PSS Findings and Recommendations

The Planetary Science Subcommittee
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NAC Workshop on Science Associated with the Lunar Exploration Architecture

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Lunar Architecture Objective Assessment

- PSS delegated to the Lunar Exploration Analysis Group (LEAG) the responsibility to evaluate and prioritize the 16 lunar science objectives.
- The Mars Exploration Program Analysis Group (MEPAG) provided an independent prioritization from the perspective of Mars exploration.
- PSS discussed and affirmed these evaluations.

Lunar Science Objectives

mGEO1: Use passive seismic data to determine the internal structure and dynamics of the Moon to constrain the origin, composition, and structure of the Moon and other planetary bodies. [10]

mGEO2: Determine the composition and evolution of the lunar crust and mantle to constrain the origin and evolution of the Moon and other planetary bodies. [10]

mGEO3: Characterize the global lunar geophysical state variables to constrain the origin, composition, and structure of the Moon and other planetary bodies. [9]

mGEO4: Determine the origin and distribution of endogenous lunar volatiles as one input to understanding the origin, composition, and structure of the Moon and other planetary bodies. [7]

mGEO5: Characterize the crustal geology of the Moon via the regolith to identify the range of geological materials present. [9]

mGEO6: Characterize the impact process on the Moon and other planetary bodies. [9]

mGEO7: Characterize impact flux over the Moon's geologic history, to understand the impact history of the inner solar system. [10]

mGEO8: Study meteorite impacts on the Moon to understand the early Earth history and origin of life (including the search for early Earth meteorites). [7]

mGEO9: Study the lunar regolith to understand the nature and history of solar emissions, galactic cosmic rays, and the local interstellar medium. [9]

mGEO10: Determine lunar regolith properties to understand the surface geology of the Moon and other planetary bodies. [7]

mGEO11: Characterize the lunar regolith to understand the space weathering process from different crustal environments. [6]

mGEO12: Characterize lunar volatiles at the poles to reveal the nature of impactors on the Moon. [8]

mGEO13: Characterize transport of volatiles to understand the processes of polar volatile deposit genesis and evolution. [7]

mGEO14: Characterize resources to understand their potential for exploration utilization. [7]

mGEO15: Provide documentation and curatorial facilities and technologies to ensure contamination control for lunar samples. [10]

mGEO16: Provide sample analysis instruments on the Moon to analyze selected lunar samples before returning them to Earth (e.g., high-grading samples for return and also for samples whose properties may change over time). [9]

Objectives Grouped under Five Overarching Themes

- Investigation of the geological evolution of the Moon and other terrestrial bodies (Range = 9-10).
- Quantification of impact processes and impact history of the inner solar system (7-10).
- Characterization of regolith and mechanisms of regolith formation and evolution (6-9).
- Development and implementation of sample return technologies and protocols (9-10).
- Study of endogenous and exogenous volatiles on the Moon and other planetary bodies (7-8).

Next Steps

- On the basis of the overarching themes and subsidiary objectives, LEAG has been charged to map the objectives to an implementation plan.
- Mapping will include measurement objectives, geographic coverage, and sampling strategy.
- Objectives will be distinguished on the basis of whether major progress can be made through the current exploration architecture.

Robotic Missions

- The sentiment at the Workshop is that robotic missions are essential for carrying out many of the highest-priority lunar science objectives.
- The precursor missions defined by ESMD would provide ground truth for many of the premises underlying the exploration plan as well as a means for achieving several critical basic and applied science objectives (e.g., nature of polar volatiles, habitat safety).
- To achieve the highest-ranked lunar science objectives, continued robotic sortie missions will be needed, even after human presence is established.

Networks

- Achievement of several of the highest-ranked lunar science objectives requires the deployment of long-lived geophysical monitoring networks. Precursory technology investments are needed, e.g., development of a long-lived power source and a deployment strategy for such stations.
- Networks could be built up in partnership with other space agencies, provided that a framework for compatible timing and data standards is established.
- The trade off between station lifetime and the timeframe for network deployment should be fully explored.

Sample Return

- Achievement of several of the highest-ranked scientific objectives requires the development of a strategy to maximize the mass and diversity of returned lunar samples.
- The PSS views the sample mass allocation in the current exploration architecture for geological sample return as too low to support the top science objectives. We are asking that CAPTEM undertake a study of this issue with specific recommendations for sample return specifications to be made by April 1, 2007.
- The PSS recommends that NASA establish a well-defined protocol for the collection, return, and curation of lunar samples to maximize scientific return while protecting the integrity of the lunar samples.

Mobility

- To maximize scientific return within the current exploration architecture, options should be defined and developed for local (~50 km), regional (up to 500 km), and global access from an outpost location.
- It is important that access to scientifically high-priority sites not be compromised by mobility limitations, both for outpost and sortie missions.

Other Essential Considerations - 1

- The PSS recommends that the Crew Exploration Vehicle (CEV) have a capability similar to the Apollo science instrument module (SIM) to facilitate scientific measurements and the deployment of payloads from lunar orbit.

- As part of the developing lunar exploration architecture, the PSS recommends that extensive geological and geophysical field training be established as an essential component in the preparation of astronaut crews and the associated support community for future missions to the Moon.

- Scientific input should be an integral component of the decision-making process for landing site targets for a lunar outpost or any lunar mission.

Other Essential Considerations - 2

- Lunar data sets from all past missions, LRO, and future international missions should be geodetically controlled and accurately registered to create cartographic products that will enable landing site characterization, descent and landed operations, and resource identification and utilization.

- The area of planetary astronomy largely fell between the PSS and APS at this Workshop, because the PSS focused on lunar science and the APS focused primarily on astronomical targets outside the Solar System. Topics such as utilizing the Moon or lunar orbital platforms to search for near-Earth objects and characterizing zodiacal dust should be integrated further into lunar exploration science planning.

Technology Developments

• A lunar instrument and technology development program is needed to achieve several of the highest-ranked scientific objectives (e.g., long-lived 1-10 W power supplies; deployment of networks from orbit; sampling in permanently shadowed regions; development of robotically deployable heat-flow probes).

Sustained Scientific Input to Lunar Exploration Planning

- **Regular reviews of the major decisions** that will influence the science outcome and legacy of lunar exploration should be carried out by the NAC science subcommittees, and their findings and recommendations transmitted to the NAC. Topics for such reviews should include:
- Options for full access to the Moon (low, mid, and high latitudes; nearside and farside; polar).
- Pre- and post-landing robotic exploration opportunities and missions.
- Appropriate mix of human and robotic exploration.
- Surface science experiments and operations at the human outpost.
- Surface science experiments and operations during human sorties.
- Critical items in space hardware design, including:
    - Delivery of science experiments to the lunar surface
    - Upload of science (samples, data) from the lunar surface
    - Orbiting module science requirements (e.g., SIM bay)
    - Crew orbiting science operational requirements (e.g., portholes).
- Mission Control science requirements during operations.