

LEAG Report to the Planetary Science Advisory Committee

Clive R. Neal¹ & Sam Lawrence^{2*}

Lunar Exploration Analysis Group

www.lpi.usra.edu/leag

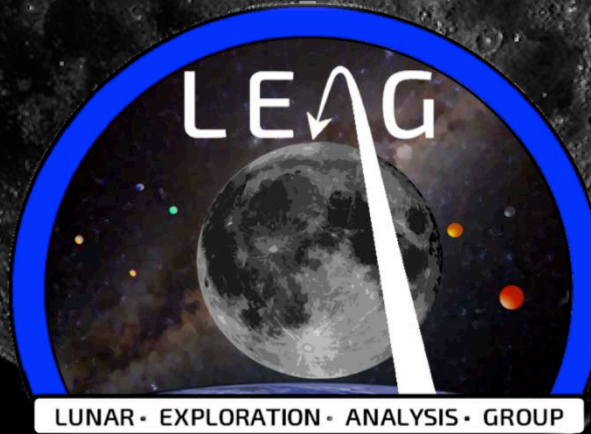
neal.1@nd.edu, samuel.j.lawrence@nasa.gov

1 = Chair. University of Notre Dame

2 = Vice-Chair. NASA

Johnson Space Center

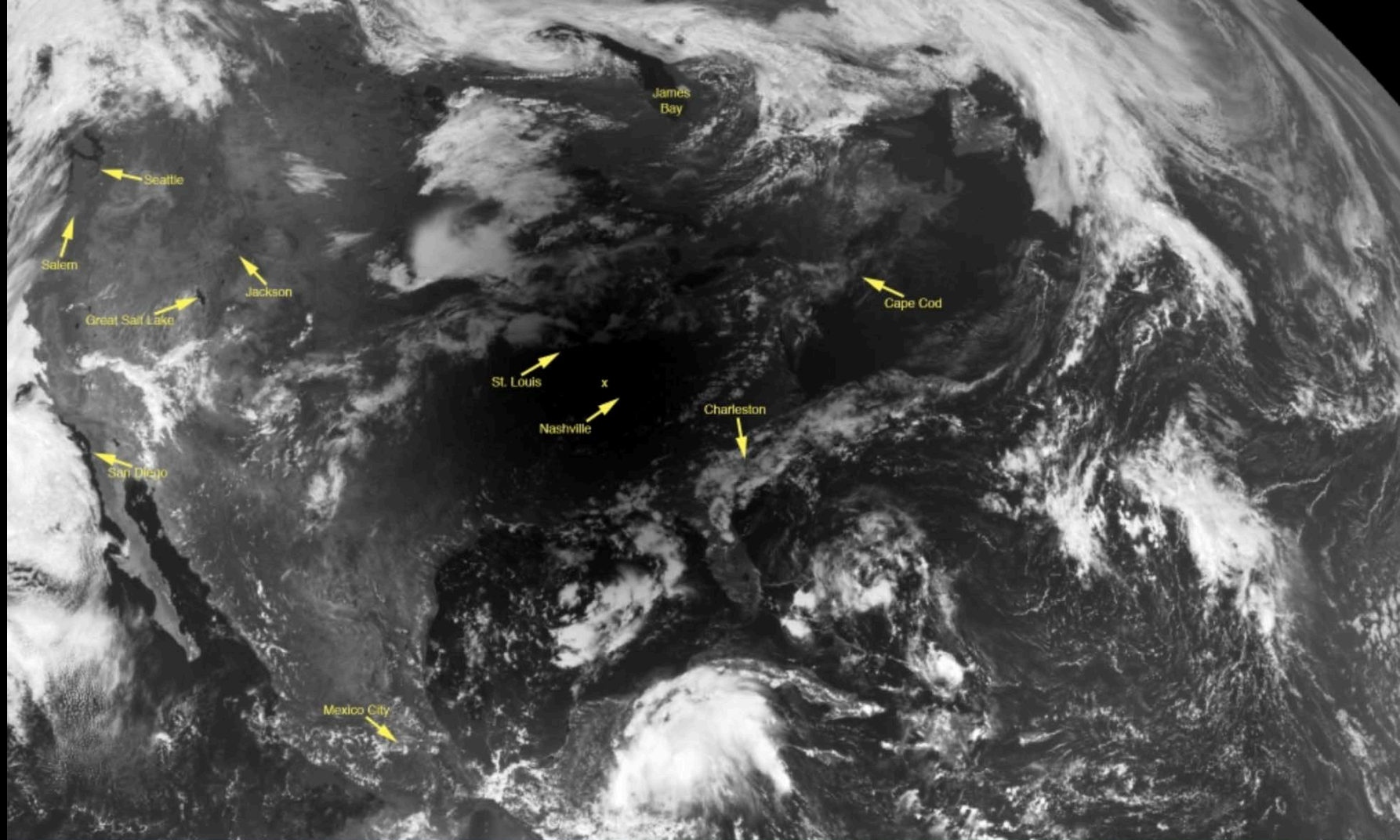
* Becomes Chair 21 March 2018





SOLAR ECLIPSE

2017



Activities

- 2017 Solar Eclipse
- LEAG Commercial Advisory Board
- Planetary Science Vision 2050
- LEAG @ LPSC 48
- LEAG Annual Meeting (2016, 2017)
- Two “Back 2 the Moon” Workshops
- Advancing Science of the Moon-SAT
- Next Steps on the Moon Specific Action Team (NEXT-SAT)
- Volatiles-2-SAT
- Lunar Capabilities Roadmap
- Lunar Science for Landed Missions Workshop
- Town Hall Meeting, Exploration Science Forum
- Review of GER-3
- Moon Village Association presentation of the LEAG Roadmap
- Decadal mid-term input
- New Views of the Moon 2
- moon vs. Moon
- LEAG participation in a Korean Parliament Expert Panel
- Anniversary of Apollo 17

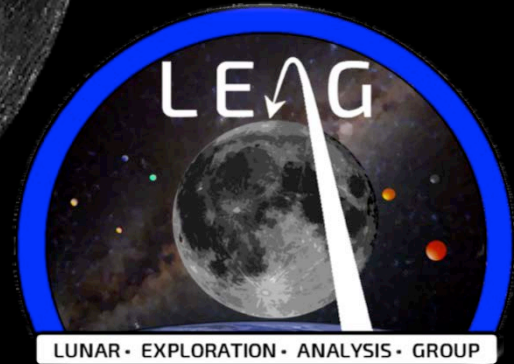


LEAG-CAB

(Commercial Advisory Board)

- Established in 2015.
- >20 individual lunar-related companies represented of varying sizes.
- Established regular telecons and an annual CAB meeting.

In order to carry out it's duties for the commercial/private sector, LEAG has constituted a Commercial Advisory Board (CAB) to develop better connections as well as synergies between commercial lunar and the broader lunar community. This includes, but is not limited to, engagement of the commercial/private sector with Specific Action Teams (SATs) where appropriate, and developing more commercial/private sector involvement at the annual LEAG meetings.

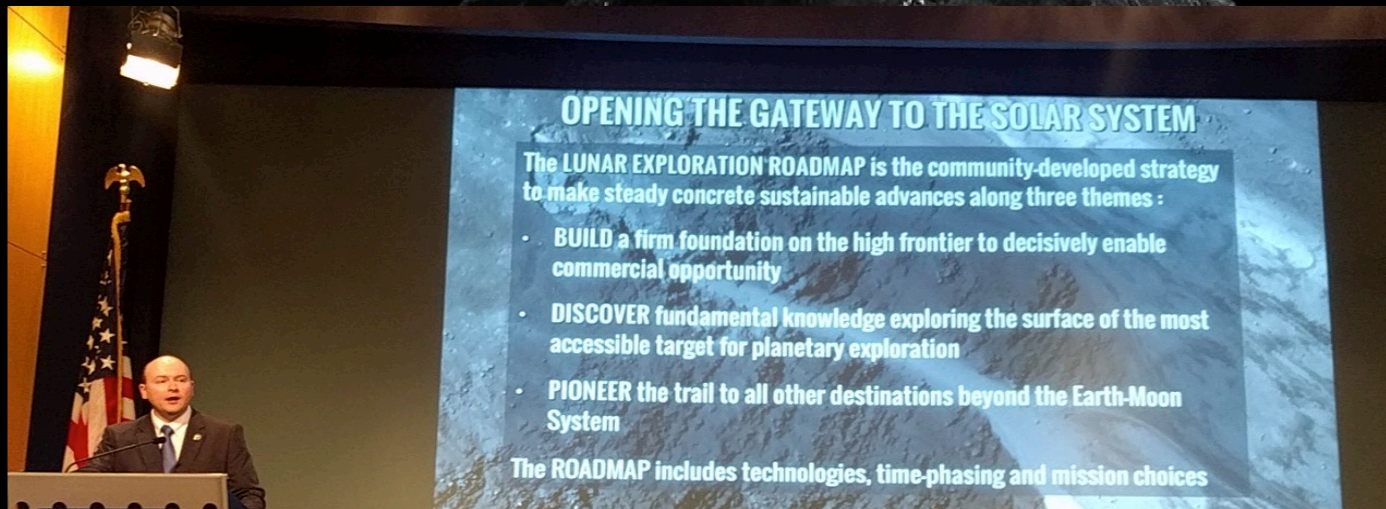


LEAG-CAB

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

Planetary Science Vision 2050

27 Feb - 1 Mar 2017



- Talk by Lawrence (The Opened Gateway: The Vision for Lunar Exploration in 2050)
- Mini-talk by Neal (The Value of Lunar Sample Return)
- Poster by Hurley (LEAG Volatile Exploration Strategy)
- 17 lunar contributions.



LEAG @ LPSC 48

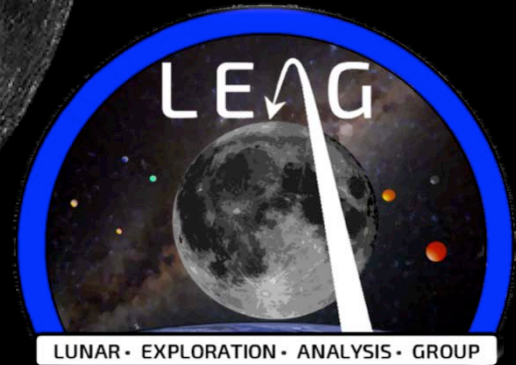
- LEAG Town Hall event to inform the community of developments and gather feedback.
- LEAG Networking evolved from an ad hoc gathering in the poster area on Wednesday to one sponsored by **Moon Express** (>145 participants) – breaks down barriers between the next generation and the more “established” lunatics.



Annual LEAG Meetings

2016 (1-3 November):

- 142 participants
- Special guest: **Rep. Jim Bridenstine** “This is our Sputnik moment”
- 9 Findings, 3 Consensus Statements (<https://www.hou.usra.edu/meetings/leag2016/Meeting-Findings.pdf>)
- A big “thank you” to **Moon Express** who sponsored the reception.



Annual LEAG Meetings

2017 (10-12 October):

- Largest number of participants (172) since 2005!
- Special guest: **Jeffrey Manber** - Nannoracks
- 11 Findings (<https://www.hou.usra.edu/meetings/leag2017/Meeting-Findings.pdf>)
- Reception once again sponsored by **Moon Express**.



2018 Meeting = 14-16 November @ USRA HQ,
Columbia, Maryland



Major Findings

- **Resource Prospector Mission** – Currently in HEOMD. Accelerate the development & launch, make it more capable by joint sponsorship with SMD-PSD. Incredible science value in this mission.
- **Polar Volatiles**: Joint target for science and exploration (“science enables exploration and exploration enables science” – LROC).
- **Expansion of the SALMON** - to include commercial providers.
- **The Moon is a Strategic Destination**: enables Solar System Science and Exploration.
- **Technology Development** for Lunar Sample return & other Missions
- **Establishing Milestones to Develop the Cislunar Economy** – 1-2 years, 3-5 years, 5-10 years

Back 2 the Moon Workshops



Workshop 1: 21-22 June, Commercial Advisory Board

- **Finding**: NASA can enable rapid development of the commercial lunar industry by offering to be a customer. The sooner NASA does this, the faster commercial capabilities will be developed. The range of capabilities offered would reflect the breadth of investigations that NASA could offer.
- **Finding**: 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.

<https://www.lpi.usra.edu/leag/Back2MoonWorkshopExecSummary.pdf>

Back 2 the Moon Workshops



Workshop 2: 12-13 October 2017 @ USRA HQ. Lunar Community – discussion panels.

- **Finding:** *To achieve an efficient and lasting presence in space by fully incorporating the Moon into our economic sphere of influence, the exploration architecture should include a regular flight cadence, incorporate ready lunar surface access, optimize the use of lunar resources, promote reusability and hardware/subsystem interoperability, and establish public-private partnerships and international collaborations.*
- Discussions covered topics related to future human spaceflight
 - Importance of lunar resources and their utilization
 - Near-term importance of surface access and activities
 - NASA as a reliable customer of commercial capabilities important
 - Need to focus only on what is absolutely necessary for lunar landings and surface infrastructure

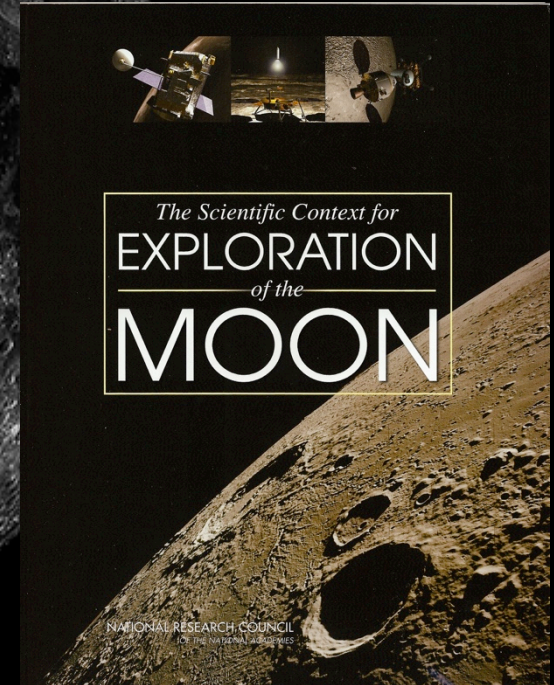
Back 2 the Moon Workshops

Workshop 2: 12-13 October 2017. Lunar Community – discussion panels.

- **Finding:** Encouraging growth in the U.S. commercial sector would foster a market for multiple providers, which will drive down costs, promote efficiency, increase innovation, and grow the American aerospace industry.
- **Finding:** Owing to the significant potential for lunar resources to reduce the cost and increase the capabilities of space activities, NASA should establish a **dedicated Lunar Exploration Program Office** with sufficient programmatic and budgetary authority to carry out directed missions to study the scientific value of lunar resources, begin resource prospecting, and demonstrate the immense scientific and technological value of lunar in-situ resource utilization.

Advancing Science of the Moon - SAT

- LEAG was tasked by the SMD-PSD to conduct a review of progress made to address the major lunar science priorities described in the 2007 National Academies report “*The Scientific Context for the Exploration of the Moon*,”
- For each of the Concepts and associated Goals from the 2007 report, ASM-SAT assessed progress and identified new concepts whose importance was not known when the 2007 report was formulated. The ASM-SAT did not attempt to reassess the prioritization set forth in the 2007 NRC report.



Advancing Science of the Moon - SAT



- The objectives and goals of the 2007 NRC Report on the Scientific Context for the Exploration of the Moon are still the benchmark describing the scientific importance and rationale for exploring the Moon in the 21st century.
- The progress made has also highlighted three new areas for consideration:
 - The Lunar Volatile Cycle
 - The Origin of the Moon
 - Lunar Tectonism and Seismicity

To make progress towards SCEM goals, a **dedicated lunar exploration program** is needed to ensure regular surface access with robots and humans.

See www.lpi.usra.edu/leag for the full report.

[https://www.lpi.usra.edu/leag/reports/ASM_SAT_Interim_Report_2-18-2018%20\(2\).pdf](https://www.lpi.usra.edu/leag/reports/ASM_SAT_Interim_Report_2-18-2018%20(2).pdf)

NEXT-SAT

- Assess lunar missions needed to address new lunar science questions revealed by progress in lunar sample studies as well as results from recent lunar missions.
- Determine desirable precursor instruments and/or missions to enhance human exploration and address Strategic Knowledge Gaps
- Determine on-ramps for potential commercial involvement
- Consider science activity enhancements offered by human presence on the lunar surface
- Activities or new modes of operation that could be employed by existing lunar assets to facilitate future discoveries or surface activities
- Identify potential technology developments that would enhance lunar and Solar System science

NEXT-SAT



Finding: There are numerous opportunities for lunar missions to address key questions that would provide openings to make dramatic, paradigm-shifting advances in planetary science.

Finding: There are numerous potential opportunities for commercial services, with NASA as a customer, to play a role in lunar surface exploration.

Finding: LRO observations of the Chang'e-3 mission activities on the surface pointed to the kinds of science and operational support that LRO data can enable and support for future missions.

Report gives examples of missions and developments that could address major lunar and Solar System science questions: **Orbiters; ≤ 40 kg to the surface; 40-500 kg to the surface; Sample return; Technology investments.**

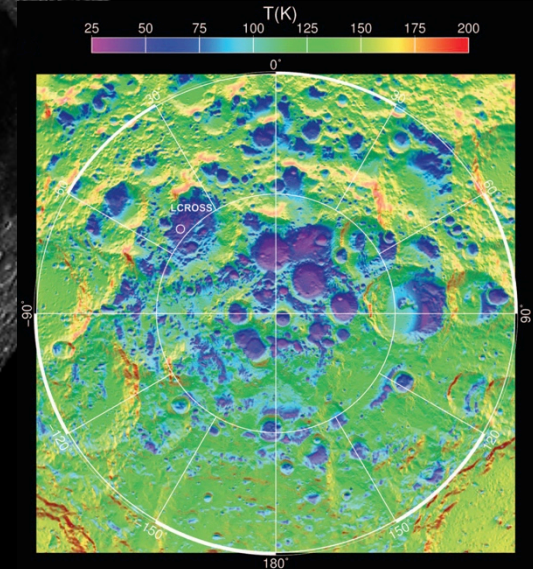
Volatiles-2-SAT

- Requested by ISECG through NASA – coordinate 8 international missions to the lunar south pole.
- International team: USA, Canada, China, Korea, Japan, UK, Germany, including representatives from NASA, ESA, KIGAM, and JAXA.
- Build on the V-SAT report of 2015 https://www.lpi.usra.edu/leag/reports/vsat_report_123114x.pdf
- The LEAG SAT could provide input or suggestions related to:
 - Landing sites.
 - Orbital plans.
 - Payload complement/instrumentation.
 - Measurement objectives.
 - Communications architectures.
 - Sample return or analysis efforts.
 - Instrumentation calibration and/or validation.
 - Data sharing and the potential for joint or multilateral science investigator teams.

Volatiles-2-SAT

18 Findings! Highlights:

- Missions should visit different sites.
- Essential measurements to be made at each site.
- Communications relay infrastructure is enabling for polar exploration.
- Resource prospecting should be a coordinated 2-phases process:
 - Common and comparable measurements at diverse sites across the region to find the best locations;
 - Comprehensive characterization of the ore grade and distribution and enable future development at a narrow set of promising sites.



Lunar Capabilities Roadmap



2015 LEAG Meeting Finding:

The participants of the 2015 LEAG meeting endorse the construction of a Lunar Capabilities Roadmap by LEAG, deduced from the Lunar Exploration Roadmap, that would highlight instrumentation and technologies critical for science and exploration of the Moon and potentially beyond.

- Details monitoring investigations, in situ analyses, mobility, sample return, communications and navigation, electronics, regolith manipulation, etc.
- Suggested developments to support human stays for up to one lunar day/night cycle and supporting robotic precursors.
- Comprehensive document completed and undergoing review.

Lunar Science for Landed Missions



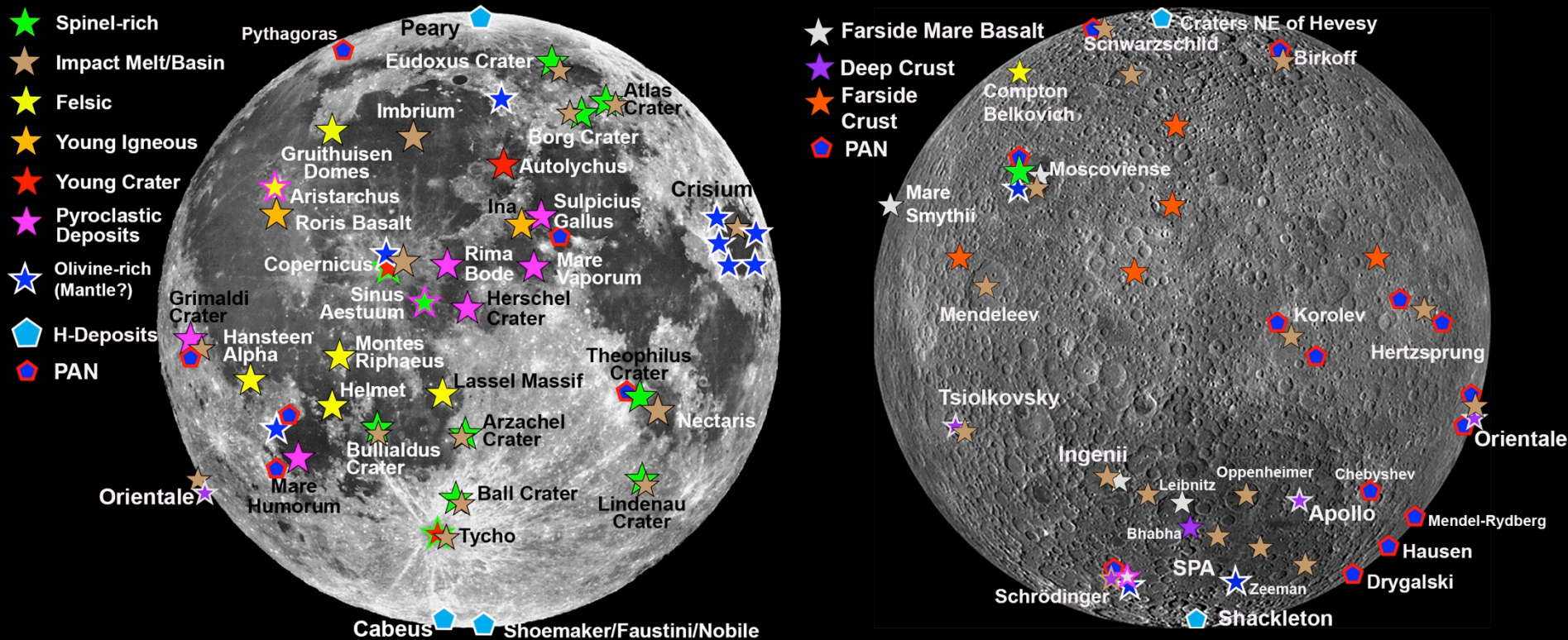
Co-sponsored by SSERVI and LEAG. Overarching themes.

- **Impacts**: Establish a precise impact chronology
- **Volatiles**: Understand the source, form, and concentration of lunar volatiles
- **Volcanism**: Determine the origin, evolution of lunar volcanism through space & time
- **Geophysics/Astrophysics**: Constrain the interior structure & evolution of the Moon
- **Space Weathering**: Examine regolith formation and space weathering processes

Enabling Technologies:

- Communications Relay
- Surviving the lunar night
- Cryogenic sampling, transportation, storage, analysis
- Automated hazard avoidance
- Mobility

Lunar Science for Landed Missions



Notional landing sites for in situ analysis and sample return

Draft full report due before LPSC.....!

Other Activities



- Participation in a Korean Parliament Expert Panel 11 July 2017 – presentation of the LEAG Roadmap
- Town Hall Meeting, Exploration Science Forum
- Review of GER-3: 2 rounds of reviews by the LEAG Executive Committee
- Moon Village Association 19-21 November presentation about LEAG and the LEAG Roadmap
- Decadal mid-term input
- New Views of the Moon 2 – LEAG-LPI initiative
- moon vs. Moon!
- Anniversary of Apollo 17 @ LPSC 49

