Lunar Surface Innovation CONSORTIUM

Hosted by the Johns Hopkins Applied Physics Laboratory

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# 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.

DIRECTOR'S UPDATE

# Director's Update

It's hard to believe that the summer is already coming to an end, and the Fall Meeting will be here before we know it. As we've mentioned before, we have been planning this meeting to be hosted at Bowie State University. We're working with the University to ensure that our in-person content is consistent with all COVID restrictions, and we are grateful for your patience and understanding as we navigate this hybrid experience. Even after COVID restrictions are lifted, we plan to continue to provide online accessible semi-annual LSIC meetings to ensure that as many participants can join us as possible, so we will gather feedback and lessons learned from this meeting to feed into future meetings. If you would like to attend in person, please register for the meeting early, as we will be limiting attendance (we will stay in close communication with those considering attending in person, as we know things can change rapidly).

For the meeting itself, we look forward to exciting information about developments in autonomy and robotics. We will focus our breakout discussions on autonomy needs for the development, maintenance, and operation of lunar surface infrastructure, identifying existing capabilities and key gaps and concerns. Virtual and in-person attendees will participate in shared plenary sessions, but dedicated virtual breakout and networking sessions are planned so that online attendees can participate fully. We look forward to many fruitful discussions!

**Rachel Klima**
**Director, Lunar Surface Innovation Consortium**
SES-LSIC-Director@jhuapl.edu

## 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**
Last Fridays at 3PM Eastern

**Extreme Environments**
Second Tuesdays at 3PM Eastern

**Surface Power**
Fourth Thursdays at 11AM Eastern

# LSIC General Updates

## LSIC Fall Meeting: 03-04 November

The Fall Meeting of the Lunar Surface Innovation Consortium is scheduled for 03-04 November 2021, and will be held at Bowie State University in Bowie MD (with most content and some sessions also available online). The registration portal is now open! This year's technical theme is Autonomy and Robotics, and will be used to focus invited presentations and technical breakout discussions. To register and find additional details, please visit the event page here: http://lsic.jhuapl.edu/News-and-Events/Agenda/index.php?id=148

## CIRCUIT Intern Introduction: Sebastian Cabrejos

Each month LSIC will be featuring one of our CIRCUIT interns, to introduce them to the wider LSIC community. This month, we're happy to feature Sebastian Cabrejos.

I'm Sebastian Cabrejos, a member of the Lunar Surface Innovation Initiative (LSII) Cohort with the Cohort-based Integrated Research Community for Undergraduate Innovation and Trailblazing (CIRCUIT) program. I work primarily under the Excavation & Construction (E&C) Focus Group. Over this past summer, I've worked on several projects to improve our understanding of the Lunar Surface and facilitate conversations amongst the Lunar Surface Initiative Consortium (LSIC). I have developed an early-stage "lunar base simulator" to determine the exact power and mass requirements across a wide-range of tools, equipment, and other related materials with the support of my fellow CIRCUIT colleagues. I've also contributed to building a database to determine the success of LSIC and how to improve our outreach. My ongoing objectives are to finalize the "lunar base simulator", increase the ease of use of the LSIC database, and complete several other newly-assigned tasks by the end of my tenure as a CIRCUIT Fellow in May 2022. If you're interested in learning more about my interests and research, please feel free to contact me at sebastian.cabrejos@jhuapl.edu.

## Focus Area Updates

**Dust Mitigation**: The Dust Mitigation (DM) focus group held monthly meetings in late July and August featuring guest speakers on the topics of the impact of dust on surface power, and dust-plasma interactions and its impact on surface exploration, respectively. In addition, we stood up multiple dust mitigation subgroups focused on specific technology areas, including Materials and Surface Coatings; Seals, Soft Goods and Fabrics; Mechanisms; Monitoring and Filtration; Modeling; Lunar Surface Modification; and Isolation Technologies. To join any of the subgroups, you can sign up here: https://docs.google.com/forms/u/1/d/e/1FAIpQLScB6iT2fgPqj2zIaP0s-rwWQDQ04TPfgVyiC5zn0AQPAT5CZA/viewform. We are also soliciting feedback from the community on how we are doing and what people would like to see in Year 2 here: https://docs.google.com/forms/d/e/1FAIpQLSdjuTIK_TLMnCM4_aSMLAzLS762qtzbgmcOd2fgizICsab6KQ/viewform. Finally, the DM LSIC website and Confluence pages have been updated to better facilitate collaborations, discussions, and access to resources. In September, we will kick-off the subgroups and their work over the next year as well as feature a technology spotlight at the monthly focus group meeting.

**Excavation & Construction**: In the month of August, the E&C focus group was involved in planning and organizing the E&C Workshop in which E&C capability needs and technology gaps were discussed in details. The workshop was a great success with over 100 participants and highly interactive breakout sessions in which various aspects of E&C activities were discussed. A report of the workshop will be released in September. The E&C page on LSIC's website and its Confluence space were substantially upgraded in August. We plan to have the three winners of Break the Ice Challenge (Phase I) talk about their concepts in our September monthly meeting on 9/24 at 3 PM Eastern.

**Extreme Access**: We are working through the steps of our annual goal! We stood up several subgroups to facilitate more in-depth conversations regarding specific technologies and needs in the themes of: Mobility, Communications, Terrain Relative Navigation, Lunar Service Sheds, and Position, Navigation, and Timing. The subgroups meet once a month, offset from the main focus group telecon. You can add your name to the EA subgroup Confluence pages if you'd like to be involved. We also had several guest speakers over the past month on the topics of LunaNet (August), LunaSAR (July), and the Intuitive Machines Lunar Micro-nova Deployable Hopper (July). In September, we will continue working through the technology needs for Extreme Access into lunar pits, lava tubes, and PSRs, and will have additional technology spotlights at the main telecon.

**Extreme Environments**: The Extreme Environments focus group monthly meeting covered the Lunar Surface Technology Research (LuSTR) Opportunities as well has hosting a presentation from Brian Hamill on "Overview of the Lunar Thermal Analysis Guidebook - LTAG - HLS-UG-001". The subgroups met to further the development of their resource guides. EE Facilitator interviews with members of the community are underway to receive feedback on how we are doing and what is to come. In September, we will have a presentation from Wes Chambers at our monthly meeting covering the plasma environment.

**ISRU**: The ISRU Focus group continued its discussions into its four newly established thematic areas: H2O mining and prospecting, O2 extraction, ValueChain Mapping, and Facilities including presentations by Michael Miller, SwRI and Clive Neal, Notre Dame. Active discussions in these areas continue through their respective Confluence pages. To map your company within the value network analysis, please help to populate this Google spreadsheet with your institutions' relevant information: https://docs.google.com/spreadsheets/d/1AxV0-ueLwej2fgu1NgoX-BS-ANNU0e77XAXLMc6Xrq0/edit?usp=sharing. Additionally, needs with regards to ground based experimental facilities to support ISRU technology maturation is being solicited through a survey available at: https://forms.gle/TxXbvb1LwN4XzQT47. We anticipate continuing these discussions in our future Focus Group meetings.

**Power**: In late July, the Surface Power Focus Group held a workshop on Power Beaming for the Lunar Surface, and slides and videos are now available here http://lsic.jhuapl.edu/News-and-Events/Agenda/index.php?id=142. In our August telecon, we reviewed NASA's draft gap/closure plans and initiated several smaller analysis groups on the main themes. Please reach out if you'd like to be involved! The Surface Power Group will be continuing and expanding our discussion of Modular Open Systems Approach (MOSA) as related to interoperability of power systems (and more!).

# Feature Article

## Perspectives On Autonomy & Robotics From NASA

To gain more insights on autonomy and robotics from NASA, Terry Fong (STMD Autonomous Systems Capability Team Leader) and Shaun Azimi (STMD Robotics Principal Technologist) were interviewed to get a snapshot of their perspectives on this important topic, especially as we prepare for the LSIC Fall Meeting, which will focus on the same theme.

*What feedback would be most helpful to get from the community about autonomy and robotics at the LSIC Fall Meeting?*

**Terry**: I think at the top level, what we're interested in understanding is what direction industry is focusing on for the next five to fifteen years of lunar missions. Specifically we'd like to hear about what they're most uncertain about in terms of what needs to be developed. Next, we'd be interested in what NASA could do to significantly assist and accelerate those development efforts. I'm framing this primarily in terms of industry because in the last 15-20 years, NASA has worked with academia for terrestrial research and development. But now we're focusing on developing commercial systems and uses of the Moon, which is a totally different thing. The fact that we have the CLPS program, with 14 companies working to provide launch, landing, and even additional services is an excellent starting point. One asterisk might be that although we're recognizing CLPS vendors as those who have the greatest ongoing connection to NASA, we believe that there is a much larger community out there dedicated to autonomous systems and robotics, comprised of all kinds of companies, small and large.

**Shaun**: I often come back to asking the question of what roadblocks exist for companies in terms of technologies they want to demonstrate, or systems to deploy on the lunar surface, that have obstacles preventing them from being fully developed. Identifying a shared infrastructure, or sharing information they need to move forward, those kinds of things also flow from what Terry just said.

*Is NASA intending to release any assessments on autonomy and robotics in the future?*

**Terry**: In terms of assessments, the Office of the Chief Technologist recently completed a study called The Operation Of Autonomous Space Missions. I believe that will be made public in the near future. It is basically NASA's look at the future as missions become increasingly autonomous and independent of Earth mission control. The study was primarily focused on science missions with robots operating far beyond Earth orbit, whether for Mars sample return or investigation of the interior of Europa – looking to answer how that could be done with robots. I think that a lot of the conclusions from this study could apply to human space missions that are also increasingly far from Earth. It was really motivated by NASA's need to better understand what changes are required from our current practice to be able to deal with systems that operate more independently of mission control.

**Shaun**: It seems clear from mission architecture plans that there's a desire to have autonomous capabilities. There's going to be some iterations, with cycles of releasing some information then receiving feedback, using that to define the problem better, and continuing to clarify the architecture. For example, the Lunar Terrain Vehicle (LTV) crew rover won't only be operated by astronauts directly on-board, but will also have some level of remote operation capabilities with

commanding from Earth and potentially by astronauts inside of other elements, such as the orbiting Gateway or crew lander. These remote operations will require some level of autonomy in order to achieve the broad array of potential tasks ranging from science instrument deployment and operation, to resource mapping for ISRU, as well as surface assembly and construction.

*What are the highest-level challenges in autonomy & robotics for a sustained presence on the lunar surface?*

**Terry**: Within the Space Technology Mission Directorate, Shaun and I have been working to develop an overall strategy for autonomy and robotics. It would be informed by our envisioned future, or what we'd like to do if we're successful with our current technology development as well as the kinds of future missions we'd like to carry out. An example is that we'd like to be able to effectively and efficiently operate multiple spacecraft that work cooperatively with each other. Robotics in that case is broadly defined, and could include satellites, planetary rovers, hoppers, and landers, but we'd like them to operate as a team. Another area we're looking at is high progress rate autonomous robots. The rovers on Mars do not really drive that far, both because of the science they're doing but also because of the limitations of onboard computing and sensors. What we'd be interested in doing is trying to create systems that are more similar to the self-driving cars we see today on Earth, where they make a lot of progress through difficult situations, primarily using their onboard systems. We'd also like to have robots that can help with caretaking inside of human spacecraft, especially during periods when crew are not present (which for Gateway could be 11 months out of the year). This could be tasks like routine and preventative maintenance, inventory and logistics management, as well as running experiments. The point here is you need to create robotic systems to operate reliably and deal with failures or unexpected situations in a consistent manner that will earn the trust of mission operations. Those are the kinds of things we'd like to accomplish over the next 10-15 years.

**Shaun**: I think one of the main ways I'd like to frame that question is to think in terms of how we can bridge from existing communities of practice, for example like the CubeSat community, to lunar surface operations. In particular, leveraging the experience academic and commercial organizations have with CubeSats and bringing that to this new environment. For example, understanding the space qualification aspect of it. There are a lot of environmental things that are different, but many of the component technologies are similar. I feel like that's an area where there's already a strong community, and we can find out the best support for folks to venture into either lunar satellites or lunar surface operations with small rovers or payloads on CLPS landers, or maybe even on other assets like the LTV rover in the future.

*What are you most excited to see happening now and in the near future?*

**Shaun**: We're trying to support all the future development that Terry mentioned by promoting standards and open frameworks for hardware and software to help promote interoperability and reuse. One of the frameworks we're looking at is the Robot Operating System or ROS, and a project being run right now by Blue Origin in collaboration with NASA is called Space ROS. It might be a good opportunity to bring up what kinds of standards and frameworks are being used by LSIC participants, and what their interest may be in using ROS or one of its variants. Separately, there's an RFI going out pretty soon to collect input about Space ROS specifically and space qualified modules within that framework, in terms of which could be most important to industry.

**Terry**: The most interesting thing to me is the parallels between the terrestrial autonomy and robotics community, which has exploded over the past 10-15 years. Partly that's driven by the fact that these systems are now being viewed as essential for some activities, which opens up the door to future ways of doing business. For example, look at the huge investments in self-driving cars and autonomous drones for package delivery. The question is, when is that wave going to come for lunar surface applications, how do we best support that, and how can we help it arrive sooner so we can benefit from all these technologies. If you ask it that way, the things Shaun talked about become really important. Nobody has the time and resources to do everything themselves. The whole domain grows best when everyone can build on each other. If you have a standard, or common things you can build on, interoperable frameworks allowing plug-and-play based on what others are doing, that makes everything better for everybody. We view NASA's role in all this as helping to make that possible. If NASA needs to take a risk in order to help explore how to make common technology possible, then that's what NASA should do. If we need to build a system to show how we can use standardized components and software all working together, that's what NASA should do. But at the end of the day we want to accomplish a scenario much more similar to what we see going on here on Earth, and see that same kind of progress going on in space.

# Member Spotlight

## Honeybee Robotics

Honeybee Robotics was founded almost forty years ago in Manhattan, NY by two friends, Chris Chapman and Steve Gorevan. They initially worked to develop robotics for companies including IBM, Merck, and Con Edison. Their first NASA contract with Goddard Space Flight Center in 1986 was to develop a digging mole for Mars. The success of that work has paved the way for many more NASA contracts for developing space mining and excavation systems. Honeybee Robotics has grown to be seen as a spacecraft mechanism company doggedly pursuing its motto, which is "Touch Life, Mine The Sky."

A first major breakthrough was developing the Rock Abrasion Tool (RAT), which allowed scientists to drill into both soft and hard Martian rocks. Across the many different projects they have worked on, the company has focused on problem solving, especially for In Situ Resource Utilization (ISRU) and sampling for science missions. Honeybee has established a record of success when breaking ground to solve new problems. This has meant that Honeybee has amassed a number of 'firsts' – developing the first tool to touch the interior of a Martian rock, being the first to collect ice on Mars, and soon will be the first to collect ice on the lunar surface.

The company is well known for sampling systems dedicated to extraction as well as handling for both science and ISRU objectives. Having built a lot of drills, rasps, and shovels, one could also think of them as space excavators. But that's only part of their legacy – their extensive research and development operations explore areas such as sample caching systems, planetary protection, and dust tolerance as well. And when developing these technologies, Honeybee doesn't rely on short mission durations to define their component survival timelines. Their tools have been tested extensively in extreme environments, both terrestrially and in space, and have a proven record of lasting for years.

With their recent acquisition of Avior (a company specializing in actuators and other high-performance and reliable motion control components), Honeybee has also become more vertically integrated. Almost 80% of the hardware and capabilities required to develop, test, and operate space robots lies within the organization. Currently, Honeybee develops its own motors, motor drivers, avionics, structures, flight software and controls, as well as mechanisms.

An important focus of Honeybee has been to partner with other companies, academia, NASA, and non-profits. "We think there's enough business for everybody," said Hunter Williams, Business Development Engineer. "Because we have so much experience getting smaller payloads through TRL 6 and onto flight missions, we are particularly good at partnering with organizations and getting them out of the 'TRL valley of death,' keeping projects from languishing in the lab."

Honeybee's efforts to develop space mining robots have brought them to an exciting new opportunity: mining sunlight with Lunar Vertical Solar Array Technology (LVSAT). They see LVSAT as proof that technology developed for drilling deep below the ground can also be utilized for developing solar arrays 20 meters tall (they are flipping the drill up-side down!). Most drills Honeybee builds have integrated power and data in the drill pipe. LVSAT also requires power and data and must endure both vertical and side forces as well as wear from the extremely abrasive lunar regolith – just like the drill. Honeybee was one of a handful of companies selected to pursue this technology. "One of the reasons I think we won, something I'm proud of, is how we planned for dust

tolerance in every respect," explained Williams. "There are several different technologies of ours that are being used in other missions that we can integrate into LVSAT. Every piece of this design is going to be useful for ISRU in the future."

For many decades, people have been trying to get ISRU in space to a tipping point, and now Honeybee sees the stars aligning for their technologies. Honeybee will be starting their launch to the Moon cadence with the NASA PRIME1 mission, which will deploy their TRIDENT ice mining drill at the lunar South Pole. This will follow three more missions to the Moon in 2023, including a VIPER rover with the TRIDENT drill and two promising pneumatic based technologies – PlanetVac for delivering surface samples, and LISTER for pneumatically drilling to 3m depth. Other exciting missions include a mining system for JAXA's MMX mission to bring samples from Phobos as well as a sampling system for NASA Dragonfly mission to explore Titan.

Honeybee has a wide range of technologies under development, some of which will be ready in a few years, while others will be available in decades. RedWater, a water extraction system for Mars with a capability to produce 1 ton of water per day, should achieve TRL 6 in 2023, while SLUSH, a nuclear powered melt probe for exploration of Europa ocean won't be ready until 2030s.

NASA has demonstrated a sustained interest over two presidencies, and private industry has started to get involved in a big way. Because of programs like SBIR, small companies can compete on the same playing field as bigger players. Honeybee anticipates, especially with upcoming CLPS. missions, that many small chunks of the supply chain are being proven out, which will have a cascading effect that will make a lot of things possible in the near future. They appreciate seeing NASA come through with programs like CLPS and their extensive Artemis funding, which is stimulating smaller technology developers and incentivizing larger companies to get into ISRU.

'Dual-use' is a term that gets used frequently when discussing Honeybee's work products. First, there is both their terrestrial and extraterrestrial technology development, and the many Earth-bound mining companies they work with to increase efficiency and making terrestrial mining more 'green'. And second, 'dual-use' is especially applicable when discussing technology for both traditional science missions and ISRU. They have been working to get as close as possible to full ISRU while still serving NASA's needs for science missions. And finally, even beyond 'dual-use' is the ability for Honeybee's technologies to be utilized on whatever extraterrestrial bodies NASA targets in the coming years. As NASA's focus moves from the Moon to Mars and beyond, Honeybee is working to be ready with what they'll need to achieve their science goals and capitalize on ISRU.

"Honeybee would not be here without NASA," said Kris Zacny, VP Exploration Systems. "NASA not only provided funding to develop technologies, but even more importantly, worked together with us to develop these technologies. It's been a win-win partnership."

# NASA News

## NASA Seeks Student Tech Ideas for Suborbital Launch

*18 August 2021 (RELEASE 21-103)*: NASA is calling on all sixth through 12th-grade educators and students to submit experiments for possible suborbital flights as a way of gaining firsthand experience with the design and testing process used by NASA researchers. The NASA TechRise Student Challenge invites students to design, build, and launch experiments on suborbital rockets and high-altitude balloons. The challenge aims to inspire a deeper understanding of Earth's atmosphere, space exploration, coding, electronics, and the value of test data. Click here to read more: https://www.nasa.gov/press-release/nasa-seeks-student-tech-ideas-for-suborbital-launch

## NASA Awards $18 Million for Research at Minority Serving Institutions

*12 August 2021 (RELEASE 21-109)*: NASA and Minority-Serving Institutions (MSIs) across the United States are teaming up to bring untapped talent and diverse perspectives to several of the agency's top priorities: understanding and monitoring global ocean health, returning humans to the Moon through the Artemis program, and helping build a more inclusive workforce. NASA will fund an array of projects proposed by MSIs – with a total of approximately $18 million – through four new opportunities from the agency's Minority University Research and Education Project (MUREP). These funding opportunities will enable institutions to take on some of NASA's most pressing challenges while increasing their own research capabilities, allowing them to become more competitive for future awards. The awards also will allow the institutions to broaden their participation in science, technology, engineering, and math (STEM) fields. Click here to read more: https://www.nasa.gov/press-release/nasa-awards-18-million-for-research-at-minority-serving-institutions

## NASA Renews Support of Vertical Lift Research Centers of Excellence

*10 August 2021 (RELEASE 21-101)*: NASA is continuing its support of university research into technologies for future helicopters and other vertical lift aircraft in partnership with the U.S. Army and Navy. With their unique ability to take off and land from any spot, as well as hover in place, vertical lift vehicles are increasingly being contemplated for use in providing the public with new air travel options. To that end, the agency has designated academic teams – led by colleges in Georgia, Maryland, and Pennsylvania – as Vertical Lift Research Centers of Excellence (VLRCOE). Click here to read more: https://www.nasa.gov/press-release/nasa-renews-support-of-vertical-lift-research-centers-of-excellence

# Funding Opportunities

## Tech Development

- Lunar TORCH Challenge
https://www.nasa.gov/solve/lunar_torch_challenge

  Deadline: September 13, 2021

- Lunar Surface Technology Research (LuSTR) Solicitation
https://nspires.nasaprs.com/external/solicitations/summary.do?solId=%7bFC8AA32D-180F-9B49-AE48-7C30FCD68E9B%7d&path=&method=init

  Final Proposals Due: September 17th, 2021

- SpaceTech-REDDI-2021: Tech Flights Solicitation
https://tinyurl.com/NASA-21FO-F1

  Full Proposals due on or before October 4, 2021

- NASA Human-Autonomy Teaming Task Battery Challenge
https://www.nasa.gov/nasa-hattb

  Deadline: December 29, 2021

- 2022 Breakthrough, Innovative and Game-Changing (BIG) Idea Challenge: Extreme Terrain Mobility Challenge
http://bigidea.nianet.org/competition-basics/

  Proposal and Video deadline: January 18, 2022

## Student Tech Development

- NASA TechRise Student Challenge
https://www.nasa.gov/press-release/new-nasa-student-challenge-offers-hands-on-tech-development

  Submission Deadline: November 3, 2021

For more funding opportunities, please visit LSIC's website here: http://lsic.jhuapl.edu/Resources/Funding-Opportunities.php