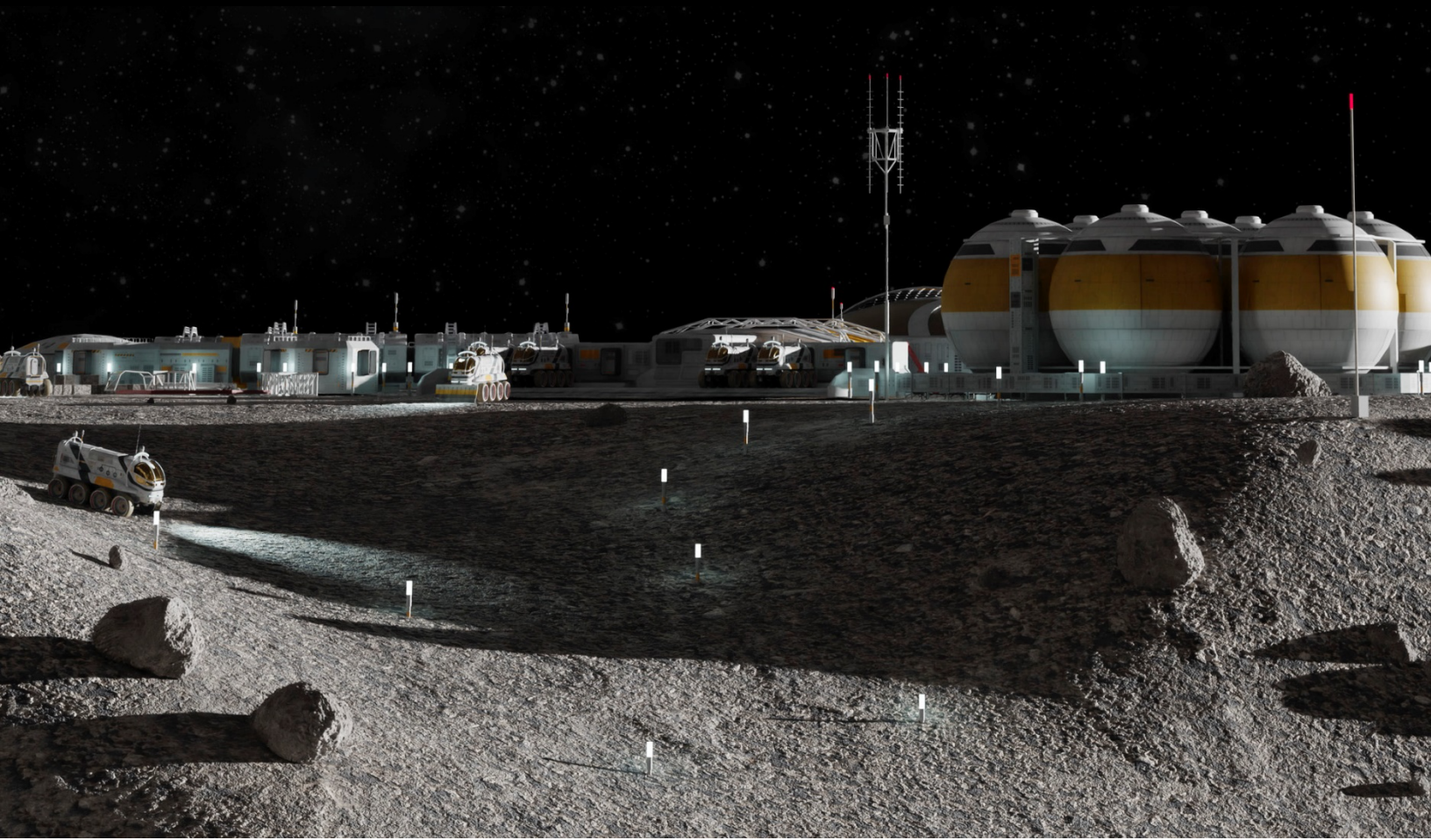

SEMI-ANNUAL MEETING REPORT:

Lunar Surface Innovation Consortium Spring Meeting 2022

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EXECUTIVE SUMMARY

The Lunar Surface Innovation Consortium (LSIC) 2022 Spring Meeting was held on May 4th-5th at the Johns Hopkins University 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, and 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 presentations 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 and 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 the 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), first championed by the Department of Defense, 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:

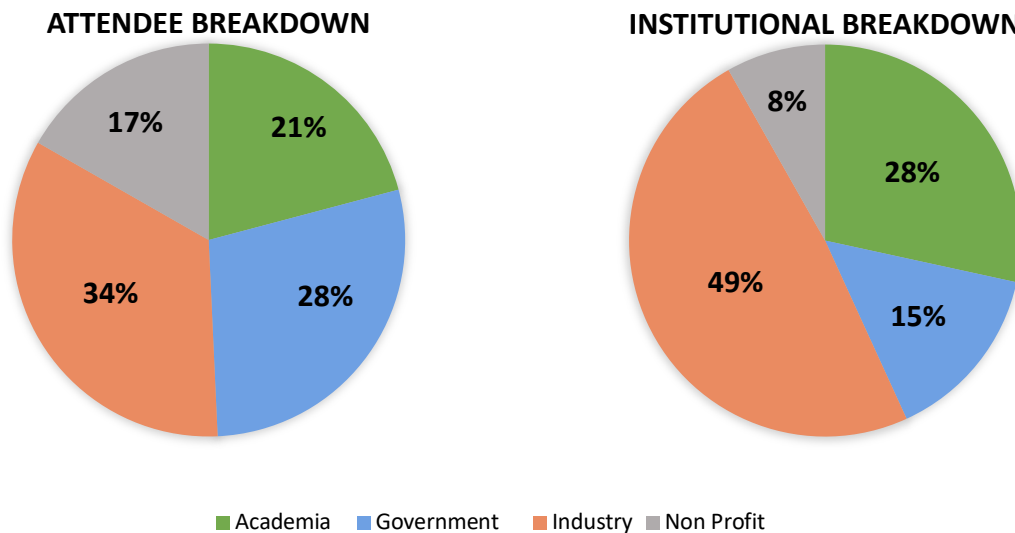
- Industry and academia are eager to make use of the Commercial Lunar Payload Services or other launch opportunities to prove their technology is ready to feed into NASA missions and architecture.
- A "Mock Preliminary Design Review (PDR)" could be leveraged as a mechanism for defining expectations and communicating to industry what the requirements of Envisioned Futures technical solutions ought to be, identifying knowledge gaps and stakeholders.
- 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.
- The community appreciates that NASA strives to improve funding opportunities to make them accessible. However, there is still confusion about the intended frequency of calls, eligibility, etc. NASA and LSIC could help the community navigate this via workshops, interactive flowcharts, or other resources.

MEETING ATTENDANCE AND DEMOGRAPHICS

The Lunar Surface Innovation Consortium (LSIC) 2022 Spring Meeting was held on May 4th-5th, 2021 at the Johns Hopkins Applied Physics Laboratory in Laurel, MD. Attendance included 430 (160 in-person) individuals representing 189 institutions, from 18 countries, 30 states, and Washington, DC. Approximately 39% of individuals had not attended an LSIC meeting in the past, and 47% had never worked with NASA’s Space Technology Mission Directorate (Space Tech) before.

Just over half (53%) of the individuals who attended the Spring Meeting were also registered as participants of LSIC. Of attendees whose institution classification was known, a majority (34%) were from industry, followed by government (28%), academia (21%), and nonprofits (17%). In comparison with the last LSIC-wide meeting in Fall of 2021, this represents a more even distribution, with more academic and non-profit participation and slightly fewer government attendees.

When attendance is examined by institution, industry still dominates attendance (49%), followed by academia (28%), government (15%), and non-profits (8%). Industry attendees included active large and small space companies, as well as companies outside of the space domain. Academic institutions included those from across the US and the world, including Europe, Australia, South America, and Asia. Government organizations, other than NASA centers, that were represented at the Spring Meeting included the National Science Foundation, National Geospatial Intelligence Agency, United States Geological Survey, National Renewable Energy Laboratory, Naval Observatory, and the White House-US National Space Council. Also in attendance were participants from several foreign space agencies, including the Canadian Space Agency, Mexican Space Agency, Korea Aerospace Research Institute, German Aerospace Center (DLR), and European Space Agency.



KEY FINDINGS

- LSIC meetings continue to draw attendance from across the US (and world).
- The distribution of attendees is becoming more balanced across the public and private sector.
- Academic attendance, as well as that of non-space industry members, is increasing.

MEETING CONTENT

The primary objective of the LSIC Spring Meeting was to provide a forum for NASA to present several themes of their 'LIVE' Envisioned Futures, which outline the strategic investments that they have identified in key technical areas necessary for establishing a sustained presence on the lunar surface (In Situ Resource Utilization (ISRU), Surface Power, Excavation and Construction, and Thermal). All semi-annual LSIC meetings also aim to feature topics that were highlighted by the community as areas of interest to learn more about and/or discuss in more detail, as well as to provide an opportunity for the community to share their own technical developments and expertise. To this end, the meeting included a panel discussing space law and one discussing standardization, as well as contributed posters and lightning talks from the community.

The LSIC Spring Meeting was run in a hybrid format, with questions during plenary sessions being taken only via a digital tool (Slido) to try to provide a more equitable experience for online attendees. Because not all questions submitted to Slido were able to be answered live, panelists and other speakers have provided written answers to some of those questions, and these are included on the meeting website along with the presentations, posters, and videos from the meeting. Plenary presenters and panelists were welcome to participate virtually or in-person, with some panels including a mix of both. Poster sessions were held in GatherTown for virtual attendees, and in-person for those who attended the meeting at APL. Hybrid-format lightning talks highlighted selected posters to the full group in a plenary session. Breakout groups, which provided an opportunity to discuss the main topics from the meeting in more detail, were convened in a hybrid format, with each room equipped with an OWL camera to help virtual attendees follow who was speaking in the room. Of the attendees, just over one third were in-person, with the remainder online.

Plenary Sessions

INDIVIDUAL PRESENTATIONS

The LSIC Spring Meeting technical sessions began with a Key Note address by NASA Associate Administrator, Bob Cabana, who discussed the Artemis Program and the Moon to Mars strategy. He described the program architecture as a whole, including the Lunar Gateway and the buildup of surface elements for Artemis basecamp. He stressed that the goal of Artemis is to help humanity learn to live off-world, and that elements of the program were designed to build capabilities to not only establish a presence on the Moon, but to use that presence to learn about living on extraterrestrial surfaces. When asked for NASA's definition of sustainability, he replied that crewed surface stays would initially be for 'weeks to months', but that NASA was focused on maintaining an ultimate goal of sending humans on to Mars.

NASA Associate Administrator for Space Technology, Jim Reuter, followed with an overview of the elements and objectives of the Space Technology Mission Directorate (Space Tech), and how technology drives the space economy. He discussed how the Commercial Lunar Payload Services (CLPS) program is being used to fly Space Tech investments to the Moon. He also shared the timeline for community feedback on the NASA Strategic Technology Framework, the 'LIVE' portion of which would be discussed on the following day, as well as information about the upcoming funding opportunities from Space Tech. Questions from the audience centered around concerns about what opportunities might need to be deferred or delayed due to then unexpected funding shortfalls, as well as how and what types of data from any of the missions would be shared publicly.

After Associate Administrator, Jim Reuter's, talk, the LSIC Director, Dr. Rachel Klima, provided an update on LSIC goals and recent activities, including the release of a new simulant report on the LSIC website and the establishment

of the Modular Open Systems Approach (MOSA) working group. She highlighted findings from the last meeting, and how those had fed into the topical focus of panels for the day.

Technical presentations on the second day began with an introduction by Walter Engelund, the Space Tech Deputy Associate Administrator for Programs, who presented the Strategic Technology Framework and Envisioned Futures Overview. Engelund described the process implemented by Space Tech to develop the Envisioned Futures, which included discussions with the NASA Science and Human Exploration and Operations Mission Directorates as well as key members of the commercial space sector to better understand what technology gaps exist that must be filled in order to establish a sustained presence on the lunar surface. Capability areas were mapped to specific 'thrusters', GO: which focuses on transportation-related technology; LAND: which enables access to diverse locations on the Moon and beyond; LIVE: which encompasses technologies necessary for sustained operations and establishment of long-term infrastructure; and, EXPLORE: which includes development of communications infrastructure, computing, robotics, and other instrumentation that enable exploration both now and into the future. He shared that NASA is releasing Requests for Information (RFIs) to solicit additional feedback from the entire community about these Envisioned Futures. Most audience questions concerned the details of the RFI, however one member asked about what infrastructure NASA expected to leave in place on the Moon when it ultimately shifts its focus to Mars.

The first of the Envisioned Futures shared was the Power and Energy Storage Systems presentation by John Scott, Principal Technologist for Power and energy Storage at NASA . The goal of this topic is to develop sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations. As the key commodity to enable sustained operations on the Moon, power production, distribution, and storage are seen as critical areas where investments by the government are needed to create the building blocks that will enable ISRU and construction of infrastructure at and beyond the poles. Key gaps to achieve the power needed for ISRU, which is seen as the biggest driver for power in the beginning, were discussed, along with the investments being made to try to close the gaps. A number of audience members were interested in whether the specific site for a future base had been settled on as being at Shackleton, as well as what special considerations are needed for the safety of crew interaction with energized systems during EVA. The response was that the site has not been finalized at this point.

Dr. Julie Kleinhenz, Deputy for ISRU System Capability Leadership Team at NASA, followed with the ISRU Envisioned Future, which centers around developing exploration technologies and enabling a vibrant space economy with supporting utilities and commodities. To enable this, they have focused on four specific aspects: (1) commercial scale water, oxygen, and metal prospecting and production; (2) production of commodities for habitats and life support; (3) feedstock for construction; and (4) commodities for in-space and surface transportation depots. Dr. Kleinhenz worked through the complexities of what could be considered ISRU and how they have tried to focus on 'prospect to product' specifically, while working with other areas to talk about cross-cutting requirements. She went on to detail the investments and flight demonstrations planned to mature key ISRU technologies, including work to improve ground testing capabilities. Many audience members expressed concern that after VIPER, there were no planned ice prospecting missions, asking how NASA would close the gap of finding and mapping any ice reserves near Artemis basecamp. One member also suggested that NASA should consider the recycling of disposed-of elements and components for additive manufacturing, perhaps keeping them in a fixed "graveyard" in proximity to the ISRU facility.

Angela Krenn, Principal Technologist for Thermal at NASA, presented the Envisioned Future for Thermal Management Systems, one of the key areas under the purview of the Extreme Environments focus group. In particular, she focused on thermal control for surface operations, including heat rejection and cold survival technologies, dust tolerance, and advanced modeling. She walked through the current and planned investments that NASA has made, and suggested that novel fluids and dust tolerance were high priorities to achieve surface goals.

She also noted that late-mid stage investments were needed to lower the risk for flight demonstrations, as many of the technologies being funded were still at a low to mid technology readiness level (TRL).

Finally, Mark Hilburger, Principal Technologist for Structures, Materials, and Nanotechnology at NASA, presented the Excavation Construction and Outfitting (ECO) Envisioned Future. This area includes infrastructure to support many of NASA's thrusts, including providing landing site infrastructure to enable repeat landings, structures to support all aspects of living on the surface, and construction to enable exploration both across the lunar surface as well as deeper into space. In all cases, autonomy plays a critical role. He described the current plan, which involves creating a logical development timeline and defining requirements. He described the current investments and gaps for supporting the needs of ISRU as well as for establishing surface construction and outfitting. Closing the gaps related to ISRU was deemed a top priority, as it feeds back into ECO capabilities. Many in the audience were curious about NASA/Space Tech work on assessing or mitigating the impact of industrial scale operations on the lunar environment. Many comments concerned details for habitat development, including whether a switch to mobile habitats would affect the EF development plans. The audience also recognized the value in engaging the terrestrial mining community to understand what technology could be adapted for lunar uses vs. developed completely new.

Following the NASA Envisioned Future talks, the LSIC Focus Group leads each presented an overview of their current and upcoming annual goals, activities undertaken in the past year, and key findings from ongoing focus groups and workshops. Each of the focus groups has convened at least one workshop over the last year, and many have also held cross-group meetings or extended technology deep-dives to evaluate specific technology gaps. All noted that the communities enjoy the opportunity to network with one another. For commercial members of the consortium, supply and demand-centered workshops have been particularly helpful. Audience members voiced an interest in what workshops were on the horizon, as well as what the focus group leads' reactions were to the NASA Envisioned Futures. One suggested that LSIC could produce an all-inclusive environmental model to help industry design around to reduce barrier to entry for commercialization.

The meeting plenaries concluded with three talks specifically geared towards funding and partnerships. The first of these was presented by Maggie Yancey, who described the new NASA Innovation Corps (I-Corps) pilot. I-Corps had been highlighted in previous LSIC semi-annual meetings by commercial consortium members as being extremely valuable for small businesses. The new pilot, open to leadership by academic and non-profit institutions, seeks to promote entrepreneurship through mentoring and courses. Harri Vanhala of NASA followed with a presentation about the LuSTR program. Although LuSTR proposals must be led by academic institutions, up to 40% of the (~\$1-2M per award) funding can be used to fund partners in non-profit or commercial companies. LuSTR is focused on low to mid TRL development, and provides post-award infusion opportunities. Finally, Dr. Kirby Runyon and Jibu Abraham presented an ongoing effort to develop an interactive tool where members can describe their technological inputs and outputs, and from that explore connections to other potential partners in the community. The audience had a number of questions on the details of the I-Corps pilot and LuSTR program eligibility, and asked whether the value mapping tool would be able to identify gaps in the lunar supply chain. The presenters of the latter clarified that this is among the goals of the tool; not only is it geared towards finding customers, but it could also be used for members to identify areas where investment or development is lacking that they might target.

KEY FINDINGS

- The community continues to seek clarification on what NASA considers sustainable. While NASA has reinforced that they expect to work with industry to try to build up infrastructure as one of many customers, the community is eager to understand what types of infrastructure NASA expects to leave on the Moon and when (or whether) they intend to transition to focusing explicitly on Mars.

- The audience is nervous about how funding shortfalls to NASA Space Tech will result in delaying or deferring opportunities for the community to propose their technology for development. They appreciate the funding opportunities provided by Space Tech and the efforts to help foster entrepreneurship and small business development.
- There are concerns about the lack of prospecting missions in the works, and how that feeds into the selection of the ultimate site for Artemis basecamp.
- The community supports efforts to engage terrestrial industry members who may provide expertise or solutions that can be adapted to the lunar environment. They also appreciate the efforts to foster partnerships and identify supply chain gaps that might be opportunities for businesses to develop critical technology and build their customer base.

Panel Discussions

Three panel discussions were held on the first day of the spring meeting, two of which followed up on topics that had been identified in previous LSIC meetings as being areas of interest for the community, and one that provided an opportunity for the LSIC Executive Committee to speak to the group about their perspective on a sustained presence on the Moon, in particular focusing on technology maturation, including flight opportunities and testing.

The first, a Space Law Panel, was dedicated to exploring key lunar law and tech-policy issues. The objective of the panel was to discuss the legal and policy challenges and opportunities to foster new scientific advances and sustainable, economic growth in the lunar ecosystem. Noting that sustainability is achieved by leveraging the extensive natural resources of the Moon, the panel advocated how best to shape the legal and regulatory infrastructure across the global and domestic landscapes in a manner that maximizes use of the lunar resources and increases investment confidence while also aligning with the core tenets of international law. The panel included space lawyers and policy experts who discussed the following topics:

- Property rights to extracted resources/mining claims
- International perspectives to lunar laws
- Resource governance approaches
- Regulatory clarity without excessive regulation
- Contractual mechanisms to spur innovation

Chris Johnson, a space law advisor for the Secure World Foundation, and Professor of Law at Georgetown University Law Center, walked through foundational international and domestic space law. Dr. Timiebi Aganaba, a British-Canadian-Nigerian Outer Space Lawyer and Professor of Space and Society at the School for the Future of Innovation and Society at Arizona State brought unique international perspectives to existing legislation. Jessy Kate Schingler, an expert in space governance and institution design, leads Policy and Governance at Open Lunar Foundation. She discussed unique governance approaches and resource management. Mary Guenther, a Hill veteran and Director of Space Policy at the Commercial Spaceflight Federation shared the commercial perspectives, and talked about the importance of norms and the art of achieving regulatory balance. Brian Stanford, a senior attorney in the Contracts and Acquisition group at NASA shared how NASA leverages innovative procurement mechanisms to expedite technology development for lunar exploration.

Due to time constraints, panelists were not able to address the large number of audience questions during the event. However, questions from the audience were captured and provided to the panelists, and panelists responded to them in writing so that they could be shared with the community. The questions and answers are available on the meeting website (<https://lsic.jhuapl.edu/Events/Agenda/index.php?id=200>) and in Appendix 2. A number of questions centered around the legal framework for land use, as well as salvage and waste (for instance, when is

something trash and when is it cultural heritage? And, if disposed, what are the original owner's rights over the equipment?). Others focused on understanding the interplay between the Artemis Accords and the Outer Space Treaty, as well as whether there are stakeholders who are not, but should be, included in discussions about norms.

The second panel of Day 1 included several representatives from the Executive Committee: Dr. Ryan Watkins, of NASA Science Mission Directorate's ESSIO office; Dr. George Sowers, of Colorado School of Mines; Dr. Michael Miller, of Southwest Research Institute; Jessy Kate Schingler, of Open Lunar Foundation; and Dr. Ariel Ekblaw, of Massachusetts Institute of Technology's Space Exploration Initiative. The panel addressed questions from the audience, many of which concerned flight opportunities such as the Commercial Lunar Payload Services (CLPS) and whether there might be future opportunities enabled by Starship. Audience members expressed a strong interest in having a CLPS opportunity that was dedicated to technology development and demonstrations, and wanted to hear the panels' perspective on where the boundary was between technology that could have key risks retired through shorter parabolic flights vs. needing landed flight demonstrations on the lunar surface. They were also interested in the committee's perspective on how smaller businesses could form co-ops for transportation to the lunar surface, and how the international community could be engaged to fund future missions.

The final panel of Day 1 followed up on community questions about standardization of interfaces, and featured Mark Mazzara, Robotics Interoperability Engineer and Project Manager for the US Army; Meera Day Towler, Senior Research Engineer at Southwest Research Institute; Matt DeMinico, Power Portfolio Manager at NASA Glenn Research Center; Amalaya Oyake, Senior Flight Software Engineer at Blue Origin; and, Chad Thrasher, Systems Interoperability Lead for NASA's Artemis Campaign Development Division. The panel started with a high level discussion of what a Modular Open System Approach (MOSA) is, and then each panelist gave their perspectives on interoperability. The overall sentiment of panelists was that it is critical to start setting these standards now to ensure a sustainable presence on the Moon. Industry, academia, and government should work on defining interface standards together. As a first step, the community needs to identify the top systems that need a interoperability plan. In addition to the many technical aspects of interoperability, it is crucial to include requirements for operator experience, repairability, and maintenance. The audience expressed extensive interest in how MOSA is implemented with the DOD. For instance, they were curious about whether the DOD or industry has the final say on defining interfaces, and how they prevent monopolies if certain standardized interfaces lend themselves more easily to one company's platform over another. A number of comments suggested that the community is interested in working together to define standards, and somewhat hesitant to have standards directed without strong community/industry support.

KEY FINDINGS

- The community remains concerned about the legal framework for land and resource use, as well as salvage and waste, and supports involving a broad audience, beyond just those signatories on the Artemis Accords, in discussions about norms.
- The community is eager for flight opportunities, and interested in exploring creative partnerships such as co-ops or international collaborations to provide greater access to the lunar surface for technology demonstration and maturation.
- The audience expressed extensive interest in MOSA, but was concerned about details such as how to avoid monopolies if a standard is favorable to a particular company and whether they would have a voice in identifying the optimal standards for a given interface.

Community Sessions

As a hybrid meeting, community presentations at the Spring Meeting were handled as a plenary lightning talk session, where presentations selected by the technical committee based on contributed abstracts could be shared either in the main meeting room or via zoom, followed by a poster session at APL and a parallel session on GatherTown.

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 sessions. Lightning talks included a broad range of topics, including wireless power transfer, regenerative fuel cells, resource management, and dust shielding. All of the lightning talks are available for viewing through the event page (direct link: <https://www.youtube.com/watch?v=Lqq3vYKBMGM>).

POSTERS AND GATHERTOWN ENVIRONMENT

Posters were hosted both in person and online using the GatherTown environment. GatherTown allows individuals to log in and walk around a virtual conference hall as an avatar (similar to a low-resolution video game), interacting with people within a small radius of them. Posters that were presented in GatherTown as well as some of those that were presented in-person are also posted on the LSIC Meeting website, and will remain available for reference. Abstracts for all presentations are available in the program book, also available on the meeting webpage (<https://lsic.jhuapl.edu/Events/Agenda/index.php?id=200>).

Breakout Sessions

For this meeting, we convened all breakout sessions in a hybrid format over zoom, using rooms equipped with an OWL camera/microphone where the camera is designed to follow anyone who speaks in the room. Each group had two moderators and a note-taker, with one of the moderators assigned specifically to making sure that those online were noticed when they had questions and could participate fully in discussions. Breakout sessions provided a space to discuss elements of this meeting in more detail, as well as follow up on the recent Regolith to Rebar workshop. Session moderators were free to use Confluence, Miro (a tool for brainstorming and organizing thoughts), or other tools to capture notes, as desired. Breakout attendance ranged from ~20 to over 50 people in the different rooms.

ENVISIONED FUTURES

The Envisioned Futures (EF) breakout followed conference sessions on NASA's EF vision (regarding Surface Power, ISRU, Thermal, and ECO) and explored LIVE thrust concepts further. This breakout functioned in the style of "Audience as the Panel" - discussing open needs of the community in order create solutions that enable LIVE EF technology capabilities as well as ideation of LSIC activities that could help the community pursue this. The community appreciated the Envisioned Futures sessions and the insight they provided into the investments that have so far been made by NASA, which allowed them to better understand areas that they might focus their efforts on. One recommendation was that it would be useful to have a model similar to the Decadal Surveys in other fields, where the community provides a recommended vision for the next decade as well as a minimum level to keep advancing towards the goal of a sustained presence. One standout takeaway is the idea of hosting a Mock Preliminary Design Review (PDR). Such an initiative could be leveraged as a mechanism for defining and

communicating specific requirements of EF technical solutions to industry, identifying knowledge gaps, understanding stakeholders, and more.

SPACE LAW, MOSA, AND THE BIG PICTURE

The breakout room discussed many 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. It was suggested that there should be an organizing body that helps establish these norms along with overseeing technical and system standards.

With respect to issues of space law, the group discussed that a working group on space resources exists, and that resource rights are permissible under current treaties; however, questions center around benefit sharing and duration of usage. Transparency and communication with the international community is key to minimizing conflicts in exploration. The group noted that salvage rights are a known issue on Capitol Hill. The group acknowledged that establishing norms without hard law is challenging, and discussed how players who violated military rules of the Moon might be dealt with through sanctions and loss of reputation.

On the topic of MOSA and standardization, some of the key points discussed were contracting norms/standards, safety standards, and what should be considered contamination on the lunar surface. The group noted that the Artemis Accords do contain a statement on interoperability. Members of the discussion felt that as long as NASA maintained a portfolio of multiple companies who could compete with one another, concerns of monopolies should be unnecessary. It was also noted that a standard does not have to be prescriptive, but can be in the form of requiring explicitly defined hardware and software interfaces. The group felt that the most important issues to address in the near term were hardware and software interface standardization as well as plug and play avionics standards. They also concluded that:

- Norms are critical for uniform behavior and the timing to identify them is now. Other nations will be looking at what we do.
- Proprietary “standards” are considered harmful and classified standards cannot be readily distributed in an international environment.
- There needs to be an organizational structure (leadership/regulatory structure) to oversee standards and provide leadership that follows best practices. The US must play a big role in this process.

FUNDING OPPORTUNITIES

The funding opportunities breakout panel talked about some of the differences between industry and academic-focused NASA funding opportunities and got input from attendees on what they would find helpful for learning more about these opportunities. Attendees agreed that an LSIC-sponsored workshop that covered what opportunities are available and their target audience would be helpful. Many attendees have prior experience with funding through agencies such as National Science Foundation, and were interested in learning how NASA is different. Attendees also had questions about the funding calendar – for instance whether NASA releases certain types of funding opportunities at particular times. Attendees agreed that having advance notice that a funding opportunity would become available would help put together a successful proposal since the time between release and deadline frequently is not enough to complete a full proposal. Those attendees who had worked with NASA in the past agreed that NASA has been a great sponsor for their work.

REGOLITH TO REBAR – NEXT STEPS

This breakout group focused on following up on the Regolith to Rebar workshop that took place in February of 2022. The group reviewed the main findings from the workshop. Extraction of metals from regolith is still in its infancy, so the goal of both the workshop and this follow-up was to facilitate conversations between architects and technologists. At the workshop, supply-side discussions included Molten Regolith Electrolysis (MRE), carbothermal reactions, Molten Salt Electrolysis (MSE), vapor pyrolysis, and hydrogen reduction, with demand side including companies needing aluminum for connectors as well as for infrastructure construction. The group considered whether, with the capabilities of Starship, it is cheaper to transport materials or to produce them in situ. There is likely to be a balance between structures that can be easily deployed and those that are best constructed in situ from local materials. For a future meeting, the group suggested focusing on specific material types, such as functional or structural materials.

It was clear from the meetings that industry needs help with a commercialization strategy. In order to fully understand the gaps and feasibility of different techniques, the community needs to identify the necessary purity for specific uses, as well as where standards for specific elements like wheels would benefit from standardization to simplify replacement parts. Many of the technologies can be tested, at least to a first order, on Earth with appropriate simulants. The ultimate goal would be to have a “fully circular economy”: capturing by-products and storing or using them for other processes. There was interest in the group in following up on these topics with other workshops.

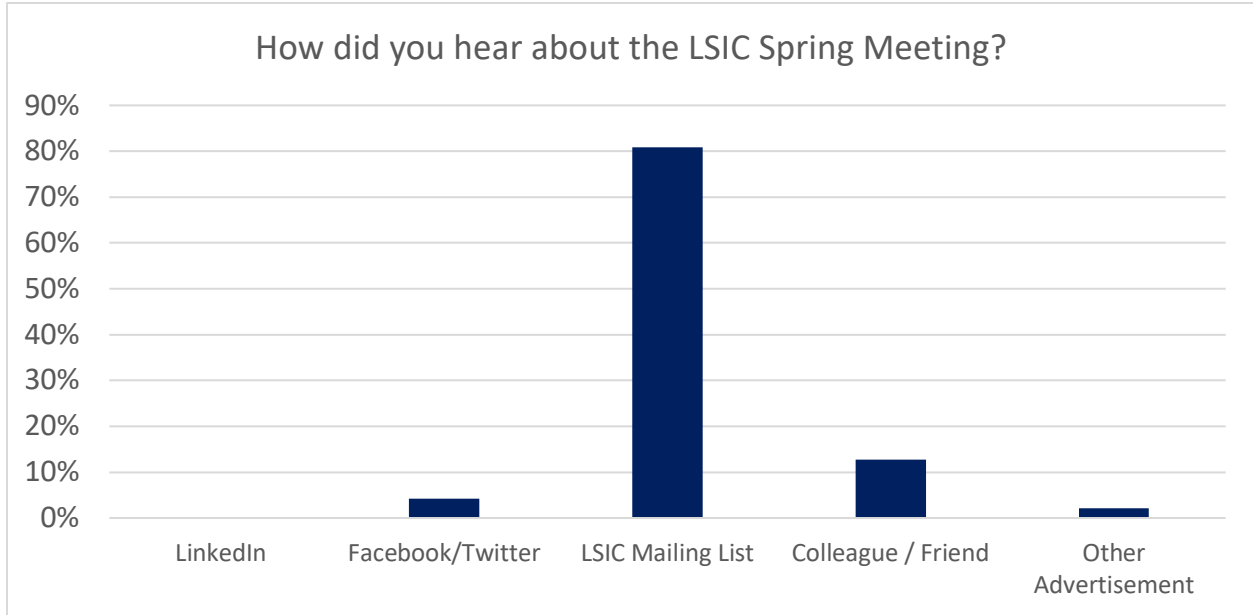
KEY FINDINGS

- A "Mock Preliminary Design Review (PDR)" could be leveraged as a mechanism for defining expectations and communicating to industry what the requirements of Envisioned Futures technical solutions ought to be, identifying knowledge gaps and stakeholders.
- 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.
- The community appreciates that NASA strives to improve funding opportunities to make them accessible. However, there is still confusion about the intended frequency of calls, eligibility, etc. NASA and LSIC could help the community navigate this via workshops, interactive flowcharts, or other resources.
- The community advocates for maintaining a goal of achieving a “fully circular economy”: capturing by-products and storing or using them for other processes.

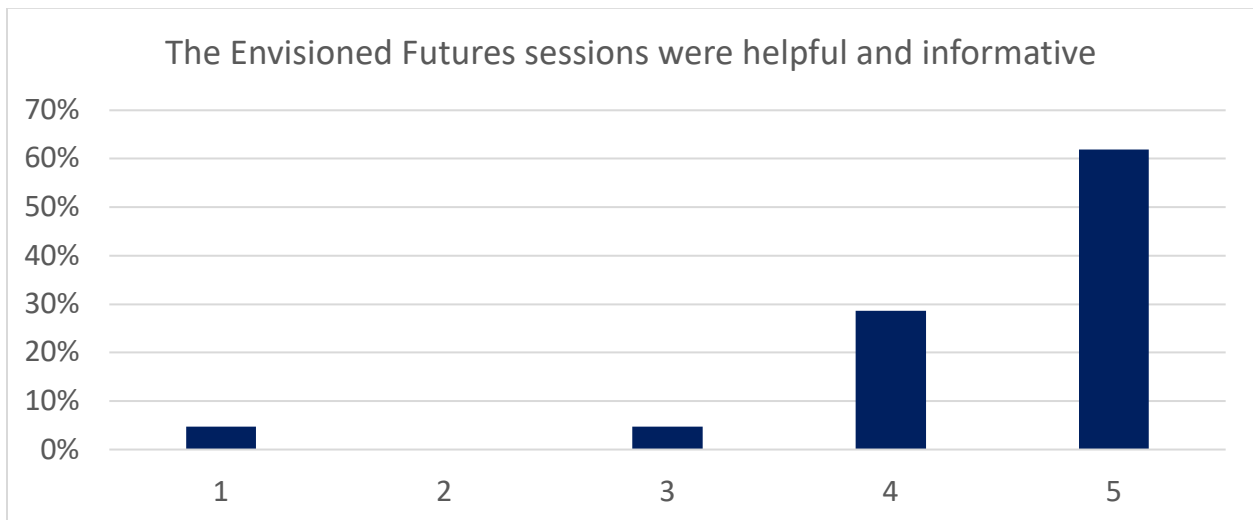
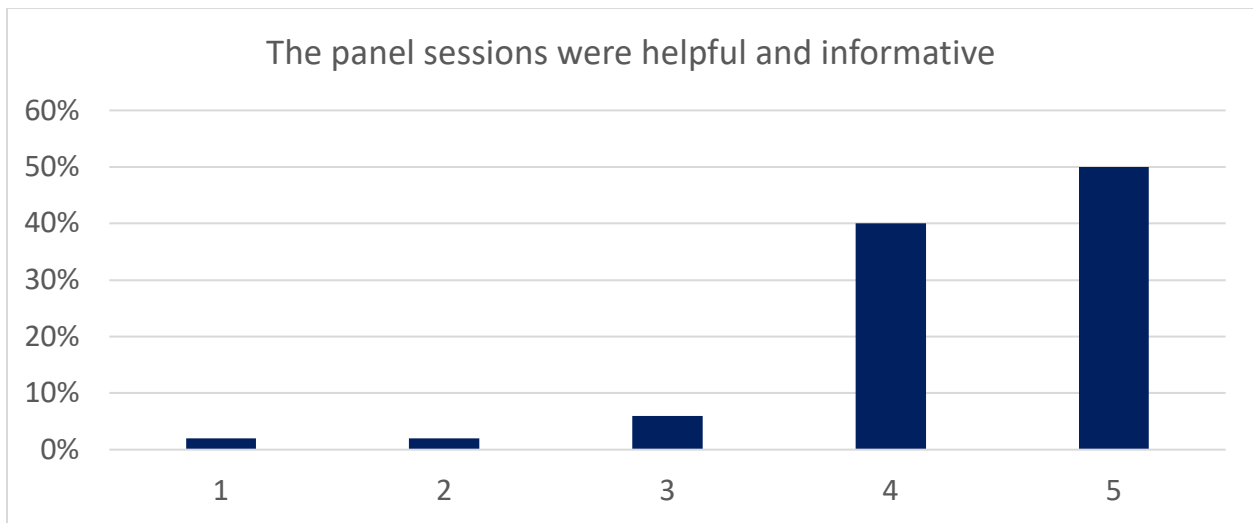
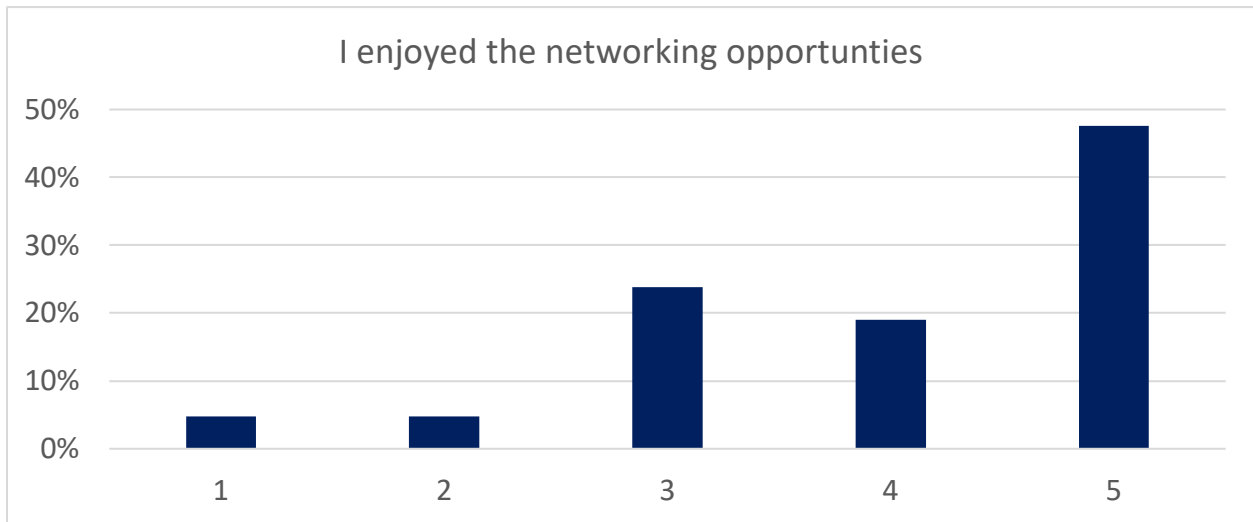
APPENDIX 1 – MEETING FEEDBACK

Feedback for this meeting was collected throughout and after the meeting through the Slido interface. This significantly improved the number of responses, relative to surveys for previous meetings (52 respondents for post meeting survey). LSIC involvement numbers are drawn from intake survey for attendees (430 respondents). In the 'Sessions' and 'Logistics' sections, the scale ranges from 1: strongly disagree to 5: strongly agree. Note that some respondents clarified their ratings in the written feedback section.

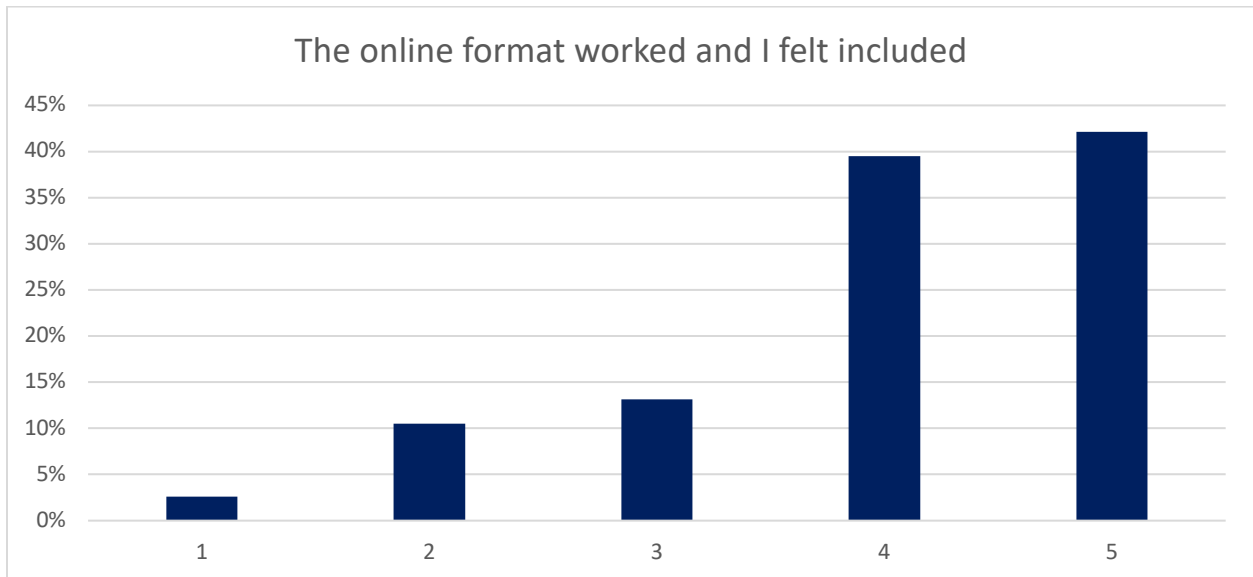
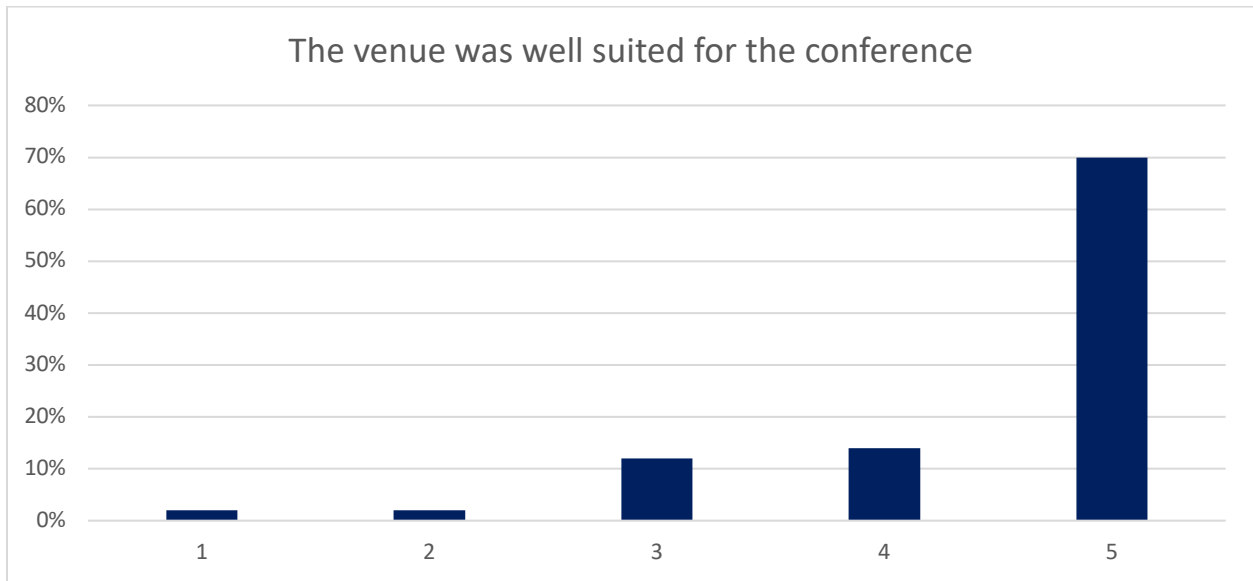
Background Information



Session Feedback



Logistics Feedback



Written Feedback

Question: What aspects of the meeting did you attend and like (or dislike)?
All aspects, including lightning talks.
Felt the room was too crowded, considering COVID, and hard to navigate for anyone with mobility issues. Captions for the virtual Zoom would have been useful. Appreciated the snacks!
As someone new to LSIC, slightly more structured networking opportunities would have been nice! The poster session was great but could have been twice as long.
Loved it all, only thing I would change is increasing the length of break times between sessions.
I really enjoyed the panel presentations that spotlighted the potential legal issues and standardization needs of exploring the Moon.
Loved Bob Cabana's talk and the lightning talks. Kind of wished the lightning talks were earlier so I could find specific people to talk with but the format and schedule were overall very well done.
Attended all. Liked the topic panels.
Robotics discussions
Attended all of it. Catered lunch allows for more networking opportunities. Executive committee panel wasn't particularly interesting
Bob Cabana, Bobby Braun, & MOSA
attended all, liked the law and policy panel and would have liked more time for QandA
I really liked the panels. The Q&A for the panels was fun to listen to. Although I do wish the in-person guests could submit questions without using a personal electronic device.
The first panel was not a panel so much as a series of talks. More interaction would have been better, as achieved by other panels.
attended all but the morning coffee hour. panel presentations with Q&A are the most interesting.
Not really enough opportunity to browse posters much until the last hour.
I attended virtually from the morning through most of the Lightning Talks. I enjoyed hearing about different areas of the lunar/space industry and the different types of organizations/academia involved. I cannot think of anything I disliked.
All in-person, panels need discussion. Need to keep panelists to time limit
All, it was good
Liked all of it.
I really enjoyed the Envisioned Futures talks as well as the Breakout Sessions
I attended both days. I missed the breakout sessions.
I enjoyed the LSIC Spring Meeting and attended virtually. I thought the session lengths were appropriate for the topics, and I was pleased with the material content. I attended the Law/MOSA break out session, and the one

<p>issue I did experience with this session involved some poor audio. It is always a struggle to provide high quality audio when conducting a round table discussion, but I wanted to mention this issue as one or two other attendees experienced the same challenge. I certainly appreciate all the work the LSIC folks did in preparing for this event. I thought the activities flowed very well. Also, I appreciate the opportunity to participate in the LSIC community and look forward to future interactions with this group. Thanks again for your efforts.</p>
<p>Would appreciate a Greater emphasis on networking rather than talks / panels. One breakout session was not sufficient.</p>
<p>My three star answer regarding the venue is intended to be neutral since I attended virtually. The panel discussions were more focused on short presentations or pitches vs. a panel discussion in which the moderator poses topics and questions for discussion and the panelists offer their views and opinions on the topic. The keynote was excellent and gave a good overall view of the Artemis program and future goals of NASA.</p>
<p>I was online only, and didn't find a way to watch the day 1 panel discussions in the afternoon. I recommend the website Events page list past events too, since finding the youtube stream the following week wasn't straightforward.</p>
<p>I attended all of the meeting and really liked the panel discussions that touched on policy.</p>
<p>Opening talks were informative about the overall program. I was most interested in the Extreme Environment section.</p>
<p>NASA's various updates</p>
<p>Side note: PLEASE MAKE SURE TO SEND INVITATIONS TO MONTHLY MEETINGS USING GOOGLE CALENDAR INVITATION INSTEAD OF EMAIL SO WE CAN ADD IT TO OUR CALENDARS. THANKS, A LOT!</p>
<p>Loved the panels and enjoyed the breakout sessions too.</p>

KEY FINDINGS

- Soliciting feedback through Sli.do at breaks and the end of each day significantly improved the amount of feedback received.
- The LSIC mailing list remains the primary source where attendees heard about the meeting.
- All sessions were well received, with most ranked as excellent or great.

LSIC 2022

Space Law and Policy Follow-up Questions

1. ***The Articles of the Outer Space Treaty seem to remain relevant, but can we expect this to be adhered to by States who may have signed 55 years ago and are now considered adversaries?***

Chris Johnson: I would say that yes, in almost all circumstances, States will observe and obey the obligations and restrictions in the Outer Space Treaty. That a treaty is old, but still in effect, is a testament to its longevity - rather than a sign of its irrelevance. Because the Treaty is so old, and so widely accepted (111 Parties) means that it exists as binding international law as a treaty, but also as another form of international law – customary international law, and therefore binding even on States which are NOT a party to the treaty. So, there really is no getting out of the Treaty and its obligations without severe consequence, such as many other States (whom you have to work with in space) noticing and condemning violations of the Outer Space Treaty. Also note that the US, as well as Russia and China, are long standing parties to the Treaty, have yet to violate it, and have often made reference to the Treaty as the most important source of international space law.

2. ***How do we dispose of things on the moon/in lunar orbit— Crash satellites into the surface (similar to a Pacific Graveyard)? Lunar dumps? Lunar graveyard orbits?***

Chris Johnson: There are the general obligations to avoid “harmful contamination” and the obligation to adopt appropriate measures to avoid such harmful contamination, both found in Article IX of the Outer Space Treaty, which give some guidance as to how to behave in this regard. However, they don’t give that much guidance. Specific to disposal, there is no international space law specifically mandating how things must be disposed of on the Moon, or in lunar orbits. It is likely an unintentional gap in international space law, i.e., an area of activity that the drafters and negotiators of the OST did not imagine, consider, or legislate upon. Consequently, it is up for debate as to what an actor should do.

- ***Additionally, how does this fit into the Outer Space Cultural Heritage? What is cultural heritage and what is debris? From a Native American point of view, there’s no unnecessary debris on the moon***

Jess Kate Schingler: We don’t have any rules about this yet. Some folks have suggested that satellites should be disposed of by kicking them out to a solar orbit. Left unattended, depending on the orbit, some will crash to the lunar surface, but others in stable orbits might just remain, eventually cluttering the orbits and making them less useful for others. There aren’t any norms yet for surface disposal, and there’s no atmosphere for them to burn up in, and no oceans to crash into.

Chris Johnson: The Outer Space Treaty is essentially silent on cultural heritage in space. The Treaty regulates the behavior of States and their sub-national actors in space, rather than regulating the domains of outer space or celestial bodies. Many might consider human-created hardware on the Moon as culturally significant – this is a growing field amongst space archeologists, for example.

3. *Are there any definitions of what constitutes "harmful contamination"? Who decides, and how?*

Chris Johnson: On the Moon, this is an unanswered question. Harmful interference is a topic in the regulation of frequency use in space telecommunications, and perhaps we can draw some analogies from harmful interference – for example by parsing out what makes interference “harmful” and what are the qualities that make it harmful. Perhaps ‘harmful’ is something like ‘negatively affecting the interests or activities of other actors’ in that regime. If so, then we might be able to use that to discuss harmful contamination.

Another area to consider is that COSPAR’s planetary protection guidelines have elaborated what they consider, for the purposes of astrobiology, what is harmful, and what should be avoided. In planetary protection, harmful is probably any materials, whether chemical or biological, that might harm / interfere / ruin / prejudice the search for past or present life on celestial bodies. For the Moon, however, COSPAR considers it largely a dead world, but we can still take the qualities or elements of COSPAR’s thought – where a scientific inquiry is imperiled or ruined – and we can transpose that risk of peril or ruination over to other activities we’d like to do on the Moon. However, none of this is written into either international space law, or national space laws or regulation (at present). Feel free to follow up with me on this interesting inquiry, as the time to start these discussions is absolutely now.

4. *Terrestrial international law is challenging to enforce and seldom is. How are space laws like the Outer Space Treaty enforced?*

Chris Johnson: I would contend that public international law, as the law governing the relations between States, fundamentally supports our globalized and interconnected world, and is complied with and observed almost all of the time, and in almost all circumstances – and that it is the egregious exceptions and violations of this overwhelming compliance which people notice. The American Society of International Law (ASIL) has a very excellent resource to explain this, at:

<https://www.asil.org/resources/100Ways>

As far as enforcement of space law, of course this can happen in space if possible, but it can also be enforced here on Earth. Spacecraft are the responsibility of their launching States, and States retain jurisdiction and control over their registered space objects, and over any personnel on those spacecraft. So, enforcement over a State’s national space activities (including private space activities) is quite direct. For actions done by foreign actors, the consequences of violation can take a number of avenues, depending on how the State wants to respond. These can be direct judicial proceedings through the judicial arm of the United Nations, such as the International Court of Justice (ICJ) or the Permanent Court of Arbitration (PCA), both in the Hague, Netherlands. Or, direct bilateral consultations and negotiations with the other State. Or, unilateral actions by the victim State, including everything from economic responses such as the loss of favored nation trading status of the violating State, tariffs and sanctions, or the revoking of diplomatic and consular staff, or naming and shaming in the public sphere and in diplomatic fora. There are many peaceful but asserting responses that a victim State (or coalition of States) can choose to take, outside of more forceful responses.

5. *Would issuing exclusive, but temporary rights of an area on the lunar surface be in violation of Article 1 and 2 of the OST?*

Jess Kate Schingler: There has not yet been a decision about this in the international community one way or the other! But it has been discussed fairly extensively, in particular developed by the [Hague Building Blocks](#) process a few years ago.

Chris Johnson: In principle, I would say ‘No.’ A State issuing a license to one of its national space actors (whether they be a governmental actor or a private, non-governmental entity) to conduct an activity on the Moon – with the governmental promise to protect that licensee against other national space actors which would interfere with that activity, and to not grant other licenses to national actors which would interfere with that activity, would not rise to the level of violating Article II’s requirement that national appropriation of the Moon is legally impossible.

Article I of the Outer Space Treaty, as well as the preamble and the very title of the Treaty, make it clear that a wide range of exploration and use of the lunar surface was envisioned and is permissible in conformity with the Treaty, and an exclusive but temporary right to a wide variety of otherwise lawful activity, does not run afoul of those freedoms.

6. *How do rights change as material changes hands or are processed? For example, for ISRU, once metals or fuel has been extracted/processed from lunar soil?*

Jess Kate Schingler: We don’t really know yet, but by default it’s likely that norms and rules about objects and ownership would transfer from the approaches we have on Earth, to the extent that they can be applied without being seen to conflict with the Outer Space Treaty.

Chris Johnson: United States Code (USC) Title 51, Chapter 513 states:

§51303 Asteroid resource and space resource rights.

A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.

This law can be found at (and click “PDF”):

<https://www.govinfo.gov/app/details/USCODE-2015-title51/USCODE-2015-title51-subtitleV-chap513>

And in the above law, keep in mind the definition of “asteroid resource” and “space resource” included in the definitions sections of Chapter 513. I’m no expert on property law, but it appears that the rights over space resources don’t really change if the resource has already been extracted from their previous location, or processed or used in other materials. Note that the definition above includes a broad range of rights: “possess, own, transport, use, and sell”. If the owner of the space resource owned them before those resources were processed, they continue to have all of those rights listed in §51303 after they have processed or manipulated them. The words “possess” as well as “use” in the above definition seem to show that an owner can extract and process lunar material.

7. ***Laws of Salvage on the Moon: When a lander or surface element is considered “disposed,” what are the original owner’s rights to that equipment? Arbitration?***

Jess Kate Schingler: There is no definition of “disposed” yet (this is part of why we think coming up with some agreements about this would be useful). I believe by default an owned object would stay that way unless something happens to change that. But it’s not just about rights— it’s also about obligations and liability. If some equipment leaks a hazardous material or interferes with the mission of another operator, then the owner would be liable for that. We also don’t have any precedents for what that means!

Chris Johnson: Ownership of a spacecraft, rover, or other such space object, if it was launched from Earth and ends up on the Moon, does not change due to the location of the object. The ownership rights of the owner persist. Now, if ownership of the object is transferred to another entity (a State, company, or person) then that second entity retains all of the rights of ownership and possession of that space object. Unless they contract away those rights, such as including some type of reversion clause in the contract or sale between the original owner and the purchase.

8. ***If I land on the Moon, and claim a 5 km “safety zone” around me where nobody can operate, is not appropriation of territory de facto if not de jure?***

Jessy Kate Schingler: This is exactly the concern that a lot of folks have with the idea of “safety zones” and why they are considered contentious in the international community. Many are proposing that they be called “notification” or “coordination” zones which more accurately represents what is being proposed, which is that these regions are ones where notification/coordination is requested. So far, we also don’t have a mechanism for how one would assert one of these zones, who has a right to assert them, what conditions have to be met, how long they last, etc. These are important questions to ask!

Chris Johnson: A government would be the entity proclaiming a safety zone, and that unilateral claim by one State would, in principle, be seen as largely a political & scientific action, and not a legally operative proclamation. If the government was a party to the Artemis Accords, then likely the other Artemis partner countries would give more weight to that proclamation. Nevertheless, a statement by an actor of a safety zone is not appropriation pursuant to Article II of the Outer Space Treaty. It is more likely seen as the exercise of a right created under Article IX of the Outer Space Treaty, whereby states must adhere to the principles of cooperation, mutual assistance, and due regard to the corresponding interest of other States. As such, the proclamation of a safety zone allows other actors to observe their obligations of cooperation, mutual assistance, and due regard with greater clarity, as now they know with more precision where and how the first actor (the one making the safety zone proclamation) will be performing activities on the Moon.

9. ***As a rookie in the industry, could you help me understand how industry will legally perform full scale ISRU on the Moon? Water extraction -> fuel sale?***

Jessy Kate Schingler: This is a complicated question and we don’t know yet :). But some of the legal questions that will need to be answered include priority rights to prospected areas, legal rights to extracted materials, the possibility of any requirements for benefit sharing or other commitments/obligations to the wider community as a result of undertaking these activities, conditions around/rights to site occupancy

(conditions for a claim, duration, limitations), and any decisions around areas to be excluded/limited for ISRU activities.

Chris Johnson: Not sure I understand the full scope of the question, but at least in the US we have the beginnings of a regulatory regime in place, under Title 51 USC, in the chapter dealing with space resources. The regime is pretty minimal at present.

10. *Are the Artemis Accords a treaty? And what are the implications of treaties vs. other international agreements?*

Chris Johnson: The Artemis Accords are actually, despite their public reception, NOT a treaty. Section One – Purpose and Scope of the Accords reads (in part) “[t]he Accords **represent a political commitment** to the principles described herein, many of which provide for operational implementation of important obligations contained in the Outer Space Treaty and other instruments.” Also see the Preamble, which calls them a “political understanding”.

Regarding the second question, this is a much larger discussion, but I would just add that the further development of norms for cislunar activity will happen at the UN level, as well as bilaterally and multilaterally outside of the UN (i.e., as the Artemis Accords were done), as well as at the national level with further national space legislation and regulation, as well as lower down at the operator level – through contractual arrangements between industrial partners, and through industry-led consortia and standard setting by industrial groups. This multiplicity of norm creation is what Jessy Kate Schingler at Open Lunar often discusses as polycentricity in norms for outer space behavior.

11. *Who is the trustee for the Breaking Ground trust?*

Jessy Kate Schingler: I should have mentioned this! You can find them all on our website at <https://breakingground.space/about#team> (full disclosure: I am one of the currently 4 trustees; there is also a special role called a “trust enforcer” which is a role distinct to the perpetual purpose trust).

12. *Do you also include power distribution systems and facilities in these areas that have to be developed and the standards governance processes?*

Jessy Kate Schingler: Power distribution systems and facilities will definitely need governance and standards! Many of the same questions that come up for ISRU (see other answer) will also apply to power distribution. In addition, another question I could see coming up is whether you have a right to limit who your customers are or are required to provide service to all lunar actors. In any service provision, understanding liability will also be relevant.

13. *Can lessons from Commons’ government on Earth be applied to the Moon?*

Jessy Kate Schingler: Absolutely. Most successful examples of Commons governance involve bringing together the key stakeholders to make decisions together about how to manage a resource, which creates buy-in and commitment to upholding the rules. There are several analogies we can look to for commons governance— the arctic has an arctic council with a number of associated multi-stakeholder groups; the antarctic isn’t exactly a Commons but is divided up into territorial “management” areas; the high seas has

its Deep Seabed Mining Authority, which is an IGO; and the internet has the Internet Engineering Task Force (IETF) and Internet Association for Assigned Names and Numbers (ICANN), among a few others. Each has a slightly different approach which reflects the characteristics and needs of that resource and its stakeholders' interests.

14. *How many Artemis Accord members already have a mineral resource property law mirroring the US Asteroid Mining Act?*

Jessy Kate Schingler: The ones I know about are Luxembourg and Japan, though I am not familiar with each in detail.

Chris Johnson: Yes, as far as I know, just Luxembourg and Japan.

15. *Are Artemis Accord nations that lack such a law planning to implement an enabling legal mechanism in the near term?*

Jessy Kate Schingler: That's unclear, but most likely they will wait and see what the major space actors do.

Chris Johnson: They may be waiting to see what develops at the UN level, or they otherwise waiting for it to be a more urgent matter.

16. *What are some proposed responses to bad actors?*

Jessy Kate Schingler: It depends on the nature of the bad behavior of course, but if the bad actor is a commercial one, then revoking future launch licenses or licenses to operate could be one option. Litigation could be another. Much of contract law we have on Earth would in general extend to the Moon, so we can draw on that as well.

17. *Are there any stakeholders who you feel are not currently represented in conversations about norms?*

Jessy Kate Schingler: Formally speaking, industry is not represented in any of the discussions happening at the UN, though informally they can express their views through observer organizations. Beyond that, there are not really any forums for civil society at large! So there are indeed many voices missing from all walks of life.

Chris Johnson: Non-space experts such as environmentalists, economists, civil society, those who work in international humanitarian work – they all need to be in discussions about space activities. We also need more space scientists, such as planetary scientists and astrobiologists, to be present to inform the work of space lawyers and diplomats who are making decisions on norms for space. The private sector is present, but we need them to continue to participate in discussions at the international level, if possible.

18. *Any recommendations for learning more about Space Law and engaging further (Especially Healthcare Policy)? Professional Societies/conferences/books/podcasts?*

Jessy Kate Schingler: Good question! Following space law folks on twitter is a really great way to follow discussions of current affairs and new articles that are released. [Chris Johnson](#), [Timiebi Aganaba](#), [Brian](#)

Weeden, Victoria Samson, Jessica West, Thomas Cheney, Dr. Cassandra Steer, Daniel Porras, SGACSpaceLaw, Jessica West, European Space Policy Institute, Cris van Eijk, EAGLE Team, Theresa Hitchens, and myself.

There's also [Space News](#) and [The Space Review](#). Organizations of interest might include: Secure World Foundation, Moon Dialogs, ISU, and Open Lunar.

Chris Johnson: There are a few excellent text books on space law, such as the *Space Law – A Treatise*, by Lyall and Larsen (this is what I use to teach with), but first start with reading the five UN treaties on outer space. From there, attending (even virtually) the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), as well as the Colloquium of the International Institute of Space Law (IISL) which is held annually during the International Astronautical Congress (IAC), and reading any papers presented there that sound interesting.

If you are in DC, the annual Galloway Symposium on Critical Issues of Space Law is held each December, at the Cosmos Club in Washington DC. Attendance is free, and this is both a great networking and educational event.

19. *How do you test the legal framework you are setting up? Buy lunar dirt from someone, do something with it, and see if anyone calls “foul”?*

Jessy Kate Schingler: That's one way, yes. But first we are working to develop the framework in conversation and collaboration with stakeholders, to get their buy-in/endorsement for the approach we're taking. We can also collaborate with others developing formal implementations to harmonize approaches, whether they be countries or private operators.