

# Lunar Exploration Analysis Group 2018 Annual Meeting Report

*1 October 2019*

The 2018 Annual Meeting of the Lunar Exploration Analysis Group occurred on November 14 and 15 at the Headquarters of the Universities Space Research Association in Columbia, MD. With almost 300 attendees, this was the most highly attended LEAG meeting in history and featured a robust set of discussions regarding the next steps on the Moon. The population that attended LEAG 2018 included participants from a diverse set of backgrounds: commercial entities, engineers (e.g., civil, aerospace, mining, extravehicular activity), policymakers, and scientists from a broad variety of disciplines (astronomy, astrophysics, biology, physics, planetary science, geology, economic geology, and materials science, to name a few). The clear excitement about the long-overdue return of the Moon to the forefront of United States exploration planning permeated the meeting.



*LEAG Chair Dr. Samuel Lawrence opens LEAG 2018 with a tribute to Dr. Paul Spudis.*

## 2018 Community Findings

As part of the LEAG Annual Meeting, the entire assembled LEAG community generates community consensus findings. These are developed interactively in real-time at the meeting by the entire LEAG community, then edited for grammar and content by the Executive Committee, and reproduced below.

### Finding: SMD has made impressive progress implementing PSPD-1

Following briefings from SMD Deputy Associate Administrator for Exploration Steven Clarke, **it is clear that SMD has made concrete, impressive progress in organizing and leading the way towards near-term missions to the lunar surface through the Lunar Discovery and Exploration Program.**

A productive, collaborative, teamwork-based approach between industry, academia, and government is required to ensure the success of the National Exploration Campaign, and we deeply appreciate DAA Clarke's active participation in the entire meeting and willingness to constructively engage with the community.

### Finding: We Need to Continue Enabling the Cislunar Economy

**The LEAG community is encouraged by the quantity of commercial landers and proposed payloads, which provide evidence of a growing ecosystem for Moon exploration, commerce, and science.** LEAG strongly supports the Commercial Lunar Payload Services program as a way to increase competition, drive down costs, provide flight opportunities for multiple payloads, increase the diversity of our field, and define a bold new paradigm of conducting planetary science research in this country. LEAG strongly supports the continuing selection of instruments and technology development efforts as part of the National Exploration Campaign, and the development of future instruments through the LSITP and DALI programs.

### Finding: We Need to Enable the Objectives of the Lunar Exploration Roadmap

The LEAG Lunar Exploration Roadmap (LER) is a broad-based, community priorities document that clearly reflects the integrated science, exploration, and commercial goals of the

community. The US-LER will be used to judge how well United States lunar exploration activities meet the needs of the community. However, at the present time, the relationship between the SMD-led Lunar Discovery and Exploration Program, STMD-led space resource utilization efforts, and HEOMD-led cislunar activities is not clear, nor is it clear how these programs will interact to enable the implementation of the LER. **As called for in the [2017 LEAG Back to the Moon workshop consensus findings](#), NASA Headquarters should consider an integrated program office or mission directorate solely focused on optimizing lunar exploration activities to promote a robust lunar exploration enterprise, grow the cislunar economy, and achieve LER objectives.** NASA should establish clear timelines, goals, and objectives for the entirety of the lunar exploration program, based on the Lunar Exploration Roadmap, including a clear statement of the roles of commercial and international partners and a timetable for reaching the surface for resource exploration and utilization.

## Finding: The Human Architecture Must Enable A Robust Continuum of Surface Activities

As presented on 14 November 2018 at the LEAG meeting by HEOMD Advanced Exploration Systems director Jason Crusan, it was noted that the programmatic emphasis of the nascent human lunar program remains the proposed Lunar Orbital Platform-Gateway (LOP-G, previously known as the Deep Space Gateway, also variously referred to in other contexts as the Lunar Gateway, or occasionally simply the Gateway). The outcomes of the [Denver Gateway utilization workshop](#) which were presented at the 2018 Lunar and Planetary Science Conference, tend to indicate that the Gateway will only have a limited role in enabling lunar surface exploration. The community understands that the plans for the proposed Gateway and associated lunar surface access architectural elements continue to evolve. **However, a coordinated investment strategy, including surface power systems, surface landing systems, stationary habitation systems, stationary ISRU production facilities, mobility systems, and surface cryogenics fluid management systems are also required to fully enable lunar exploration and provide the most value to the American people.** A permanent presence on the lunar surface **has immense societal, scientific, commercial, and Exploration value in its own right.**

## Finding: Preparing for the Next Decadal Surveys

**The Moon offers immense and profound value to Solar System science irrespective of activities relating to human lunar missions.** Pre-Decadal studies of lunar missions are required to objectively assess the feasibility of lunar science missions. At LEAG 2018, 27 cubesat, smallsat, Discovery, and New Frontiers with compelling Planetary Decadal level science objectives, were presented in the “Preparing for the next Decadal Surveys” community forum.

LEAG will help facilitate a strong lunar community response to the open solicitation for the Decadal New Frontiers and Flagship-mission planetary mission concept call.

## Finding: Support for the Astronomy and Astrophysics Decadal Process

LEAG also strongly supports concepts for astronomical observations from the Moon, leveraging the unique opportunities of the Moon as a platform. Several compelling mission concepts were discussed in the LEAG “Preparing for the Next Decadal Surveys” community forum. The LEAG community stands ready to support its astrophysical members as the Astro2020 Decadal process proceeds. Relevant Astro2020 white papers will be hosted on the LEAG website to promote widespread dissemination.

## Finding: Atmospheres for Human Exploration

As demonstrated by the Apollo Program, scientifically productive human lunar exploration is dependent on conducting frequent surface extravehicular activities (EVAs). The present atmospheric gas mix and pressure on ISS, 14.7 psi with  $\approx 20\%$  oxygen and  $\approx 80\%$  nitrogen, makes EVA dependent on extensive, multi-hour prebreathe protocols to reduce the risk of decompression sickness to an acceptable level. Propagation of such an atmosphere forward to the lunar surface would significantly reduce the amount of exploration EVA time leading to greatly restricted science return from the lunar surface, and would greatly diminish the benefits of bringing human crew members on the Moon. **LEAG supports the decision to include the appropriate exploration atmosphere composition and operating pressure in the Vehicle Interoperability Standards. LEAG further urges HEOMD to ensure that the designs of all systems planned for the lunar surface, including human landers, habitats, EVA pressure garments and pressurized rovers, adopt requirements to ensure that EVAs have limited prebreathe times and high work efficiency indices.**

## Finding: Workforce Development

**Diverse mission teams offer critical advantages to the NASA workforce and the nation.** As the lunar program unfolds, the LEAG community is strongly committed to diversity and ensuring broad participation from all facets of the lunar community. LEAG strongly supports the formation of diverse teams as called for in recent Announcement of Opportunities.

## Finding: Role of Orbital Assets in the National Exploration Campaign

LRO observations of the Chang'e-3 and Chang'e-4 landings and surface operations, along with the support MRO and Odyssey have provided to various Mars assets, highlight the operational support role that can be played by spacecraft like LRO in low-lunar orbit. The LEAG ASM-SAT report also highlighted that there are new science measurements that can be made with orbital assets. As the scope of lunar surface activities for science, exploration, and commerce increases during the National Exploration Campaign, consideration should be given towards leveraging the CLPS program and model to provide long-lived support capabilities in low lunar orbit, such as radio relays, and as platforms for science.

## Finding: Medium-class landers are mission-enabling

There was strong support expressed by the community for long-duration, MER or MSL-class rovers to explore high-priority lunar science questions and conduct resource exploration. There are other payloads (e.g., the proposed Kilopower system, various ISRU pilot plants, sample return missions) which could also leverage the capabilities of these medium-class landers. These types of payloads require larger landers than those presently envisioned as a near-term part of the CLPS program. **As the Lunar Discovery and Exploration Program continues, LEAG urges that medium-class landers capable of delivering 500-1000 kg to the surface be part of the National Exploration Campaign to be eventually included in the CLPS program.**

## Finding: We Must Explore and Utilize the Moon's Resources

The access and utilization of lunar resources are a key component of any future space exploration efforts in cislunar space and beyond. Desirable features of systems designed for human lunar exploration include reusability as well as extended surface presence, and both of these characteristics will benefit immensely from the use of lunar resources from the beginning. Results from the Apollo missions, coupled with results from recent missions, indicate that the resource potential of the Moon is vast, with substantial ore deposits known to be present in lunar pyroclastic deposits and the possibility of economically viable volatile deposits at the poles. While the concepts of lunar resource utilization are fairly well-developed for lunar pyroclastic deposits and Ti-rich mare basalts, more detailed information of the resource feedstock (composition, state, physical properties, and concentrations) is needed to finalize the design of the processing chain for the polar volatile deposits. Additional studies and flight demonstrations of ISRU technologies at polar and nonpolar locations are needed to mature

lunar resource utilization. **LEAG finds that a mission with equivalent goals and objectives to the former Resource Prospector mission should be flown as soon as possible as a first step towards exploring and fully leveraging a robust US-led cislunar economy.**

## Finding: Continue support for lunar participating scientist programs

LEAG strongly supports the upcoming Participating Scientist program for the Korean Lunar Pathfinder Orbiter, and we encourage NASA to facilitate similar participating scientist opportunities for future lunar missions.

## Finding: The Importance of International Collaboration

LEAG strongly supports international collaboration in lunar exploration, as exemplified by US participation in the KPLO mission, and encourages continuing efforts to promote international participation in international partner lunar missions.