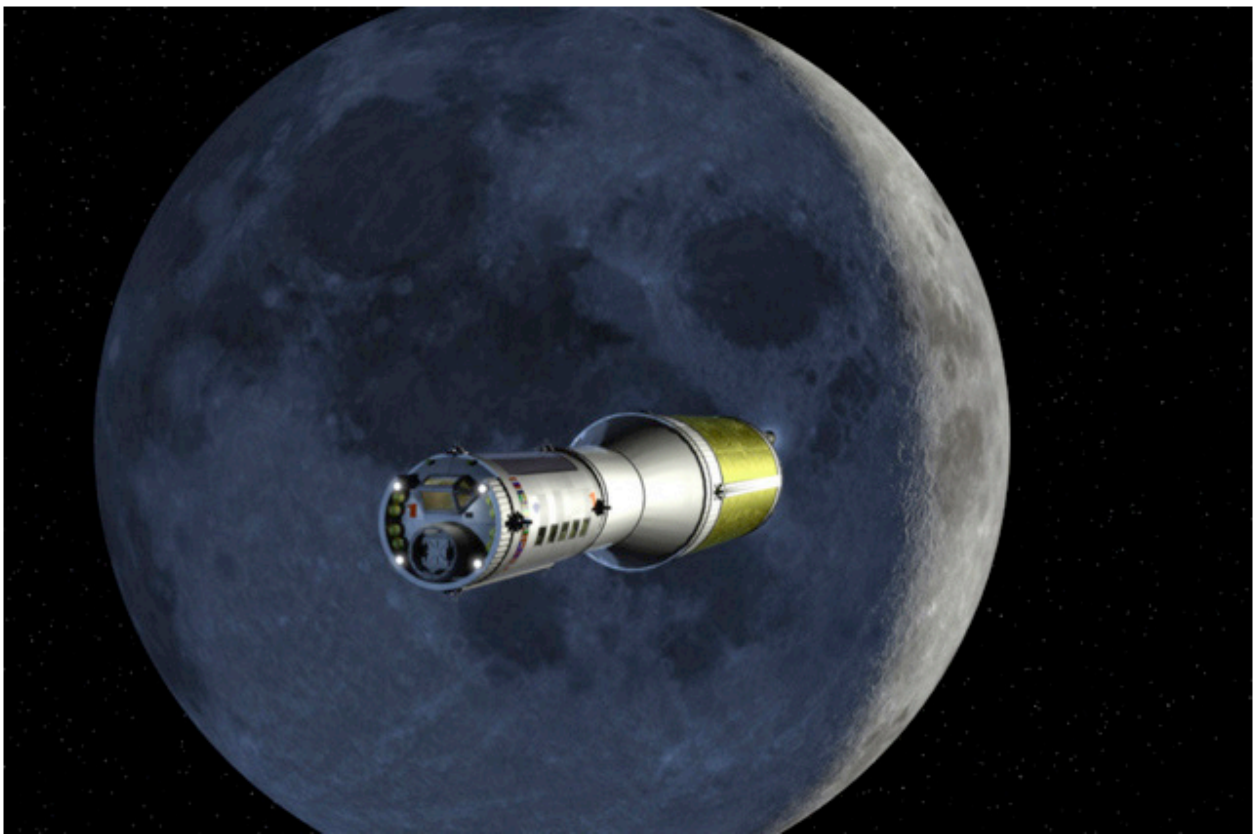
The Lunar Exploration Analysis Group (LEAG)

Community Forum on

Future Lunar Science Missions

03.25.09

40th Lunar & Planetary Science Conference



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NASA Science Mission Directorate (SMD)

Community Forum on Future SMD Lunar Missions

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INTRODUCTION

The Lunar Exploration Analysis Group (LEAG) convened a Lunar Community Forum at the 40th Lunar & Planetary Science Conference (The Woodlands, Houston, Texas) during the lunch period of Tuesday 25 March 2009. The aim of this meeting was to facilitate discussion among the lunar community about what would be the highest priority science missions after the current slate of scheduled and proposed missions (concluding with the International Lunar Network). Approximately 180 people were in attendance and the meeting lasted approximately 70 minutes.

An initial overview was given by Clive R. Neal, LEAG chair, outlining the current missions planned to go to the Moon and also the recent documents that define the major lunar science questions that remain (New Views of the Moon, 2006; LEAG GEO-SAT, 2006; NRC – Scientific Context for the Exploration of the Moon, 2007; NAC Tempe Workshop, 2007). The role of the Moon in the last Decadal Survey was also reviewed, where South Pole-Aitken sample return and investigation of the Lunar Poles were highlighted as high priority science missions.

SUMMARY OF COMMENTS

(from individual participants: no consensus sought)

General Comments:

- Exploring the Moon is good for solar system exploration because it represents a body frozen in time that records some of the earliest processes in solar system evolution (e.g., planetary differentiation, impact flux and processes).

- The Lunar Reconnaissance Orbiter Camera is targeting 50 sites for high-resolution imagery (see the LEAG LROC-SAT for details). These sites have been chosen because of science as well as other operational issues (e.g., ISRU, etc.).

- There was a cautionary view expressed in that there is a lot of new data coming in and will come in over the next few years with current and future missions. Care is required not to get too constrained in our future planning such that we cannot respond to new results.

- A general view was expressed that the Apollo landing sites need to be preserved as sites of historical interest.

- Commercial Partners: The ability to "buy rides" to the lunar surface needs to be explored, especially if the Google Lunar X-prize participants are successful.

<u>Specific Mission Scenarios</u>:

- <u>South-Pole Aitken (SPA) Sample Return</u>:

  - Still a very important high priority for constraining the impact flux of the inner solar system and is part of the last decadal survey that has not yet been addressed.
  - Age of potentially the oldest giant impact on the Moon is a vital scientific goal not only for the impact history of the Moon, but also for understanding the evolution and impact history of the inner solar system.
  - The SPA impact excavated the crust deeply, maybe even exposing the upper mantle. Returning samples could shed light on the nature of the lower lunar crust and possibly the upper mantle.
  - Mare patches and cryptomare within SPA allow the examination of the diversity of mantle sources by returning basalts from the lunar far side.
  - Determination of the ages of the large craters *within* SPA will potentially give a definitive test to the cataclysm hypothesis.
  - Volatiles are present in permanently shadowed craters around the South Pole (i.e., southern extent of the basin).

- <u>Lunar Poles</u>:

  - It is important to explore the lunar poles (specifically the volatile deposits) before the lunar environment is disturbed by future human landings, as the volatiles emitted from such landings may compromise the pristine nature of the volatile deposits.
  - Peary Crater in the North Polar region is a flat-bottomed crater that would facilitate landing and as part of it is permanently shadowed it may contain volatile deposits.
  - The topography of the lunar South Pole is not ideally suited for long distance roving. The South-Pole Aitken basin contains rough terrain from a traversing perspective. Lunar North Pole topography appears gentler (for traverses) and is closer to Mare sites. The location allows a variety of science questions to be answered (mare basalt diversity, cratering history, polar volatiles, resource potential etc.), to be explored, and lunar outpost suitability evaluated.
  - A natural follow-on to LADEE would be a rover to polar areas (permanently shadowed regions).
  - The lunar poles should be explored because this is where the Hydrogen is concentrated and to answer the following questions:
    - ⇒ What other elements are concentrated with Hydrogen?
    - ⇒ What are the origins of these deposits?
    - ⇒ How are these deposits preserved within the regolith?
    - ⇒ How do these volatiles get transported around airless bodies?

- Nectaris Basin Sample Return:
    - Nectaris Basin is another old impact basin (older than Imbrium) so returning impact melt from this basin will also help constrain the impact flux of the inner solar system.
    - The advantage is that it is on the lunar nearside as compared to SPA.
    - Nectaris also has well defined ejecta features and impact melts within its interior to tie in with ejecta blanket.
    - Age dating of Nectaris will help constrain the end of planetary accretion and whether or not there was a terminal cataclysm.

- Aristarchus Plateau Exploration and Sample Return to address the following:
    - Pyroclastic deposits from early lunar explosive volcanism may have been more common during the early history of the Moon (i.e., pre—3.8 Ga).
    - The pyroclastic deposits probably contain internal volatiles from deep within the moon – raising the possibility that the Moon never fully outgassed, which at a fundamental level is difficult to reconcile with the Giant Impact hypothesis.
    - Where are the volatiles? They could be trapped on grain surfaces, cracks, pores, and crevices.
    - Lunar pyroclastic deposits are not well explored – Aristarchus permits such exploration.
    - Gaining a better understanding of pyroclastic eruptions on the Moon has direct implications for similar eruptions on other places of the Moon, as well as, for example, Mercury and Io.
    - Possibility of fossil regolith trapped between lava flows/pyroclastic eruptions – this could give a snap shot in time of the Suns activity through trapped solar wind particles.

Technology Developments:

- Use the Moon as a training ground for the rest of the solar system, particularly for sample return from Mars, asteroids, etc.
- Develop technology for generic robotic sample return mission for the Moon - ground truth test of remote sensing data.
- Long-range rovers that are not solar powered – build on Mars Science Lab technology development – for in situ analysis and sample collection. This could return to the original landing site or a different site for sample pick up and return to Earth, either remotely or with humans.
- There is a need for instruments capable of ‘sniffing’ volatiles from a distance.
- There is a need for instruments capable of *in situ* age dating with a goal of just a few million years resolution in age determinations. This is applicable not only to the Moon (especially for determining the ages of impact craters), but also for other planetary bodies.

- Develop Lunar Hoppers to visit several places on the lunar surface during one mission (more cost efficient) – integrate this with sample return.

Potential for SMD-ESMD Joint Missions (similar to LRO/LCROSS)

- **In Situ Resource Utilization (ISRU) Technology Demonstration**: An ISRU technology demonstration on the lunar surface is critical for showing that valuable resources can be extracted from the regolith on the lunar surface. This makes establishing the lunar habitat more feasible in terms of mass to the lunar surface (water and oxygen can be generated there). Areas where such technology demonstrations could take place are of high scientific interest (e.g., Aristarchus Plateau, Lunar Poles).

- **Lunar Dust Toxicity**: Studies of lunar dust toxicity need to be conducted in situ because the returned Apollo lunar samples may have been compromised (adsorption of water and other volatiles).

- **Exploration of Lunar Magnetic Anomalies** (e.g., Reiner Gamma):
    - Understanding the plasma environment within and outside the lunar magnetic anomalies allows the nature of such anomalies to be evaluated (i.e., remnant ancient dynamo or transient impact event?).
    - Direct applicability for human exploration (protection against solar flares during extended stays at an outpost).

SYNOPSIS

Overall, there was considerable excitement from the science community about the possibilities for future exploration of the Moon. The community forum sparked a lively discussion, with plenty of input from the 180 lunar scientists present. The overriding sense is that there are plenty of science investigations to conduct on the Moon, both robotically and once humans return, and there is abundant important science to do that not only addresses questions of the origin and evolution of the Moon, but also the Earth-Moon system, the terrestrial planets, and the evolution of the early solar system and early Sun.