Returning Treasure From the Moon: Fundamental Importance of Planetary Sample Return and Fulfilling the SCEM Goals from Lunar Sample Return Targets

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Outline

1) Planetary perspective from sample return missions is unique.
2) Importance of integration of data sets.
3) Sample return mission architectures.
4) Sample return scientific rationale and targets within the context of SCEM and recent updates.
A planetary perspective from sample return

Scale

- Maximum spatial resolution.
- Ground truth for remote sensing data

Precision

- Exquisite analytical precision.
- Sample manipulation.
- Maximum sensitivity for minor and trace elements
- Types of data not obtainable by other techniques and ability to integrate data sets.

Continuous Mission, Unlimited Instrumentation

- Ability to test and follow up unforeseen results.
- Perform analyses with state-of-the-art instrumentation regardless of size.
- Continue analyses decades after mission as new technologies and science concepts evolve.
Value added and investments

Sample return missions have a symbiotic to both surface and orbital observations:

- Enhance the science value far beyond stand alone importance.
- Share technologies.

Sample return missions require:

- Investments in curation.
- Investments in laboratory instrumentation.
- Investment in sample return technologies.
- Precursor missions for planetary context.
Sample Return Issues

What is the trade off between *in situ* analyses and sample return missions?

What do we need to know before we collect samples from a planet or a place on a planet?

Sample return is not the last step in exploring a planet.

What is the trade off between simple and complex sample return missions?
Simple to complex sample return architectures

**Mobility**

- Static lander
- Rover

**Sample collection and preservation**

- Simple collection and preservation
- Complex collection and preservation

**Return to Earth**

- Direct to Earth
- Rendezvous in lunar orbit (Gateway?)
Sample Return and the Scientific Context for Exploring the Moon

2007

2018

ADVANCING SCIENCE OF THE MOON: PROGRESS TOWARD ACHIEVING THE GOALS OUTLINED IN THE SCIENTIFIC CONTEXT FOR EXPLORATION OF THE MOON REPORT.

**SCoRE scientific rationale and targets.**

- **CONCEPT 1:** The bombardment history of the inner Solar System is uniquely revealed on the Moon.
- **CONCEPT 2:** The structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated planetary body.
- **CONCEPT 3:** Key planetary processes are reflected in the diversity of lunar rocks.
- **CONCEPT 5:** Lunar volcanism provides a window into the thermal and compositional evolution of the Moon.
- **CONCEPT 7:** The Moon is a natural laboratory for regolith processes and weathering on airless bodies.
- **New Lunar Concepts (2018):** The “water” and volatile cycle.
SCEM scientific rationale and targets.

CONCEPT # in SCEM report:

Scientific rationale:

Sample material:

Targets:

Sample return architecture:
**SCEM scientific rationale and targets.**

**CONCEPT 1:** The bombardment history of the inner Solar System is uniquely revealed on the Moon.

*Scientific rationale:* Determine the age of the South Pole-Aitken basin (SPA) and other large basins to constrain models for the impact bombardment of the Moon and inner Solar System and dynamics of the outer Solar System.

*Sample Material:* Impact melt produced by the SPA event.

*Targets:* Interior of the SPA basin.

*Sample return architecture:* Static lander with capability to sieve regolith. Relatively simple sample containment. May require COMSAT.
CONCEPT 5: Lunar volcanism provides a window into the thermal and compositional evolution of the Moon.

Scientific rationale: Determine differences among basalts associated with different crustal terrains (e.g. PKT versus lunar highlands) and different ages to test models for planetary differentiation and lunar mantle evolution.

Sample Material: Mare basalts from the lunar far side and young basalts.

Target: Relatively smooth plains in SPA and Moscoviense basins; farside cryptomaria (e.g., Dewar); youngest basalts in southwest Aristarchus plateau.

Sample return architecture: Static lander or with mobility, with capability to sieve regolith and collect larger samples. Relatively simple sample containment. May require COMSAT.
**SCEM scientific rationale and targets.**

**New Lunar Concepts (2018):** The Lunar “water” and volatile cycle.

**Scientific rationale:** Determine the interaction and evolution among different volatile reservoirs (e.g., interior, surface) on the Moon.

**Sample Material:** Polar regolith, pyroclastic deposits, and recent degassing deposits.

**Target:** Samples collected from surface environments well-defined by orbital and *in situ* measurements.

**Sample return architecture:** Static lander or lander with rover. Capability to sample regolith on surface and subsurface. More complex sample containment. Require capability to seal sample containers. More complex missions may need temperature control. May also require *in situ* measurements.

Volatile deposits from lunar interior.

Volatile deposits at the lunar surface.
Summary

- Sample return offers a distinct planetary perspective, but is most valuable when integrated with other observations.

- Many well-documented and low risk sites (e.g., LRO) for sample return that would fulfill SCEM science priorities.

- Sample return missions may require a variety of capabilities from simple missions (static lander, simple sample collection and containment) to much more complex missions (sophisticated robotic manipulation and processing of materials on a planetary surface, containment and preservation, in situ instrumentation, COMSAT).

- There are technology investments that would be beneficial to reducing cost and risk of sample return missions (e.g., lander, Moon-wide communication, sampling, containment, sample return architecture, instrumentation and training).
Backup Charts
CONCEPT 7: The Moon is a natural laboratory for regolith processes and weathering on airless bodies.

Scientific rationale: Determine the influence of lunar surface environment (e.g., temperature, plasma, magmatism) on regolith evolution.

Sample Material: Bulk regolith samples.

Target: Samples collected from well-defined surface environments.

Sample return architecture: Static lander or lander with rover. Capability to sample regolith on surface and subsurface. More complex sample containment. May require capability to seal sample containers. May require magnetic sheilding. May also require in situ measurements.
SCSEM scientific rationale and targets.

CONCEPT 2: The structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated planetary body.

**Scientific rationale:** Determine the composition of the upper lunar mantle to constrain chemical/stratigraphy of the lunar interior and aid the interpretation of current and future geophysical data.

**Sample Material:** Mantle assemblages excavated during basin formation.

**Characteristics of Target:** Basin interiors with (a) thin or absent lunar crust as interpreted by GRAIL, (b) limited mare deposits, and (c) mafic central peaks.

**Sample return architecture:** Lander with mobility capability. Relatively simple sample containment.
CONCEPT 3: Key planetary processes are reflected in the diversity of lunar rocks.

Scientific rationale: Determine the nature and timing of primordial lunar differentiation.

Sample Material: Ferron anorthosite and related lithologies.

Target: The feldspathic far side highlands.

Sample return architecture: Static lander with capability to sieve regolith and collect larger samples. Relatively simple sample containment. May require COMSAT.