

## **Findings from the 2019 Annual Meeting of the Lunar Exploration Analysis Group**

Final, 19 December 2019

### **A. Artemis**

**To:** HEOMD, SMD, STMD

LEAG applauds the first steps that NASA has made in returning humans to the surface of the Moon after a nearly 50-year absence. The 2024 target date is providing urgency and guiding near-term investment and precursor mission strategies. The LEAG community is ready to participate and provide input during the planned April 2020 surface science workshop

**Finding 1.** NASA should seek to maximize the lunar sample mass to be returned by Artemis 3, to bring the current requirement of 26 kg of returned samples (35 kg total, including sample containers) more in line with the recommendations from the 2010 CAPTEM-LEAG “[Review of Sample Acquisition and Curation During Lunar Surface Activities](#)” analysis document (which recommended a minimum returned sample mass allocation of 250-300 kg, including sample containers). If the architecture does not allow for this magnitude of returned sample mass, a greater emphasis must be placed on defining what investigations the returned samples will be prioritized for, and on providing astronauts the tools and training needed for smart sample selection to enable these investigations.

**Finding 2.** A permanent presence on the lunar surface has immense societal, scientific, commercial, and exploration value in its own right. Accordingly, LEAG strongly supports Phase 2 of the Artemis program, specifically the sustainable surface presence by 2028, and encourages NASA to maintain the urgency of Phase 1 in developing a lunar surface presence that will achieve the goals of the Lunar Exploration Roadmap in terms of science, sustainability, permanence, and feed-forward to other destinations.

### **B. Lunar Resource Exploration Strategy**

**To:** HEOMD, SMD, STMD

Orbital reconnaissance and the LCROSS experiment have provided initial information on the abundance and distribution of water ice reservoirs in lunar polar regions. Determining whether water ice constitutes a reserve that can enable in-situ resource utilization (ISRU) will require development of a strategy for resource exploration (also known as resource prospecting). Critical

knowledge gaps include the vertical distribution of ice (in particular, the relationship between surface ice and deeper buried ice), extent or patchiness of water ice within a region that is of a scale relevant to ISRU operations, local water abundance (desired to be known to a few percent at locations of interest), and the geotechnical properties of the regolith-ice mixture to be excavated (see LEAG Volatiles [SAT reports](#)). Additionally, there are significant quantities of useful resources beyond the lunar polar regions, including the lunar regolith and regional pyroclastic deposits. In order to advance to the point where utilizing off-planet resources is an integral and enabling component of human exploration of the Solar System, a campaign built on the example of terrestrial resource exploration is required.

**Finding 3.** A set of realistic goals and objectives is needed for a resource prospecting campaign and ISRU demonstration. NASA should work with the community to develop such goals and objectives. Recognizing the importance of ISRU to a sustainable program of human space exploration, the LEAG community is eager to provide its assistance.

### **C. Science and Exploration Strategy of the Moon**

**To:** HEOMD, SMD, STMD

LEAG enthusiastically commends the myriad of opportunities for science enabled by the Lunar Discovery and Exploration Program (LDEP), the Commercial Lunar Payload Services (CLPS) program, continued operations of the Lunar Reconnaissance Orbiter, SIMPLEX opportunities, and the Lunar Surface Innovation Initiative. As these programs mature, they represent a strategic opportunity to accomplish high-priority science beyond what would be possible from a single mission. Although a “Science Strategy of the Moon” document has not yet been released by NASA, nor has a draft been widely circulated, development of such a strategy is critical, and will require close planning and cooperation across mission directorates if robust progress is to be made in achieving the consensus lunar science priorities that have been described and reaffirmed in community documents (Decadal Survey, The Scientific Context for Exploration of the Moon, Advancing Science of the Moon, Lunar Exploration Roadmap). LEAG appreciates hearing about the STMD Lunar Surface Innovation initiative, and stands ready to engage and proactively facilitate its success.

**Finding 4.** LEAG urges NASA to ensure that the potential to achieve high-priority planetary science and exploration objectives is fully realized by leveraging all lunar mission opportunities as part of a well-defined, coherent strategic vision. For example, as currently formulated, the CubeSat payloads for Artemis 2 are provider-funded and advance no strategic objectives; the lack of NASA-funded, lunar-focused payloads on Artemis 2 is a missed opportunity to enhance the advance knowledge of the south polar region prior to human landing.

**Finding 5.** LEAG strongly supports the CLPS program and, as it matures, task orders that require capabilities such as mobility and sample return. In many cases, rovers substantially expand the scope of science investigations possible, and many high-priority lunar science objectives are best addressed by sample return. Note also, that as part of a broad lunar science strategy, such capabilities could help alleviate the sample return mass limitations identified in Finding 1, as well as dramatically broaden geographic opportunities for sample return beyond the limited locations of human missions.

#### **D. New Frontiers 5**

**To:** SMD

LEAG reiterates the importance of using the decadal survey process to identify science priorities that should be addressed within the New Frontiers program. This process is the best route for building community consensus for large, high-priority PI-led missions. Any changes to the New Frontiers target list should be made via a formal, community-focused process, as recommended in the Planetary Decadal Midterm Review. NF5 is nominally scheduled to include a lunar geophysical network, and LEAG affirms the importance of such a mission for lunar and Solar System science, as articulated in the Lunar Exploration roadmap. LEAG reaffirms the high priority of the science goals for South Pole-Aitken basin Sample Return (SPA-SR), which would provide insight into Solar-System-wide bombardment, the conditions under which life emerged on Earth, and the lunar interior. Though the important nature of the science goals of SPA-SR have been reiterated in the last two decadal surveys, such a mission has not yet been selected. In the interim, multiple lunar orbital missions have provided a wealth of data that suggest SPA is not the only location on the Moon where these science goals could be addressed. In comparison to other New Frontiers targets that led to selected missions (e.g., Jupiter Polar Orbiter with Probes, Ocean Worlds), the mission implementation for SPA-SR that is laid out in the decadal is unduly restrictive.

**Finding 6.** LEAG recommends that more flexibility in implementation of the science goals of the SPA-SR mission be permitted for New Frontiers 5. Allowing proposals for missions that address the science goals of SPA-SR using different approaches and different targets would take advantage of both recent advances in science from numerous orbital datasets and creative implementation solutions that may emerge from the planetary science community.

## **E. Diverse Teams and Leadership**

**To:** HEOMD, SMD, STMD

NASA serves the nation and the US taxpayers. The planetary science community has taken steps to incentivize teams to take advantage of the full spectrum of workers to help teams better reflect the makeup of the nation across the spectrum of gender, race, sexual orientation, disability, career stage, etc. Diverse teams can be stronger and generate better solutions than their less diverse counterparts. Sustainability in space exploration involves more than technology and science, it also means involving the nation in a meaningful way during planning and execution.

**Finding 7.** The representatives of the commercial teams and the senior NASA leadership stand in sharp contrast to the more diverse lunar science community (which itself continues to strive to achieve full equality). LEAG encourages our leadership and our partners to take concrete steps in hiring and promotion to harness all of the nation's talent to achieve great goals.

## **F. Long-Term Lunar Exploration and Utilization**

**To:** HEOMD, SMD, STMD

At the 6th meeting of the National Space Council, the following recommendation was adopted:

"Within 60 days, the National Aeronautics and Space Administration (NASA) Administrator will designate an office and submit a plan to the Chairman of the National Space Council for sustainable lunar surface exploration and development, including necessary technologies and capabilities, to enable initial human missions to Mars."

A plan for sustainable lunar surface exploration that will feed-forward to Mars is of great importance for the future of the Artemis program. LEAG has developed a comprehensive strategy to accomplish precisely these objectives, described in the community-based [Lunar Exploration Roadmap](#), originally developed at the behest of the NASA Advisory Council and updated most recently in 2016.

**Finding 8.** The LEAG community has significant and unique domain expertise in establishing goals and objectives for sustainable lunar exploration that feed-forward to exploration of other destinations (including small bodies and Mars), and can make considerable contributions to the plan requested by the National Space Council if given the opportunity. LEAG therefore requests the opportunity to provide input into the plan, and also stands ready to contribute to other strategic plans that NASA may require in the future.