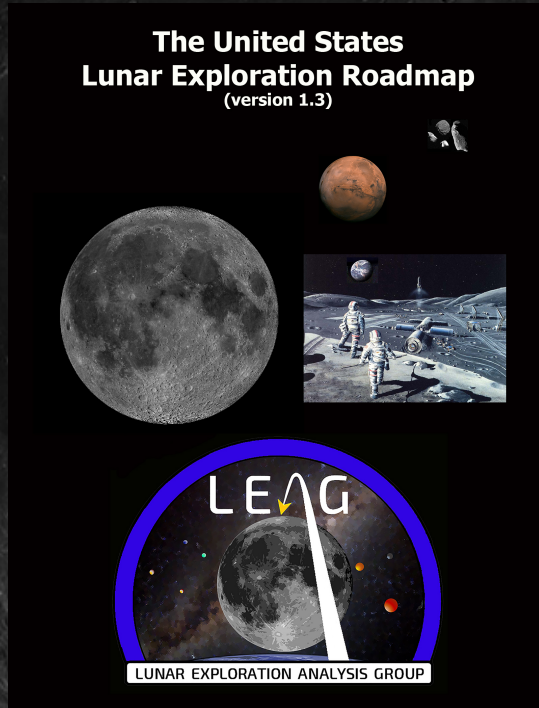


Biological and Physical Science Research Possibilities on the Lunar Surface



<https://www.lpi.usra.edu/leag/roadmap/>

Clive R. Neal
University of Notre Dame
neal.1@nd.edu
[@Neal148409276](https://twitter.com/Neal148409276)



Commercial Lunar Payload Services

Lunar Biological Science Research

ASTROBIOLOGY
Volume 10, Number 3, 2010
© Mary Ann Liebert, Inc.
DOI: 10.1089/ast.2009.0417

Review

Lunar Plant Biology—A Review of the Apollo Era

Robert J. Ferl and Anna-Lisa Paul

TABLE 1. NASA TECHNICAL REPORTS PERTAINING TO THE STUDY OF PLANTS IN LUNAR REGOLITH SAMPLES RETURNED IN THE APOLLO ERA

NASA Technical Reports Server Entry

Full abstracts can be obtained from the NASA Technical Reports Server and, in some instances, the reports themselves are available. To access, see <http://naca.larc.nasa.gov/search.jsp> then enter the Document ID.

Results of Apollo 11 and 12 quarantine studies on plants

Author(s): Horne, W.H.; Sweet, H.C.; Venketeswaran, S.; Walkinshaw, C.H.

Abstract: Botanical quarantine studies on Apollo 11 and 12 lunar soil samples effects on terrestrial plants, indicating absence of disease generating agents

NASA Center: NASA (non Center Specific)

Publication Year: 1970

Added to NTRS: 2004-11-03

Accession Number: 71A15393; Document ID: 19710034696

Analysis of vegetable seedlings grown in contact with Apollo 14 lunar surface fines

Author(s): Walkinshaw, C.H.; Johnson, P.H.

Abstract: Study of plant seedlings treated with lunar material, grown for 14 to 21 days, and then subjected to chemical analyses and other measurements. The purpose of the study was to determine whether plants growing in contact with ...

NASA Center: Johnson Space Center

Publication Year: 1971

Added to NTRS: 2004-11-03

Accession Number: 72A35925; Document ID: 19720052259

Lunar horticulture

Author(s): Walkinshaw, C.H.

Abstract: Discussion of the role that lunar horticulture may fulfill in helping establish the life support system of an earth-independent lunar colony. Such a system is expected to be a hybrid between systems which depend on lunar ...

NASA Center: Johnson Space Center

Publication Year: 1971

Added to NTRS: 2004-11-03

Accession Number: 72A35938; Document ID: 19720052272

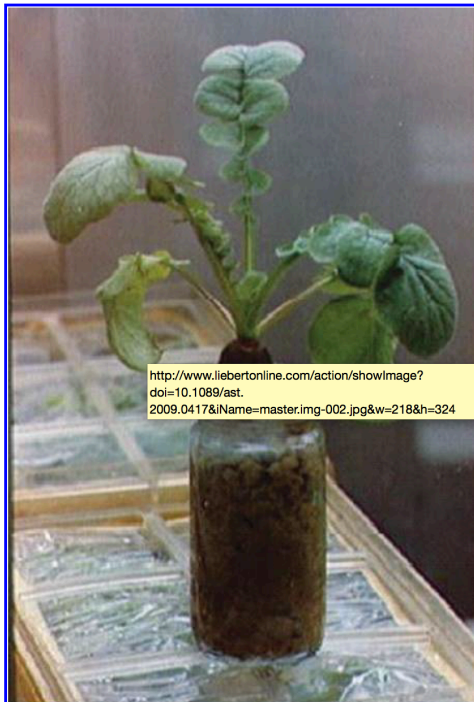
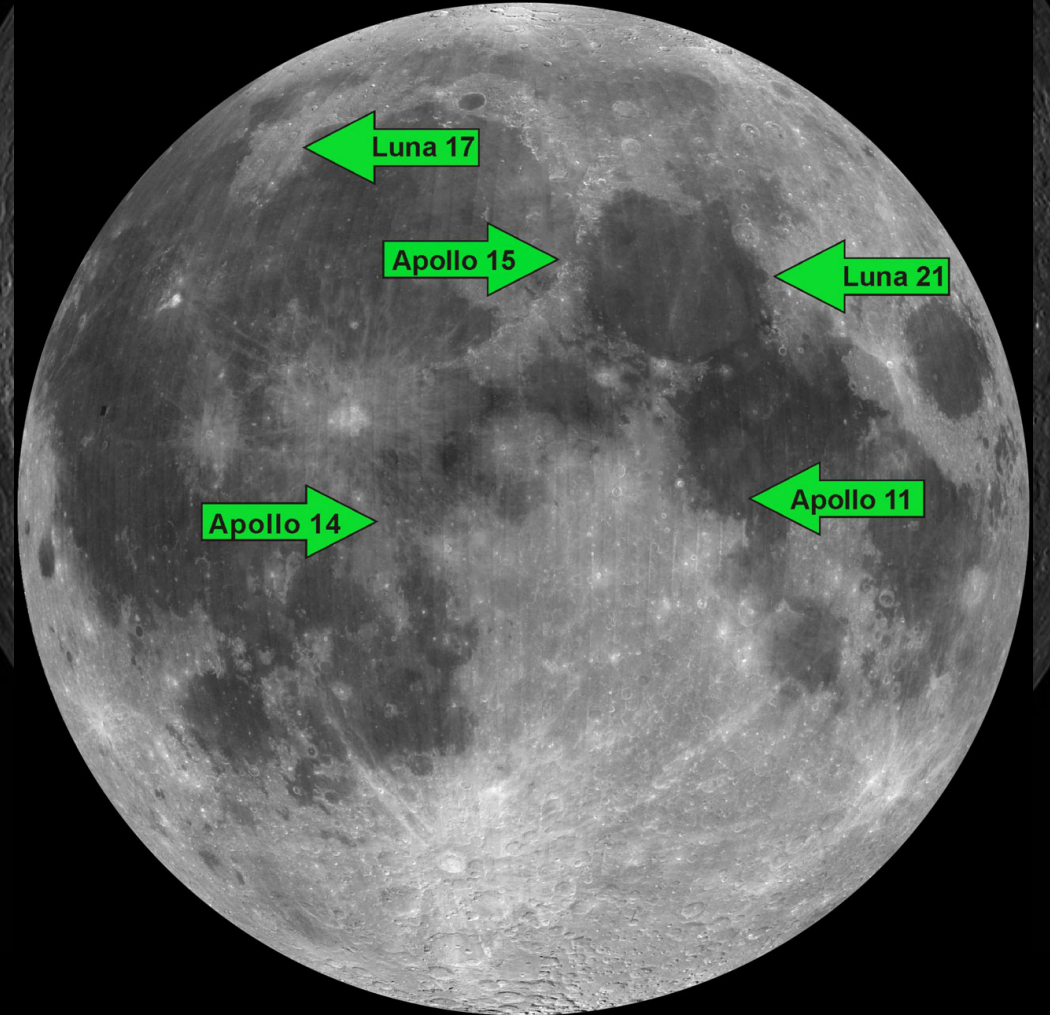
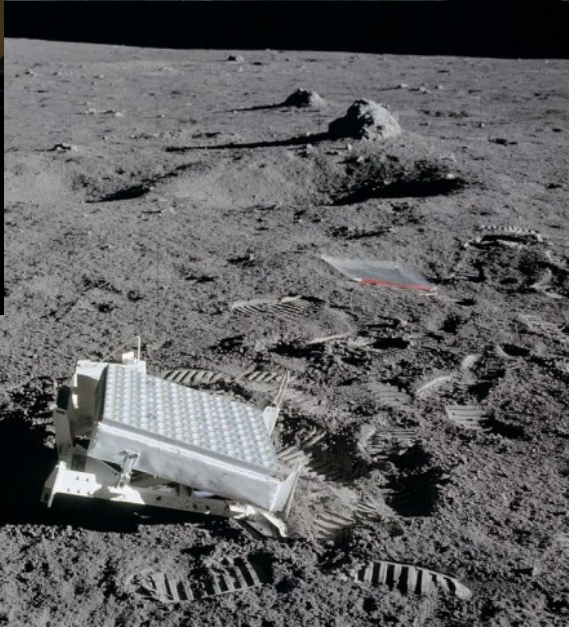


FIG. 3. A radish plant whose leaves were abraded with lunar samples. This plant, like all others in the tests, showed no pathogenic effects after being rubbed with lunar material. NTRS File Image, S70-21481. Color images available online at www.liebertonline.com/ast.

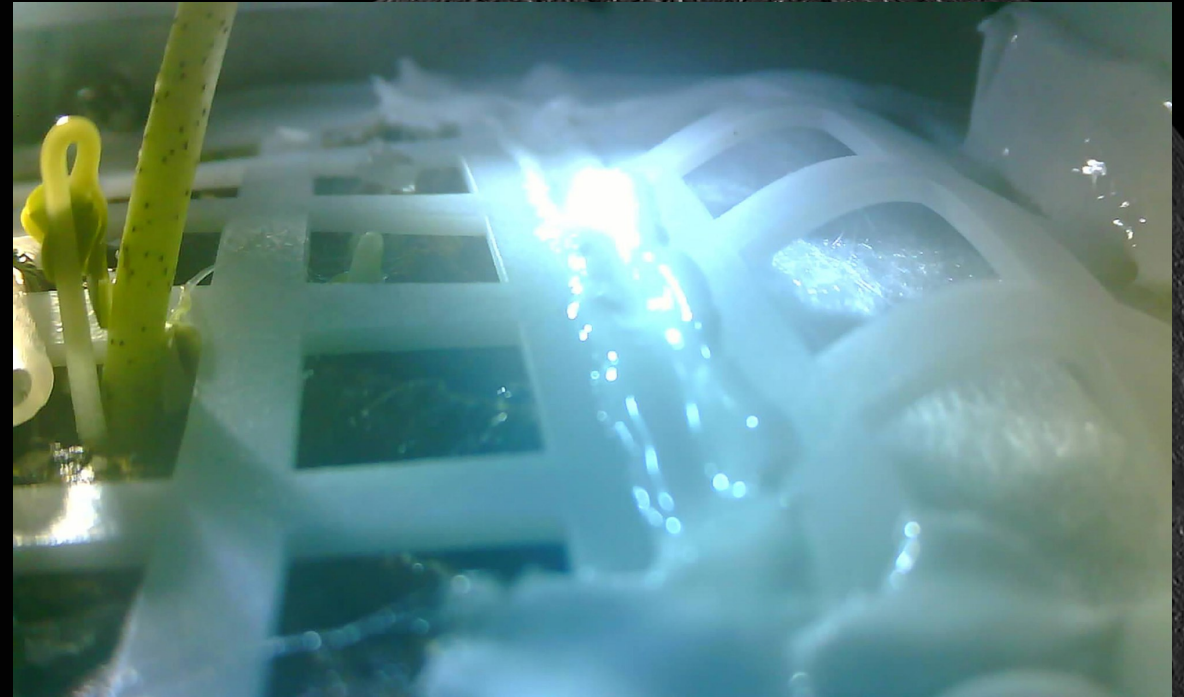
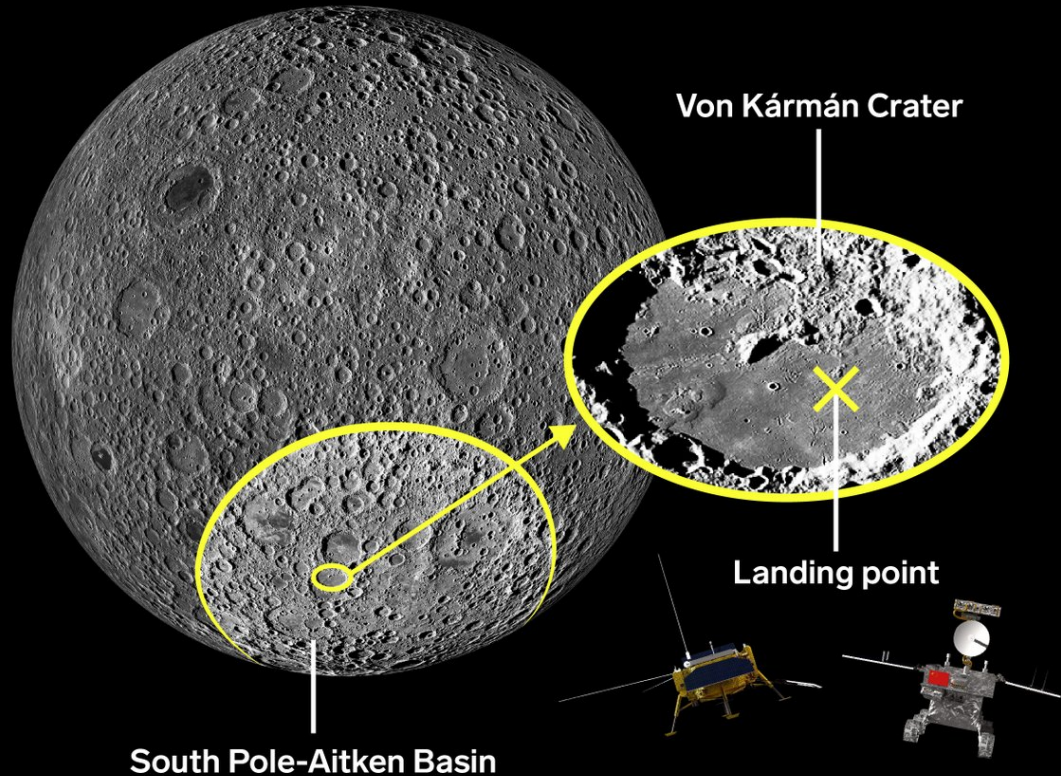
Apollo Era Astrophysics Experiments

Laser ranging contributes to testing the General Theory of Relativity, Inverse Square Law, & the Equivalence Principle. The only Apollo era experiment still in operation.



Lunar Surface Possibilities

China's landing on the far side of the Moon



Sources: NASA/Arizona State University (moon imagery); CASC/CNSA (lander/rover renderings) Insider Inc.

Commercial Lunar Payload Services

2021

Astrobotic: Lacus Mortis

Intuitive Machines: Oceanus Procellarum

2022

Masten Space Systems: Haworth Crater

Intuitive Machines: South Pole (PRIME-1 mission)

2023

Astrobotic: South Pole (VIPER rover)

Firefly: Mare Crisium

TBD: Reiner Gamma

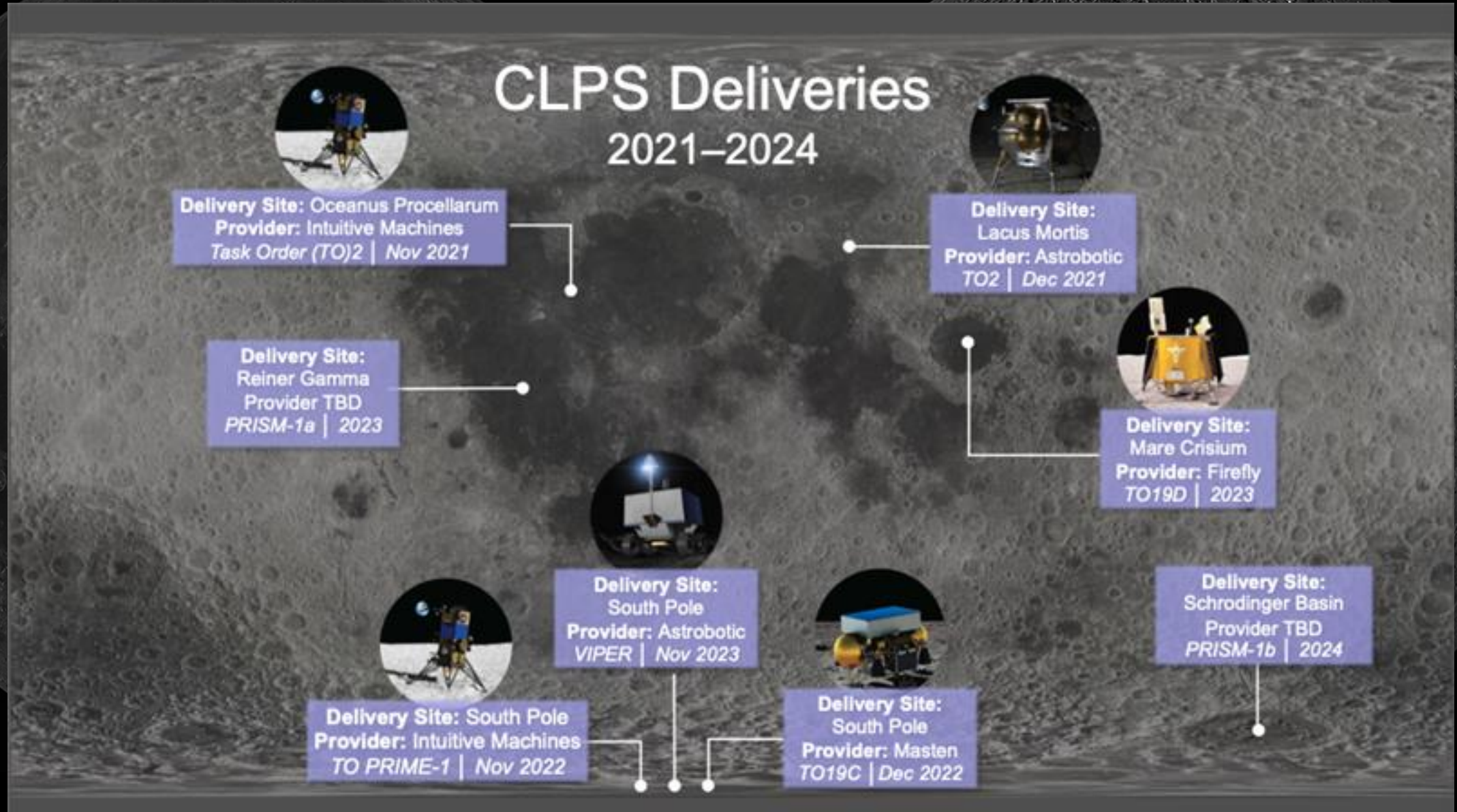
2024

TBD: Schrödinger Basin (far side)



DRAPER

Commercial Lunar Payload Services

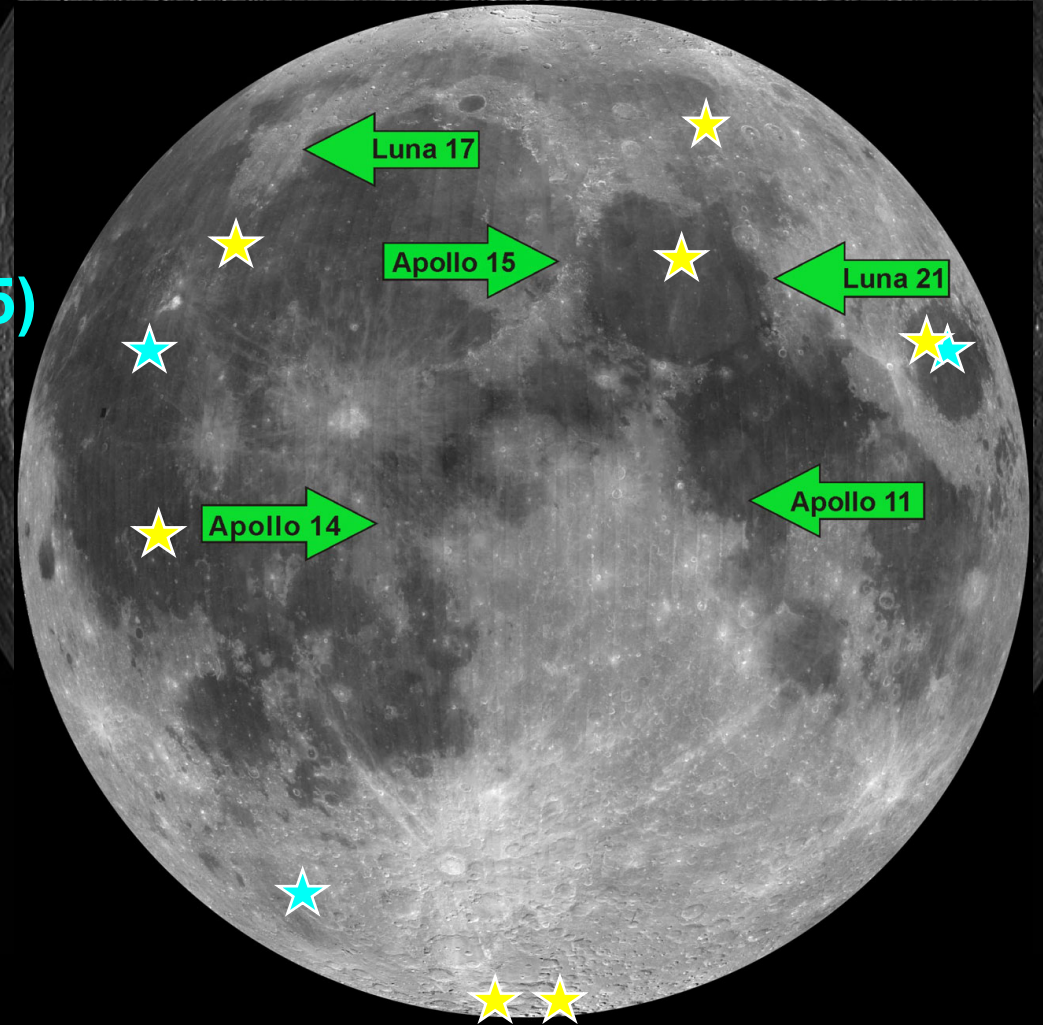
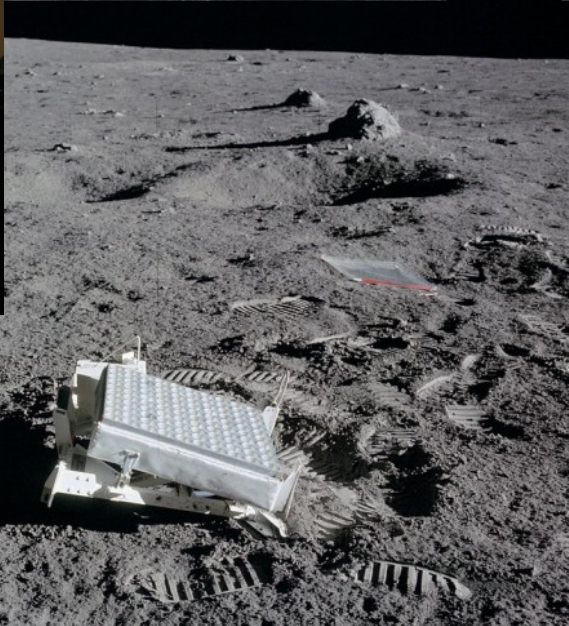


New Opportunities Astrophysics Experiments

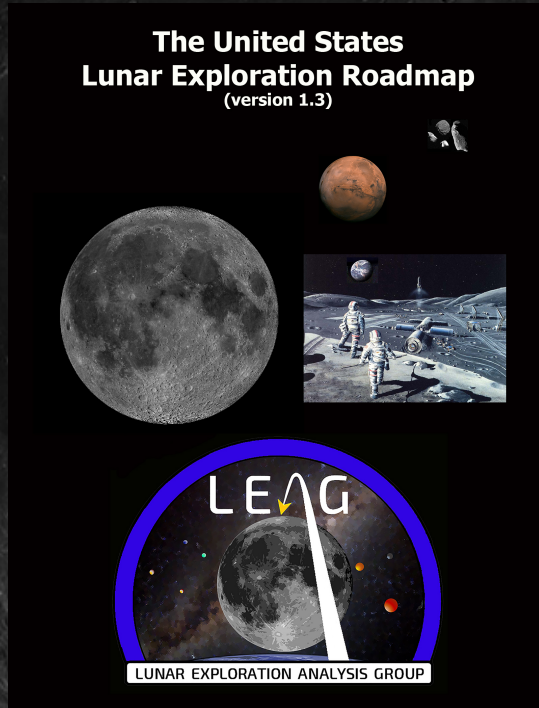
Increasing the coverage of the laser ranging stations.

CLPS

Lunar
Geophysical
Network (NF-5)



Biological and Physical Science Research Possibilities on the Lunar Surface



Lunar Exploration Analysis Group (LEAG).

Tasked to develop a lunar exploration roadmap during Constellation, which has been used for Artemis

Human Space Flight – Artemis.

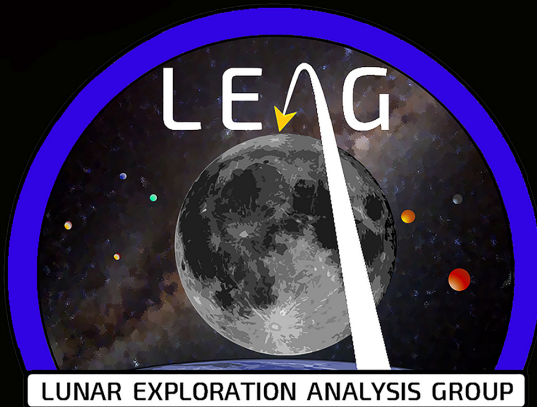
“Returning to the Moon, this time to stay”



Assume **Artemis Base Camp** = permanent base of operations that will have some lab support.

LEAG Lunar Exploration Roadmap

The United States Lunar Exploration Roadmap (version 1.3)



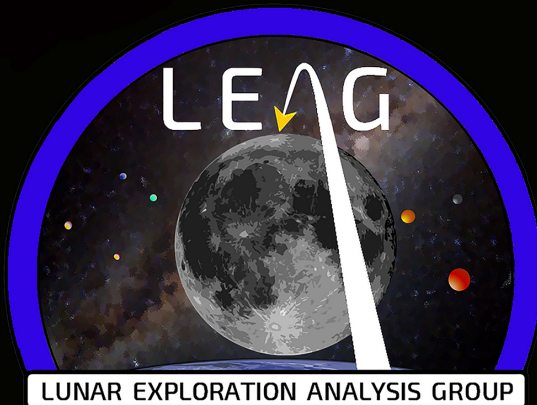
- **SCIENCE (Sci) THEME:** Pursue scientific activities to address fundamental questions about the solar system, the universe, and our place in them.
- **FEED FORWARD (FF) THEME:** Use the Moon to prepare for future missions to Mars and other destinations.
- **SUSTAINABILITY (Sust) THEME:** Extend sustained human presence to the Moon to enable eventual settlement.

Themes → Goals → Objectives → Investigations

- 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 research tool.

LEAG Lunar Exploration Roadmap

The United States Lunar Exploration Roadmap (version 1.3)



<https://www.lpi.usra.edu/leag/roadmap/>

- **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.

Themes → Goals → Objectives → Investigations

- 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 research tool.

Physical Science Research Possibilities

- 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
- Objective Sci-D-5: Obtain experimental data to anchor **multiphase flow models** in a partial gravity environment
- Objective Sci-D-6: Study **interfacial flow with and without temperature variation** to anchor theoretical/numerical models

Physical Science Research Possibilities

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

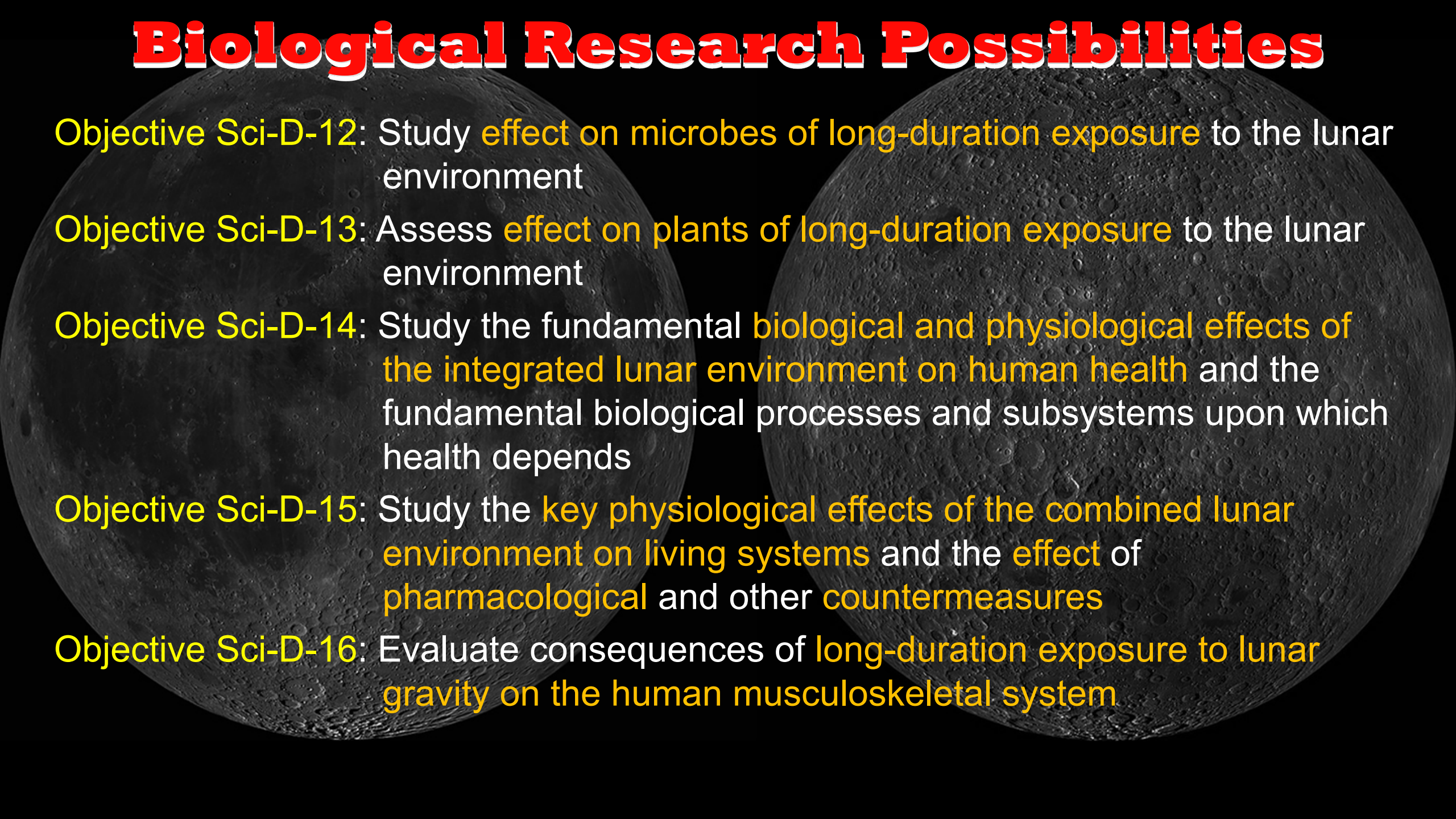
Objective Sci-D-9: Investigate the production of oxygen from lunar regolith in lunar gravity

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

Research that enables human permanence off Earth

Biological Research Possibilities

- 
- 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 and the fundamental biological processes and subsystems upon which health depends
- 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: Evaluate consequences of long-duration exposure to lunar gravity on the human musculoskeletal system

Biological Research Possibilities

Objective Sci-D-17: Study the effects of lunar radiation on biological model systems

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, & aging

Objective Sci-D-20: Study the influence of the lunar environment and its effects on short and long-term plant growth, productivity, palatability, & nutrition

Objective Sci-D-21: Understand the impact of lunar environments on terrestrial life forms and multiple generations of life that impact human health

Research that enables human permanence off Earth

Summary

- The Moon represents important opportunities for Biological and Physical Sciences, implemented both through robotic and human exploration.
- Research within these disciplines will be critical to develop on the Moon in order for humans to survive and thrive in the lunar environment.

