LEAG CONTENT SUMMARY
PUBLIC-PRIVATE PARTNERSHIPS AND LUNAR EXPLORATION

Lunar science is in a paradigm of rapid discovery and thorough analysis owing to the renewed international robotic exploration of the Moon begun the mid-1990s with the Clementine mission and continuing with 10 more missions in the past decade. Compelling science questions that are profoundly impactful for understanding the entire Solar System are captured in community road-mapping documents (e.g., *The Scientific Context for the Exploration of the Moon*, 2007). As highlighted by recent LEAG strategic planning activities, these questions include, but are not limited to:

- Measuring the absolute ages of lunar geologic units, used to calibrate the entire chronology of the Solar System;
- Quantifying lunar volatile content, form, and distribution;
- Understanding the structure of the lunar interior;
- Characterizing the formation of magnetic anomalies;
- Identifying planetary volcanic processes: styles, histories, locations;
- Relating the time-stratigraphy of basin-forming impacts;
- Assessing the best ways of using the Moon's vast resource potential;
- Determining the effects of interactions between surface material and the space environment as the type example of space weathering on airless bodies.
- Using the surface of the Moon as a platform for observations, such as low-radio frequency cosmology investigations from assets emplaced on the farside.

There are numerous options for lunar missions as part of a focused lunar exploration program to address these and the other questions highlighted in the recent *Advancing Science of the Moon (2018)* report that would provide measurements to make dramatic, paradigm-shifting advances in planetary science. These can be accomplished using both dedicated missions and hosted payloads to the lunar surface.

The LEAG community has issued numerous findings consistent with the opportunities provided by the SMD-led NASA Lunar Discovery and Exploration Program, which offers new possibilities to achieve lunar science objectives with missions executed in concert with the existing NASA New Frontiers and Discovery mission lines and the research-supporting programs of the Solar System Exploration Research Virtual Institute (SSERVI) and Lunar Data Analysis Program (LDAP). The Lunar Discovery and Exploration Program involves public-private partnerships in pursuit of focused missions to achieve Decadal science priorities and address Strategic Knowledge Gaps for extended human habitation of the Moon. This approach is therefore broadly consistent with the outcomes of the LEAG *Advancing Science of the Moon (2018)* report, the 2017 LEAG *Next Steps on the Moon* Specific Action Team, the 2017 LEAG *Back to the Moon* report, the 2016 *Strategic Knowledge Gaps 2: The "Moon First" Human Exploration Scenario*, and the consensus community Findings from the 2014, 2015, 2016, and 2017 LEAG Annual Meetings (reproduced below).

As stated in the recent *Advancing Science of the Moon* report, the Moon is a resource-rich, readily accessible target for future United States human and robotic missions that will enable fundamental scientific advances impacting our understanding of the Solar System. The large and growing community LEAG represents is looking forward to restoring US access to the lunar surface to continue achieving the goals set forth in the Lunar Exploration Roadmap.

ABOUT THE LUNAR EXPLORATION ANALYSIS GROUP

The Lunar Exploration Analysis Group (LEAG) (https://www.lpi.usra.edu/leag/) was established in 2004 to support NASA in providing analysis of scientific, commercial, technical, and operational issues to further lunar exploration objectives. LEAG was jointly established by the Science Mission Directorate (SMD) and the Human Exploration and Operations Mission Directorate (HEOMD) and blends members of both communities, building bridges between science, exploration, and commerce whenever and however possible. LEAG is led by a Chair and a Vice-Chair who serve as the principal representatives of the United States lunar exploration community to stakeholders, including NASA and the international community. LEAG has a standing Commercial Advisory Board (CAB) to offer programmatic insights into the capabilities provided by industry. LEAG is a community-based, volunteer-driven, interdisciplinary forum. Membership is open to all members of the lunar exploration community and consists of lunar and planetary scientists, life scientists, engineers, technologists, human system specialists, mission designers, managers, policymakers, and other aerospace professionals from government, academia, and the commercial sector.

ABOUT THE LUNAR EXPLORATION ROADMAP

The LEAG Lunar Exploration Roadmap (LER) is the cohesive strategic plan for using the Moon and its resources to enable the exploration of all other destinations within the Solar System by leveraging affordable investments in lunar infrastructure. Created at the request of the NASA Advisory Council, the LER is a living document developed over four years through a comprehensive community-based process and was first released in 2012. The roadmap lays out a sustainable plan for Solar System exploration that allows NASA to use its lunar surface infrastructure to explore small bodies, Mars, and beyond. Following the LER will enable commercial development, through early identification of commercial opportunities that will create wealth and jobs to offset the initial investment of the taxpayer. The roadmap will also, with careful planning, enable international cooperation to expand our scientific and economic spheres of influence while enabling an expansion of human and robotic space exploration. The Roadmap is located at: https://www.lpi.usra.edu/leag/roadmap/ and the implementation plan is located at: https://www.lpi.usra.edu/leag/reports/RoboticAnalysisLetter.pdf

RELEVANT LEAG COMMUNITY FINDINGS

From the 2018 *Advancing Science on the Moon* Report:

"Despite a decade of progress, profoundly important and compelling science questions remain that require new missions to the surface of the Moon to be addressed. But that is the nature of exploration: the more we explore, the more questions we have to answer. The objectives and goals developed in the 2007 NRC Report on the Scientific Context for the Exploration of the Moon, which established that exploring the Moon would enable quantum leaps in our understanding of fundamental Solar System processes, are wholly relevant today. The ASM-SAT deliberations demonstrated that the 2007 NRC report is still the benchmark describing the scientific importance and rationale for exploring the Moon in the 21st century, but also highlighted exciting new questions for further investigation. Addressing all of these questions requires a robust lunar exploration program that takes advantages of new technologies and commercial paradigms to produce a regular cadence of landed missions – and profound new discoveries."

From the 2017 LEAG *Next Steps on the Moon* Specific Action Team report:

- **FINDING: NEXT-SAT references the Finding 3 arising from the 2017 LEAG Commercial Advisory Board meeting. Commercial entities should be employed to the fullest practical extent to increase competition, decrease costs, and increase the flight rate.**
    - "In addition to paying for payload flights, NASA should strongly consider buying transportation services, samples, and/or data. In order for this to succeed, the nature of the samples/data required must be adequately specified."
- **FINDING: There are <u>numerous</u> potential opportunities for commercial services, with NASA as a customer, to play a role in lunar surface exploration. Commercial opportunities include, but are not limited to:**
    - Providing communications relay services to enable far side and polar missions
    - Commercial surface delivery services
    - Dedicated sample return missions
    - Rover recharging base station providing communications, power, and other utilities to surface assets

From the 2017 Annual Meeting of the Lunar Exploration Analysis Group

Finding: The LEAG Community supports international lunar prospecting missions and encourages HEOMD to enhance collaborations with STMD and SMD and to develop public-private partnerships to enhance lunar resource prospecting of multiple locations, as well as access to such resources and their utilization.

From the 2017 Annual Meeting of the Lunar Exploration Analysis Group (cont.)

Finding: Near-term milestones are required to show progress toward "*return[ing] American astronauts to the Moon, not only to leave behind footprints and flags, but to build the foundation we need to send Americans to Mars and beyond*" by developing a robust lunar economy. In keeping with the LEAG Lunar Exploration Roadmap, the LEAG community suggests the following milestones to enable the Nation's new strategic direction.

1-2 Years

- Demonstrate NASA's ability to deliver cargo- and crew-capable infrastructure via SLS to cislunar space.
- Commercial sector demonstrates lunar access capability.
- NASA procures payload opportunities on commercial and international missions (i.e., procures commercial lunar missions services **and** funds selected science/exploration instruments to ride on them).
- NASA calls for PPP(s) and international partnerships for the establishment of infrastructure to enable surface access and navigation.
- Procurement of independent economic studies of the impact of ISRU on sustaining a permanent human presence on the Moon and growing the Lunar Economy.

3-5 years:

- Commercial sector demonstrates lunar surface access and return to Earth capability.
- ISRU technology validation on the lunar surface.
- Deployment of robotic prospecting explorers to the Moon
- Develop experiments to use existing samples to promote and develop ISRU technologies

5-10 years

- Development of ISRU pilot plants and fuel depots.
- Continued missions to the lunar surface for exploration and science
- Human Lunar Landings

From the 2016 Annual Meeting of the Lunar Exploration Analysis Group:

Finding: Exploration on the lunar surface of the upper few meters of regolith in volatile-rich regions around the lunar poles is critical for science, exploration, and developing lunar commercial opportunities and public-private private partnerships. Such ground-truth is necessary for truly quantifying the amount, form, composition, and accessibility of such resources.

From the 2014 Annual Meeting of the Lunar Exploration Analysis Group:

Finding: Momentum gained with recent lunar missions (LRO, LCROSS, LADEE, GRAIL, ARTEMIS) feed forward into key NASA science and exploration goals and horizons. It is critical that this pace of discovery be maintained to support our international partners, feed-forward technology, and operational developments for future crewed missions to Mars. A key finding from the 2014 LEAG meeting is that SMD and HEOMD, maintain a sustained program of lunar missions (e.g., Discovery; New Frontiers through SPA Sample Return & Lunar Geophysical Network; directed missions, etc.) focused on addressing key science, resource, and technology development issues in line with the decadal survey and to support long-term NASA goals.

From the 2015 Annual Meeting of the Lunar Exploration Analysis Group:

Finding: LEAG's CAB is in unanimous agreement in its finding that the NASA Lunar CATALYST program and future public-private-partnerships of its kind are worthy of support and advocacy. Such support, strategically communicated to NASA and political leaders, could open new pathways for more frequent and affordable lunar science and exploration mission opportunities. In turn, these public-private partnerships demonstrate the U.S. government's leadership and support for commercial space exploration bolstering investment potential and broadening customer base. Lunar CATALYST, in particular, builds on the progress of NASA's partnerships with the U.S. commercial space industry and has been instrumental in providing commercial partners access to key support and resources to help achieve their lunar goals.

RELEVANT LEAG DOCUMENTS

Advancing Science of the Moon Report:
https://www.lpi.usra.edu/leag/reports/ASM-SAT-Report-final.pdf

Next Steps on the Moon Report:
https://www.lpi.usra.edu/leag/reports/NEXT_SAT_REPORT%20(1).pdf

LEAG 2017 Commercial Advisory Board meeting Findings:
https://www.lpi.usra.edu/leag/Back2MoonWorkshopExecSummary.pdf

Findings of the 2017 LEAG Annual meeting:
https://www.hou.usra.edu/meetings/leag2017/Meeting-Findings.pdf

Report of the 2017 LEAG Back to the Moon Workshop:
https://www.hou.usra.edu/meetings/leag2017/B2M_Report_Final.pdf

Report of the 2016 LEAG Specific Action Team Strategic Knowledge Gaps 2: The "Moon First" Human Exploration Scenario.
https://www.nasa.gov/exploration/library/skg.html