Lunar Exploration Analysis Group (LEAG)

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Lunar Exploration Analysis Group

- Community based, interdisciplinary forum
- Analyzes scientific, engineering, technology, and operational issues associated with lunar exploration to support the Vision for Space Exploration—i.e., it asks tactical questions
- Reports findings and analysis to Science Mission Directorate and Exploration Systems Mission Directorate, through NASA Chief Scientist

Goals for First Meeting

(Meeting Held January 10-12, 2005)

- Hear status reports on science, technology, human exploration, robotic exploration, LRO, and planned international robotic lunar missions
- Analyze two important questions:
  1. What will humans do on the Moon when they get there?
  2. What are the priorities and phasing for human precursor investigations and technology
- Plan next steps for LEAG
  – Specific Action Teams
  – Plan preliminary agenda for next meeting
  – Outline subsequent meetings

Major Findings

- Assumption: sustained human presence on the Moon is essential for a dynamic program of robotic and human exploration of the solar system
- Importance of In Situ Resource Utilization
- Exciting set of human activities identified
- Measurements, experiments, and other activities for robotic missions identified and rough priorities established
- Need a scientific instrumentation/facility development program

Sustained Human Presence

- Strong consensus that lunar program should lead to continuing expansion of human capabilities on the Moon
  – Learn how to live and work on another planet, essential for the human exploration of Mars and beyond
  – Allows for increasing involvement of private sector as capabilities of transportation system and lunar facility increase

Sustained Human Presence-2

- Strong consensus that program should focus on one locality that serves as a focal point for human exploration
- Advantages of single site:
  – Leads to incremental growth of the facility and its capabilities
  – Opens the way for a permanent facility that allows permanent habitation
  – Its evolutionary development and long-term operation require developing capabilities for self-sustaining operation (e.g., ISRU, closed system life support)

Sustained Human Presence-3

- Advantages (continued)
  - Develops capabilities for doing long-duration missions to Mars and beyond
  - Allows for long-duration science studies (e.g. biological medical studies, certain geoscience investigations)
  - Allows for in-depth science study of one site
  - Lends itself to developing a strategy for transition from government to private operation
  - Becomes an off-Earth village in public perception

Sustained Human Presence-4

- Disadvantages of single site:
  - Limit the number of diverse terrains studied (at least until capability for global access established)
  - Limited types of ISRU experiments
  - We may not know by 2015 where to establish the base, so it is wise to keep open the option of going to multiple landing sites for reconnaissance
  - More difficult to do global network science (e.g., seismic network to study lunar interior)
  - May need to go to more sites to meet overall mission needs (e.g., resources, experiments in human habitation out of sight of Earth)

Sustained Human Presence-5

- Disadvantages of single site (continued)
  - Danger of bureaucratic fixation of big lunar base and then maintaining it without end. Mitigated by
    - Involvement with private industry from the start
    - A strategy to transition to non-NASA operation
    - Plans to lease facilities to or from private enterprises
- Possible Modification to Single Site Approach
  - Maintain Spiral 2 as consisting of multiple reconnaissance missions to multiple location
  - Consider one location for spiral 3, for buildup of infrastructure and capabilities. Capabilities include maintaining excursion abilities to other locations

Importance of In Situ Resource Utilization

- Strong consensus that ISRU is necessary for sustainable (including affordable) human presence in space.
- Experiments on robotic and human missions needed (priority order based on timing)
  - How to move and handle regolith
  - Thermal processing of regolith (e.g., sinter to make pavement)
  - Resource extraction (e.g., oxygen via reduction of regolith, extraction of ice)

A Guiding Principle of Exploration

- Consensus that the robotic and human mission set should do the following:

1) Improve human exploration capabilities, including cislunar space and Mars (e.g., production of propellant)—I.e., Contribute to sustained human presence on the Moon to enable exploration beyond
2) Fundamental science (geoscience, space physics, astronomy, biology, human biology, materials science, etc.)
3) Experiment and innovate potential commercial and industrial applications, with private industry involvement

Robotic Measurements, Experiments, and Other Activities

- Prime objectives:
  - Resource assessment and development
  - Human safety during long-duration stays on Moon
  - Characterization of potential human mission landing sites
  - Science studies

Robotic Measurements, Experiments, and Other Activities

- Elements of robotic missions--higher priority
  - **Resource assessment (prospecting, esp. polar regions)**
  - **Experiments on regolith excavation and handling**
  - **Experiments in resource extraction and storage**
  - **Biology experiments**
  - **Baseline scientific characterization (before extensive contaminated or altered)**
    - Lunar atmosphere characterization
    - Read the scientific record of the polar volatile deposits
  - **Emplacement of infrastructure elements**
    - Modest at first (comm/nav, landing beacon)
    - Increasingly more complex with time

Robotic Measurements, Experiments, and Other Activities

- Elements of robotic missions--lower priority because they can be done later
  - Behavior of fluids at 1/6 g (ISRU, biology, closed-loop systems)
  - Dust:
    - Aerosol physics
    - Characteristics, inhalation hazard, charge state, chemical hazard, 1/6 g effects, settling/dispersion rates
    - In situ particle characterization
  - Radiation dosimetry
  - Installation of seismometers and other network science instruments
  - Gas content of undisturbed lunar regolith
- Set of orbital measurements not being done by LRO (lower priority on requirements list set forth by ORDT)

Technology Demonstrations

- Excavation, material handling, workability of regolith (early in program, high priority)
- ISRU process validation (early, high)
  - Extraction of volatiles
  - Extraction of oxygen from the regolith
- Closed loop life support system, storage of waste (early, high)
- Precision landing, hazard avoidance, hazard tolerance (early, high)
- Material processing for fabrication and construction (late, medium)
- Telerobotic experiments (early, high)
- Robotic sample collection (late, medium)
- Space weathering of materials (old hardware) (late, lower)

Robotic Mission Landing Sites

- Priority given to characterizing permanently shadowed site at lunar poles
  - Importance of polar regions
    - Ice (if it is there) is an important resource
    - Cold traps themselves might be a resource (e.g., IR telescope)
    - Places with nearly permanent illumination:
      - Might eliminate need for nuclear power
    - “Permanently” illuminated areas are more like Mars than any other place on Moon
    - Scientific value of cold traps is very high
    - Cold regions most like environments in outer solar system (icy satellites, comets, Kuiper belt objects)—the Moon, Mars, *and beyond*

Robotic Mission Landing Sites

- First landed robotic mission does not necessarily need to land in permanently shadowed location
  - May need time to assess LRO data to choose site
  - Excellent technical and scientific studies can be made in illuminated area
  - Could even land a mission in an equatorial region (e.g., on a volcanic deposit) to test systems, do biology and other experiments, and an ISRU demonstration

Other Important Matters

- Strong concensus that we need for a program to develop scientific instrumentation and facilities
- Need for private involvement from the start, including on robotic missions. (Not enough discussion to know if this is a consensus view.) Possibilities:
  – Prizes
  – Data purchases
  – NASA-industry partnerships on instrument or ISRU experiment

Action Items

- Identified need for Specific Action Teams (details still being decided):
  1. Goals Committee to establish goals, objectives, activities/measurements, and priorities for lunar exploration, including goals for lunar science
  2. Science Instrumentation and Facilities Team to define a development program in biotechnology, geoscience, materials science, and other science

Action Items

3. Analytical Lab/Sample Return Analysis Team
   - Trade off between sample mass (geological, biological, materials science), sophistication of lunar surface analytical facilities, and time spent by astronauts
   - Analytical devices needed in the field vs laboratory
   - Trade off between in situ analysis and return of samples that are difficult to preserve (e.g., ice-bearing regolith at 50K)
4. ISRU options, strategies, and priorities
   - ISRU and its role in permanent human presence on planetary surfaces
   - What constitutes a "resource"
   - How do we characterize resources?

Action Items

- Specific Action Teams 2–4 will complete their studies by the next meeting (June 2005)
    - Present their findings
    - Discussion among participants to modify and reach a consensus
- Goals Committee will begin the process, with input from the strategic roadmapping activity
    - – Discussion of goals in breakout groups during next meeting
    - – Implies that the basic structure has been developed by June 2005

Next Meetings and Their Objectives

- Next meeting, June 2005:
  - Same invited group (possibly slightly supplemented) as for first meeting
  - Discuss and reach consensus on output from SATs 2–4
  - Discussion of Goals, objectives, etc.
  - Breakout group that examines the role of LRO in providing guidance for site selection for polar lander
    - What key information LRO provides
    - When derived results will be available
    - An assessment of the number of landing sites or extent of mobility needed to characterize polar deposits
    - Assessment of hard vs soft landers
    - May evolve into a Specific Action Team

Next Meetings and Their Objectives

- June 2005 meeting (continued)
  - Breakout group to make a quantitative assessment of ISRU based on work done by SAT
- Fall 2005
  - All hands meeting
  - Something of a conference, but with emphasis on useful products, such as these examples:
    - **Roles of government and private sector**
    - Detailed look at potential testbed payloads for ISRU