CLOC-SAT Goals and Objectives & LEAG Efforts

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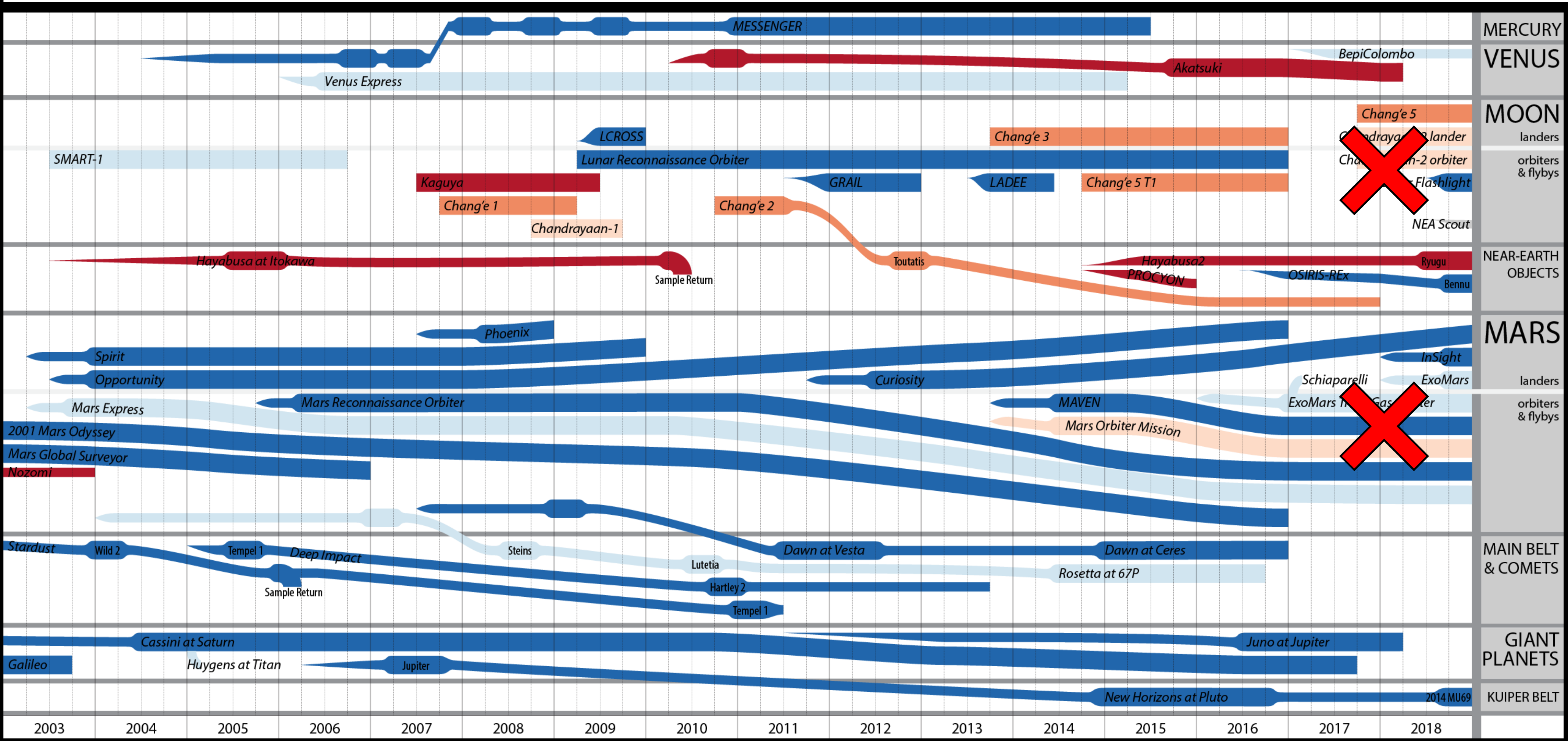
LEAG Deputy Science Chair

15 February 2022

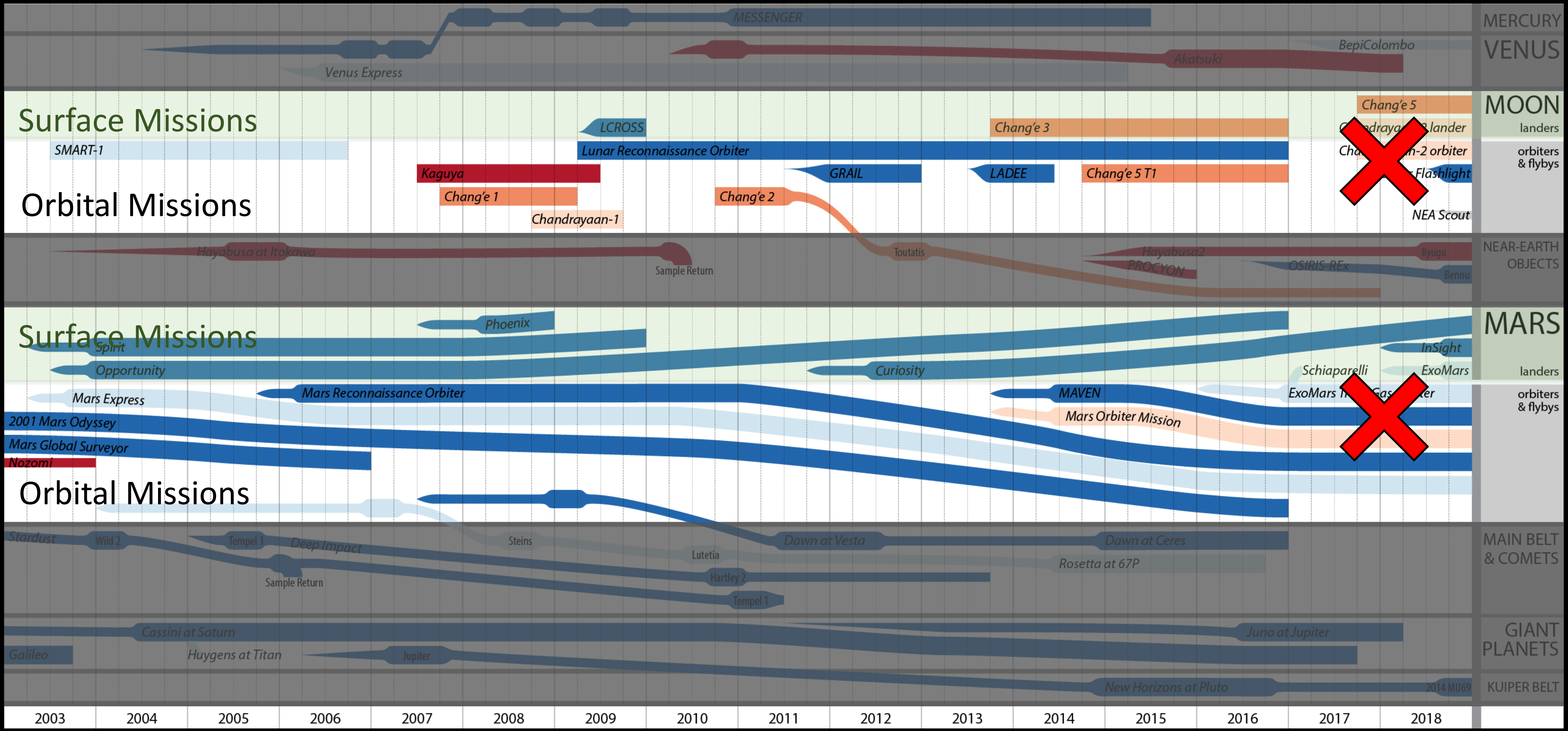
Orbital Capabilities as Part of an Integrated Strategy for Science and Exploration of the Moon



https://www.planetary.org/space-images/planetary-exploration-timeline-2003-2018-colored-by-agency-version-2015-12-31

Tuesday, February 15, 2022

Orbital Capabilities as Part of an Integrated Strategy for Science and Exploration of the Moon



https://www.planetary.org/space-images/planetary-exploration-timeline-2003-2018-colored-by-agency-version-2015-12-31

Orbital Capabilities as Part of an Integrated Strategy for Science and Exploration of the Moon

- **There is a history of integrated strategy for lunar orbital capabilities**
  - NASA accomplished flyby, orbit, land, rove, and sample return in the 1960s-1970s
- **30 years of increasingly detailed global and local context beginning with Clementine and continuing to the present**
  - Created a “New View of the Moon” that resulted in new or refined science questions and a long list of candidate landing site for future missions
- **The Artemis Era provides unprecedented access to the lunar surface**
  - 2-3 increasingly capable robotic landings per year (landers and rovers)
  - Return of humans to the lunar surface
  - Eventually a sustainable human presence

➢ **Do orbital capabilities have a significant role moving forward?**

Orbital Capabilities as Part of an Integrated Strategy for Science and Exploration of the Moon

- **NASA will continue to have a presence in lunar orbit**
  - LRO and ARTEMIS currently
  - Artemis 1 cubesats, Lunar Flashlight, and Lunar Trailblazer soon
  - Gateway and Orion
- **Science questions remain that are best answered from lunar orbit**
  - For example, Recent lunar orbiter Discovery proposals
- **Orbital capabilities support surface investigations**
  - Surface operations are significantly limited without orbital capabilities
- **Intentionally long-duration orbital capabilities provide new opportunities**

➢ **Frequent question: What happens after LRO's mission ends?**

LRO has been in operation around the Moon since 2009 and has provided a wealth of information about the Moon

- >1.3 PB delivered to PDS
- 5th extended mission proposal submitted January 2021

LEAG Annual Meeting 2020 Findings 2.8

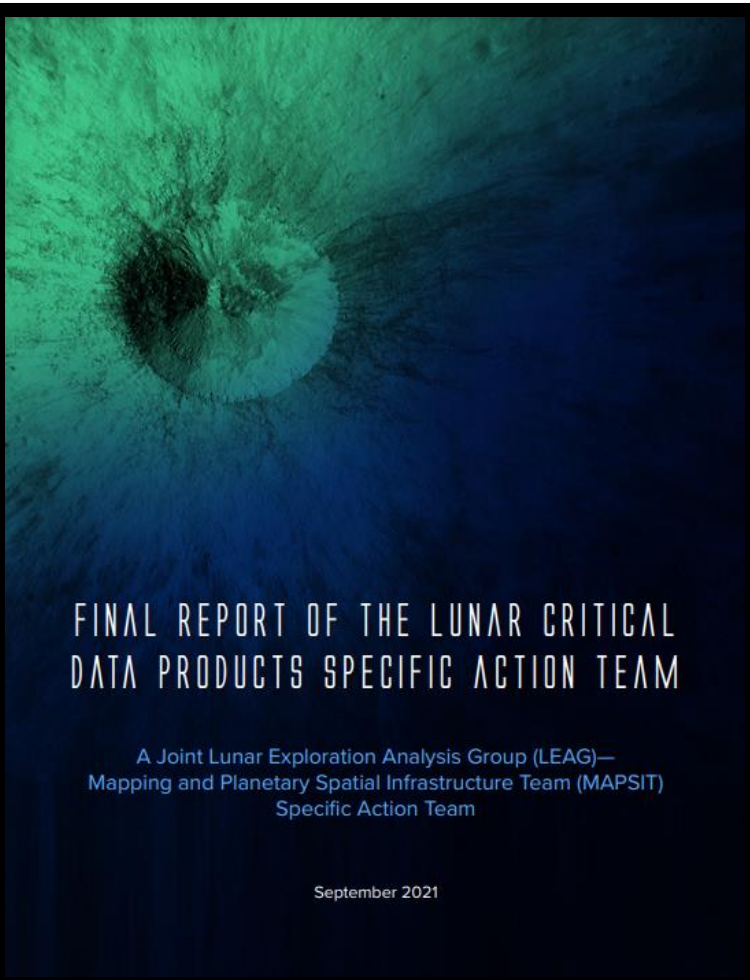
- ***LEAG supports the definition of a long-term strategy to meet orbital remote sensing and other needs beyond the life of the 2009 Lunar Reconnaissance Orbiter. Specifically, LEAG encourages NASA to engage the community in this activity, provide details on trade studies to date, and evaluate a broad range of science and exploration use cases.***
  - Orbital lunar assets provide critical capabilities in support of ongoing science and exploration and will continue to do so for the foreseeable future.

➢ **LEAG Meeting Findings and SAT Reports can be found at https://www.lpi.usra.edu/leag/**

LEAG Annual Meeting 2021 Findings 2.2

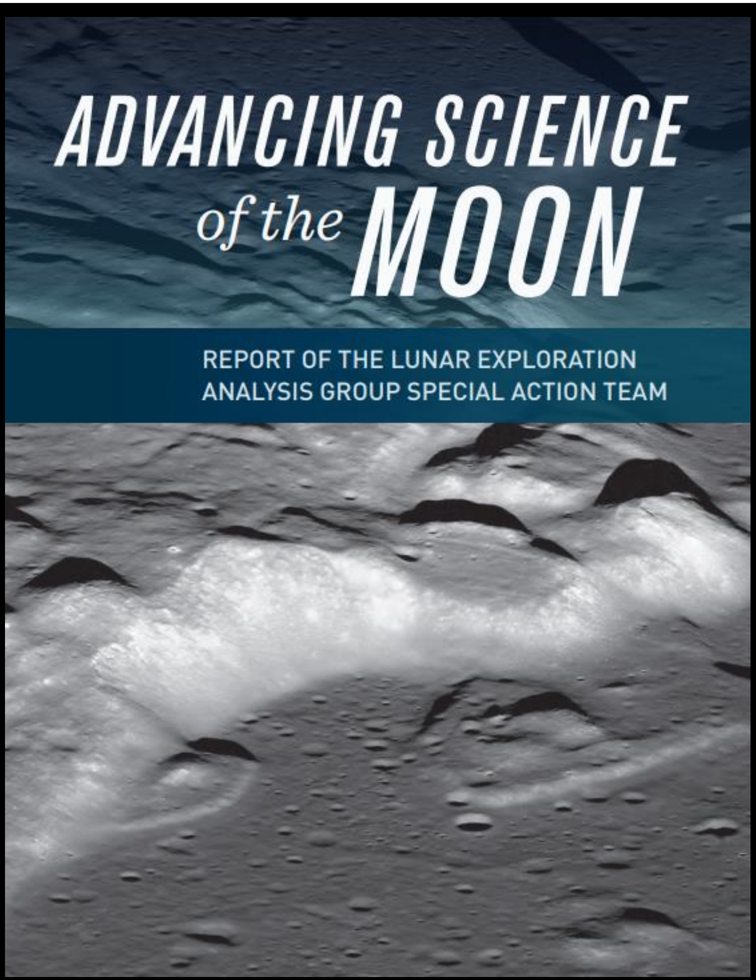
- ***NASA should work with the community towards identifying and addressing all necessary remote sensing capabilities employed around the Moon (currently and in the future) to accomplish high-priority science and exploration objectives.***
    - For example, the Lunar Reconnaissance Orbiter (LRO) has been and continues to be a tremendous asset to the lunar community as evidenced in the LRO highlights session. As such, the community supports its continuance into its proposed 5th extended mission. However, LRO will not last forever, and its successor must be developed soon. Plans must be made for formulating a next generation lunar orbiter (NGLO) capable of addressing key goals identified in the US LER, 2007 NRC SCEM Report, and the Decadal Survey (Visions and Voyages and the forthcoming report for 2023-2032). Continuity (if not overlap) between the remaining lifespan of LRO and its potential successor will be important for both science as well as for supporting Artemis and other exploration efforts. LEAG encourages a release of a Request for Information (RFI), in consultation with the Science (SMD), Exploration Systems Development (ESDMD), and Space Technology Mission Directorates (STMD), to the lunar community to assess the need, and capabilities available, for an NGLO to enable surface mission support and scientific investigation of the Moon in the post-LRO era; all three mission directorates should contribute to the NGLO, as it will be a lunar mission rather than solely a science, exploration, or technology mission. In conjunction with the RFI, LEAG supports further broad community input on the needs and required capabilities for NGLO via a virtual forum in the style of the successful Lunar Surface Science Workshops. **Finally, LEAG can initiate a Specific Action Team to further refine an NGLO concept.** Given the anticipated remaining lifetime of LRO (6-7 years), this process should begin now to ensure that the lunar science and exploration community has a long term, stable orbital asset to support Artemis and CLPS missions and to enable new investigations of the lunar surface and subsurface that would identify new, exciting landing sites.

Lunar Critical Data Products (LCDP-SAT, 2022)



- **Stood up to respond to several recommendations laid out in the Artemis III Science Definition Team (SDT) report**
- **Examples of relevant findings**
  - Finding 18: LRO and other spacecraft have, and are, providing an abundance of **critical data for planning a return to the surface** (e.g., topography, images, radar, resources, geologic information). Continuing to give high priority to opportunities using existing assets that fill in critical data gaps for future landings will maximize the use of those assets.
  - Finding 19: There is an **essential need for continuing surface and environmental observation capabilities via remote sensing to follow LRO**, including the ability for positioning of surface assets and surface station monitoring.
  - Finding 22: “Field-scale” (better than 1-m scale) images, terrain maps, topography, resource maps, line-of-sight communication maps, and illumination products, particularly for the Artemis human landings and base camp, and will be especially important for real-time surface operations (e.g., power and navigation). **These products are not possible with NASA’s existing orbital data sets; future missions could be specifically designed to support these data products.**

Advancing Science of the Moon (ASM-SAT, 2018)



- **Specifically called for new orbital measurements related to several concepts**
  - Higher spatial resolution datasets
    - Concept 3: Key planetary processes are manifested in the diversity of lunar crustal rock
    - Concept 4: The lunar poles are special environments that may bear witness to the volatile flux over the latter part of Solar System history
  - Long-duration orbital observations
    - Concept 6: The Moon is an accessible laboratory for studying the impact process on planetary scales
  - Orbital assets providing global context
    - Concept 8: Processes involved with the atmosphere and dust environment of the Moon are accessible for scientific study while the environment remains in a pristine state
- **Most concepts mention orbital support for future surface investigations**

Next Steps on the Moon (NEXT-SAT, 2018)

LEAG
LUNAR EXPLORATION ANALYSIS GROUP

NEXT STEPS ON THE MOON
REPORT OF THE SPECIFIC ACTION TEAM

Bombardment History of the Inner Solar System

- Orbiters: Long-duration global flash monitoring from orbit, particularly to gauge the current farside impact rate.
- Up to 40 kg payload to the lunar surface. No mobility, no night survival: Exploration of large exposures of impact basin melt materials (e.g., Nectaris, Crisium) involving descent imaging, surface operations imaging, major element chemistry, imaging, possible potential application for emerging in-situ geochronology techniques, depending on payload mass.
- >40-500 kg payload lander, mobility, night and out-of-comm survival: in situ geochronology, plus payload above, in-depth exploration at several exploration study areas involving exposures of impact melt deposits thought to originate from large basin-forming impact.
- Sample Return. Return of impact melt materials from major basin-forming impacts (SPA, Nectaris, Crisium).
- Desired Technology Investments: Precision landing and hazard avoidance.

- **NEXT-SAT determined key science questions and engineering questions required to address key science questions arising from recent mission and lunar sample investigations, guided by preliminary outcomes from the Advancing Science of the Moon Special Action Team**
  - Understanding Irregular Mare Patches: Texture, composition, age, volume, emplacement mechanism
  - Lunar Magnetic Anomalies
  - Understand the Structure of the Lunar Interior
  - Polar Volatiles: Composition, Physical State, Form, Distribution, and Context
  - Bombardment History of the Inner Solar System
- **Each analysis included examples of high priority orbital investigations and surface investigations**

Key Guiding Reports

- Artemis Science Plan [2020]
- Artemis III Science Definition Team Report [2020]
- NASA's Plan for Sustained Lunar Exploration and Development [2020]
- LEAG's Lunar Exploration Roadmap [2016]
- NRC's Scientific Context for the Exploration of the Moon [2008]
- NRC's Science Associated with the Lunar Exploration Architecture (aka Tempe Report) [2007]
- Relevant Decadal Surveys [e.g. Planetary 2002, 2012, 2022] and related white papers

https://www.lpi.usra.edu/leag/roadmap

CLOC-SAT Members

- **Co-Chairs**
  - Ben Greenhagen, APL
  - Carle Pieters, Brown University
- **Core Leads**
  - Mark Robinson, ASU
  - Julie Stopar, LPI
  - John Keller, NASA GSFC
- **SAT Members**
  - To be selected from community self-nominations
- **Ex Officios**
  - Amy Fagan, LEAG Chair
  - Kelsey Young, LEAG Human Exploration Chair
  - Brett Denevi, LEAG Science Chair
  - Ben Bussey, LEAG Strategic Roadmap Chair
  - Jose Hurtado, LEAG Technology Chair

CLOC-SAT Report

- **The principle deliverable of CLOC-SAT is a report responsive to the task requested by LEAG**
  - Develop integrated findings that address questions associated with lunar orbital capabilities in the years ahead, in particular ***Why? What?*** and ***How?*** These interwoven issues essentially refer to the rationale, specific needs/goals, and realistic opportunities/capabilities for assets in orbit to carry lunar science and exploration forward during the next decade(s)
- **Expected areas of focus**
  - Identify the top investigations to be carried out by future orbital mission(s)
  - Identify orbital capabilities needed for landed science/exploration activities
  - Identify where key orbital measurements and capabilities are common to or cross-cut different mission directorates
  - Identify valuable new types of measurements that are enabled by modern technology

Topical Perspectives

- **Orbital capabilities needed to support surface operations and surface science investigations**
  - Maria Banks, NASA GSFC
  - Clive Neal, Univ. Notre Dame
- **Benefits of long-term orbital capabilities**
  - Angela Stickle, APL
- **Key lunar science questions achievable through state-of-the art orbital investigations**
  - Brad Jolliff, Washington Univ.

➢ **Please hold comments/discussion for the breakout sessions**

➢ **Feel free to use the chat function to ask clarifying questions**