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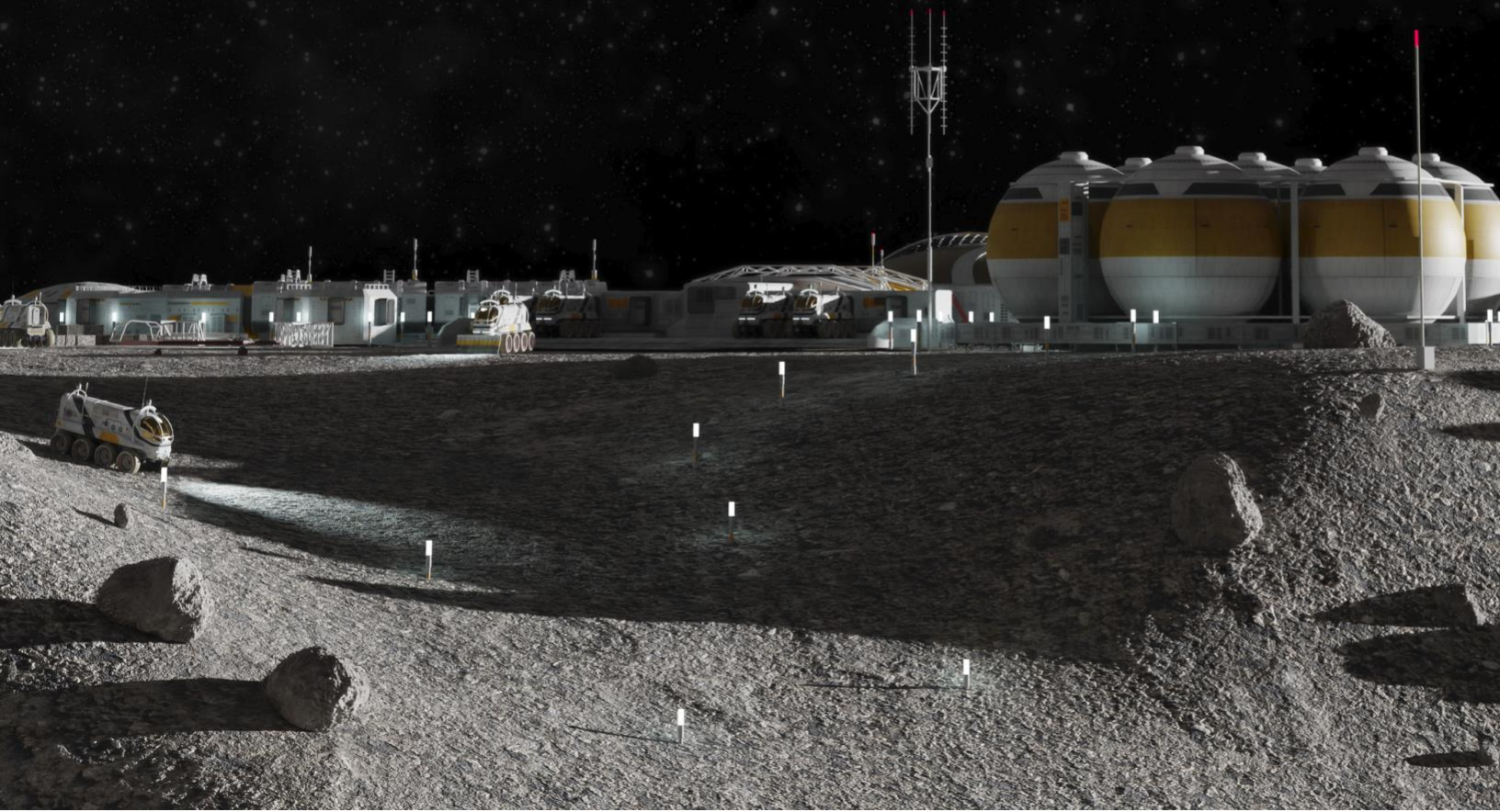
Lunar Surface Innovation Consortium Spring Meeting 2021

POC: Rachel Klima

Johns Hopkins Applied Physics Laboratory

EXECUTIVE SUMMARY

The Lunar Surface Innovation Consortium (LSIC) 2021 Spring Meeting was held on May 11-12, 2021. The objective of this meeting was to bring together NASA and the space technology community, including commercial and non-profit industry, academia, and government, to discuss the efforts and accomplishments of LSIC and key concerns for establishing a sustained presence on the lunar surface. Attendance included 546 people representing over 200 institutions that met over the course of two days. Roughly half (49%) of those who registered for the meeting had not previously attended an LSIC event, and over half (53%) have never worked with NASA's Space Technology Mission Directorate. Feedback from a post-meeting survey suggests that the sessions were all very well-received by the community.

The meeting featured a keynote address from the NASA Senior Advisor for Budget and Finance, Dr. Bhavya Lal, and presentations by Jim Reuter, NASA Associate Administrator for Space Technology, as well as Joel Kearns, Deputy Associate Administrator for Exploration in NASA's Science Mission Directorate. Consortium updates were given along with a panel discussion featuring several members of the LSIC Executive Committee constructively discussing how LSIC can engage new members and ensure that its mission is focused on key technology advancement as well as community development. Other panels discussed Space Tech funding opportunities, highlighted several projects that had been recently selected through different programs, and considered how technology enables lunar science, exploration, and commerce. Recordings of all presentations and slides for most are available online through the event website at (http://lsic.jhuapl.edu/News-and-Events/Agenda/index.php?id=124).

Breakout sessions provided a chance for the community to discuss critical needs in more detail. Four of the breakout sessions centered on areas of interest identified by the LSIC community over the last year, as well as consortium goals and activities. These were: (1) focus group goals and cross-group integration; (2) issues regarding standardization (e.g., what to and what not to standardize); (3) technology readiness and demonstrations; and (4) consortium growth, community building, and mentoring. The objective of these sessions was to engage participants directly in small-group discussions to address their needs and concerns, and to adjust the goals and activities for LSIC and the focus groups, as appropriate. The fifth (5) breakout session provided an opportunity for the LSIC community to speak directly to the NASA leads for the Watts on the Moon Challenge to discuss crafting the second phase of this challenge and to raise awareness for it among the community.

Findings from the breakout sessions included:

- Triage is important with respect to technical readiness evaluation/testing. The breakout group suggested that *LSIC could help the community and NASA by coming to a consensus on where Earth and space-based testing facilities are adequate for testing lunar technology, then determine which mission components absolutely have to be tested in-situ.*
- While standardization is a concern to ensure interoperability, safety, and sustainability, there is a need to avoid standardization with a top-down approach that may stifle creativity. *However, standardizing or channelizing development can save companies money and advance TRL more rapidly. Therefore, developing community consensus on key areas of standardization that are more likely to benefit the community as a whole and maintain innovation should be identified.*
- For smaller businesses, proposal opportunities are more accessible if they require low up-front burdens to pitch initial ideas. Techniques used by groups such as AFWERX should be examined when trying to stimulate commercial investment and engagement. *Where beneficial, LSIC should determine how to leverage these existing programs and tools to help cultivate the applicable lunar technical endeavors in each sector.*

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MEETING ATTENDANCE AND DEMOGRAPHICS

The Lunar Surface Innovation Consortium (LSIC) 2021 Spring Meeting was held on May 11-12, 2021. The meeting was held virtually, and a total of 758 individuals registered in advance. Ultimately, 546 people attended over the course of the two days. Based on a survey collected during registration, roughly half (49%) of those who registered for the meeting had not previously attended an LSIC event, and over half (53%) have never worked with NASA's Space Technology Mission Directorate.

Individual attendees at the Fall meeting were roughly split between regular members of LSIC (46%) and new participants (54%). Of these attendees, a majority were from industry (38%), with the next largest group (33%) from government agencies, including NASA. Attendees from academic institutions accounted for 17% of the individual attendees, with the remaining 12% from nonprofits.

When attendance is examined by institution, rather than individual, the attendance breakdown becomes heavily dominated by industry (59%) and academia (27%), with government and non-profit wedges shrinking down to 8% and 5%, respectively. This is a result of many of the academic or industry institutions each sending only a small number representatives to attend the meeting, while a bulk of the government and non-profit attendees came from NASA centers and only a few non-profit institutions. Other government organizations represented included DARPA, the National Geospatial Intelligence Agency, United States Geological Survey, National Renewable Energy Laboratory, and the US Naval Research Laboratory.

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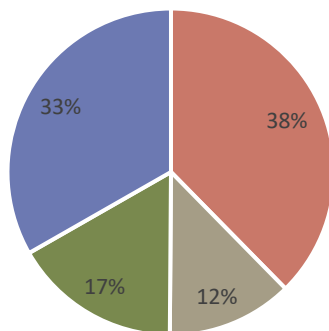
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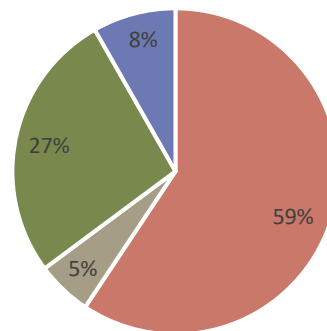
KEY FINDINGS

- Promotion of LSIC meetings is succeeding in reaching new participants (over 50% of attendees).
- Industry members are dominating the non-government LSIC participation, possibly suggesting that industry is eager to communicate and connect with NASA and the rest of the lunar community.
- Though academic institutions are well represented, an increase in efforts to grow the academic and non-profit membership in the LSIC community could lead to more varied perspectives.

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MEETING CONTENT

The objectives of the LSIC Spring Meeting are to: (1) communicate recent NASA news; (2) report on the LSIC accomplishments of the last year and goals for the next; (3) provide a forum for LSIC members to showcase their work, and (4) solicit feedback from the community on where LSIC is doing well and where it can improve. Since this year's meeting was held as a virtual meeting, it was possible to reach a large number of participants. Plenary sessions, including presentations and panel discussions, were used for the bulk of the meeting, but several interactive virtual platforms were also included to provide opportunities for smaller group discussion and networking.

Plenary Presentations

NASA AND LSIC UPDATES

The meeting began with a keynote address from the NASA Senior Advisor for Budget and Finance, and former Acting NASA Chief of Staff, Dr. Bhavya Lal. Dr. Lal spoke about the role of the Moon as a critical element in NASA's space exploration strategy, stressing that NASA would maintain its focus on the Artemis program, with the new administration committed to continuity. She emphasized that although Mars remains an ultimate goal, the Moon and cislunar space remain important targets in their own right. Her talk centered on five benefits of focusing on a sustained presence in and around the Moon: (1) developing and testing necessary technology to enable not only missions to Mars but also deep space science and exploration; (2) prospects to rebuild old and create new global alliances; (3) prospects for commercial engagement; (4) the ability to showcase to the American taxpayer and the global community, achievable targets in the near-term; and (5) the national security benefits of these endeavors. Questions from the audience concerned **international participation and collaboration**, the Artemis review report, and **how technology could help the United States secure leadership with respect to the return to the Moon**.

NASA Associate Administrator for Space Technology Jim Reuter followed with a briefing on the Space Technology Mission Directorate (Space Tech) portfolio and the funding strategy used to mature technology from early stage through flight. He highlighted the Space Tech accomplishments over the last year, as well as the Lunar Surface Innovation Initiative (LSII) strategy and funding opportunities. His presentation also included a representative timeline of the sequencing of different technology demonstrations over the next decade. A number of the questions from the audience focused on **funding opportunities and timelines**, but several also suggested that the the vision of "Go, Land, Live, Explore" should include explicity add "use", to amplify the need to **make use of local resources on the Moon and beyond**.

Following Associate Administrator Jim Reuter's talk were a series of talks about the APL LSII and LSIC efforts. Dr. Ben Bussey, APL lead for LSII, outlined strategic objectives, including (1) formulating and integrating technology maturation activities across the TRL pipeline and Space Tech projects; (2) leveraging innovative collaborations and partnerships to expedite technology development; and (3) utilizing early uncrewed lunar surface flight opportunities to inform key technology development. As a Technical Direction Agent (TDA), APL's role includes systems integration tasks, independent evaluations, and serving as a community liaison. Dr. Bussey described the systems integration tasks in more detail, focusing then on some of the ongoing work, which includes aiding with landing site assessement and selection for the PRIME-1 lunar delivery. Dr. Karen Stockstill-Cahill then spoke about another ongoing effort through LSII, the analysis of lunar simulants and their availability. Among the questions from the audience was whether LSIC could explore how the **Commercial Lunar Payload Services (CLPS) could evolve to be more enabling for the technology community, with specific funding and flight opportunities available**. The question was also

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raised about whether the simulant study was considering **how polar simulants might differ** from those designed to replicate more typical Apollo-type soils.

Dr. Rachel Klima, the LSIC Director, discussed the progress of the LSIC over the past year, as well as the plans for the future. She presented the objectives of LSIC, which are: (1) identify lunar surface technology needs and assess the readiness of relative systems and components; (2) make recommendations for a cohesive, executable strategy for development and deployment of the technologies required for successful lunar surface exploration; (3) provide a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results; and (4) foster growth of a diverse community and networking among members. Activities over the last year include establishing regular communication pathways, including a website, newsletter, and internal LSIC wiki (Confluence); establishing the technical focus groups and hosting monthly meetings of each, as well as several larger topical workshops; growing the community to include over 1000 participants, with representation across the United States, as well as internationally; and hosting a large consortium-wide meeting in the Fall. Actions planned for the next year include increased engagment with communities that are less well represented in LSIC, especially minority serving institutions; development of a facilities directory and capabilities database for participants to make connections with others to help establish partnerships; and continued technical work within the focus groups, including working towards an annual goal with concrete deliverables (described in more detail below for each focus group). Given the large number of meeting attendees, many of the audience questions focused on business concerns, including how NASA envisions **private investment vs. government as an anchor tenant on the lunar surface** and **scaleability of technology** from demonstration to market scale. There was also a suggestion that LSIC might **explore relationships with existing resources/groups such as NSF's ICorp or VentureWell** to help participants develop their businesses.

Joel Kearns, the Deputy Associate Administrator for Exploration in NASA's Science Mission Directorate (SMD), provided an overview of the Exploration Science Strategy and Integration Office (ESSIO). As a part of SMD, ESSIO manages the CLPS program, as well as supporting the development of lunar surface science instruments, mobility, and small satellites. It also interfaces with the Human Exploration and Operations Mission Directorate (HEOMD) to provide science mission planning. He described the CLPS structure and its current portfolio, including the locations to which CLPS landers would be delivered over the next several years, many of these deliveries will include payloads for technology demonstrations. Questions from the community included when there would be an **opportunity for new CLPS providers** to become eligible for the program, and whether CLPS would interface with the Lunar Exploration Transportation Services (LETS). There was also interest in what the **strategy was for selecting PRISM landing sites**.

Each of the technical focus area leads presented a review of the work that they had accomplished since the LSIC was established, as well as their annual goals, most of which include production of a white paper or road map to help guide future technology development strategies. Dr. Angela Stickle described the Extreme Access focus group, which has recently begun establishing subgroups to work on specific technologies in more detail. In addition to holding monthly meetings, the Extreme Access group held a three day workshop on precision landing and hazard avoidance. This meeting was extremely successful in bringing together technology (including software) developers and those who focus on mapping and surface analysis. Dr. Jorge Núñez followed for the Dust Mitigation group, which has also held a workshop to identify some of the highest priority challenges for developing dust mitigation strategies. Dr. Karl Hibbitts detailed the activities of the In Situ Resource Utilization (ISRU) focus group, which currently focuses primarily on O_2 and H_2O extraction and utilization. Given the specificity of lunar ISRU technology to the Moon, the ISRU team held a supply and demand workshop early on to understand how much fuel commercial providers expected to need on the lunar surface, as well considering limitations on supply for either technique. Dr. Benjamin Greenhagen described the Extreme Environments group, which early on stood up several subgroups to focus on specific aspects of environments that would be considered extreme. The group has been working to understand how these different

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environements stress technologies to provide a consolidated resource for the community and NASA. Dr. Athonu Chaterjee described the Excavation and Construction focus group, which has been working on building relationships with both space-based and terrestrial mining and construction companies, to bring these together to explore the options for developing larger-scale infrastructure such a launch pads and habitats on the Moon. Finally, Dr. Wes Fuhrman discussed the Surface Power focus group, and their ongoing efforts to understand critical issues such as power transportation and storage on the Moon. The audience responded with a number of questions and comments on some of the technical details, and were clearly eager to continue discussing them through focus group activities and the Confluence wiki site. A number of questions also focused on the **outcomes of the ISRU supply and demand study**, with one participant asking whether the **DoD was being included in discussions** as they might be another potential anchor customer for lunar materials.

PANEL DISCUSSIONS

Several sessions were run as panel discussions to provide a more engaging and interactive format than one-way presentations provide. The first of these was a panel including members from the LSIC Executive Committee: Dr. Ariel Ekblaw, Director of the Space Exploration Initiative, Massachusetts Institute of Technology; Dr. Lindy Elkins-Tanton, Vice President of the Interplanetary Initiative, Arizona State University; David Murrow, Senior Manager of Deep Space Exploration Strategy, Lockheed Martin's Corporation; Dr. Jose Hurtado, Technology Chair, Lunar Exploration Analysis Group, The University of Texas at El Paso; and Dr. Jake Bleacher, Chief Exploration Scientist, NASA Human Exploration and Operations Mission Directorate (HEOMD). The objective of this discussion was to delve into the LSIC goals and how LSIC management, including the Executive Committee, can engage new members and ensure that its mission is focused on key technology advancement as well as community development. Presentations by the different members focused on fostering an inclusive and diverse community, partnering and mentorship, and interfaces between LSIC and other groups such as the Lunar Exploration Analysis Group (LEAG), Solar System Exploration Research Virtual Institute (SSERVI), and Moon Dialogs. Jake Bleacher also provided an overview of the HEOMD plans for Artemis and the Lunar Gateway. Many of the questions from the audience centered on topics of interest to the commercial industry, including how to navigate some of these activites while **protecting Intellectual Property (IP)** and how to **foster a sustainable economic environment** on the lunar surface. **Tourism** was raised as a way to maintain activity to drive an economy, and **space telecom** was highlighted as an area that **should be readily transferrable to the lunar environment due to experience around Earth**. Several questions also centered around a desire to better understand the role envisioned for the Lunar Gateway in the efforts to establish a sustained presence on the lunar surface.

This discussion was followed by a Space Tech Opportunities panel, inlucding Gareth Meirion-Griffith, Lead, NASA Lunar Surface Technology Research Opportunity; LK Kubendran, Lead, NASA Commercial Space Technology Partnerships; Jason Derleth, Program Executive, NASA Innovative Advance Concepts; Amy Kaminski, Program Executive, NASA Prizes and Challenges; and Jason Kessler, Program Executive, NASA Small Business Innovation Research. The presenters all provided a brief introduction to the scope and requirements of their programs. As a panel, they were asked questions inlucing whether their programs were typically more focused on evolutionary or revolutionary advancements, typical proposal pitfalls, and what makes a strong proposal. In most cases, the panelists stressed that carefully reading the proposal call was extremely important. Specific questions on the technical details of programs were addressed through the chat panel, with the discussion focused more on big picture advice.

The second day of the meeting began with a panel discussion about how technology enables lunar science, exploration, and commerce, featuring Dr. Bill Carter, Program Manager, NOM4D Program, Defense Sciences Office, DARPA; Niki Werkheiser, Program Director, Technology Maturation, LSII Lead, NASA STMD; Raymond 'Corky' Clinton,

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Principal Investigator, Moon-to-Mars Planetary Autonomous Construction Technology (MMPACT) Project, NASA; Dr. Sandy Magnus, Principal, AstroPlanetview LLC; and Mark Hilburger, Principal Technologist for Structures, Materials, and Nanotechnology, NASA STMD. The goal of this panel was to explore in more depth the longer-term vision for activities on the Moon, in cislunar space, and beyond, including development of infrastructure and interfaces between industry, NASA, and other parties such as international partners or other government agencies. Corky Clinton and Mark Hilburger provided background on some of the construction goals for the next decade, while Dr. Carter described DARPA's recently released NOM4D program, which explores on-orbit construction that might potentially use materials sourced from the lunar surface. Niki Werkheiser provided insight into the vision and goals of the LSII program in general, including working intimately with commercial industry to understand how to foster a sustainable encomomy. Dr. Magnus shared her experience on the International Space Station and concerns about standardization and use cases and needing to think about this early. She suggested that the LSIC community at-large should create its own list of the infrastructure elements that are important to the community and examine how it compares with what NASA is planning. Some of the discussion included the need to **ensure that standards don't end up stifling innovation**, but are rather developed in a way that benefits **interoperability** among all involved. Audience members were concerned that automatically adopting existing terrestrial standards would be ill-advised. All panelists stressed the importance of the community identifying the **areas of highest priority for standardization and to engage all stakeholders to develop relevant standards**, from those for interfaces to those for safety. Another question to the panelists concerned what is the largest technological hurdle that needs to be overcome to achieve their visions for the next two decades. Panelists focused on a **reliable, sufficient budget** and **access to the lunar surface in order to demonstrate technologies** and approaches of the most critical elements. Dr. Carter also added that cost modeling is an issue, and that in such a different environment it is very difficult to understand what the real cost of many of these efforts will be. However, both he and Niki Werkheiser agreed that in the early stages, the government had to be willing to make the investment and take the big risks to knock down the highest hurdles. Dr. Magnus added that it was important to consider which elements developed through government investment need to remain as government IP so that all of the community can leverage and build on them.

KEY FINDINGS

- Based on a post-meeting survey, the panels and plenary presentations were generally well received (see Appendix A). Specific comments suggest that the panels were very helpful, but that the update talks were somewhat repetitive for regular members. However, the person who provided that comment noted that they understood that there is a need to balance the content for new and regular members.
- There is a lot of community interest in the details of the CLPS missions and the opportunities afforded by them. They were interested to find out when and how additional CLPS providers might be added, as well as how PRISM landing sites were to be selected. They see CLPS as an opportunity that could be incredibly enabling for the technology community, and would welcome something similar to PRISM that is focused on technology development.
- There is a strong desire to understand who will be the key anchor tenants on the Moon, and how NASA envisions fostering a sustainable economic environment. International participation and collaboration, as well as simultaneous engagement of the Department of Defense, were highlighted as important.
- A lot of concern over standards and interoperability remains. It is important to ensure that standards do not stifle innovation, but that interfaces remain straightforward. We should identify the areas of highest priority for standardization and engage all stakeholders in developing the relevant standards.

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Technical Presentations

The Spring Meeting included a number of technical presentations from the community. Several recent awardees of different Space Tech projects were invited to join the meeting to share their projects as part of a panel, where they had time for a short (~5 min) presentation and the opportunity to answer questions. Abstracts were also solicited, with the default presentation style being a poster presentation. Based on review by the technical committee, a subset of these were selected for lightning talks.

AWARDEES PANEL

The awardees panel was selected to highlight a cross-section of different focus areas and different types of Space Tech programs. The presenter were: Dr. Christy Edwards, Lockheed Martin – Vertical Solar Array Tower, Surface Power; Dr. Alian Wang, Washington University – Lunar Surface Technology and Research, ISRU; Dr. Ahsan Choudhuri, University of Texas at El Paso – Lunar Surface Technology and Research, ISRU; Mihaly Horanyi, University of Colorado Boulder – Early Stage Innovations, Dust Mitigation; Luis Maestro, Nokia of America – Tipping Point, Extreme Access; Dr. Paul van Susante, Michigan Technological University – BIG Idea Challenge, Extreme Access; and Alex McCarthy, Ai Space Factory – Announcement of Collaborative Opportunity, Construction. Dr. Edwards showcased some of Lockheed Martin's projects and strategy for lunar surface exploration, focusing on the recent award to mature their Vertical Solar Array concept for providing power on the lunar surface. On the topic of in situ resource utilization, Dr. Wang detailed a concept to develop a drill equipped with active laser to spectroscopically determine the water abundance of the regolith as it drills and Dr. Choudhuri spoke about a project to use thermal mining to extract and transport lunar ice. Turning to dust mitigation, Dr. Horanyi discussed efforts to model dust behavior to advance dust mitigation techniques. A Tipping Point project to develop communications for extreme environments, and ultimately test Nokia's LTE/4G communication on the Moon was described by Luis Maestro. Dr. Van Susante highlighted a project to called T-REX to provide extreme access using tethering, and finally Alex McCarthy discussed additive construction for 3D printing on the lunar surface.

LIGHTNING TALKS

A subset of the poster presentations were presented in the form of short (2 minute) lightning talks. These talks were intended to provide a quick overview of some of the work that would be presented in more detail in the poster session. Lightning talks covered a broad range of topics, including power generation, storage, and distribution; south polar landing site selection; sample collection technologies; and dust mitigation testing. All of the lightning talks are available online for viewing through the event page (direct link: https://www.youtube.com/watch?v=1AuLc8LEEos).

POSTERS AND GATHERTOWN ENVIRONMENT

All posters from the event were hosted in the Gather Town environment. This tool allows individuals to log in and walk around a virtual conference hall as an avatar (similar to a low-tech video game), interacting with people within a small radius of them. The Gather environment was set up with an upper level that included vendor booths for a number of the CLPS providers, and a lower level with posters. This virtual conference hall was available for networking each morning and during lunch. Posters were also posted on the LSIC Confluence (Wiki) Site, and will remain available for members to view and discuss asynchronously.

Breakout Sessions

Breakout sessions provided a chance for the community to discuss critical needs in more detail. Four of the breakout sessions centered on areas of interest identified by the LSIC community over the last year, as well as consortium goals and activities. These were: (1) focus group goals and cross-group integration; (2) issues regarding standardization (e.g., what to and what not to standardize); (3) technology readiness and demonstrations; and (4) consortium growth, community building, and mentoring. The objective of these sessions was to engage participants directly in small-group discussions to address their needs and concerns, and to adjust the goals and activities for LSIC and the focus groups, as appropriate. The fifth (5) breakout session provided an opportunity for the LSIC community to speak directly to the NASA leads for the Watts on the Moon Challenge to discuss crafting the second phase of this challenge and to raise awareness for it among the community.

Each of the Breakout sessions was held in a zoom session with a dedicated page or series of pages in Confluence for participants to add comments in writing (https://lsic-wiki.jhuapl.edu/display/2020FM/Breakout+Sessions). These spaces were also used to capture notes, so that participants could follow and contribute to the conversations of more than one breakout group, if desired.

FOCUS GROUP GOALS AND CROSS-GROUP INTEGRATION

This breakout session was intended to review any feedback on the focus group progress to date, the focus group planned goals for the next year, and ways to increase cross-focus group integration of topics. While each focus group has developed its own core network, the LSIC team recognizes that we want to continue to **foster cross-pollination** between focus areas.

The discussions in this breakout session indicate that in general the model for focus group interations are working well. The Who's Who effort, in which members voluntarily add information about themselves to a table on the internal site, is becoming quite popular. It was suggested that we add a **link directly to these tables** (which are currently located within each focus area section on the internal site) from the main wiki page. The group felt that it's **important to address certain common technology topics that pertain to multiple focus groups** and can have significant effect on any system integration. Likely examples include: thermal management, wear and abrasion, standardization of interfaces. They suggested that bilateral or joint focus group meetings would help ensure common goals are defined and evolve in a mutually beneficial way.

LSIC could improve access to the community for smaller companies or new entries by **highlight more small companies in the newsletter**, or an addendum. It is also important that it be advertised to participants that staff of LSIC and focus group facilitators can, and do, have confidential discussions with members. This an option that is open to any members, and that NDA's can be created to enable this.

STANDARDIZATION

The need for standardization to improve interoperability was highlighted by many on the "How technology enables lunar science, exploration, and commerce" panel on the second day of the meeting. This breakout session provided an opportunity to hear from the community about what areas were of highest priority for some kind of standardization.

There is an interest in having a set of **guidelines and metrics available to test against**. These should be flexible enough to change if we learn new things once we get to the Moon. It was recognized that standardizing or channelizing development can save a lot of money and help companies get technology to higher TRL faster.

Interoperability standards are an important subject to consider early on, but we need to balance against too much top-down direction which could stifle creativity. **Interoperability is critical for safety and sustainability**. An example given was Apollo 13. In an environment with many different companies involved, it is important that they are designed to work together from the start. If ISS standards make sense to extend, that's a good starting point. But this will need to be thought through carefully, because they won't make sense everywhere.

Communications standards (e.g., frequencies etc) will be really important to establish early. As standards do get created, it will be important to define them outside specific environment considerations because we will learn more about the environment as we continue to explore. There are many cases in DOD (e.g., Army robotics, autonomous ground vehicle reference architecture and library of standards) where we might draw important lessons learned for developing interoperability profiles.

The group noted that there **has to be some sort of incentive for vendors to not put everything behind proprietary technology/interfaces**. This will be untenable for actual sustained exploration. Perhaps this can be incentivized in CLPS? If companies want to grow a viable economy it cannot be all proprietary tech. Might be solvable with an "easy" solution of more networking for companies, especially for technology at low TRL. They also suggested that it might be useful for LSIC to create a table on Confluence where people can fill in pros/cons for different standards and types.

TECHNOLOGY READINESS AND DEMONSTRATIONS

In this breakout session, seven questions were discussed:

1. What are the types of technologies we need to test?
2. What are the types of test facilities we have available on Earth for testing?
3. What are the limitations of our Earth-based test facilities for simulating lunar conditions? What are lunar environment conditions we have trouble simulating on Earth?
4. What types of tech would benefit from a tech demo on the lunar surface?
5. What level of flight demo is needed for critical technologies, if any?
6. Do we want to recommend any unified plan for getting certain elements included on CLPS flights?
7. Anything else you think we should have discussed but didn't?

One of the main takeaways was the **need for triage**. Not everything can be tested on a CLPS flight. We need to determine where Earth and space-based testing facilities are inadequate for testing lunar technology, then determine which mission components absolutely have to be tested in-situ. The group identified dust mitigation technology, rover mobility, and drilling/regolith interactions as three areas that are difficult or impossible to simulate in Earth-based (or space-based) testing environments.

A related issue is that risks depend on intended operating environment. Testing a component in one area of the Moon does not guarantee it will work in another area. So we **need to determine the critical environments where testing should be conducted**.

Even within a single environment, different applications (for example, rover mobility and ISRU) will interact with the environment in different ways. For rovers, the mechanical nature of the regolith will be more important than the chemistry, whereas for ISRU, the chemistry will be vital.

Finally, a couple of participants mentioned the need to remember biological and human factors testing, since those areas have tended to be overlooked when discussing lunar technology.

CONSORTIUM GROWTH, COMMUNITY BUILDING, AND MENTORING

The focus of this breakout session was to review the efforts of LSIC so far to reach new and diverse participants, and to help small business and new technologists become active members of the lunar community. Another topic was exploring how LSIC could help with mentorship at all levels, including helping small businesses develop themselves.

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The first question considered was how to effectively reach different potential members. The attendees stressed the importance of LSIC anouncements being in more periodicals or community bulletin boards, such as Orbital Index Newsletter, Moon Monday, the Planetary Exploration Newsletter and others. There are also certain slack channels we can post to such as https://www.afwerx.af.mil/ . While LSIC has a presence on Linked In, regular news briefs or blog posts, posted to the LSIC website, could be shared on Linked In to draw in new participants.

The next question addressed was how LSIC can improve community building. Some of the participants were eager to see more cross-focus group content. Dedicated networking sessions (as the ISRU group has implemented) were appreciated. Typically, participants expressed that the breakout sessions at the semi-annual meetings had been effective. They also suggested that perhaps a monthly **LSIC-wide happy hour/networking session**, potentially with breakout groups, could help increase teaming and partnerships. In such sessions, it is important to **mix members from different types of institutions together to discuss a certain problem**, as each have different perspectives.

Finally, the group discussed mentorship. It was recognized that there are several types of mentoring needed, some of which might be best satisfied by connecting with existing government programs such as the small business administration mentoring program. A first step for LSIC-specific mentoring would be a list of those looking for mentorship and those willing to serve as mentors. In general, **studying the programs available and determining which we might be able to simply partner with, versus which we might like to emulate** but tailor to the LSIC community, will be critical. For helping participants connect with proper funding lines, it was suggested that NASA needs to understand that proposals with large up-front burden and low win rates are unlikely to be accessible to smaller businesses. Funding models where a short step one proposal with a high level idea is first submitted are helpful, as they let companies know whether their ideas are likely to be of interest or not.

CENTENNIAL CHALLENGES: WATTS ON THE MOON PHASE 2

This breakout session was slightly different from the others, in that it focused specifically on a single funding opportunity, providing a chance for the team designing the challenge to get immediate feedback from potential proposesr before crafting the initial RFI for the challenge.

The Watts on the Moon breakout session was well-attended and lively (58 participants), and many of the participants who spoke are not common contributors to the standing monthly surface power telecons. The challenge reps responded afterwards that they felt they had reached some who otherwise would not have engaged, and praised our moderation of the event. Feedback from the community included that the designated rules might not be compatible with an ideal solution. For instance, precluding any auxiliary power may incur otherwise unnecessary design choices that could be readily solved, e.g., with RHUs. Overall, the audience generally accepted that the nature of the challenge necessitated limiting the scope of proposals, and felt that the feedback session was helpful. Main discussion items included how best to shape challenge limitations, issues of comparing disparate technologies, and terrestrial facilities needed to test during phase two.

KEY FINDINGS

- LSIC networking efforts have generally been successful. However, more opportunities for cross-focus group networking would be welcome so that members with different types of expertise can address areas of common technological interest.

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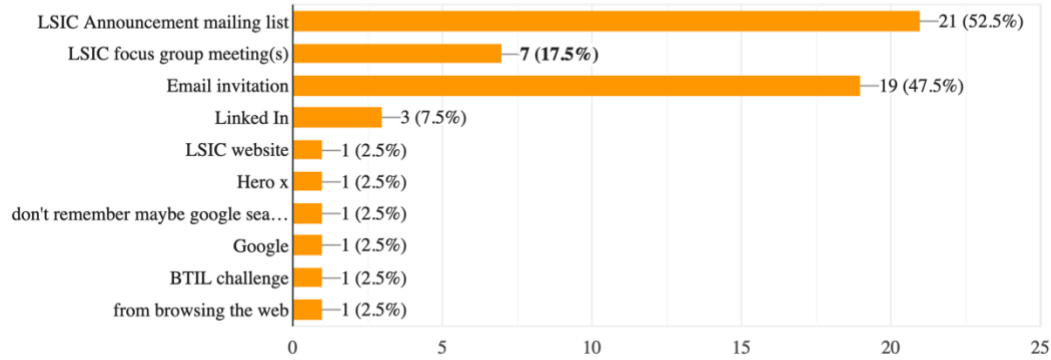
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- While standardization is a concern to ensure interoperability, safety, and sustainability, there is a need to avoid standardization with a top-down approach that may stifle creativity. However, standardizing or channelizing development can save companies money and advance TRL more rapidly. Therefore, developing community consensus on key areas of standardization that are more likely to benefit the community as a whole and maintain innovation should be identified.
- Triage is important with respect to technical readiness evaluation/testing. The breakout group suggested that LSIC could help the community and NASA by coming to a consensus on where Earth and space-based testing facilities are adequate for testing lunar technology, then determine which mission components absolutely have to be tested in-situ.
- For smaller businesses, proposal opportunities are more accessible if they require low up-front burdens to pitch initial ideas. Techniques used by groups such as AFWERX should be examined when trying to stimulate commercial investment and engagement. Where beneficial, LSIC should determine how to leverage these existing programs and tools to help cultivate the applicable lunar technical endeavors in each sector.

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APPENDIX 1 – MEETING FEEDBACK

Background Information

How did you hear about the LSIC Spring meeting?
40 responses

Source	Count
LSIC Announcement mailing list	21 (52.5%)
LSIC focus group meeting(s)	7 (17.5%)
Email invitation	19 (47.5%)
Linked In	3 (7.5%)
LSIC website	1 (2.5%)
Hero x	1 (2.5%)
don't remember maybe google sea…	1 (2.5%)
Google	1 (2.5%)
BTIL challenge	1 (2.5%)
from browsing the web	1 (2.5%)

How involved have you been with LSIC prior to this meeting?
40 responses

Involvement	Count
I attended the Kickoff meeting in February	12 (30%)
I attended the 2020 Fall meeting in October	10 (25%)
I attended one or more workshop (ISRU Supply&Demand, TRN, or…	13 (32.5%)
I have attended at least one focus group meeting	16 (40%)
I participate in focus group meetings regularly	12 (30%)
This was my first LSIC meeting	15 (37.5%)
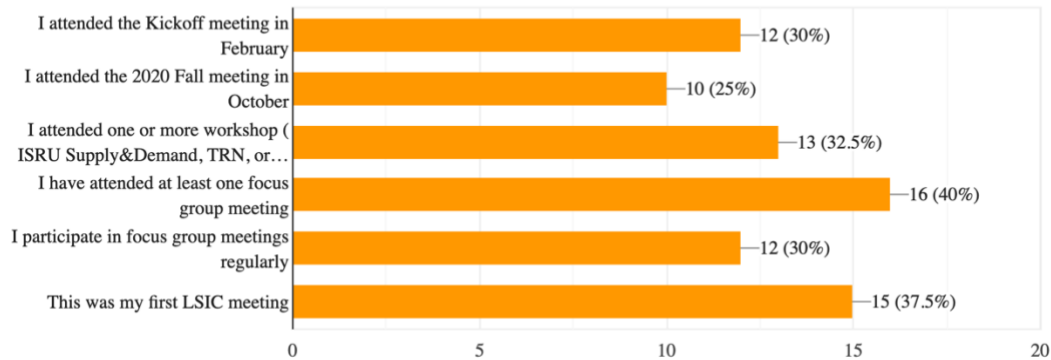
Attendance

Were you able to attend the 2021 LSIC Spring Meeting?
40 responses

- Yes
- No (note that other questions are optional)
- No, but I plan to watch the videos once they are posted and/or explore the meeting content on Confluence

97.5%
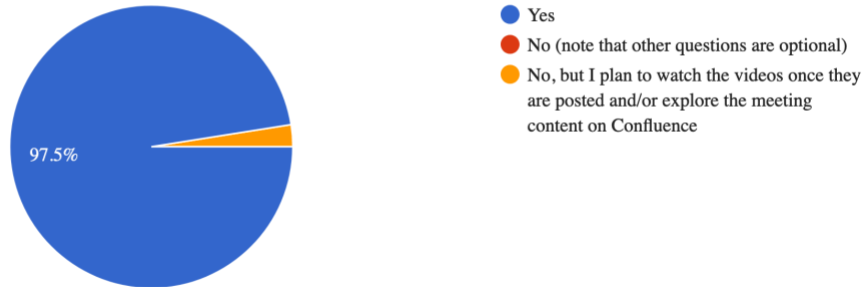
What parts of this meeting did you attend?
39 responses

Session	Responses
Tuesday (11 May) plenary session(s)	39 (100%)
Tuesday (11 May) networking session(s) in GatherTown	22 (56.4%)
Wednesday (12 May) plenary session(s)	31 (79.5%)
Wednesday (12 May) poster session in GatherTown	20 (51.3%)
Wednesday (12 May) breakout sessions	25 (64.1%)

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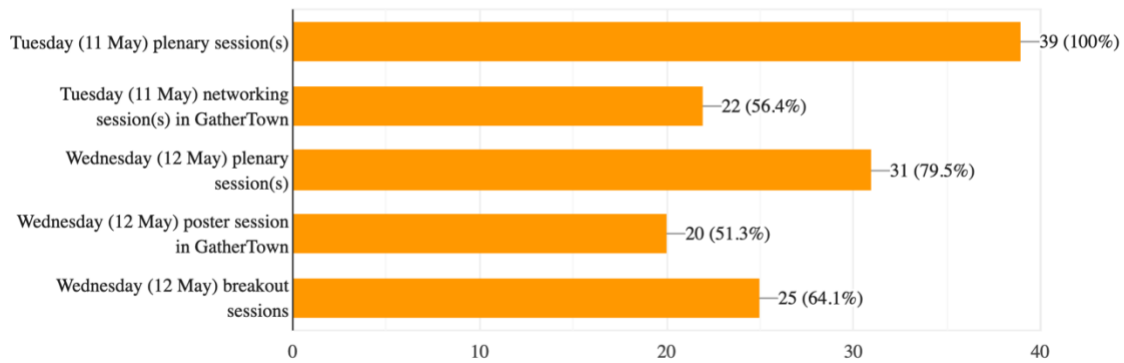
Tools Feedback

How was your user experience with the following tools used during the meeting? (1=poor, 5=excellent)
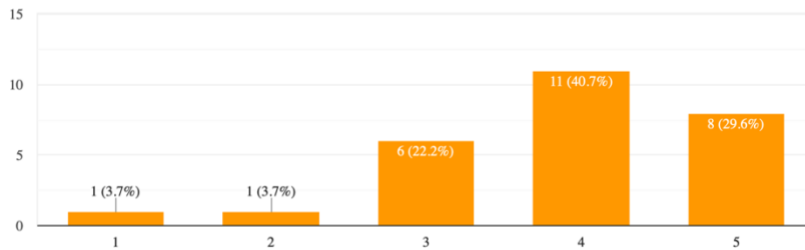
Zoom
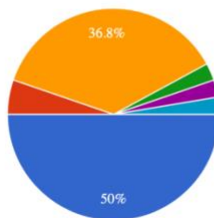39 responses
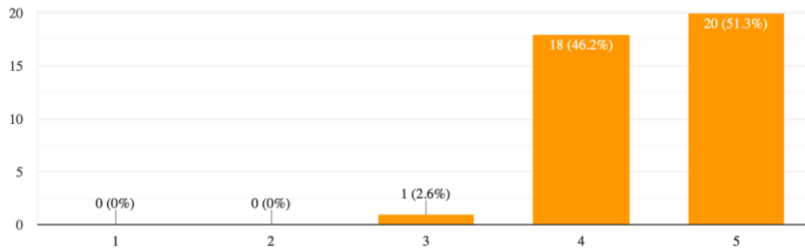
GatherTown
25 responses
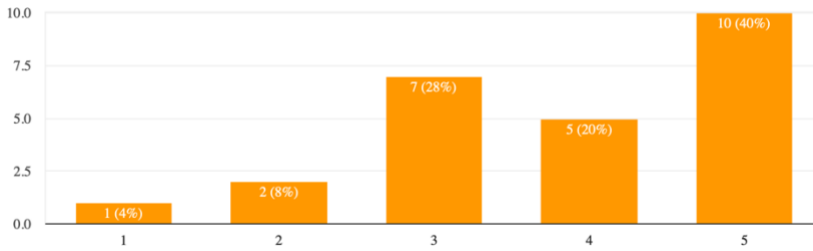
Confluence
27 responses

Do you plan to continue to use Confluence to interact with the community?
38 responses

- Yes
- No
- Maybe
- Wasn't given access even though I registered, help desk didn't know why
- Could not access Confluance, but I would love to use it
- Haven't signed up for account yet, but I plan on using it for interaction

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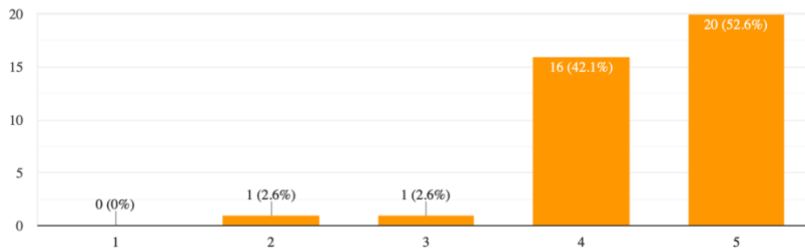APPLIED PHYSICS LABORATORY

Session Feedback

How would you rate the overall content of the plenary sessions?
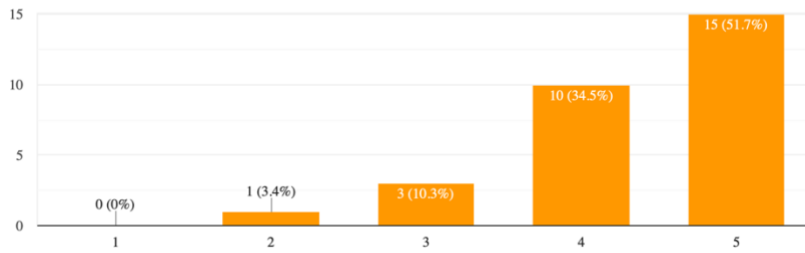39 responses
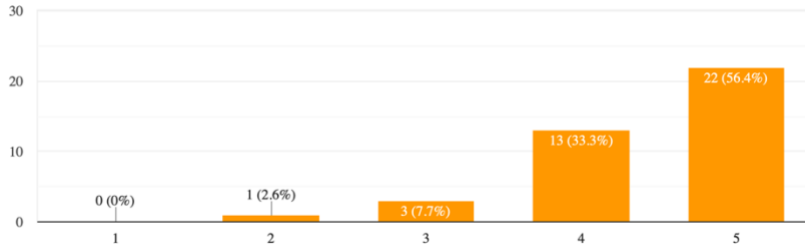
How would you rate the overall content of the panel presentations?
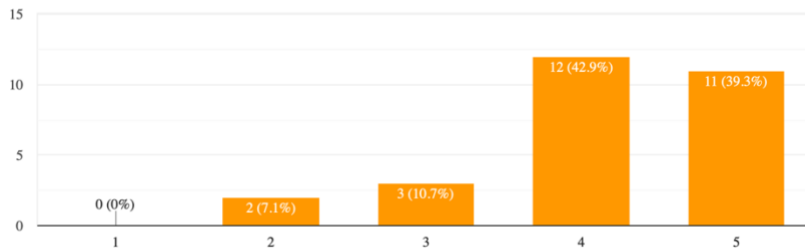38 responses

How would you rate the overall content of the breakout sessions?
29 responses

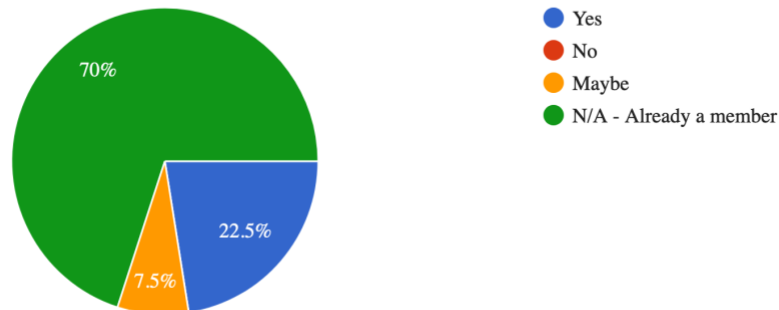How would you rate the overall content of the poster session?
28 responses

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Other Feedback

If you are not already involved in LSIC, are you interested in joining?
40 responses

Legend:
- Yes
- No
- Maybe
- N/A - Already a member

70%
22.5%
7.5%

Additional Feedback (open form):

- I have attended two other virtual conferences this year and this has by far been the best organized. I admit I was a bit skeptical about Gather Town but it turned out to be great! The interactivity was beyond my expectations and there were no glitches. Well done.
- One of the things, I mentioned in the breakout session in Focus Group is to use Moon Dust Residue as a form of thermal energy. Dust Mitigation is Good, But instead of total irradication, Moon Dust Residue given it is Salt or possess elements of, can be used through a proper emission control system to fuel/refuel engines. Recall, NO2 and Toyota Prados...this is what Toyota did, we could borrow their idea.
- Given virtual, LSIC Spring 2021 was excellent. Gather site very cool and useful.
- Lunar Power Lander (LPL) will incorporate (place-hold) VSAT, T-REX inputs and outputs and hot docks. Docks for autonomous vehicles such as T-REX and GPR- hot cone &c. We will also incorporate a landing pad vac on each lander. LPLs with have solar panels even when landing in PSR. PSR equipment should outfitted with solar panels with assumption of concentrated solar reflection illumination from the rim similar to what UVA BELLE has proposed. If solar mirrors can be put in lunar orbit all the better. I think these ideas will help set standards, compatibility, and interoperability. Let us talk to each other now, so our machines and equipment and talk to each other on the lunar surface. Great conference. Tribal leaders will get a great report from me going into council.
- Break out sessions where the best part getting to talk and interact with project leader's. Wish they'd been longer, Zoom was done well and speakers respected the time table. Well done No feedback on the flash talk was going too happen or not as the approval process was done blind and without notice. Members where openly hostile too non profit organizations during the poster party. With derogatory remarks on our research before funding approach. It didn't make a good first impression, and hope further meetings this won't happen. Gather town broke day one and it removed our poster from session. It was fixed promptly and laughted it off. See you next time Alex
- I wonder if any form of "speed dating" could be useful in getting people to make new connections.
- Disappointed in the keynote, panels were very good
- I found the Gathertown very confusing. It took the entire first session to figure out how to get around, but the second session was productive.

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- The vast amounts of work being done toward sustained presence away from Earth is absolutely amazing! What I don't see is a clear path to onramp that work into the architecture for the actual missions. Simply having NASA folks involved and exposed to the information is not a path to successful onramps. I would love to see the next step in the process - the incorporation methodology for these technologies and great ideas!
- I ended up with a bunch of emails with peoples edits to confluence. Yikes! But I did read them there...most after the conference, and then deleted them presuming they were captured on confluence.
- Thank you so much!
- Such high-level discussions and presenters, I felt privileged to be privy to this. Thank YOU!
- The event production was great. I just wish that there was less repetition with previous events and the standard presentations given by NASA folks. Many of us can almost give those presentations ourselves at this point. How do we create an event that adds value to the existing community while remaining accessible to newcomers?
- Overall, this meeting was fascinating, and illuminating, the poster sessions at GatherTown where incredibly useful and I made several contacts that I hope to work with in the future. My only additional note is that it would be nice if the Confluance wiki was more accessible, perhaps readable by unregistered users and writable by registered users so that some of these ideas can be shared
- Was very educational
- Good event! I wish there was more scheduled time for networking but that can be accomplished via email as well.
- For access to recording, it will save time if the date of the past meeting is given
- Less administrative info [which is not important but rather hinders to innovators/pioneers], more focus on solutions [which naturally get the 'job' done]. Keep politics and personal biases out of the picture and focus on solving problems.