Lunar Exploration Analysis Group
Report of Analysis Results of the Habitation Specific Action Team (HAB-SAT)

Introduction

HAB-SAT represents an activity of phase 2 of the Themes, Objectives, and Time Phasing (TOP) Specific Action Team (SAT) that was requested by NASA ESMD and approved by the chair of the NASA Advisory Council. Its purpose was to suggest relative rankings of the objectives for lunar exploration within the core theme of lunar habitation ("Extend sustained human presence to the Moon to enable eventual settlement"). HAB-SAT made its rankings by assuming that NASA's role in fulfilling the habitation theme was to establish sufficient capabilities to enable long-duration (many lunar days) human presence on the Moon, hence setting the stage for permanent settlement.

Participants

HAB-SAT participants represented a range of specialties, including science, engineering, resource utilization, biomedical science, life support systems, construction, and habitat design, with each having a broad overview of the entire enterprise.

Stephen Mackwell, Lunar and Planetary Institute (co-chair)
Jeff Taylor, University of Hawaii (co-chair)

Daniel Barta, NASA Johnson Space Center
James Blacic, Consultant
Don Bogard, NASA Johnson Space Center
Ben Bussey, Applied Physics Laboratory
Mike Duke, Colorado School of Mines
Leslie Gertsch, University of Missouri-Rolla
Anthony Hanford, ESCG/NASA Johnson Space Center
Mark Henley, Boeing Corporation
Antony Jeevarajan, NASA Johnson Space Center
Jeff Jones, NASA Johnson Space Center
Jitendra Joshi, NASA Headquarters
Noreen Khan-Mayberry, NASA Johnson Space Center
David Kring, Lunar and Planetary Institute
Rob Landis, NASA Johnson Space Center
Sam Lawrence, University of Hawaii
Mark Lee, NASA Headquarters
James Locke, NASA Johnson Space Center
Wendell Mendell, NASA Johnson Space Center
Lewis Peach, University Space Research Association
Tony Ricco, Stanford University

Gerald Sanders, NASA Johnson Space Center
Rick Scheuring, University of Texas Medical Branch/NASA Johnson Space Center
Camille Shea, NASA Johnson Space Center
Paul Spudis, Applied Physics Laboratory
Larry Taylor, University of Tennessee
Michael Wargo, NASA Headquarters
Robert Wegeng, NASA Headquarters

Procedures

The product produced by HAB-SAT is a spreadsheet containing the list of objectives and their descriptions, summaries, and value, along with our ranking and an estimate for when work needs to begin to meet each objective and when the objective needs to be either implemented or achieved.

Ranking

HAB-SAT used a numerical ranking that used the entire scale between 1 and 10. We first ranked each objective into broad categories of high, medium, and low priority (*for the habitation theme*), as follows:
High (8−10): essential for long-duration lunar habitation
Medium (4−7): Useful to somewhat useful for long-duration lunar habitation
Low (1−3): Not useful to achieve long-duration lunar habitation

The group then ranked each objective numerically by voting on the most appropriate score for each objective. For example, for objective ranked "high" the chair asked for a show of hands for ranking it 8, then 9, then 10. The predominant value was assigned to the objective, using integers only. This produced a reasonable consensus on the value of each objective.

Many objectives were ranked as **not applicable** (n/a on the spreadsheet) because they have nothing to do with the habitation theme. Many objectives with low rankings are important to other themes, such as science. Their low ranking shows that they are not central to habitation, but that they do make some contribution. Some objectives were **not ranked** by HAB-SAT. These were in categories that may be very important to the habitation theme, but are less important in developing the lunar architecture. An example is public engagement. HAB-SAT participants are enthusiastic about public engagement and its great benefits to achieving the vision for space exploration and believes it to be applicable (hence could not be ranked "n/a"), but did not rank those objectives explicitly.

Time scales

To further aid NASA planning, HAB-SAT also assessed when an objective should be either implemented or achieved, and when work on achieving the objective needs to start.

Early—Everything before the second human mission to the Moon.

Middle—Through the time when humans remain through an entire lunar day (hence through a lunar night – total duration of around 28 earth days).

Late—Multiple lunar days, hence multiple nights, but before a large settlement begins to be constructed.

New objective added
In assessing the relative rankings of the objectives, HAB-SAT noticed a gap in the objectives in the transportation category. It suggests adding one that calls for the establishment of a sustained cis-lunar space transportation system based on the use of space resources. We added that as objective mTRANS5, which is highlighted in orange on the spreadsheet.

HAB-SAT Comments
The team added a column in which to write comments on its ranking or the time phasing of an objective. Most cases did not require comments.

Other Notes

Near-Earth Asteroids
The team discussed the value of using near-Earth objects (NEOs) for their resources, in addition to lunar resources. Resource utilization is clearly important to long-duration habitation of the Moon. Near-Earth Objects have abundant resources, including bulk material for shielding in space, metallic iron-nickel, and H_2O. In fact, if meteorites are a good guide, some NEOs could contain up to 20 wt% of H_2O, a considerable resource available at relatively small delta V. Their use may greatly enhance exploration capabilities. HAB-SAT suggests that the possible role of NEOs should be included as the exploration architecture is developed.

Science and permanent presence
HAB-SAT notes that there is an important interplay between human habitation and science activities on the Moon. A permanent human presence will enable the achievement of many science objectives. In addition, the design of EVA equipment, surface mobility systems, and surface habitats will in some part be driven by the requirements defined by the science tasks to be performed on the lunar surface.

Public engagement
As noted above, although we did not rank public engagement, HAB-SAT believes that public engagement is an important part of the exploration program.

Commerce
While we did not rank the commercial development objectives, extensive commercial involvement is important to facilitate the sustainability of long-term lunar habitation.