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LEAG

Report to:

Commercial Development Summit on NASA's Lunar Activities

May 13, 2008

Washington, DC

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LEAG Leadership

Appointed by the Chair of the NAC

Chair:	Clive Neal, UND
Vice Chair:	Chip Shearer, UNM
Previous Chair:	Jeff Taylor, U Hawaii
Executive Secretary:	Mike Wargo, HQ
SMD:	Kelly Snook, HQ
SOMD:	Michelle Gates, HQ
Lunar Community Liaison:	Steve Mackwell, LPI
ISRU Subgroup Chair:	Jerry Sanders, JSC
Commerce Subgroup Chair:	Paul Eckert, Boeing

Lunar Exploration Analysis Group (LEAG) Terms of Reference

The Lunar Exploration Analysis Group (LEAG) is responsible for analyzing scientific, technical, commercial, and operational issues associated with lunar exploration in response to requests by NASA. The LEAG serves as a community-based, interdisciplinary forum for future exploration and provides analysis in support of lunar exploration objectives and their implications for lunar architecture planning and activity prioritization. It provides findings and analysis to NASA through the NASA Advisory Council (the Council) within which the LEAG Chair is a member of the Planetary Science Subcommittee (PSS).

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

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Lunar Exploration Analysis Group

What we do:

- Community based, **interdisciplinary** forum
- Analyzes scientific, engineering, technology, and operational issues associated with lunar exploration to support the Vision for Space Exploration
- Not limited to science — covers exploration activities, science, resource utilization, and commerce
- Reports findings and analysis to Exploration Systems Mission Directorate, Science Mission Directorate and Space Operations Mission Directorate, through NASA Advisory Council

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LEAG Activities

- Workshop on Lunar Knowledge Requirements for Human Exploration, March, 2004
- - Examined state of knowledge of lunar basic and applied science
- - ORDT for LRO
- First formal meeting, January, 2005
  - Examined issues surrounding human missions:
    - Sorties vs single base
    - Role of Resource Utilization
    - Commercial involvement
  - Studied robotic measurements and experiments; set rough priorities
  - Developed list of technology demonstrations
- Specific Action Team: Nature of Second Lunar mission, March, 2005

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LEAG Activities ctd.

- Specific Action Team: Science Activities and Site Selection, June-July, 2005
- Co-sponsored “Space Resources Roundtable VII: LEAG Conference on Lunar Exploration”, October, 2005
- Specific Action Team: Review of Plans Developed by the RLEP 2 Measurement Team, March, 2006
- LEAG_TOP-SAT: Review of Themes and Objectives Phasing Document for Lunar Exploration Strategy, July, 2006
- LEAG_HAB-SAT: To assess the relative importance and time phasing of objectives in relation to the theme of Human Habitation of the Moon, Oct. 12-13, 2006
- LEAG_GEO-SAT: To assess the relative importance of objectives in relation to the theme of Geological Activities on the Moon, Nov. 2006
- OSEWG/LEAG Workshop on Architecture Issues Associated with Sampling: June 25-26, 2007
- LEAG Meeting: October 1-5, 2007

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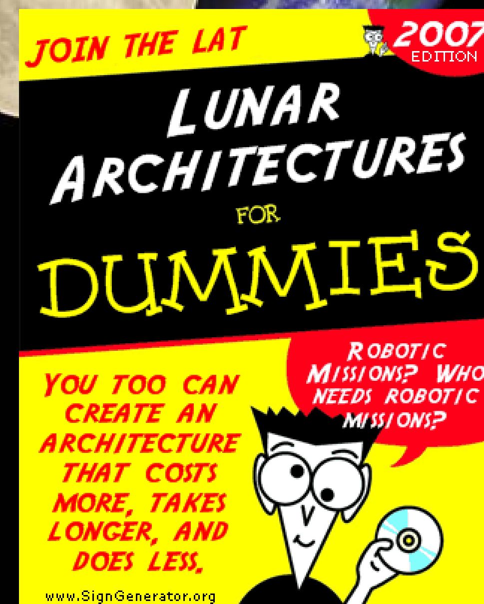
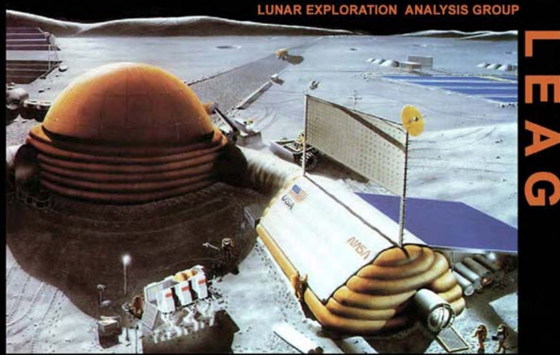
LAT-2 Review - Potential Task

New Charge?

Further lunar exploration architecture concept developments should be reviewed by the Lunar Exploration Analysis Group, which represents a variety of lunar exploration stake holders and partners, including the science community, to assess how well continued developments align with the recommendations of the NAC from the 2007 Tempe workshop.



Still negotiating the final charge.



The Lunar Exploration Roadmap

Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

A Community Effort Coordinated by the Lunar Exploration Analysis Group (LEAG)

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Lunar Exploration Roadmap

The Charge from the NAC

The Science Committee recommends that the Lunar Exploration Analysis Group (LEAG) be tasked to prepare a “Lunar Goals Roadmap” that maps science goals to objectives, and to observations and measurements. This roadmap should include an assessment of needed technology developments, areas of potential coordinated activities for commercial and international participation, and potential feed-forward activities for the exploration of Mars and beyond.

With input from:

- Global Exploration Workshop, April 2006
- NASA/NAC Workshop on Science Associated with the Lunar Exploration Architecture, Feb. 2007
- NRC Science Context for Exploration of the Moon, 2007

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Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

A Community Effort Coordinated by the Lunar Exploration Analysis Group

Themes: Why are we going to the Moon?

Theme 1: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

Theme 2: Use the Moon to prepare for future missions to Mars and other destinations.

Theme 3: Extend sustained human presence to the Moon to enable eventual settlement.

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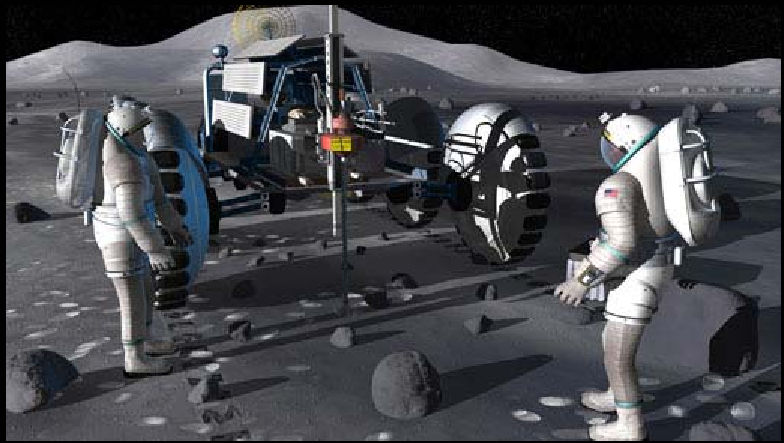
Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

A Community Effort Coordinated by the Lunar Exploration Analysis Group

Crosscutting Themes:

- Learn to live and work successfully on another world.
- Expand Earth's economic sphere to encompass the Moon, and pursue lunar activities with direct benefits to life on Earth.
- Strengthen existing and create new global partnerships.
- Engage, inspire, and educate the public.



Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

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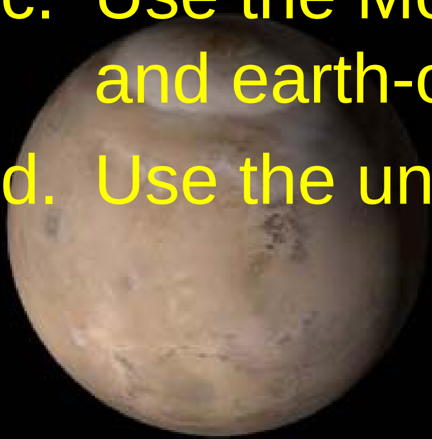
Theme 1: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

a. Understand the formation, evolution and current state of the Moon.

b. Use the Moon as a "witness plate" for solar system evolution.

c. Use the Moon as a platform for astrophysical, heliophysical, and earth-observing studies.

d. Use the unique lunar environment as a research tool.



IMP-SAT has been folded into Theme 1

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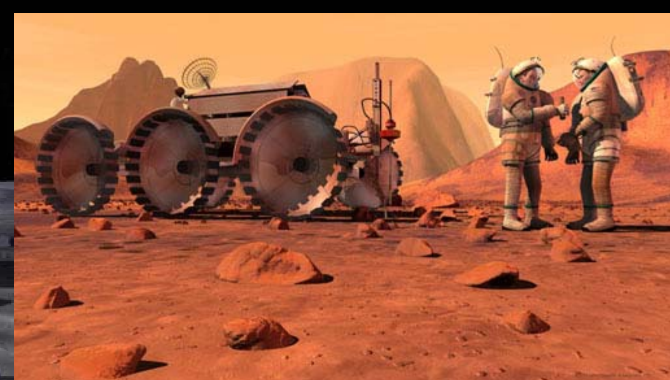
Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

Theme 2: Use the Moon to prepare for future missions to Mars and other destinations.

a. Identify and test technologies on the Moon to enable robotic and human solar system science and exploration.

b. Use the Moon as a test-bed for systems, flight operations, and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond.



Lunar Exploration Roadmap

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Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

Theme 3: Extend sustained human presence to the Moon to enable eventual settlement.

a. Identify, develop, and mature technologies and deploy initial infrastructure capabilities.

b. Reduce the cost of re-supply and dependency on Earth.

c. Keep humans healthy and safe off-planet.

d. Facilitate development of self-sustaining economic activity.

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Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

Themes and Goals are currently on the web for public comment – 2 week window:

https://www.lpi.usra.edu/survey/LEAG_ThemesGoals/

Login: leag   Password: moonorbust

Three SATs are being formed - reports by end of May.

Public comment on the reports via the web.

Special session at the Lunar Science Conference at Ames in July for further community input.

Unveil the Roadmap at the LEAG meeting in October.

Exploring the Moon in the 21st Century: Themes, Goals, Objectives, Investigations, and Priorities, 2008

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IMPORTANT: NASA needs an exit strategy from the Moon that allows it to got to Mars and beyond, but doesn't abandon the infrastructure it has built up, which can still be used for science purposes.

Commercial on-ramps are vital - these center around ISRU capabilities, which are also important for the "feed-forward" focus on Mars.

LEAG Milestones

2003	2004	2005	2006	2007	2008	2009	2010	2011

3/1 ♦ Workshop on Lunar Knowledge Req'ts for Human Exploration

1/1 ♦ First Formal LEAG Meeting

3/1 ♦ Specific Action Team: Nature of 2nd Lunar Mission

7/1 ♦ SAT: Science Activities and Site Selection

10/1 ♦ SRR VII / LEAG Conference

3/1 ♦ SAT: RLEP2 Measurement Team Plans Review

7/11 ♦ LEAG_TOP-SAT: GES Themes/Objectives Review

10/12 ♦ LEAG_HAB-SAT: Prioritization of Objectives Against Habitation

11/15 ♦ LEAG_GEO-SAT Prioritization of Objectives against Geology

6/25 ♦ OSEWG / LEAG Architecture and Sampling

10/1 ♦ LEAG Meeting

5/31 ♦ 3 SAT Reports due

7/1 ♦ NLSI LSC at Ames

10/28 ♦ LEAG Meeting; Road map unveiled

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NASA Budget

LEAG views the 2009 NASA budget with optimism as it is a great start for going to the Moon to get to Mars and beyond.

The Moon can address key Solar System issues that can then be applied to other planets (e.g., crater chronology, magma ocean evolution, space weathering, etc.).

The resources being devoted to the Moon are timely and required to advance the vision.

Lunar Exploration Roadmap

LEAG Meeting 2008

October 28-31, 2008
(coincide with LRO launch).

Joint with ILEWG and SRR.

Radisson Resort at the Port, in Cape Canaveral, Florida.

Plenary and concurrent sessions - focused on questions pertinent to achieving the “vision” - similar to the last LEAG meeting.

http://www.lpi.usra.edu/meetings/leagilewg2008/

Lunar Exploration Roadmap

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LUNAR EXPLORATION ANALYSIS GROUP
INTERNATIONAL LUNAR EXPLORATION WORKING GROUP
SPACE RESOURCES ROUNDTABLE

JOINT ANNUAL MEETING OF LEAG–ICEUM–SRR

October 28–31, 2008 + Cape Canaveral, Florida

LEAG - ICEUM - SRR

Backup slides

Theme 1: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

Goal 1A: Understand the formation, evolution and current state of the Moon.

The Moon has been and will continue to be the scientific foundation for our knowledge of the early evolution of the terrestrial planets. Therefore, understanding the formation, evolution and current state of the Moon is vital for understanding the early evolution of the inner solar system. The remotely sensed and sample data allow us to define investigations that test and further refine models established for lunar origin and evolution. For example, documenting the diversity of crustal rock types and the composition of the shallow and deep lunar mantle will allow refinements of the lunar magma ocean hypothesis. Unequivocally establishing the presence of a lunar core (along with its dimensions and composition) and establishing the nature of the deep lower mantle will aid in establishing the bulk composition of the Moon and global differentiation processes. Important in understanding the evolution of the Moon is establishing an end-member state - that is, the current geophysical, cosmochemical, and tectonic condition of the Moon.

Theme 1: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

Goal 1B: Use the Moon as a "witness plate" for solar system evolution.

As the Moon has been relatively tectonically quiet over the last 3 byr., it contains a record of early events shaping the inner solar system has long since vanished from the Earth and has been at least partially erased from Mars.

- The Moon retains the history of the early impact environment of the inner solar system, at a time when life may have first arisen on Earth and perhaps Mars. The changes in this impact environment over 4.5 billion years have implications for the evolution of life and potentially events in the outer solar system.

- The Moon contains the remnants of one of the basic mechanisms of early planetary differentiation: magma ocean. It also retains the thermal and magmatic history of a dynamic terrestrial planet from its conception to its last dying breath. Placing this history within the context of the structure of the lunar interior will give us a much richer understanding of how terrestrial planets work.

- The lunar regolith bears witness the to the process of space weathering, the interactions between the surface and space. Such interactions can be extrapolated to other airless bodies. These interactions preserve a record of solar activity and evolution.

Theme 1: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

Goal 1C: Use the Moon as a platform for astrophysical, heliophysical, and earth-observing studies.

The Moon provides a unique stable platform for observations of the Earth, the Sun and the Universe. While distant from the Earth, observatories on the Moon are able to provide important data on Earth’s surface, atmosphere and magnetosphere, complementing and enhancing satellite and ground-based observations. The Moon’s position relative to Earth’s magnetosphere makes it an excellent location to study the solar wind, investigate Earth’s magnetotail, characterize the effects of the Moon on the local plasma environment, and perform observations of the Sun over a broad frequency spectrum. Astrophysical studies may be performed from the Moon, especially at frequency ranges not favorable for space-based telescopes. In particular, the lunar surface offers unique opportunities for long-wavelength radio astronomy from the radio-quiet far side of the Moon.

Theme 1: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

Goal 1D: Use the unique lunar environment as a research tool.

The Moon has a unique combination of environmental characteristics, establishing experimental boundary conditions, not collectively attainable on Earth, that may be valuable and necessary to the investigation of high priority scientific questions. [The following examples of lunar environmental characteristics should be considered illustrative and not exhaustive.] A significant and unique environmental characteristic is the long duration, steady 1/6 g environment on the surface of the Moon. Many physical and biological systems are known to be sensitive to both the magnitude, direction, and temporal ("g-jitter") characteristics of local acceleration. Phenomena that are driven by competing processes may exhibit nonmonotonic behavior with respect to g, i.e. an extremum response may exist somewhere between the microgravity environment available in free fall (orbit) and the 1 g environment characteristic of Earth's surface. The Moon's 1/6 g offers a unique opportunity to definitively baseline human physiological and performance responses compared to those obtained in Earth gravity and microgravity on ISS. Rigorous physiological data collection during lunar missions, combined with analyses of integrated archived human health data from previous space missions, would enable us to compensate for the small sample sizes on individual flights and inform subsequent planning for Mars. While the space radiation environment on the lunar surface is not unique (principally a combination of galactic cosmic rays, solar energetic particles, and commensurate neutron albedo), its combination with 1/6 g is. This is also true with respect to the plasma and vacuum (hard vacuum combined with near infinite pumping speed) environments. Therefore, the possibilities exist for unique, high value, experiments/investigations to be performed at the proposed outpost.

Theme 2: Use the Moon to prepare for future missions to Mars and other destinations.

Goal 2A: Identify and test technologies on the Moon to enable robotic and human solar system science and exploration.

There is a need to develop technologies to a sufficiently mature stage for flight so as to be ready for surface and orbital operations. A smooth pathway is necessary to bring identified technologies to a high technology readiness level (TRL) so their development does not hinder progress in the exploration of the solar system and/or achieving science goals. This is particularly important for lunar surface operations and feed-forward technologies for the exploration of Mars and beyond.

The Moon will serve as a test bed for technologies that will enable sustained human exploration of Mars and beyond. These technologies include closed-loop life support and in-situ resource utilization systems to reduce the mass of consumables that must be resupplied from Earth, fission surface power systems to provide abundant power far from the sun, advanced robotics for assembly and maintenance of remote outposts, surface mobility and EVA systems that will allow the crew to explore regions hundreds of kilometers away from their outpost, and habitation systems to enable the crew to live and work in hazardous environments on long-duration missions.

Theme 2: Use the Moon to prepare for future missions to Mars and other destinations.

Goal 2B: Use the Moon as a test-bed for systems, flight operations, and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond.

While the Moon and Mars have different gravities and drastically different environments and soil properties, both are still hostile environments that require similar functional capabilities for humans to explore and live off Earth. The nearness of the Moon with respect to Earth allows for opportunities in testing exploration techniques and these functional capabilities without the concern that help from Earth or the ability of the crew to return safely is more than a year away. The purpose of this goal is to evaluate what general exploration systems, operations and exploration techniques can be tested on the Moon to enhance the future successes of missions to Mars and beyond. Exploration crews living on the moon offer a unique opportunity to study and understand human behavioral adaptation to space in an operational realistic setting, with the goal of understanding, enhancing and maintaining crew behavioral health during extended-duration missions. Both ISS and ground-analogs offer platforms to compare and amplify lessons learned in lunar studies about living and performing in isolated and confined micro-societies over 2-3 year periods. The lunar outpost missions also offer a unique environment to facilitate collection of human biomedical data over extended periods and validate biomedical capabilities for autonomous health care during exploration missions.

Theme 3: Extend sustained human presence to the Moon to enable eventual settlement.

Goal 3A: Identify, develop, and mature technologies and deploy initial infrastructure capabilities.

Science, exploration, and commerce all require the development and emplacement of infrastructure to provide basic services (e.g., transportation, communications, navigation, power, habitation). It is essential that the technical, economic, and legal/regulatory/policy considerations relevant to infrastructure development be addressed in an affordable and sustainable manner.

Theme 3: Extend sustained human presence to the Moon to enable eventual settlement.

Goal 3B: Reduce the cost of re-supply and dependency on Earth.

Past and current human exploration activities in and beyond Earth orbit require a significant amounts of logistics to keep the crew alive and systems running. The logistics required include everything from food, water, and oxygen to sustain the crew and perform extra vehicular activities to replacement hardware and spares to fix hardware that has failed. In order to attain the goal of sustainable human presence on the lunar surface it is an imperative that the life support loop is closed in consonance with the mission duration. Longer missions will deem increased closure of the air, water and food loops. Systems level demonstrations will allow us to gain confidence in the performance of the subsystems in relevant environments. Currently plans dictate that all exploration and infrastructure capabilities must be built and delivered from Earth, so exploration and contingency recovery is completely dependent on if and when Earth delivery is possible. This goal should address the following and similar investigations:

- Examining and using other remote human operations (e.g. Antarctic science stations) to test and validate technologies to gain system level confidence and adopt the lessons learnt into human lunar exploration plans?
- Investigate alternative transportation architectures that re-use or refuel assets more than once either initially or evolved from the current architecture?

Theme 3: Extend sustained human presence to the Moon to enable eventual settlement.

Goal 3C: Keep humans healthy and safe off-planet.

This goal is supported by the need to comply with agency-level standards designed to assure the health and safety, and career longevity of the astronauts. From these standards flow a number of requirements that drive the design of systems for keeping the astronauts safe and healthy. They also drive procedures and processes for mission operations and space life sciences personnel to assure a healthy and fit astronaut corps. These activities require the close collaboration of:

- life sciences (space medicine, biomedical research for countermeasures, and Environmental health/human factors and habitability);
- Engineering;
- Mission operations;
- Extravehicular activity (EVA) projects;
- Flight crew.

The results of this interaction will include services to assure:

- optimum physical and behavioral health before, during, and after a mission;
- medical care for all mission related activities;
- crew training, to include crew medical officer training;
- contingency planning; the provision of life support;
- optimum EVA mobility and suit design;
- effective exercise countermeasures;
- identification of and protection from environmental exposures;
- optimum habitat for the various design reference missions;
- mission specific performance and human factors;
- attention to food and nutrition for quality, re-supply, and/or regeneration;
- reasonable crew schedules;
- safe launch, re-entry, and recovery.

Theme 3: Extend sustained human presence to the Moon to enable eventual settlement.

Goal 3D: Facilitate development of self-sustaining economic activity.

Sustainability and growth of lunar presence will require that resources come not only from government but also from the private sector. Public-private partnerships are needed to ensure that government activity facilitates to the greatest possible extent the development of commercial and other private-sector initiatives. Encouragement of entrepreneurship and private investment will play a key role in fueling innovation and economic expansion.