:00-4:00 pm – ISRU
  - 3rd Thursday of the Month 12:00-1:00 pm – Dust Mitigation
  - 4th Thursday of the Month 11:00 am-12:00 pm – Surface Power
  - Last Friday of the Month 3:00-4:00 – Excavation and Construction
- **Thematic Workshops** (as identified by FGs and NASA POCs)
  - Workshops In development Funding, CLPS Provider, and Power Beaming

Lunar Surface Innovation CONSORTIUM

Get to know the community

https://lsic-wiki.jhuapl.edu/x/0IVf



Who's Who in ISRU: https://lsic-wiki.jhuapl.edu/display/ISRU/Who%27s+Who+in+ISRU
Who's Who in Surface Power: https://lsic-wiki.jhuapl.edu/display/SP/Who%27s+Who+in+LSIC-Surface+Power
Who's Who in E&C: https://lsic-wiki.jhuapl.edu/pages/viewpage.action?pageId=6260179
Who's Who in EE: https://lsic-wiki.jhuapl.edu/display/EE/Who%27s+Who+in+LSIC-EE

STMD Opportunities for Academia and Industry

STMD anticipates awarding ~$600M to academia and industry supporting 2020 solicitations & awards

- **STMD Tipping Point Multiple Awards:** ***Jan – Mar 2020*** — $250M
- **Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Phases I, II, II-E, Civilian Commercialization Readiness Pilot Program (CCRPP), Sequential:** ***Phase I Solicitation Jan – Apr 2020*** — $212M
- **Announcement of Collaborative Opportunity (ACO):** ***Jan – Mar 2020*** — $10M
- **Flight Opportunities Tech Flights:** ***Feb – May 2020*** — $10M
- **Early Career Faculty (ECF):** ***Feb – Apr 2020*** — $6M
- **Early Stage Innovations (ESI):** ***Apr – Jun 2020*** — $9M
- **NASA Innovative Advanced Concepts (NIAC) Phases I, II, III:** ***Phase I Solicitation Jun – Jul 2020*** — $4M
- **Space Technology Research Institutes (STRI):** ***Jun – Aug 2020*** — $30M
- **NASA Space Technology Graduate Research Opportunities (NSTGRO):** ***Sep – Nov 2020*** — $19M
- **SmallSat Technology Partnerships (STP):** ***Sep – Nov 2021*** — $3M
- **Centennial Challenges:** ***Varied release dates*** — $8M
- **NextSTEP Broad Agency Announcements (BAAs):** ***Varied release dates*** — *Varies*
- **Lunar Surface Technology Research (LuSTR) Opportunities:** ***Coming soon!!!*** — $30M

Note: Funding awards are approximate and subject to change

- Open Solicitations as of June 5, 2020
- Solicitations were/will be open *in the timeframe specified in italics*