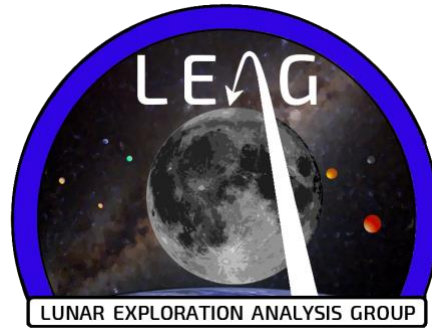


## 2022 ANNUAL MEETING OF THE LUNAR EXPLORATION ANALYSIS GROUP: SUMMARY AND FINDINGS



### FORWARD

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This document contains the finalized findings based on community discussion at the 2022 annual meeting of the Lunar Exploration Analysis Group (LEAG), which was held in a Hybrid format August 23-25, 2022; in-person components were held at the Johns Hopkins University Applied Physics Lab. The LEAG Executive Committee (ExComm), on behalf of the attendees of the meeting, endorse the findings contained within. These findings are grouped into themes and are expanded upon with specific findings and rationale in the following pages.

Findings from the annual meeting evolved as they were developed. *Initial* findings were drafted by members of the LEAG Executive Committee and presented to the community in the last session of the 2022 LEAG Annual Meeting. *Potential* additional findings were compiled during a community discussion period that engaged both in-person and virtual participants. In a closed-door meeting, members of the LEAG ExComm revisited each finding to discuss how to proceed with generating the final, formal findings to submit to NASA and the Planetary Science Advisory Committee (PAC). Based on previous feedback from members of the community the ExComm determined to alter the format for findings compared to previous years such that the final summary document would contain: (I) an **Introduction** that summarizes the meeting and some of the main topics that were raised during discussions; (II) notes of **appreciation and gratitude to NASA** for listening to the community and adapting/responding; and (III) high-level **actionable findings**.

### EXECUTIVE COMMITTEE MEMBERS (AUGUST 2022)

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Amy Fagan	Chair	Western Carolina Univ.
Samuel Lawrence	Emeritus Chair	NASA, Johnson Space Center
Elizabeth Frank	Commercial Advisory Board Chair	Quantum Space
Brett Denevi	Science Chair	Johns Hopkins Univ. Applied Physics Lab.
Benjamin Greenhagen	Deputy Science Chair	Johns Hopkins Univ. Applied Physics Lab.
Kelsey Young	Human Exploration Chair	NASA, Goddard Space Flight Center (GSFC)
Jose Hurtado	Technology Chair	Univ. of Texas, El Paso
Erica Jawin	Operations Chair	Smithsonian Institution
Sarah Valencia	Workforce Development Chair	Univ. of Maryland, College Park/NASA GSFC
Kristen Bennett	Equity, Diversity, and Inclusion Chair	United States Geological Survey
Hannah Sargeant	At-Large Member	Univ. of Central Florida
Alexander Hegedus	Astrophysics Community Liaison	Univ. of Michigan, Ann Arbor

## 2022 ANNUAL MEETING OF THE LUNAR EXPLORATION ANALYSIS GROUP: SUMMARY AND FINDINGS

### I. INTRODUCTION AND SUMMARY OF CROSS-CUTTING MEETING TOPICS IN DISCUSSIONS AND QUESTIONS

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The 2022 Annual LEAG meeting focused on various updates from NASA and the rest of the lunar community, including international representation. The meeting was composed of formal presentations, panels, and ample time for questions and discussion.

Throughout the meeting, there were many oft-repeated topics and ideas, which are described below:

- i. The community expressed excitement that candidate **landing regions for Artemis III** have been selected, that community feedback will be solicited and will be involved in the down-select process. Although there was great enthusiasm for this endeavor, there was some concern about being able to support community involvement without funding lines for time effort, particularly for community members who are “soft-money.”
- ii. When we go to the Moon, we go together as members of various communities in the United States as well as our international colleagues. By following **best practices for diversity, inclusion, and accessibility**, we strengthen our community and the returns on investment. There are three new documents<sup>1</sup> outlining best practices and paths forward as well as workshops and documents being planned to help the community to develop Inclusion Plans. We look forward to seeing how Planetary Science will continue to make progress in these efforts, and we appreciate NASA’s effort to engage and support the community.
- iii. Previous LEAG findings and participation from the community in the Continuous Lunar Orbital Capabilities Specific Action Team (CLOC-SAT) demonstrate strong community support for **continuous orbital capabilities** around the Moon. The community encourages NASA to include orbital assets in the Lunar Discovery and Exploration Program (LDEP) strategy.
- iv. Both science and exploration benefit from a **close coordination between remote observations/measurements** (e.g., from lunar orbit or Earth), **lunar surface observations/measurements**, and **sample analysis** (in situ and in Earth labs). This was reflected in presentations regarding candidate Artemis III landing site regions, PRISM and CLPS updates, ANGSA updates, and CLOC-SAT summary.
- v. **The in situ resource utilization (ISRU) and science communities** should move forward in **tandem (not opposition)**. Best practices for resource utilization have already been established on Earth to ensure responsible use. Guidance from Earth-based practices can enable further coordination between ISRU and Science on the Moon and other destinations in the solar system, in particular coordination between nation states.
- vi. The LEAG community will continue to work to respond to the latest Decadal Survey to facilitate a **“structured approach to setting science goals and measurement objectives at the Moon, led by the lunar science community.”** The first step for identifying the lunar science goals was undertaken through a small-group activity based on Box 22.2 from *Origins, Worlds, and Life*.
- vii. The Moon was featured prominently as an object of scientific merit in the *Origins, Worlds, and Life* Decadal Survey, but some members of the community are wary of how proposed lunar missions (e.g., New Frontiers) will fare due to programmatic balance. If these missions are not selected, there is unease of how to adequately address and implement Decadal-level science objective investigations.
- viii. There are many lessons learned between Lunar Surface Instrument and Technology Payloads (LSITP) and PRISM programs, and yet many community members are not privy to them. There was support for encouragement of **coordination and exchange of lessons learned** between LSITP and PRISM participants with the broader community to better support lunar infrastructure.

### II. NOTES OF APPRECIATION AND GRATITUDE TOWARDS NASA

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The LEAG community acknowledges the continued work that NASA does towards expanding exploration and science opportunities for the Moon. In particular, we express appreciation and gratitude to NASA's Planetary Science Division (PSD) and Exploration Science Strategy Integration Office (ESSIO) for actively listening, engaging, and adapting/responding to community feedback in the following ways since the 2021 Annual Meeting:

- i. A portion of the LEAG 2021 Annual Meeting Finding #2.3 supported “examining pathways to fly Trailblazer earlier than its scheduled launch date.” We acknowledge and appreciate NASA working through hurdles to move **Lunar Trailblazer** onto a rideshare with CLPS.
- ii. Since Fall 2021, LEAG members have encouraged NASA to consider allowing PRISM proposers to include the ideal landing site for their proposed science rather than prescribing the landing site and soliciting science instrument proposals for a single site. We applaud NASA for listening and examining how this change could work for both proposers and commercial partners and for subsequently **allowing PRISM 3 proposers to propose landing sites with their instrument suites**.
- iii. LEAG 2021 Annual Meeting Finding #2.4 encouraged the development of “*a roadmap of future task orders and pathways*” for CLPS providers, “particularly when they involve a new capability such as mobility, surviving the lunar night, sample return, or pre-deployment of surface assets for Artemis III.” Surviving the lunar night has been a capability of interest for LEAG for several years, and a NASA-hosted workshop on this topic was held in conjunction with the 2018 LEAG Annual Meeting. We thank NASA for adding “**survive the lunar night**” as an option to **PRISM 3 proposers and a goal for commercial partners**.
- iv. The LEAG Continuous Lunar Orbital Capabilities Specific Action Team (CLOC-SAT) has examined why orbital capabilities are needed, what the needed measurements are to address science objectives, and how those measurements can be achieved. The CLOC-SAT solicited community engagement through a white paper call, open call for membership in the SAT, and feedback to their report drafts. We appreciate NASA representatives expressing interest and excitement at its forthcoming release and their interest in **using the CLOC-SAT Report** as an input into future orbital strategies.
- v. Prior to releasing a call for proposals to support the Analysis Groups (AGs), NASA actively engaged with the AGs to identify the support needs of each group, including supporting the travel of a number of early career participants. This year marks the first use of those travel funds to help increase the number of in-person early career participants. Numerous participants at the 2022 meeting remarked how wonderful it was to have so many early career participants who likely would not have otherwise been able to attend in-person. We thank NASA for providing these **travel grants** for early career participants, which actively encourage their participation in the AGs.
- vi. NASA released a Request For Information (RFI) for the **Moon to Mars Objectives** to actively solicit comments on the draft objectives. In addition, selected members of the community, including several from the LEAG Executive Committee and commercial partners, were invited to provide additional context and discussion at an in-person workshop. Furthermore, NASA has updated the community on progress at the 2022 LEAG Annual Meeting and did not shy away from displaying some of the critical comments from the community. We appreciate being asked to comment on the objectives and for ESSIO providing evidence that those comments were heard and acted upon.

**III. Actionable Findings from the 2022 Annual Meeting of the Lunar Exploration Analysis Group:**

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1. **LEAG strongly urges NASA to engage the lunar community actively and continually in the development of the *Integrated Lunar Strategy* through a variety of means.** At the November 2021 meeting of the Planetary Science Advisory Committee (PAC), LEAG presented an action request for “the development of a broad lunar science and exploration strategy with clear hierarchy/authority....” In addition, the development of a “strategic lunar program” was recommended by the *Origins, Worlds, and Life* Decadal Survey to “achieve decadal-level science goals at the Moon.” We applaud PSD for taking action on these requests and for actively working to develop an integrated strategy. LEAG stands ready to facilitate active community involvement in its development and strongly urges the Planetary Science Division to rapidly form a community working group (such as a specific action team) to aid in the development of this *Strategy*; such a group would be akin to the current involvement of the Mars community in the development of a ten-year strategy through the Mars Concurrent Exploration Science Analysis Group ([MCE-SAG](#)). In addition to having active participation from various stakeholders in the lunar community (e.g., government, academia, commercial), we encourage NASA to provide periodic updates to the entire community as the *Strategy* is developed, including communicating the scope of the strategy and how the broader community can provide feedback during its continued development and evolution.
2. **LEAG renews its emphasis on the scientific importance of the collection and return to Earth of samples from the South Pole Aiken basin (SPA) to address a long-standing top priority for lunar and planetary science, and we encourage NASA to continue to explore and openly communicate options for implementation.** Despite the continued recognition of the importance of this sample collection and analysis, a mission to accomplish this has not yet been selected through New Frontiers. The recent *Origins, Worlds, and Life* Decadal Survey identified a new mechanism to accomplishing SPA sample return through the Endurance mission concept, which was the highest rated mission in the Survey. We strongly encourage NASA to actively involve the planetary science community as it considers how best to implement the Endurance concept. In addition, we urge regular updates to the community regarding study results of budget, implementation options, and timeline. We look forward to seeing how the out-of-the-box thinking of the Endurance mission will finally begin to address this priority and we eagerly await news of the mission development.
3. **The LEAG Commercial Advisory Board (CAB) encourages continued engagement with the Commercial Lunar Payload Service (CLPS) providers to (1) develop long-term capability plans and (2) open pathways for long-lived presence on the lunar surface.** The CAB continues to support several findings from the 2021 annual LEAG meeting (e.g., 2.4, 2.6) that endorsed the development of a CLPS capabilities roadmap to allow for development time of the necessary technologies and to enable the community to address long-standing science objectives. The Exploration Systems Science Integration Office (ESSIO) and the CLPS Program Office should actively work with CLPS providers to develop a technology roadmap that evolves CLPS capabilities to advance science and exploration objectives prioritized by the lunar community. Such capabilities may include sample return, mobility, surviving the lunar night, or long-term surface assets. We note that, although nuclear power on the lunar surface is enabling for lunar surface operations, commercial use of nuclear power is currently hamstrung by a complex regulatory environment. NASA should work with CLPS providers and other partners with appropriate regulatory authorities to develop a pathway for commercial delivery of nuclear-powered payloads to the lunar surface.

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4. **LEAG encourages NASA to clearly convey its plan for sustainable post-Artemis III exploration to the community forthwith and include specifically how it will result in an increase in the flight rate and extended human surface durations (i.e., Artemis Base Camp).** Artemis will not be truly sustainable unless it includes a robust surface infrastructure and development strategy at a single location on the Moon to catalyze and enable commercial and exploration activities. Progress to date on the Artemis III mission is encouraging, but details of the “sustained” phase of the Artemis campaign are nebulous to the broader community. Current plans suggest a roughly annual cadence of missions of short (<30 days) duration on the surface of the Moon with an emphasis on future mobility (i.e., not for Artemis III), but this does not adequately address the goals set forth in the Lunar Exploration Roadmap. Accordingly, LEAG urges NASA to articulate plans to enable the construction of the Artemis Base Camp and establishment of large-scale resource production by 2030, thereby supporting a permanent human presence on the lunar surface and growth of a vigorous cislunar economy.
5. **LEAG encourages the establishment of a joint Specific Action Team with the Extraterrestrial Materials Analysis Group (ExMAG) to examine the needs for persistent and sustainable lunar sample return through human and robotic exploration.** Sample return is a critical pathway for addressing high-priority lunar and planetary science goals such as those identified in the current and past Decadal Surveys as well as other key community documents (e.g., 2007 NAC report, “Scientific Context for Exploration of the Moon;” US Lunar Exploration Roadmap; etc.). As we move towards a renewed era of lunar surface exploration through a variety of endeavors (e.g., Artemis; Commercial Lunar Payload Services), we expect an upcoming influx of scientifically priceless material returned to Earth, and the sample community (and their laboratory facilities) must be prepared to properly curate and analyze these samples. The 2019 “Strategic Investments in Instrumentation and Facilities for Extraterrestrial Sample Curation and Analysis” report (National Academies Press) expressed concern about the future of sample return missions with a number of older facilities in need of updating and a need for investing in new personnel. A joint LEAG-ExMAG sample-return activity could examine and review a multitude of topics including, but not limited to: (1) current state of sample-return science objectives; (2) highest priority sample-return materials and landing sites of interest to the community; (3) implementation and infrastructure approaches for sample-return (e.g., human and/or robotic); (4) Earth-based curation of materials to ensure maximum pristinity for future generations; (5) Earth-based analysis approaches and technological development needs; and (6) Earth-based analytical facility and personnel needs to ensure a strong lunar sample infrastructure.
6. **LEAG encourages the establishment of a joint Specific Action Team with the Mapping and Planetary Spatial Infrastructure Team (MAPSIT) to re-examine dataset management and archiving approaches as well as the suitability of existing data infrastructures.** For over a decade, the vast majority of lunar data collected and publicly archived has been managed by the LRO project and LRO instruments. As numerous new instruments begin to collect data from lunar orbit and surface, the architectures in place need to be reevaluated to ensure resiliencies to support these less-centralized efforts. In addition to traditional, PI-led investigation teams, commercial providers are also collecting valuable datasets that should be archived and available for use by the community. Furthermore, with renewed human exploration of the Moon’s surface, new datasets collected at rates and with volumes orders of magnitudes larger than robotic exploration may be realized. It is essential that agreements be reached between all stakeholders to ensure public access to these data and the tools required to analyze them. A joint activity between LEAG and MAPSIT could be established to identify: (1) the expected spikes and shoulders in returned data volumes over the next decade and infrastructure for the return of data (e.g., downlink capabilities); (2) hurdles to different stakeholders (e.g., science/investigation teams, commercial providers, human exploration) to archiving data and tools; (3) potential standards for data formats and metadata for a wide range of data types; and (4) new tools and software that may be required to support different types of future data sets.

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<sup>i</sup> National Academies of Sciences, Engineering, and Medicine. (2022) *Origins, Worlds, Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*. Washington, DC: The National Academies Press.  
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