CHALLENGES FOR SAMPLE RETURN FROM THE LUNAR SOUTH POLE – AITKEN BASIN.

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The South Pole – Aitken (SPA) Basin is the oldest, deepest impact basin on the Moon. It was excavated during the early bombardment history of the Moon, prior to 3.9 billion years ago, possibly as part of the "terminal cataclysm," during which the near side mare basins were excavated. According to current models, such basins would have been immediately surfaced by breccia and melt rock created by the impact and perhaps by lower crust or even mantle blocks uplifted during the event. Subsequently, several multi-ring basins within and outside of SPA added debris to what must be a thick regolith (see [1]). Subsequently, mare basalts were locally added to the mix, although the basin was not filled with basalt as were the near side mare. The age and complexity of this mixture of materials provides a significant challenge for sample return missions.

A SPA sample return mission ("Moonraker") was proposed to NASA's Discovery Program in 2000 [2]. The principal goals of this mission were to document the range of materials that constitute the breccia/melt sheet of SPA in order to determine the presence of lower crust and mantle components and to test the terminal cataclysm hypothesis. It would have addressed other significant issues, such as the subsequent impact history of the Moon, the definition of a yet unsampled major lunar terrane, and the thermal history of SPA. To fit within the budget restrictions of that time, a simple mission concept was developed, in which a single lander would be flown to a site on the Moon selected on the basis of remote sensing data (at the time, Clementine data). The lander was equipped with a sampling arm and a device for screening regolith material to concentrate fragments in the 2-10 mm size range, with the objective of collecting approximately 750 g of coarse fines and 250 g of regolith. The samples were to be returned automatically to Earth for analysis by the scientific community.

Because the SPA lies on the lunar far side, a communications relay element was required. To maintain a lowest cost approach, the mission was constrained to spend less than 150 hours on the surface. No surface mobility was included, and the only instruments carried were multispectral imagers to document the context of the samples (descent imager and panoramic imager) and to assist in surface operations (arm imager).

The proposed baseline concept fit within the budget constraints of the Discovery Program, but was judged by reviewers to be risky for several reasons: (1) Concern that fragments, obtained from a single surface location, would be such a complex mixture of materials that fragments could not be adequately correlated to Basin units and address the principal goals of the mission (sample complexity); (2) There were no descope options – if costs were to rise, there was little in the mission concept that could be modified to reduce costs (programmatics); (3) Cost and mass margins were judged insufficient for a mission of such complexity; (4) The amount of time available for adapting to unforeseen anomalies was limited; and (5) There was insufficient consideration of landing risks.

The NRC's recent Decadal Survey of Planetary Exploration [3] identified SPA sample return as a high priority mission of moderate cost that could be included in NASA's New Frontiers Program. This new program is expected to have a less restricted budget ceiling than did the Discovery Program. In considering how the Moonraker concept might be modified to fit this new context, emphasis must be given to addressing the principal issues identified by reviewers of the Discovery proposal.

The sample complexity issue must be addressed primarily through a careful site selection process, based on remote sensing data. Progress has been made recently in the interpretations of Clementine Vis-IR data, which allow distinctive units to be characterized. Lunar Prospector data are useful as well, but not generally of high enough resolution to be used in detailed site selection. In the studies by Pieters et al [4], areas around relatively fresh impact craters are interpreted to represent SPA original breccia/melt rock and basalt (Figure 1). As these are relatively recent impact features, they have not been masked by the subsequent impact mixing of the regolith and should be readily identifiable in samples taken nearby. Also, [1] argues that, in central regions of SPA, the amount of foreign material provided by internal and external impact basins constitutes about 20% of the regolith. Therefore, it is probable that units can be mapped by remote sensing and also can be sampled. It is expected that the ability to characterize lunar surface compositional units will increase within the next few years due to data returned by the ESA SMART-1 and Japanese

SELENE orbiters, both of which include more powerful sensors than were available for Clementine.

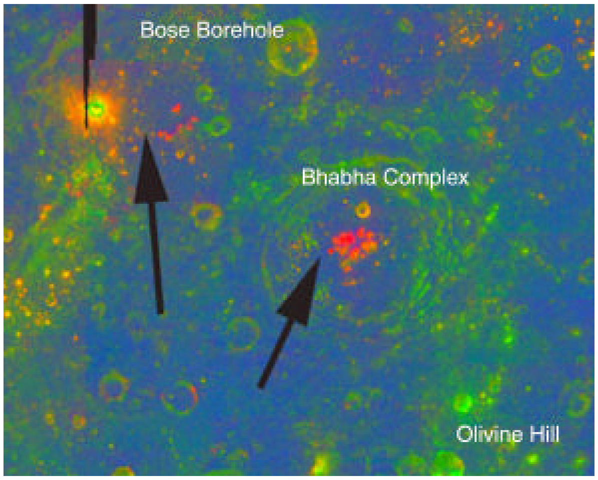

Fig. 1. An area in the central SPA Basin [from [4]). Red and yellow areas are believed to represent noritic materials of SPA breccia/melt rock; green areas, basaltic or possibly ultramafic lithologies. These areas are correlated with rugged terrain, such as crater rims, central peaks and fresh craters.

A collection of 750 grams of rock fragments will provide several thousand fragments for study. There is some debate about the right range of rock fragment size and mass to collect. In the Moonraker concept, the range assumed was 2-10 mm, which will provide more, diverse fragments; however, 4-10 mm would allow coordinated analysis by multiple means to be carried out on a larger number of fragments. In either case, the large number of fragments should allow the characterization of the most abundant materials available at the sample site with statistical certainty (e.g. if there are up to 10 different rock types in equal quantities, each might be represented by hundreds of fragments). This should aid in addressing the sample complexity issue.

The issue of programmatic risk (e.g. descope options) can be addressed in a number of ways, principally by increasing redundancy. A two lander/sample return architecture, in which a single launch vehicle delivers dual systems to the lunar surface, is a promising approach. In this architecture, the descope option becomes to fly one lander instead of two, if the cost of the dual mission rises for unforeseen reasons. However, the two-lander strategy also addresses sampling issues as well, as the landers can be targeted to different areas where cross-calibration of both remote sensing and sample data can be used to improve the probability that correct identifications of sample provenance will be made. Other approaches to increasing the robustness include providing redundancy in critical systems, conducting additional testing and certification, and adding new technologies that can improve performance, perhaps at higher cost.

Cost and mass margins clearly can be improved over the Moonraker concept for a one-lander mission, with an increased New Frontiers Program budget. However, recent mission failures, including the Mars 1998 missions and CONTOUR are likely to increase the proposed cost of new missions, as standard manufacturing and testing approaches are strengthened. It is likely that a two-lander strategy will have to face the cost margin issue, even within the New Frontiers Program. However, the tradeoff between cost and risk will be qualitatively different for a two-mission strategy.

The short period of time spent on the lunar surface could be extended, but extending the mission to more than one lunar day will add costs associated with maintaining systems through the lunar night. A capable communications link that is available throughout the surface mission can improve the effectiveness of surface operations and allow the opportunity to recover from some types of problems. The collection of samples should not be the rate-controlling process, as it is expected that less than 50 kilograms of regolith would have to be sampled to obtain the desired sample collection. This is well within the capacity of typical sampling systems such as robotic arms. The rate of processing of these samples, removing the coarse fines from the finer material, is probably the rate-controlling step. The landing risk issue can be addressed by designing a more robust lander.

With the risk reduction approaches identified here, a robust South Pole – Aitken Basin sample return mission should constitute a viable competitor in the New Frontiers Program. Major elements of the project, including site selection, sampling strategies, sample characterization, the preliminary analyses when samples are on Earth, and the analytical effort that will be expended on these samples will involve a wide range of the lunar science community in development and operational tasks.

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