THE LUNAR EXPLORATION ANALYSIS GROUP: DEFINING AND EVALUATING OBJECTIVES FOR EXPLORATION. G.J. Taylor[1] and S. Mackwell[2] [1]Hawaii Inst. of Geophys. and Planetology, Univ. of Hawaii, Honolulu, HI 96822 (gjtaylor@higp.hawaii.edu); [2]Lunar and Planetary Institute, Houston (mackwell@lpi.usra.edu).

Introduction: The Lunar Exploration Analysis Group (LEAG) is a community-based, interdisciplinary forum that analyzes scientific, engineering, technology, and operational issues associated with lunar exploration to support the Vision for Space Exploration. The emphasis in this white paper is on lunar science, but LEAG activities are not limited to science alone. They cover exploration, science, resource utilization, and commerce. LEAG reports its findings and analyses to the Exploration Systems and Science Mission Directorates, through the NASA Advisory Council.

LEAG has organized two open meetings (January 2005 and October 2005), but most of its analysis activities have been conducted through Specific Action Teams (SATs). SATs are *ad hoc* groups assembled to analyze specific issues. We summarize the results of the meetings and the SATs below, with special attention to the latest one, GEO-SAT, which evaluated and ranked the objectives for basic and applied lunar science. Reports of the SATs and meetings are available at the LPI website:

http://www.lpi.usra.edu/leag/

First Meeting: The first LEAG meeting (10-12 Jan. 2005) was large, but open to invited participants only. Its main findings [1] were: (1) Sustained human presence on the Moon is essential for a dynamic program of robotic and human exploration of the solar system. (2) *In Situ* Resource Utilization is necessary for sustainable (including affordable) human presence in space. (3) It is important to have private involvement from the start, including on robotic missions. (Not enough discussion to know if this is a consensus view.) (4) It is important to create a scientific instrumentation/facility development program.

Second Meeting: The second LEAG meeting (24-28 Oct. 2005) was sponsored jointly by the Lunar and Planetary Institute, the Space Resources Roundtable, and NASA, in collaboration with the Lunar Exploration Executive Roundtable. Its chief accomplishment was to bring a diverse group of exploration experts together. See [2] for details.

Second lunar robotic mission SAT: The first LEAG SAT focused on defining the main objectives for the robotic mission to follow LRO. It recommended a lander [3], which developed into the RLEP-2 mission concept.

Scientific activities and site selection SAT: This SAT looked at lunar and other science opportunities during short-duration sortie missions and at an outpost [4]. It was convened to support the ESAS architecture study.

Review of RLEP-2 measurement requirements: As a quick check on the measurement requirements being developed by the Measurement Team associated with the second robotic lunar mission, a SAT was convened to review them. Its report [5] confirmed that the measurement requirements were reasonable and made several suggestions.

Themes, Objectives, and Phasing SAT (TOP-SAT): After numerous inputs (including LEAG reports), ESMD planners developed a set of themes and objectives for lunar exploration. LEAG organized a SAT to comment on the themes and objectives. It was a large, diverse group (membership listed in the report [6]) that met in a series of telecons over a two-week period to comment on almost 200 objectives. The revised objectives were given to ESMD planners.

Habitation SAT (HAB-SAT): LEAG organized a SAT to analyze the objectives and to rank them within the Human Habitation theme (HAB-SAT). The HAB-SAT membership included specialists in science, engineering, resource utilization, biomedical science, life support systems, construction, and habitat design. It ranked the objectives [7]according to their importance in achieving the habitation of the Moon, and also assessed when an objective should be either implemented or achieved, and when work on achieving the objective needs to start.

Geology-Geophysics SAT: The purpose of the GEO-SAT activity was to suggest relative rankings of the objectives related to lunar geoscience for lunar exploration within the core theme of science [8]. Many lunar science objectives cannot be achieved without global access (and a long duration), but given the possibilitiy of a single outpost the SAT added comments for each objective addressing the question, "If there is only a single outpost site, to what extent can this objective be addressed?"

Lunar science objectives and rankings: GEO-SAT considered objectives in three categories only: geology, environmental characterization, and ISRU. The first is clearly focused on science, but some objectives in the other two categories also contribute to major science questions. GEO-SAT ranked each objective into broad categories of high,

medium, and low priority (*for the Science theme*), as follows: High (8−10): first-order science problem; Medium (4−7): Useful for addressing scientific problems; Low (1−3): Not useful or only marginally useful to addressing scientific problems. See [8] for details.

Understand the origin and structure of the Moon -- Seismology to probe the interior. Ranking: 10. Single site: This objective cannot be addressed from a single site, but a seismic station at an outpost site would represent a start towards establishing a long-duration global seismic network.

Understand the origin and structure of the Moon -- Determine the structure and evolution of the lunar crust and mantle. Ranking: 10. Single site: Significant progress can be made by intensive study of one site by studying the rock components present in the regolith and in crater ejecta. How much progress can be made depends on the geological setting of the specific site chosen; proximity to a diversity of geologic terrains is particularly important.

Understand the origin and structure of the Moon -- Global geophysical properties. Ranking: 8. Single site: Little progress can be made on this objective from a single site, with the exception of a heat flow measurement.

Understand the origin and structure of the Moon -- Endogeneous volatile elements. Ranking: 7. Single site: If the outpost site were chosen with this objective in mind, significant progress could be made.

Study meteorite impactors on the Moon -- Search for samples of the ancient Earth. Ranking: 6. Single site: A single outpost site that is permanently inhabitated and making use of in situ resources would enable this objective to be achieved. If large amounts of regolith were being processed and techinques were developed to search the mined materials for key indicators (e.g., quartz, alkali feldspar), then this needle-in-the-haystack search would be feasible.

Study meteorite impactors on the Moon -- Composition of basin-forming impactors. Ranking: 7. Single site: Depending on the location of the outpost site, modest progress could be made on the objective.

Characterize and understand the regolith -- Structure and evolution of the regolith. Ranking: 8. This objective can be achieved best at a single, permanently inhabited site.

Characterize and understand the regolith -- Space weathering. Ranking: 6. Single site: A single site is all that is required.

Characterize lunar volatiles -- Polar cold traps. Ranking: 8. Single site: A base is unlikely to be located within a permanently-shadowed region. This is best done by robotic mission.

Characterize lunar volatiles -- Composition of atmosphere (exosphere). Ranking: 7. Single site: Atmospheric measurements at a single outpost site would allow study of the fate of gases added to the lunar atmosphere.

Characterize potential resources. Ranking: 7. Single site: Detailed studies and sampling of the regolith can address this objective at a single site.

Characterize the impact process. Ranking: 8. Single site: Significant progress can be made at a single site by studying one or more craters in detail.

Explore the uppermost subsurface structure of the Moon. Ranking: 6. Single site: A single outpost site allows detailed studies of the local subsurface.

Establish curation and contamination control. Ranking: 10, as this is strongly science enabling. Single site: Most important at a single, long-duration site.

Analyze lunar samples in-situ. Ranking: 9. Single site: Important at a single long-duration site.

Highly-ranked objectives in the environmental characterization and ISRU categories:

Map the gravity field of the Moon. Ranking: 8

Understand and map seismic activity of the Moon. Ranking: 9. Single site: More than one site required, but significant to understanding the seismic environment at the site.

Characterize and quantify the resource potential of the Moon. Ranking: 8. Single site: Good progress can be made at one site.

References:

[1] Report of the first LEAG meeting, http://www.lpi.usra.edu/leag/leag05/j-taylor-1-05.pdf

[2] Report of the Space Resources Roundtable VII: LEAG Conference on Lunar Exploration, http://www.lpi.usra.edu/meetings/leag2005/final_report.pdf

[3] Second lunar mission SAT report, http://www.lpi.usra.edu/leag/leag05/LEAG_SAT.pdf

[4] Science activities and site selection SAT, http://www.lpi.usra.edu/leag/reports/SASS_SAT_Report_7-12-05.pdf

[5] Review of RLEP-2 measurement requirements, http://www.lpi.usra.edu/leag/reports/rlep2_4_4_06.pdf

[6] Report of the Lunar Exploration Analysis Group Themes, Objectives, and Phasing Specific Action Team (LEAG TOP-SAT) http://www.lpi.usra.edu/leag/reports.html

[7] Report of Analysis Results of the Habitation Specific Action Team (HAB-SAT), http://www.lpi.usra.edu/leag/reports.html

[8] Report of Analysis Results of the Geology-Geophysics Specific Action Team (GEO-SAT), http://www.lpi.usra.edu/leag/reports.html