IMPORTANCE OF SAMPLE SCIENCE-SAMPLE RETURN AND POTENTIAL SAMPLE TARGETS.

Charles K. Shearer, Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87133. (Chair, **C**uration and **A**nalysis **P**lanning **T**eam for **E**xtraterrestrial **M**aterials) and Clive Neal, Department of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, IN 46556 (Chair, Lunar Allocation Subcommittee, CAPTEM). Submitted as a contribution from CAPTEM http://www.lpi.usra.edu/captem/ (cshearer@unm.edu).

Introduction: The intent of this white paper is to illustrate the importance of sample return in the exploration of the Moon and advocate a series of strategic, sample return missions to other lunar terranes that would shed light on important scientific questions concerning the evolution of both the Earth-Moon system and inner solar system.

Sample return and lunar science: Samples returned from the surface of planetary bodies are both complementary to orbital and in situ observations and provide a unique perspective for understanding the nature and evolution of that body. This unique perspective is based on the scale the sample is viewed (mm to angstroms), the ability to manipulate the sample, the capability to analyze the sample at high degrees of precision and accuracy, and the ability to significantly modify experiments as logic and technology dictates over an extended period of time (decades). Science that has been done on the Moon over the last several decades illustrates these points [1,2].

Previous human and robotic sampling of the Moon occurred within a limited area located on the east-central near-side of the Moon. Only lunar meteorites have provided samples that potential represent other lunar terranes. Further, since the Apollo missions, technological advances in sample science (i.e. secondary ion mass spectrometry, mass spectrometry) and their integration with newly collected remotely sensed data (i.e. Lunar Prospector) has opened a plethora of important scientific questions that can only be answered with the return of samples from strategically identified locations on the Moon. The return of additional samples from unexplored regions of the Moon can be used to gain far-reaching insights into both fundamental lunar processes and evolutionary pathways of other terrestrial planetary bodies in the solar system. Ryder et al. [3] identified important scientific problems that remained unanswered and proposed 59 sample return targets. More recently, Shearer and Borg [1] proposed lunar science goals and placed potential targets for sample return within the context of these goals. A detailed scientific rationale for sample return is reviewed in "New Views of the Moon" [2]. Here, we placed potential sample return sites (Table 1) within the context of seven scientific themes: (1) Early planetary differentiation, (2) Thermal and magmatic history of the Moon, (3) The internal structure of the Moon and the evolution of planetary interiors, (4) Impact history of the inner solar system, (5) Formation and evolution of large impact basins, (6) Evolution of surfaces on airless planetary bodies, (7) Volatile reservoirs on airless planetary bodies, and (8) Evolution of the Earth-Moon system.

The role of sample return and sample science in the human exploration and habitation of the Moon: Sample return and sample science have a substantial role to play in the human exploration and eventual habitation of the Moon. In the identification of landing sites for human missions, sample return provides a validation for global orbital observations. Sample return combined with orbital, geological, and geophysical data is key for identifying potential resources (i.e. pyroclastic deposits, H-deposits) and establishing their economic significance (i.e. size of resource, extraction potential). In addition to assisting in locating sites for initial sorties, sample return should be an important component in better identifying the geology of potential lunar outpost sites. This includes the structure of the regolith at depth and the identification of resources adjacent to sites of human activity. Further, sample return will assist in determining the geotechnical characteristics of regolith either at depth or in regions outside the "Apollo trapezoid" (i.e. permanently shaded regions).

Sample return fits into many different types of lunar exploration architectures. Robotic sample return may be useful in exploring unique lunar terranes either prior to or in conjunction with initial human sorties. Although this approach would return small sample volumes, numerous terranes could be sampled in a cost-effective means (versus human sorties) and the resulting information could be utilized to identify sites for human sorties. Lessons learned from the Apollo missions and associated science documents the important science that can be extracted from small samples [1]. Alternatively, sample return maybe tied to only human sorties. Within this scenario, larger volumes of material would be returned. However, if human sorties return to the same site to build outpost infrastructure or scout a limited number of well defined sites, the sampling of diverse terranes may be sacrificed. However, upon establishing a lunar outpost, human-robotic integration could result in a much more extensive sampling of the Moon. In this case, robotic rovers or human sorties could sample remote and diverse terranes and return samples to a lunar outpost.

Findings:

- Scientific exploration of the Moon provides insights into the origin and evolution of the Earth-Moon system and provides a record of the history of the solar system.
- Sample science provides a unique data set that is critical for understanding the Moon that can be extended to other terrestrial bodies, and is important for human exploration.
- Sample science and sample return has a symbiotic relationship with orbital science and surface science. Samples are most valuable scientifically when they can be placed within a planetary and regional context by orbital, robotic rover, and human missions.
- Sample return and subsequent analysis provides valuable geochronologic and geochemical ground truth for remotely sensed data.
- Data derived from samples provide a unique perspective not offered by either orbital or in situ data. This unique perspective is based on scale (down to angstroms), precision, and ability to modify analytical experiments as logic and technology dictates.
- Small samples provide a wealth of information concerning a planet- and solar system scale processes [1].
- Sample return fits within a variety of architectures for lunar exploration.
- With current information, sampling sites can be targeted that will address important problems concerning the origin and evolution of both the Earth-Moon system and solar system. Ten potential sample return sites are identified based on scientific return. They are not prioritized in this white paper (Table 1).

References: [1] Shearer, C.K. and Borg, L. (2006) Chemie der Erde Geochemistry 66, 163-185. [2] New Views of the Moon (2006) Editors: B.J. Jolliff, M.A. Wieczorek, C.K. Shearer, C.R. Neal. Reviews in Mineralogy and Geochemistry. Vol. 60, 721p. [3] Ryder, G. et al. (1989) EOS 70, 1495-1509.

Table 1. Examples of potential sampling targets and scientific rationale.

Potential Sampling Targets	Description of Targets	Scientific Objective
Roris basalt in Oceanus Procellarum	One of the youngest basalts in the PKT (1 Ga).	Themes 1, 2, 3
Mare Moscoviense	Typical far-side mare.	Themes 1, 2, 3, 6
Schickard	Old mare.	Themes 1, 2, 3, 6
South-pole Aitken basin	(1) Basalts outside of the PKT. (2) Unique lunar crustal lithologies. (3) Large H deposits. (4) Basin filling melt sheets useful in testing the cataclysm model, clasts of deep lunar crust in melt sheet.	Themes 1, 2, 3, 4, 5, 6, 7, 8.
Orientale basin	Youngest multi-ring basin with modest mare fill and anorthosites.	Themes 1, 2, 3, 4, 5, 8.
Aristarchus plateau	Large pyroclastic deposit with potential vents.	Themes 1, 2, 3, 7,8
Rima Bode	Large pyroclastic deposit with vents. Potential source for lunar mantle xenoliths.	Themes 1, 2, 3, 7,8
Tsiolkovsky	Far-side “primary”crust exposed in central peak.	Themes 1, 2, 3, 6,8
Hertzsprung	Far-side Mg-suite plutons exposed on crater floor.	Themes 1, 2, 3, 6
Giordano Bruno	Melt sheets in youngest large crater on Moon.	Themes 4, 5, 8