

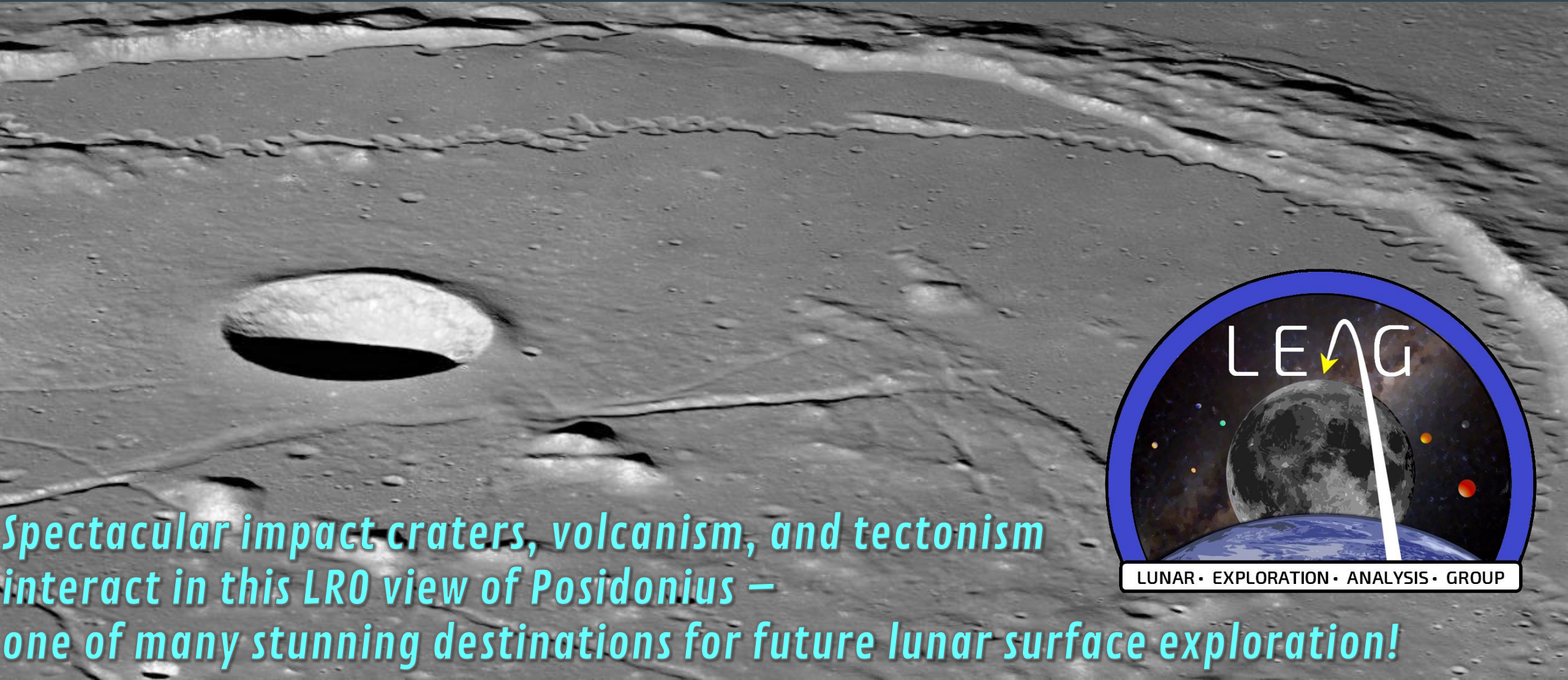
# 2017 ANNUAL MEETING OF THE LUNAR EXPLORATION ANALYSIS GROUP

CONSENSUS MEETING FINDINGS

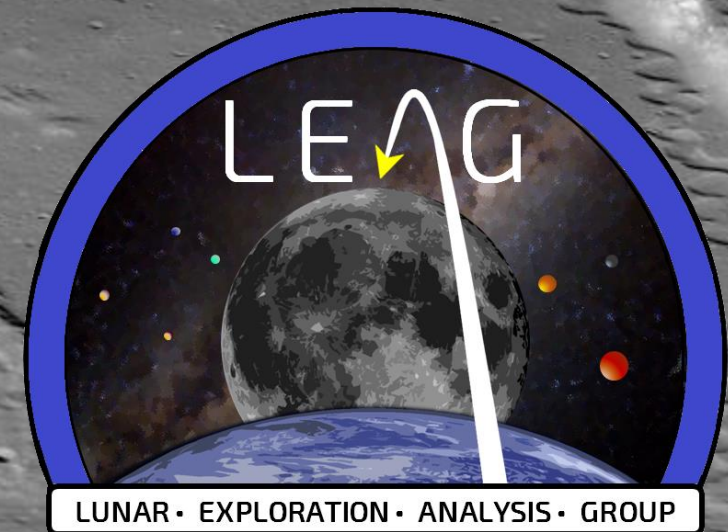
10-12 OCTOBER 2017

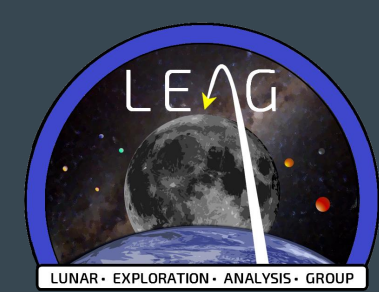
USRA HEADQUARTERS

COLUMBIA, MD, USA



*Spectacular impact craters, volcanism, and tectonism interact in this LRO view of Posidonius – one of many stunning destinations for future lunar surface exploration!*





# LEAG: REPRESENTING A LARGE VIBRANT COMMUNITY

The Lunar Exploration Analysis Group (LEAG) was established in 2004 to support NASA in providing analysis of scientific, commercial, technical, and operational issues in support of lunar exploration objectives, as well as their implications for lunar architecture planning and activity prioritization.

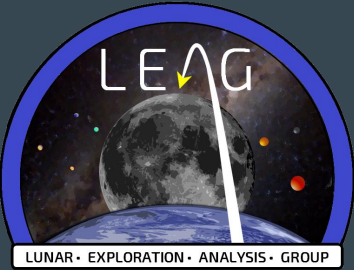
LEAG is jointly chartered by the Science Mission Directorate (SMD) and the Human Exploration and Operations Mission Directorate (HEOMD) and blends members of both communities, building bridges and synergies between science, exploration, and commerce whenever and however possible. LEAG has a standing Commercial Advisory Board 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.



# EXECUTIVE COMMITTEE of the LUNAR EXPLORATION ANALYSIS GROUP

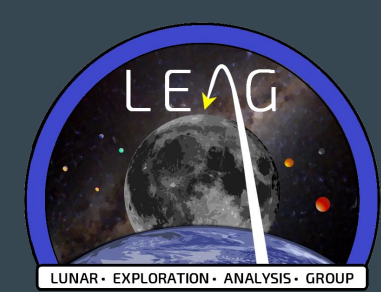
- Chair: Dr. Clive Neal, University of Notre Dame
  - Vice-Chair: Dr. Samuel Lawrence, NASA Johnson Space Center (Becomes Chair, March 2018)
  - Past Chair: Dr. Jeff Plescia, JHUAPL
  - Volatiles Chair: Dr. Dana Hurley, JHUAPL
  - NGLSE Rep: Dr. Ryan Clegg-Watkins, Washington University in St. Louis
  - LPI Director: Dr. Louise Prockter, Lunar and Planetary Institute/USRA
  - LRO Representative: Dr. Noah Petro, NASA Goddard Space Flight Center
  - ARTEMIS Representative: Dr. Jasper Halekas, University of Iowa
  - ISRU Representative: Jerry Sanders, NASA Johnson Space Center
  - Commercial Advisory Board Chair: Kurt Klaus, Lunar and Planetary Institute
  - ESA Representative: Dr. James Carpenter, ESA
- Ex Officio Members:
- Dr. Sarah Noble, NASA Headquarters, Science Mission Directorate
  - Dr. Ben Bussey, NASA Headquarters, Human Exploration and Operations Mission Directorate
  - Greg Schmidt, Solar System Exploration Research Virtual Institute



# COMMERCIAL ADVISORY BOARD OCT. 2017

## LUNAR EXPLORATION ANALYSIS GROUP

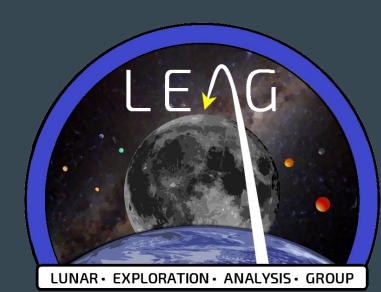
- CHAIR: Kurt Klaus, Lunar and Planetary Institute
- LEAG Chair: Clive Neal, Notre Dame
- LEAG Vice-Chair: Samuel Lawrence, NASA JSC
- Kyle Acierno, iSpace
- Dallas Bienhoff, Cislunar Space Development Corporation
- Dale Boucher, Deltion
- Joshua Brost, SpaceX
- Thomas Diedrich, Airbus
- Leslie Gerstch, Missouri University of Science and Tech.
- Sam Gunderson, Blue Origin
- A. C. Charania, Blue Origin
- Dan Hendrickson, Astrobotic
- Jeff Hopkins, Astrobotic
- Susan Jason, Surrey Satellites
- Khaki Rodway, Newspace NYC
- Nathan O’Konek, Space Florida
- Dennis Poulos, Poulos Air & Space
- Jim Keravala, Off World Consortium
- David Kornuta, United Launch Alliance
- Bernard Kutter, United Launch Alliance
- Eva-Jane Lark, Investment Advisor
- Sean Mahoney, Masten Space Systems
- Maria Antonietta Perino, Thales Alenia Space Italia
- Bruce Pittman, NASA Ames
- Sridhar Ramasubban, Team INDUS
- Eric Reiners, Caterpillar
- Bob Richards, Moon Express
- Melissa Sampson, United Launch Alliance
- George Sowers, Sowers Space Solutions
- Kris Zacny, Honeybee Robotics
- Ryutaro Ichikawa, iSpace
- Jason Aspiotis, Finosphy, Inc.
- Jeff Greenblatt, Emerging Futures, LLC
- Kieran Corroll, GEDEX
- Bradley Cheetham, Advanced Space



# THE MOON IS A STRATEGIC DESTINATION

The LEAG Community endorses the recent Space Council announcement that the United States will “*return 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*”, which is consistent with the LEAG Lunar Exploration Roadmap. LEAG and the community it represents is ready to assist NASA and the country in achieving this vital strategic goal.

To: NASA HEOMD-AES, SMD-PSD, Space Council



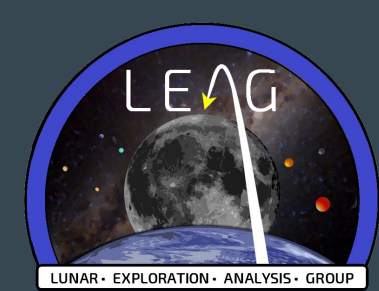
# LUNAR SCIENCE AND EXPLORATION ARCHITECTURES

Based on the presentations at the LEAG 2017 Annual Meeting, there is an emerging international consensus of a feasible path forward for lunar exploration, the characteristics of which are:

- Permanence,
- Sustainability,
- Multilateral participation,
- Surface and orbital infrastructure,
- Use of local resources,
- Economic benefits.

A lunar exploration architecture can be defined in a way that facilitates and enables international participation, sustainability, commercial activity, and includes a permanent surface infrastructure and continuous human presence, while delivering benefits for science and society.

To: NASA HEOMD-AES, SMD-PSD, Space Council

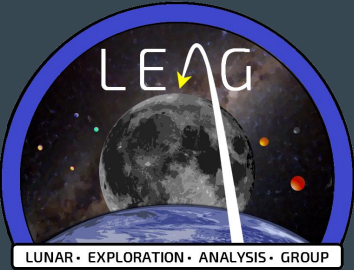


# ENABLING THE CISLUNAR ECONOMY

The LEAG community encourages NASA to include the private sector in developing the architecture requested by the Space Council for establishing a presence on the lunar surface. This could start with LEAG (including its Commercial Advisory Board, or CAB) involvement in NASA studies regarding establishing a robust near-term surface access program for robots and humans, establishing a lunar power and communications-navigation infrastructure, as well as demonstrating the abundance and usefulness of lunar resources (and creating a market for these). NASA is further encouraged, therefore, to act on the recent RFI responses with solicitations for developing the lunar economy.

To: NASA HEOMD-AES

Background: The recent announcement directing that US Astronauts be sent to the lunar surface presents a paradigm-shifting opportunity for the United States to support and enable the cislunar economy by taking advantage of the growing interest of the private sector in the Moon. The LEAG CAB represents a spectrum of scientific, engineering, and commercial capabilities now available in the private sector that can be integrated into a comprehensive architecture that should include bringing the Moon into our economic sphere of influence. These capabilities have been matured without the reliance on government contracts and are now available to partner with NASA.



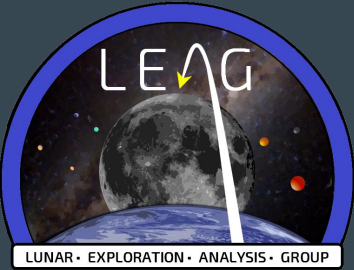
# ACCELERATING THE LAUNCH OF RESOURCE PROSPECTOR (RP)

The LEAG community strongly supports the finding that the Resource Prospector mission be flown without any further delay, and encourages an accelerated development to flight. LEAG also encourages continued dialogue between SMD-PSD and HEOMD-AES to develop a science and exploration partnership for the RP mission, which should start with a Participating Scientist program for RP well before the launch to help inform the mission profile.

To: NASA HEOMD-AES, SMD-PSD

**Background:** Resource Prospector has taken on new significance given there are 6 international landed missions proposed for exploration of lunar resources. In addition, the recent Space Council announcement establishing returning US Astronauts to the surface of the Moon to build the firm foundation for voyages to Mars and beyond as a strategic goal has given this mission added significance.

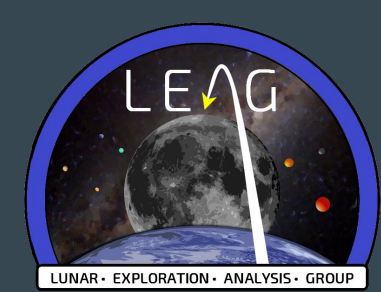




# PROPOSED DEEP SPACE HABITAT/GATEWAY

With the paramount strategic objective of human lunar return having been recently established by the Space Council, any development of the proposed Deep Space Habitat/Gateway should be specifically designed to support long-term human and robotic presence on the lunar surface. If the decision is made to proceed with the proposed Deep Space Habitat/Gateway, decisions such as the orbit, design, and capabilities of the proposed infrastructure, as well as commercial and international opportunities, should be driven by the strategic direction to return US Astronauts to the lunar surface. The LEAG community stands ready to help define NASA's lunar exploration strategy.

TO: NASA HEOMD-AES



# PREPARING FOR THE NEXT DECADAL SURVEY

SMD-PSD is encouraged to support detailed mission concept studies of the high-priority missions that have been identified by the National Research Council's Committee on Astrobiology and Planetary Science and the LEAG Next Steps on the Moon Special Action Team.

To: NASA SMD-PSD

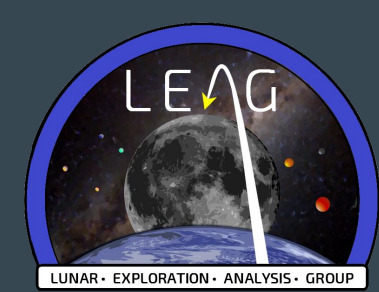
**Background:** Presentations at the LEAG 2017 Annual Meeting demonstrated that the Moon remains the cornerstone of planetary science and is an absolutely pivotal destination for science missions impacting our understanding of the entire Solar System.



## KPLO MISSION

The LEAG community applauds and thanks Jim Green for the announcement at the annual meeting that a Participating Scientist program for the Korean Pathfinder Lunar Orbiter mission will be in the ROSES 2018 call.

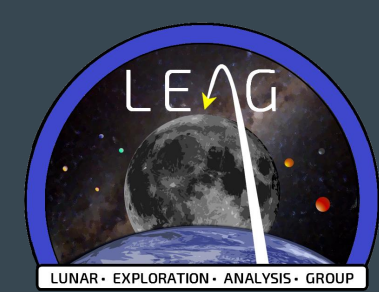
To: NASA SMD-PSD, HEOMD-AES



# SALMON AO EXPANSION OF SCOPE

The LEAG community would like to thank Jim Green for expanding the SALMON-AO to include SIMPLEX and an open call for cubesats and smallsat missions, which would have opportunities for transportation to their targets as secondary payloads on previously selected NASA missions, or payloads on commercial or other space program carriers. LEAG encourages NASA to expand that program as a growing number of commercial carriers (orbiters, landers, including targets beside the Moon) become available.

To: NASA SMD-PSD



# TECHNOLOGY DEVELOPMENT FOR LUNAR SCIENCE MISSIONS

We encourage SMD-PSD to recognize the importance of research and technology investments to advancing the readiness of such mission concepts for Discovery and New Frontiers proposals, as well as funded concept studies, providing “mission pull” for instrument maturation and landing site analysis.

To: NASA SMD-PSD

**Background:** The LEAG community is working hard on mission concepts and ideas that incorporate Decadal-level science. Multiple mission proposal ideas are being developed, including: investigations of lunar polar volatiles, magnetic anomalies/swirls, geochronology of key surface units, sample return, and young volcanic deposits.

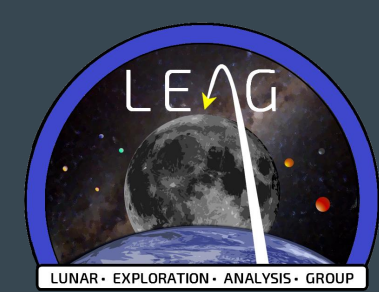


# PROSPECTING FOR AND USE OF LUNAR RESOURCES

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.

To: NASA HEOMD-AES, SMD-PSD, STMD

**Background:** Presentations at the LEAG 2017 Annual Meeting demonstrated the international and commercial emphasis on lunar resources and proving that these are reserves through robotic prospecting. Cross-directorate cooperation and collaboration will enhance the technological development, exploration and commercial potential, and science return. Such reserves are critical for making any human Solar System exploration sustainable (see the [LEAG Lunar Exploration Roadmap](#)).

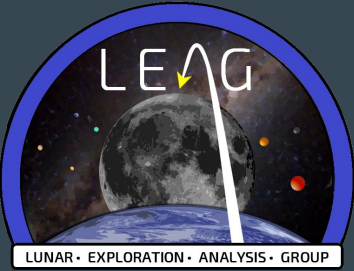


# ESTABLISHING EARLY MILESTONES TO DEVELOP THE CISLUNAR ECONOMY (1/2)

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.



# ESTABLISHING EARLY MILESTONES TO DEVELOP THE CISLUNAR ECONOMY (2/2)

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.

## 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

To: NASA HEOMD-AES, Space Council