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CONSORTIUM

LSIC ISRU Focus Group Monthly

http://lsic.jhuapl.edu/
http://lsic-wiki.jhuapl.edu/ (Confluence sign-up required)

September 28, 2022

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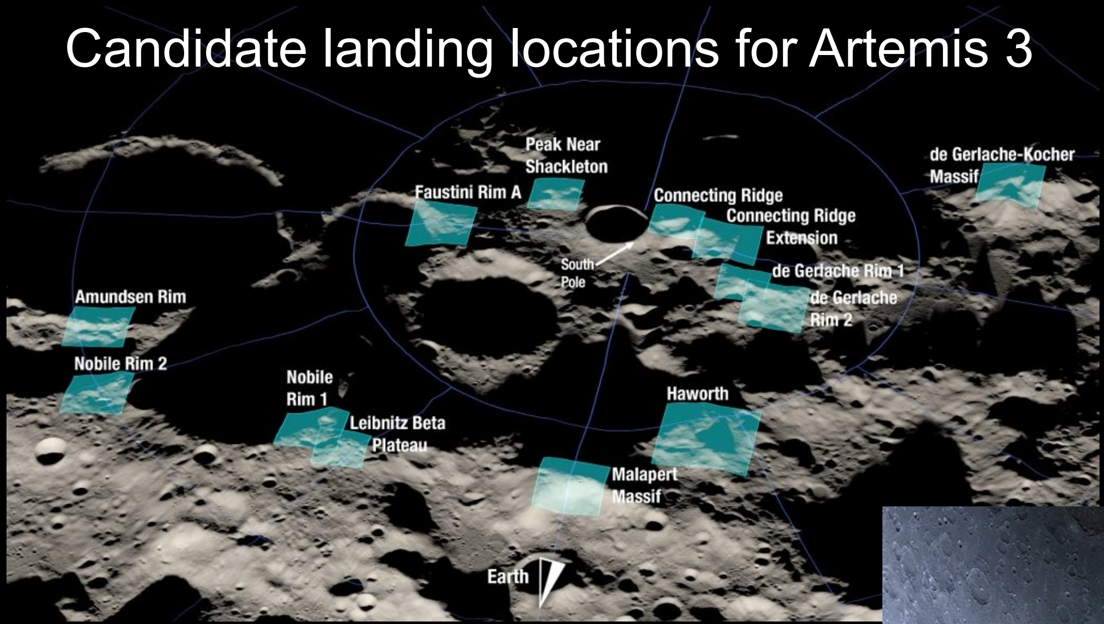
Agenda

- General updates and house-keeping
  - APL is happy to consult as appropriate with ISRU and related technologies. We can provide advice on how to build for launch and operate in extreme environments. We are considering posting guidelines and holding "Office Hours". Comments solicited.
  - Data Buys: Survey Reminder
  - Low-T Power Workshop Recap (Julie Peck)
- Amourette McDonagh (Black Moon Space Technology): Welding in Space
- ~~Carlos Espejel (iSpace): Resources Evaluation and Standards~~
- IAC impressions, thoughts, opinions
- Coffee and Donuts discussion, teaser for future Facilities Workshop: "If you had unlimited resources (money, time), what aspect of your technology would you test on Earth to prepare for the Moon?"

Lunar Surface Innovation Consortium

Notable News

Candidate landing locations for Artemis 3



https://go.nasa.gov/3BUkHGL

Final – Sept 2022	
SE-3^{LM}	Develop the capability to **retrieve core samples of frozen volatiles** from permanently shadowed regions on the Moon and volatile-bearing sites on Mars and to deliver them in pristine states to modern curation facilities on Earth.
PS-3^{LM}	Reveal inner solar system volatile origin and delivery processes by determining the age, origin, distribution, abundance, composition, transport**, and sequestration of lunar and martian volatiles**.
TH-3^{L}	Develop system(s) to allow crew to explore, operate, and live on the lunar surface and in lunar orbit with scalability to continuous presence; conducting scientific and **industrial utilization** as well as Mars analog activities.
LI-7^{L}	Demonstrate **industrial scale ISRU** capabilities in support of continuous human lunar presence and a robust lunar economy.
LI-8^{L}	Demonstrate technologies supporting cislunar orbital/surface depots, construction and manufacturing **maximizing the use of in-situ resources**, and support systems needed for continuous human/robotic presence.
TH-7^{M}	Develop systems for crew to explore, operate, and live on the martian surface to address key questions with respect to science and **resources.**
OP-3^{LM}	**Characterize accessible resources,** gather scientific research data, and analyze **potential reserves** to satisfy science and technology objectives and enable use of resources on successive missions.
AS-3^{LM}	**Characterize accessible lunar and martian resources,** gather scientific research data, and analyze **potential reserves** to satisfy science and technology objectives and enable In-Situ Resource Utilization (ISRU) on successive missions.
OP-8^{LM}:	Demonstrate the capability to find, service, upgrade, or utilize instruments and equipment from robotic landers or previous human missions on the surface of the Moon and Mars
OP-11^{LM}	Demonstrate the **capability to use commodities** produced from planetary surface or in-space resources to reduce the mass required to be transported from Earth.
MI-4^{M}	Develop **Mars ISRU capabilities** to support an initial human Mars exploration campaign.

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Upcoming Meetings

Some upcoming IRSU-related meetings to be aware of:

- **Karl to plug: Lunar Surface Science Workshop 18: "Lunar Resource Evaluation Campaign - Implementing", Oct. 14**
  - Abstract deadline passed, but registration open and free: https://www.hou.usra.edu/meetings/lunarsurface2020/registration/

- **CLPS: Survive the Night Technology Workshop, Dec. 6-8**
  - Abstract deadline passed, but registration opening soon: https://www.hou.usra.edu/meetings/clps2022/registration/
- **Next-generation Suborbital Researchers Conference Feb. 27 – Mar. 1 2023:** https://nsrc.boulder.swri.edu/
  - Submit Notice of Interest: https://www.boulder.swri.edu/NSRC2020/Site5/Home.html
- **Lunar Polar Volatiles, Nov. 2-4:** https://www.hou.usra.edu/meetings/lunarpolar2022/
- **LSIC Fall Meeting! (next slide)**

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Fall LSIC Meeting

- **November 2-3, 2022**
- University of Texas El Paso, **Hybrid!**
- Focus will be on how the 6 Focus Areas (think ISRU!) relate to Excavation and Construction.
- Abstract deadline has passed, registration is open until mid-Oct!
- https://lsic.jhuapl.edu/Events/Agenda/index.php?id=350

Credit: UTEP

Funding Opportunities

- **2023 NASA BIG Idea Challenge (grads/undergrads)**
  - Lunar Forge: Producing Metal Products on the Moon
  - E.g., storage vessels for liquids and gases, extrusions, pipes, power cables, and supporting structures
  - NOI due Sep. 30! https://bigidea.nianet.org/
- **Break the Ice Challenge due Sep. 30:**
  - Design a system for excavating and delivering icy regolith
  - https://breaktheicechallenge.com/

ROSES-22 Amendment 51: F.10 PRISM Final Text and Due Dates

Step 1: Oct. 22 | Step 2: Dec. 20

NSTGRO due Nov. 2

The National Aeronautics and Space Administration (NASA) Headquarters has released a solicitation, titled NASA Space Technology Graduate Research Opportunities (NSTGRO) - Fall 2023, on September 2, 2022. The solicitation is available by opening the NASA Research Opportunities homepage at https://nspires.nasaprs.com.

This fellowship opportunity, titled *NASA Space Technology Graduate Research Opportunities – Fall 2023 (NSTGRO23)*, solicits proposals on behalf individuals pursuing or planning to pursue master's or doctoral (Ph.D.) degrees in relevant space technology disciplines at accredited U.S. universities.

NASA Space Technology Graduate Research Fellows will perform research at their respective campuses and at NASA Centers. Each recipient will be matched with a technically relevant and community-engaged NASA researcher who will serve as the research collaborator on the award. Through this collaboration, graduate students will be able to take advantage of broader and/or deeper space technology research opportunities directly related to their academic and career objectives, acquire a more detailed understanding of the potential end applications of their space technology efforts, and directly disseminate their research results within the NASA community.

Explore and Land RFI due Oct. 6

STMD EXPLORE and LAND RFI

STMD has released the third and final Request for Information (RFI), this time for the EXPLORE and LAND thrusts, in our series of STAR RFI's that are intended to help us learn from the space community what they think of our technology development priorities. The RFI is available at this link: Responses are due October 6th. The link to the solicitation is available here: NSPIRES - Solicitations Summary (nasaprs.com)

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Community Interest in Data Buys

NASA is interested to learn more about the interest in the LSIC community of NASA conducting data buys from commercial providers

1. Data acquired as a by-product of landing on the Moon
2. Dedicated data that require a specific instrument to be flown

Does NASA buy an entire data set and put it in PDS?
Do users buy data directly from the providers?
What data would YOU want?

https://forms.gle/tuhzwAUaQLDivQ2D7

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Low-T Power Workshop Recap

LSIC Workshop: Low Temperature Power and Energy Storage

This workshop, held July 28 2022, was an investigation into near-term solutions for power during the lunar night and in extremely cold environments at the sub-kW regime. The ~6-hour virtual workshop included:

- Overview of lunar thermal environments
- Panel discussion with representatives from various industry and academia perspectives
- Lightning talks to rapidly survey new technologies
- Presentation on low-temperature batteries from Dr. Marshall Smart at JPL
- 3 breakout discussions targeting specific scenarios at different power regimes

Attendance Statistics:

- Registered: 204
  - Academia: 33 (16%)
  - Government: 60 (29%)
  - Industry: 88 (43%)
  - Nonprofit: 21 (10%)
  - Other: 2 (1%)
- Attended: 129
  - JHUAPL: 26
  - NASA: 54

Overview of Lunar Thermal Environments (Ben Greenhagen, APL)

The Extreme Environments focus group is an excellent resource for all aspects of the lunar environment, and started out this workshop by presenting a well-organized overview of thermal considerations. Ben's talk deftly considered the lunar thermal environment in two categories:

Global Environment

- Equatorial daytime maximums: 387-397 K
- Equatorial nighttime minimum: ~95 K
- Long periods of no direct solar illumination even at mid-latitudes (~14.75 Earth days of lunar day/night)
  - Other sources of illumination at night (Earthshine, Lyman-alpha, zodiacal light) provide rough equivalent of a 60-Watt bulb 2-3 meters overhead

Poles as Special Environments

- Permanently shadowed regions (PSRs) are always cold
- Areas that get even small amounts of illumination warm and cool rapidly
- Terrain can have drastic effects – higher areas get more light!

Panel Session

Panelists included:

- Richard Oeftering, NASA GRC
- Pamela Clark, Morehead State University
- Joshua Ruedin, Nanohmics Inc.
- Chris Morrison, USNC
- Ian Jakupca, NASA GRC
- Mike Provenzano, Astrobotic

The panelists explored near-term technologies for system solutions, including RTG systems, parabolic radiators/reflectors, cryo-electronics, RHUs, thermal switches, and more. A consensus was reached that there is no single solution that will apply, rather, s**ystems will need to incorporate multiple technologies** to achieve desired performance. While *surviving* the night can be done; the current challenge to address is how best to promote *operability* during the night.

Low Temperature Li-Ion Batteries for NASA Applications (Marshall Smart, JPL)

- Marshall Smart gave an excellent summary of the latest state of the art battery technology employed in recent missions, as well as ongoing work that will pave the way for the future
- Different types of Li-Ion electrolytes have been infused into several missions including MER, Phoenix, Juno, Grail, MSL, and InSight
- New technologies have been demonstrated to provide excellent low-temperature characteristics and will be viable for future missions
  - Quallion BTE cells and 12 Ah cells have been demonstrated to operate *continuously* at -60° C and are operational down to -90° C (PUFFER program)
  - 18650-size E-One Moli Li-ion cells operational down to -60° C, and demonstrated over 167 Wh/kg at -40° C with low rates

LSIC Workshop: Low Temperature Power and Energy Storage

Lightning Talks

The community had the opportunity to view 12 pre-recorded lightning talks reviewing the latest advancements in low-temperature power technology:

Richard Ambrosi (University of Leicester)	European Radioisotope Power and Heat Solutions for Lunar Applications
Gary Barnhard (XISP-Inc)	Surviving The Lunar Night: Power and Ancillary Services Beaming as Part of an End-to-End Power System V1-1
John Bucknell (Virtus Solis Technologies, Inc)	Highly Efficient Thermoelectric Storage for Lunar Small-Scale Consumers
David Bugby (JPL, CalTech)	Passive Thermal Management Technologies for Lunar Day/Night Survivability
Nathan Davis (OxEon Energy)	A SOXE-PEM Hybrid Energy Storage System for Continuously Powered Lunar Operations (HESS-CPLO)
Shanti Garman (University of Washington)	Wireless Power Transfer as a Thermal Management Solution for Mobility Energy Storage: CubeRover Lunar Night Survival Study Using Magnetically Coupled Resonators
Christopher Greer (Penn State)	Surviving the Lunar Night Using Metal Oxidation Warming Systems with Electricity Cogeneration
Alex Ignatiev (Metox Technologies)	Using Lunar Superconducting Magnetic Energy Storage (LSMES) for NASA Artemis Program
Randall Kirschman	Electronics for Cryogenic Temperatures – Real and Ready
Richard Oeftering (NASA GRC)	Battery and Electronics Technologies for Lunar Power Hibernation
Nick Rolston (Arizona State University)	Improving Thermomechanical Reliability of Li-Ion Batteries to Withstand Freeze-Thaw Process (Thermal Cycling)
Arjit Sengupta (Vanderbilt University)	Operation of Silicon Carbide Power Devices under Lunar Surface Temperatures

LSIC Workshop: Low Temperature Power and Energy Storage

Breakout Scenario Takeaways

CLPS-scale	VIPER++	Mini-Rovers

• Thermal Isolation:
  ◦ Must be considered from both the environment and other parts of the lander
  ◦ Weak points are in the interfaces: wiring, optics, sensors, etc.
• Separating power generation from avionics to make weight distribution work out complicates thermal design
• Should payloads and the bus be self-sufficient through the night or share thermal resources?
	• Regulatory approval is needed for DRPS/RPS as a power option, but this is crucial for non-solar, non-tethered power
	  ◦ Need a clear list of options available for DRPS development; may help to have a person/office to make this information readily available
	• Autonomous operations in traversing terrain would mean less human operation and less need for constant communication
		• Three options for operational modes:
		  ◦ Hibernation during lunar night
		  ◦ Part-time operations in lunar night/cold
		  ◦ Full operation in lunar night/cold
		• RHUs will be a good, compact tool to support this scale of low-temperature operation
		• Wireless charging, such as that designed for Astrobotic's CubeRover will be highly impactful for operation at night/in PSRs

General Themes

- There is a need to probe the regulatory framework for launching alternative radioisotopes. The technology is understood and will be impactful once it clears regulatory hurdles.
- Delivering anything beyond modest levels of continuous power (10’s of We) through the lunar night will be hard in the near/mid-term.
- Minimal operational modes/survival would be viable at these and lower levels, and efforts towards achieving this will deliver high-value in the near term
- If payloads can draw on small-scale power through the night and expect full power and comms to return, the scope of the possible opens up dramatically. This is possible in the near-term

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Topical Discussion

Amourette McDonagh
Black Moon Space Technology

"Welding in Space"

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IAC Conference: Input, Thoughts, Opinions?

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Johns Hopkins
Applied Physics Laboratory

Coffee and Donuts

If you had unlimited resources (money, time), what aspect of your technology would you test on Earth to prepare for the Moon?

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