The US Lunar Exploration Analysis Group (LEAG) & the Lunar Exploration Roadmap


Michael J. Wargo ScD
LEAG Executive Secretary
Lunar Exploration Analysis Group (LEAG)

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

Operates under a charter from NASA.

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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.

A Community Effort Coordinated by the Lunar Exploration Analysis Group

Themes: Why are we going to the Moon?

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

Feed Forward (FF) Theme: Use the Moon to prepare for future missions to Mars and other destinations.

Sustainability (Sust) Theme: Extend sustained human presence to the Moon to enable eventual settlement.

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**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.
Science (Sci) Theme: Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.

GOALS

a. Understand the formation, evolution and current state of the Moon (9 Objectives, 35 Investigations).

b. Use the Moon as a “witness plate” for solar system evolution (2 Objectives, 9 Investigations).

c. Use the Moon as a platform for astrophysical, heliophysical, and earth-observing studies (3 Objectives, 25 Investigations).

d. Use the unique lunar environment as a research tool (15 Objectives, 38 Investigations).
Feed Forward (FF) Theme: Use the Moon to prepare for future missions to Mars and other destinations.

GOALS

a) Identify and test technologies on the Moon to enable robotic and human solar system science and exploration (9 Objectives, 38 Investigations).

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 (2 Objectives, 10 Investigations).
Sustainability (Sust) Theme: Extend sustained human presence to the Moon to enable eventual settlement.

GOALS

a. **Expand Science**: Provide support, services, and infrastructure to enhance and enable new science to the Moon, on the Moon, and from the Moon (crossover with Sci Theme) (5 Objectives, Investigations TBD);

b. **Expand Human Exploration**: Expand in-space and surface transportation capabilities beyond initial NASA transportation architecture to discover and reach new territories (crossover with Sci and FF Themes) (7 Objectives, Investigations TBD);
Sustainability (Sust) Theme: Extend sustained human presence to the Moon to enable eventual settlement.

GOALS (cont.)

c. **Enhance Security**: Protect and benefit Earth, and guarantee peace and safety both for settlers and for the home planet (6 Objectives, Investigations TBD);

d. **Commercial on ramps** (Enable space economic activity to benefit Earth and lunar settlement and to enable NASA to explore beyond the Moon) (3 Objectives, Investigations TBD);

e. **Sustaining Human Presence on the Moon** (6 Objectives, Investigations TBD).
IMPORTANT: NASA needs a transition strategy from the Moon that allows it to go 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.
• Community effort.
• Input at targeted sessions at conferences.
• Web site for more detailed input.
• Sustainability is the key:
  - Transition strategy outlined;
  - Commercial “on ramps” are defined;
  - International cooperation is critical.
The Lunar Exploration Roadmap

3 Themes

**Science (Sci) Theme:** Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them

**Feed Forward (FF) Theme:** Use the Moon to Prepare for Future Missions to Mars and Other Destinations

**Sustainability (Sust) Theme:** Extend Sustained Human Presence to the Moon to Enable Eventual Settlement

*Why are we going back to the Moon?*

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.

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Traceability to previous studies:

- The Report from the Lunar Geoscience Observer Workshop (1986);
- The Status and Future of Lunar Geoscience (1986);
- A Site Selection Strategy for a Lunar Outpost: Science and Operational Parameters (1990);
- Geoscience and a Lunar Base: A Comprehensive Plan for Lunar Exploration (1990);
- A Planetary Science Strategy for the Moon by the Lunar Exploration Science Working Group (LExSWG, 1992);
- Lunar Surface Exploration Strategy (LExSWG, 1995);
- A Renewed Spirit of Discovery: The President's Vision for US Space Exploration (2004);
- COSPAR/ILEWG Declarations
- US National Space Policy (2006);
- The Vision for Space Exploration (2004);
- New Views of the Moon (2006);
- LEAG GEO-SAT (2006);
- The Global Exploration Strategy: The Framework for Coordination (2007);
- NASA Advisory Council Workshop on Science Associated with the Lunar Exploration Architecture, Tempe, AZ (2007);
Science Theme = 4 Goals

**Science (Sci) Theme:** Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them

- **Goal Sci-A:** Understand the formation, evolution, and current state of the Moon
- **Goal Sci-B:** Use the Moon as a “witness plate” for solar system evolution
- **Goal Sci-C:** Use the Moon as a platform for Astrophysical, Heliophysical, and Earth-Observing studies
- **Goal Sci-D:** Use the unique lunar environment as a research tool
Goal Sci-A: Understand the formation, evolution, and current state of the Moon

9 Objectives
36 Investigations

Objectives Sci-A:

- Objective Sci-A-1: Understand the environmental impacts of lunar exploration
- Objective Sci-A-2: Development and implementation of sample return technologies and protocols
- Objective Sci-A-3: Characterize the environment and processes in lunar polar regions and in the lunar exosphere
- Objective Sci-A-4: Understand the dynamical evolution and space weathering of the regolith
- Objective Sci-A-6: Understand volcanic processes
- Objective Sci-A-7: Understand the impact process
- Objective Sci-A-8: Determine the stratigraphy, structure, and geological history of the Moon
- Objective Sci-A-9: Understand formation of the Earth-Moon system

Investigations:

- 2 Investigations
- 4 Investigations
- 4 Investigations
- 5 Investigations
- 5 Investigations
- 4 Investigations
- 5 Investigations
- 4 Investigations
- 3 Investigations
Science: Inner Solar System

**Goal Sci-B:** Use the Moon as a “witness plate” for solar system evolution

**Objective Sci-B-1:** Understand the impact history of the inner Solar System as recorded on the Moon

4 Investigations

**Objective Sci-B-2:** Regolith as a recorder of extra-lunar processes

5 Investigations

2 Objectives; 9 Investigations

Science: From the Moon

**Goal Sci-C:** Use the Moon as a platform for Astrophysical, Heliophysical, and Earth-Observing studies

**Objective Sci-C-1:** Astrophysical Investigations using the Moon

8 Investigations

**Objective Sci-C-2:** Heliophysical Investigations using the Moon

12 Investigations

**Objective Sci-C-3:** Use the Moon as a platform for Earth-Observing studies

8 Investigations

3 Objectives; 28 Investigations
**Goal Sci-D:** Use the unique lunar environment as a research tool

**Objective Sci-D-1:** Investigate and characterize the fundamental interactions of combustion and buoyant convection in lunar gravity

**Objective Sci-D-2:** Perform tests to understand and possibly discover new regimes of combustion

**Objective Sci-D-3:** Investigate interactions of multiphase combustion processes and convection at lunar gravity

**Objective Sci-D-4:** Use the unique environment of the lunar surface to perform experiments in the area of fundamental physics

14 Investigations
Science: Fluid Physics & Heat Transfer

**Goal Sci-D:** Use the unique lunar environment as a research tool

**Objective Sci-D-5:** Obtain experimental data to anchor multiphase flow models in partial gravity environment

**Objective Sci-D-6:** Study interfacial flow with and without temperature variation to anchor theoretical/numerical models

**Objective Sci-D-7:** Study behavior of granular media in the lunar environment

**Objective Sci-D-8:** Investigate precipitation behavior in supercritical water in partial gravity environment

11 Investigations
Science: Materials Processing

**Goal Sci-D:** Use the unique lunar environment as research tool

**Objective Sci-D-9:** Investigate the production of oxygen from lunar regolith in lunar gravity

**Objective Sci-D-10:** Investigate the behavior of liquid-phase sintering under lunar gravity

**Objective Sci-D-11:** Study and assess effects on materials of long-duration exposure to the lunar environment

5 Investigations
Goal Sci-D: Use the unique lunar environment as a research tool

17 Investigations

**Life Sciences**

**Objective Sci-D-12**: Study effect on microbes of long-duration exposure to the lunar environment

**Objective Sci-D-13**: Assess effect on plants of long-duration exposure to the lunar environment

**Objective Sci-D-14**: Study the fundamental biological and physiological effects of the integrated lunar environment on human health

**Objective Sci-D-15**: Study the key physiological effects of the combined lunar environment on living systems and the effect of pharmacological and other countermeasures

**Objective Sci-D-16**: Study the effects of lunar radiation on biological model systems

**Objective Sci-D-17**: Study the effects of lunar radiation on biological model systems
Goal Sci-D: Use the unique lunar environment as a research tool

Objective Sci-D-18: Use biological model specimens to conduct single and multigenerational studies on the long term effects of the lunar environment and transportation to and from the Moon on biological processes.

Objective Sci-D-19: Understand the effects/interactions of lunar gravity and the transitions between lunar gravity, microgravity; and Earth-normal gravity on reproduction and development, genetic stability, and aging.

Objective Sci-D-20: Study the influence of the lunar environment and its effects on short and long-term plant growth, productivity (as a food source), palatability, and nutrition.

Objective Sci-D-21: Evaluate the use and effectiveness of model plants in ecological life support systems.

Objective Sci-D-22: Monitor real-time environmental variables affecting safe operations, which includes monitoring for meteors, micrometeors, and other space debris.

11 Investigations