



LSIC

Newsletter

The Lunar Surface Innovation Consortium is administered by the Johns Hopkins Applied Physics Laboratory, and operates in collaboration with the NASA Space Technology Mission Directorate under the Lunar Surface Innovation Initiative. Its purpose is to harness the creativity, energy, and resources of the nation to help NASA keep the United States at the forefront of lunar exploration. To find out more, sign up to participate, or access past additions of this newsletter, please visit lsic.jhuapl.edu.

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Director's Update

I would like to thank everyone who participated in our Spring Meeting last month! It was wonderful to get to see and chat with so many of you, and we are glad to have you with us as members of the community. I am excited to see discussions of the 'LIVE' portion of the NASA Envisioned Futures continuing through the focus group and subgroup monthly meetings. I also want to encourage all of you to also make your voices heard directly to NASA through their formal Request for Information (RFI) here: <https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7bEE5AA24F-0DB4-7413-DC4C-B0A50FB99A86%7d&path=&method=init> (Due June 23rd). Note that there is an informational session today (June 1) at 3:30 EDT as well (https://www.nasa.gov/directorates/spacetech/strategic_framework).

As the community continues to examine, review, and contribute feedback to the technical Envisioned Futures, we have had the suggestion from a member of the community that a workshop could be convened at which industry could share their own visions for architectures, and help NASA understand what sustainable means from the commercial perspective. This discussion could include both technical and business-related gaps, which could provide NASA additional insight into what infrastructure and/or services they would need to invest in to foster an economically sustainable ecosystem. We are excited to develop this idea, and hope that as you continue reviewing NASA's plans, you also spend time thinking about how they relate to the future you envision.



Rachel Klima

Director, Lunar Surface Innovation Consortium
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Focus Areas

Monthly Telecon Schedule

Dust Mitigation

Third Thursdays at 12PM Eastern

Extreme Access

Second Thursdays at 3PM Eastern

In Situ Resource Utilization

Third Wednesdays at 3PM Eastern

Excavation & Construction

Fourth Wednesdays at 2PM Eastern

Extreme Environments

Second Tuesdays at 3PM Eastern

Surface Power

Fourth Thursdays at 11AM Eastern

LSIC General Updates

As a reminder, If you don't have access to LSIC's Confluence wiki, please email Andrea Harman at ams573@alumni.psu.edu to get signed up.

Workshop: Low Temperature Power and Energy Storage for the Lunar Surface (28 July)

While technologies such as nuclear fission and regenerative fuel cells offer large-scale solutions for power needs during periods of darkness, lower-power needs such as batteries that will survive or operate within PSRs, as well as and strategies that ensure survival through hibernation are immediate needs critical for the lunar surface and beyond. Meeting these needs will unlock dramatic potential, including enabling longer-term CPLS missions and resource prospecting within permanently shadowed regions that will inform avenues for commercialization of the Moon.

In this workshop, we will discuss near-term options for power during the lunar night at the sub-kW regime, with particular interest in the following topics:

1. Hibernation
2. Thermal management/design
3. Low-T battery chemistry
4. Radioisotope thermal support/power
5. Fuel cells/chemical heat/power

Registration for this event will be opening soon! This and additional information will be available on the event page here: <https://lsic.jhuapl.edu/Events/Agenda/index.php?id=214>

Focus Group Updates

Dust Mitigation

The Dust Mitigation (DM) Focus Group held its monthly focus group meeting on May 19th. The May focus group meeting centered on following up on the 2022 LSIC Spring Meeting held on May 4-5 and a discussion led by Sarah Hasnain on NASA STMD's recently released NASA Envisioned Futures, which were also presented at the LSIC Spring Meeting. The Envisioned Futures describe possible futures for establishing a sustained presence on the lunar surface ("LIVE Thrust") that are enabled by technology investments in key capability areas. The LIVE Thrust Envisioned Futures charts, along with the Strategic Outcomes, can be downloaded from NASA TechPort: <https://techport.nasa.gov/framework>. The discussion on the Envisioned Futures charts focused on the challenges posed by lunar dust and dust mitigation gaps/needs within each of the capability areas. Results from the discussion will be used to provide feedback to NASA STMD to help improve the Envisioned Futures charts. The community is also invited to submit a response to the NASA STMD Request for Information (RFI) on the NASA Envisioned Futures charts at the following link: <https://nspires.nasaprs.com/external/solicitations/summary.do?solId={EE5AA24F-0DB4-7413-DC4C-BOA50FB99A86}&path=&method=init>

Our next focus group meeting will be held on Thursday, June 16th at 12:00 pm Eastern Time. The topic for the meeting will focus on "Dust Tolerant Mechanisms." The meeting will include featured

technology presentations along with a discussion session.

Excavation & Construction

The Excavation & Construction focus group enjoyed connecting with the community at LSIC Spring Meeting. The E&C annual update was presented at the meeting to the LSIC community. We also played a leading role in facilitating a breakout session as a follow-up to the Regolith to Rebar metal workshop held February. An important finding was that another workshop is necessary that will, among other things, discuss commercialization aspects of lunar activities.

During the May monthly meeting, we hosted Dr. Rauno Heikkilä, a professor at the University of Oulu, Finland and head of the Structures and Construction Technology Research Unit. Dr. Heikkilä provided an introduction to Open Building Information Modeling (BIM), as well as overviews of use cases including an autonomous Smart Excavator and their next research project, an autonomous Machine Swarm. The session concluded with suggestions for research collaboration regarding Earth and Lunar Construction Automation

Extreme Access

The Extreme Access focus group took the month off from our large telecon this month, but the EA subgroups have still been busy! Thanks to everyone who has provided input to the LunaNet interoperability standards feedback during the Comms and PNT meetings! The most recent draft is on the LSIC EA Confluence page (<https://lsic-wiki.jhuapl.edu/x/4acxAg>) and will be submitted to NASA soon. At the June telecon, we will discuss responses to the open LIVE RFI and also hear from Dave Israel (NASA) about the Laser communications relay demonstration (LCRD).

Extreme Environments

In May, Extreme Environments took a month off from the monthly meetings following our fantastic LSIC Spring Meeting! Our May subgroup meetings covered each of the 5 parts of the Live RFI. If you have inputs to share, please feel free to post them on Confluence at <https://lsic-wiki.jhuapl.edu/x/YacxAg>.

The EE and EA workshop titled “Designing for the Extremes” is postponed due to other lunar workshop conflicts. We are working on a new date and will most likely be in early August. Our June speaker, Tom McCarthy, from Motiv Space Systems, Inc. will cover the extreme environment technologies his company has been developing in the motion control arena. The applications are wide ranging from LTV mobility drive systems, manipulators, cargo off-load systems, ISRU processing equipment, etc. The motivation behind their technology developments is to design the systems with expanded capability to address the extreme environments. As always, if community members have ideas for what they would like to see or discuss, please reach out to any member of EE leadership.

ISRU

The ISRU focus group held its May monthly meeting on the 20th, with presentations focused on the need for an international lunar resource evaluation campaign by Dr. Clive Neal, Notre Dame, and by Trent Hare, USGS, on how to map and keep track of resources on the surface of the Moon. The breakout groups continue to address the challenges associated with lunar ISRU from formulating a prospecting mission or campaign, as well as extracting O₂ and metals from the regolith, connecting

industry with each other and government to form a value network for sustained business model of lunar ISRU, and finally in enabling long term ISRU operations through understanding modularity and in-situ maintenance.

Surface Power

This month, the Surface Power team participated in the Nuclear and Emerging Technology for Space conference, the LSIC Spring Meeting, as well as held the monthly telecon with breakouts to discuss the “LIVE” RFI recently released by NASA (and presented by John Scott at the LSIC Spring Meeting). We also honed the upcoming summer workshop on low-temperature power to one day, and focused on near-term solutions at sub-kW power levels. Registration will be opening shortly!

Working Group – MOSA

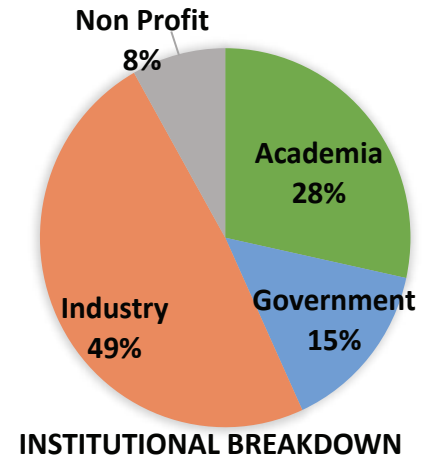
The LSIC Modular Open Systems Approach (MOSA) working group (WG) hosted its first telecon on April 6th, where Chad Thrasher (NASA’s Artemis Campaign Development Division, Systems Interoperability Lead) presented Artemis’ Graphical User Interface (GUI) standards. Following the presentation, we had great question and answer session, and soon the telecon recording and slides will be posted on LSIC webpage. The MOSA WG also held a MOSA panel session at the 2022 LSIC Spring Meeting, where panelists from various institutions addressed key questions on how best to proceed with ensuring lunar interoperability. More information on the session, the session recording, and session slides are here: <https://lsic.jhuapl.edu/Events/Agenda/index.php?id=200>

Looking forward, the MOSA WG will be hosting its second monthly telecon on June 8th 2022 at 12:00 (noon) PM ET, where Dr. Katherine Morse (Principal Professional Staff at JHU/APL, IEEE Fellow), will be presenting standards development processes. If you are interested in joining the MOSA WG please sign-up here <https://forms.gle/RQ816yqYLL1BvRUF8> to get the latest updates and information on upcoming LSIC MOSA events. Also, the MOSA WG has been developing several resources on confluence that are located here: <https://lsic-wiki.jhuapl.edu/x/4YAxAg>. This page also lists the points of contact for the WG.

Feature Article

LSIC Spring Meeting Summary

The Lunar Surface Innovation Consortium (LSIC) 2022 Spring Meeting was held on May 4th-5th, 2021 at the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, MD. The primary objective of this meeting was to provide a forum for NASA to present several themes of their 'LIVE' Envisioned Futures, which outline the strategic investments in key technical areas necessary for establishing a sustained presence on the lunar surface. The meeting included panel discussions, breakout sessions, community presentations. Attendance included 430 individuals representing 189 institutions (from 18 countries, 30 states, and Washington DC) that met in a hybrid format over the course of two days. Roughly 47% of individual attendees had not participated in LSIC or worked with the Space Technology Mission Directorate (Space Tech) previously.



The meeting's technical sessions featured a Key Note address about the Artemis strategy by NASA Associate Administrator Bob Cabana, an overview of Space Tech high-level strategy and objectives by NASA Associate Administrator for Space Technology Jim Reuter, and a series of presentations about NASA's Envisioned Futures, including an overview of the process by Walter Engelund, Space Tech Deputy Associate Administrator for Programs, as well as presentation of specific strategic frameworks in the areas of power and energy storage, in situ resource utilization, thermal management systems, and excavation, construction, and outfitting, by NASA the technical leads for those areas. Other NASA presentations included an introduction to the new NASA I-Corps program and an overview of the Lunar Surface Technology Research (LuSTR) program.

Panel discussions followed up on two high-priority areas of interest that had been identified by the community in previous LSIC meetings: Space Law and Standardization. For the first panel, experts in space law discussed the policy framework provided by Outer Space Treaty and how issues surrounding utilization of the lunar environment impact technology developers and the commercial space sector. In the second panel, the concept of the Modular Open Systems Approach (MOSA) and how it is implemented in other sectors was presented to the group, who then discussed how such an approach could benefit efforts to develop a sustained presence on the Moon.

Following the technical presentations, several breakout sessions were convened to allow more discussion on themes from the meeting, including NASA's Envisioned Futures, Space Law and MOSA, Funding Opportunities, and a follow-up discussion on the recent "Regolith to Rebar" workshop. The meeting program with abstracts, videos of all plenary presentations, posters from community presenters, and written answers to questions posed of the law panel are posted on the meeting website at: <https://lsic.jhuapl.edu/Events/Agenda/index.php?id=200>. Key findings, based on questions, comments, and breakout discussions with the community include:

- Industry and academia are eager to make use of the Commercial Lunar Payload Services or

other launch opportunities to prove their technology is ready to feed into NASA missions and architecture.

- The LSIC community supports ensuring that funds for technical maturation are a high priority.
- A “Mock Preliminary Design Review (PDR)” could be leveraged as a mechanism for defining expectations and communicating to industry what the requirements of EF technical solutions ought to be, identifying knowledge gaps, stakeholders, and more.
- There are many unresolved and important policy questions on resource rights, disposal management, and how lunar norms will be set. We have a great opportunity now to establish those norms and standards as a community before parties start to arrive on the lunar surface. An official organizing body could help establish these norms and oversee technical and system standards.

Member Spotlight

Southwest Research Institute

Michael Miller (Institute Scientist) & Kurt Retherford (Senior Program Manager)

Michael Miller and Kurt Retherford have both enjoyed many years at the Southwest Research Institute (SwRI). Prior to joining SwRI, Miller worked at the University of Texas Health Science Center San Antonio while finishing his undergraduate degree in chemistry. After graduating, he was recruited in 1985 to SwRI's Chemistry and Chemical Engineering Division under the Applied Chemistry Department, applying his analytical chemistry skills to develop pharmaceutical formulations and conducting analytical and computational chemistry work. From there Miller moved more towards his passion, which is physical and synthetic chemistry, and joined the Materials Engineering Department. Retherford started his academic career at the University of Wisconsin at Madison, then completed his graduate work at The Johns Hopkins University, and now serves not only as a Program Manager at SwRI but also as faculty for the University of Texas at San Antonio's Physics and Astronomy graduate program. Both men have a passion for space and the Moon, and have conducted significant research towards advancing science and technology needed for development of the lunar surface throughout their careers.

SwRI was founded in 1947 and is headquartered in San Antonio, Texas. It has offices throughout the United States as well as in China and the United Kingdom. The nonprofit applied research organization was started on a ranch in south Texas by Tom Slick, an oil businessman who had a grand vision of a research institution which he realized into one of the nation's largest R&D organizations. "We like to say that our motto is 'from deep sea to deep space, and everything in between,'" explained Miller. SwRI has developed many technologies for deep offshore applications, such as the pressure hull for the Alvin (DSV-2), a crewed deep-ocean research submersible owned by the US Navy. And SwRI's many contributions to space engineering and science include acting as the principal investigating institution for the IMAGE, New Horizons, Juno, and Lucy missions, among others. There are nine main divisions that make up the larger organization: Automotive & Transportation, Biomedical & Health, Chemistry & Materials, Defense & Security, Earth & Space, Electronics & Automation, Energy & Environment, and Manufacturing & Construction, and Mechanical Engineering. SwRI also conducts a comprehensive Internal Research and Development Program (IR&D), through which many of its innovations are created.

During the heyday of advanced polymer composites in the early 90s, Miller supported work building advanced machinery that went on to be enhanced with artificial intelligence to manufacture composites for aerospace applications. This included embedded sensors with models that could run in the background, algorithms that would tell the machinery what to do next. That work has gone on to include materials synthesis and modeling, computational methods, and is now culminating in the development of a framework for discovering novel alloys, a program that's being worked under SwRI's IR&D program. "Each division is a bit like a college on a university campus," describes Miller. "We're into autonomous vehicles, robotics, in silico drug screening, drug formulations, oil and gas engineering, engine design, optimization, hybridization..." his list continued on, with clean energy research identified as near the top of the list along with space science and engineering. And as a public nonprofit, SwRI has a revenue mix of about 35% from commercial programs, 30% from government subcontracts, and direct government funding making up the final 35%. In terms of

the overall number of projects, there is an approximate 50/50 split of government and sponsored projects.

Retherford is another of the 2,774 employees SwRI boasted as of 2021. Since joining the nonprofit in 2002, he has and is serving on multiple space missions including Europa Clipper, the Hubble Space Telescope, the Lunar Reconnaissance Orbiter (LRO), and more. “I’ve been a lunatic for a long time,” laughed Retherford, and explained that while planetary volatiles and exospheres are his main specialty, his interests are very diverse, “and planetary surface mineralogy is the next thing I’m tackling.” He’s interested in seeing more exploration of the Moon’s polar regions, specifically to build understanding of the volatiles that exist there and figuring out how to utilize them. One project he is working through SwRI’s IR&D program is developing a new kind of deep ultraviolet Raman spectrograph instrument for use either as part of NASA’s Development and Advancement of Lunar Instrumentation (DALI) or Commercial Lunar Payload Services (CLPS) programs. As it turns out, Miller and Retherford are collaborating across their respective divisions on the Raman spectrograph and another instrument called the Volatiles Analyzer and Prospector of Regolith Resources (VAPORR), a probe that employs laser-induced thermal desorption mass spectrometry coupled with a plasma source to identify and quantify lunar volatiles. Retherford especially highlighted that SwRI’s San Antonio headquarters has expanded the number of planetary scientists it has on staff to ~30, complementing the ~40 or so in SwRI’s branch office in Boulder Colorado. He was especially excited to be acting as the Organizing Chair for the American Astronomical Society Division for Planetary Sciences meeting that will be held in downtown San Antonio in 2023.

While some of SwRI’s space research, especially that which has been funded by NASA, has gotten publicity over the years, the organization tends to keep a low profile regarding their work to protect the intellectual property of their clients (as many other applied research facilities do). This means that some of their efforts are less well known, though of course they are no less important. Miller was energized when sharing about another of his research projects dating back to the 90s, which involved assessing different technologies for producing propellants on Mars and the Moon. SwRI coined the term In Situ Propellant Production (ISPP) instead of In Situ Resource Utilization (ISRU) which has become more standard in the industry. They designed and tested subscale systems for propellant production. Coincidentally, Miller directed a 10-year program funded by the Department of Energy that established a lab for research and assessment of solid-state hydrogen storage technologies. That program had an opportunity to build a state-of-the-art laboratory for sorption science, which is a vital aspect for understanding lunar volatiles and regolith. “When the original program using that lab ended, we opened it up to other opportunities having less to do with hydrogen and more to do with synthetic and natural minerals, to study volatile sorption properties of minerals, and their ability to interact with water, methane and the heavy noble gases – so that’s what the nature of the laboratory currently is,” shared Miller.

Retherford and Miller see involvement in LSIC as an opportunity to tell the lunar surface development community about their work and solicit interest while also giving more visibility to the important work being done at SwRI. They can provide their opinions based on the knowledge and experience they’ve gained through their work, and can provide more direction around the knowledge gaps that are coming to light. The organization has an enormous reserve of research and talent to draw from across different industrial and commercial sectors, and they’re excited to apply that to relevant lunar science and technology development. “We know about drilling from working with our oil and gas clients, we know about materials synthesis out of our department of materials engineering, which we’ve been doing for many years – and not just ordinary synthesis, but under extraordinary conditions,” disclosed Miller. “We know from both our Earth & Space and Chemistry &

Materials divisions about building hardware and instrumentation, and we have a deep background in analytical sciences. We have this broad knowledge base, and are ready to apply it to different lunar technology development problems.”

One of the biggest challenges both Retherford and Miller identified, and Miller directly mentioned during his participation in the ExComm panel during the LSIC Spring Meeting, is that a better understanding of partial gravity effects is needed for the transfer of fluids in proposed chemical plants on the lunar surface. This incomplete understanding of partial gravity effects also applies to moving regolith on the Moon. SwRI is launching an internally funded research project using parabolic flight to investigate simple fluid surface interactions to begin tackling this knowledge gap. “I’m excited to learn how to operate in and use new environments, and take on the unexpected challenges we’ll face because of the partial gravity on the Moon,” declared Miller. He went on to explain that while operating on the lunar nightside without nuclear power supplies will be a challenge, it’s possibly surmountable by some of the new technologies such as thermal control devices and improved solar arrays that have been discussed at LSIC events.

Find out more about the Southwest Research Institute here: <https://www.swri.org/>

NASA and Community News

NASA Supports Small Business Research to Power Future Exploration

26 May 2022 \ \ NASA News

<https://www.nasa.gov/press-release/nasa-supports-small-business-research-to-power-future-exploration>

Sometimes a Moonshot Is Literally a Moonshot

25 May 2022 \ \ Medium \ \ Gareth Keane

<https://medium.com/go-build-something/sometimes-a-moonshot-is-not-really-a-moonshot-c583fac4c7c2>

Lunar Outpost Announces \$12 Million Seed Investment, to Scale Mobility Technology Enabling Commercial Lunar Advancement

24 May 2022 \ \ BusinessWire

<https://www.businesswire.com/news/home/20220524005399/en/Lunar-Outpost-Announces-12-Million-Seed-Investment-to-Scale-Mobility-Technology-Enabling-Commercial-Lunar-Advancement>

Biden vows to expand space cooperation with South Korea, Japan

23 May 2022 \ \ SpaceNews \ \ Park Si-soo

<https://spacenews.com/biden-vows-to-expand-space-cooperation-with-south-korea-japan/>

The space industry is on its way to reach \$1 trillion in revenue by 2040, Citi says

21 May 2022 \ \ CNBC \ \ Michael Sheetz

<https://www.cnbc.com/2022/05/21/space-industry-is-on-its-way-to-1-trillion-in-revenue-by-2040-citi.html>

Engineers Design an Electrical Microgrid for a Lunar Base

16 May 2022 \ \ Universe Today \ \ Matt Williams

<https://www.universetoday.com/155906/engineers-design-an-electrical-microgrid-for-a-lunar-base/>

Astra reveals details of next, larger rocket

12 May 2022 \ \ SpaceNews \ \ Jeff Foust

<https://spacenews.com/astra-reveals-details-of-next-larger-rocket/>

NASA Welcomes Vice President of Colombia for Artemis Accords Signing

10 May 2022 \ \ NASA News

<https://www.nasa.gov/feature/nasa-welcomes-vice-president-of-colombia-for-artemis-accords-signing>

How an ex-Blue Origin intern got a \$500,000 check from Mark Cuban to build a major SpaceX rival

07 May 2022 \ \ CNBC \ \ Tom Huddleston Jr.

<https://www.cnbc.com/2022/05/07/this-4-billion-space-start-up-began-with-a-cold-email-to-mark-cuban.html>

Mini Crowdsourced Payloads Could Support NASA's Artemis Missions

04 May 2022 \\ NASA News

<https://www.nasa.gov/mini-crowdsourced-payloads-support-nasa-artemis-missions>

NASA Seeks Space and Earth Science Technologies for Flight Testing

02 May 2022 \\ NASA News

<https://www.nasa.gov/directorates/spacetech/flightopportunities/space-earth-tech-for-flight-testing.html>

Funding Opportunities

Tech Development

- Technology Advancement Utilizing Suborbital and Orbital Flight Opportunities “TechFlights”
<https://sam.gov/opp/b428ab6bded1484bb12791197a48d83e/view>
Proposals Due 6/2/2022
- Watts on the Moon Challenge, Phase 2
https://www.nasa.gov/directorates/spacetech/centennial_challenges/watts-on-the-moon/index.html
Registration due: June 15, 2022 at 5 p.m. EDT
- Announcement for Partnership Proposals (AFPP) to Advance Tipping Point Technologies
<https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7b9987D88F-0A12-5203-FC25-423773FAF134%7d&path=&method=init>
Final proposals due: July 28, 2022
- Space Technology Announcement of Collaboration Opportunity (ACO)
<https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7bA9C79925-6F41-69E8-4BE0-5325903D777C%7d&path=&method=init>
Final proposals due: July 28, 2022

Request for Information (RFIs)

- NASA’s Strategic Technology Framework “LIVE Thrust”
<https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7bEE5AA24F-0DB4-7413-DC4C-B0A50FB99A86%7d&path=&method=init>
Feedback Due: 23 June, 2022

For more funding opportunities, please visit LSIc’s website here: <http://lsic.jhuapl.edu/Resources/Funding-Opportunities.php>