A LUNAR ANALOGUE MISSION: SAMPLE RETURN TO THE SOUTH POLE–AITKEN BASIN.

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Introduction: Impact cratering is considered the most important geological process on the Moon [1]. This is manifest in the immense number of impact craters on the lunar surface, from the small to the large, with the South–Pole Aitken (SPA) basin at ~2,500 km in diameter being the largest impact structure in the Solar System (Fig. 1). The impact flux in the inner Solar System is such that impact cratering was also undoubtedly a dominant geological process during the early history of Earth and other planetary bodies [2]. Furthermore, impact events have also played an important role throughout Earth's history and to the present-day, shaping the geological landscape, affecting the evolution of life [3, 4], and producing economic benefits (e.g., Sudbury mining district) [5].

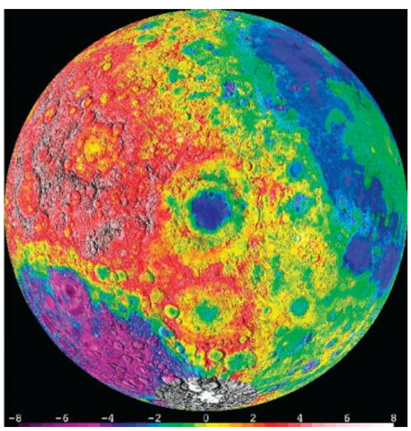

Figure 1. Topography of the Moon centered on the ~900 km diameter Orientale basin (19°S, 95°W). The South Pole–Aitken basin is the purple patch on the limb to lower left. Scale is in km. Image: LPI.

The recent confirmation that the Moon possesses potentially large reserves of H_2O ice in its polar regions [6] also has major implications for the understanding of the Moon and raises exciting possibilities for long-duration missions utilizing *in situ* resources.

This contribution presents an overview of an analogue mission in support of future lunar missions. Several companion abstracts at this meeting will present more detailed results.

The role of terrestrial analogues: Terrestrial analogues are places on Earth that approximate the geological, environmental, and putative biological conditions on Mars and other planetary bodies, either at the present-day or sometime in the past [7, 8]. Three key themes dominate terrestrial analogue activities [7]: (1) comparative planetary geology, including process studies and the characterization of analogue materials; (2) astrobiology; and (3) exploration science, which includes instrument testing and development, astronaut training, and exploration-related activities. Analogue sites are also important focal points for education and public outreach activities. In the context of exploration, so-called "analogue missions" are being increasingly recognized as being an important and relatively inexpensive, method to prepare and train for future planetary exploration missions, particularly in terms of mission operations and technology development.

Analogue mission overview: In response to a Request for Proposals issued by the Canadian Space Agency, our team successfully proposed to carry out "An Analogue Mission in Support of Future Sample Return Missions to the South Pole–Aitken Basin". This analogue mission comprises a series of scientific, operational, and technical objectives that will address CSEW6 Objective PG-L-4 ("estimate the rates, processes and effects of lunar impact cratering") in its entirety, namely:

- The ages and rates of impact bombardment on the Moon and, by extension, for the entire inner Solar System (PG-L-4-Investigation 1);
- Shock processes in lunar materials and terrestrial analogues (PG-L-4-Investigation 2);
- Impact ejecta emplacement processes (PG-L-4-Investigation 3);
- Resources within lunar impact craters.

The return of samples from the SPA basin on the Moon is a high priority target for Canadian, U.S., and international scientific communities [9]. Analysis of materials from this oldest and deepest of the lunar basins is fundamental for addressing questions such as the bombardment history of the inner Solar System, the role of large basins in modifying planetary surfaces, and the differentiation of planetary bodies.

A New Frontiers Phase A concept study, called MoonRise, is designed specifically to address these questions (http://moonrise.jpl.nasa.gov/). Using a robotic lander, this mission proposes to collect materials from the Moon's SPA basin and return them to Earth for analysis. In order to prepare and train for such a mission, and for future potential robotic and human sample return missions in general, we plan to carry out a series of analogue missions on the Earth that will be used to develop and test procedures and techniques.

One of the main goals of this analogue mission is to develop mapping, analysis, selection, and sampling protocols for identifying and collecting specified target materials. This will require a detailed set of decision-making processes for outcrop mapping, site targeting, micro-imaging, sample selection, and sample acquisition. It is also recognized that today's robotic technologies are also far more advanced than what was available during the Apollo era. Therefore, it is important to re-evaluate which operational strategies are appropriate for robotic vs human activities. This comprises the final objective for this mission, to evaluate the optimal combination of robot and/or human workers for each task, be it astronaut only, astronauts with robotic assistants, or unmanned robotic surrogates. Analogue missions such as this are also important for highlighting the technological developments that are needed to enable a sustainable lunar and solar system exploration program.

Analogue mission scenarios: Two scenarios are planned: (1) A robotic sample return mission to SPA; (2) A robotic precursor mission to SPA with a follow-on 7-day human sortie mission.

Scenario 1. Robotic sample return is widely accepted as a priority for lunar science. The first scenario, therefore, will consider a purely robotic mission, such as the proposed MoonRise concept mission. MoonRise, led by PI Brad Jolliff from Washington University and a technical team from the Jet Propulsion Laboratory, consists of a lander that will set down in the SPA, deploy a robotic arm and collect regolith samples that will then be returned to Earth for analysis.

Scenario 2. The ultimate goal of lunar exploration, however, includes astronauts. Scenario 2 considers a robotic precursor mission to SPA that is followed, approximately 6 months later, by a human sortie mission. The precursor mission would involve robotic surveying and prospecting of Sites of Interest (SOIs) in preparation for human field geology operations.

Timetable and sites: We plan to execute the robotic scenario 1 in Spring 2011 at the *Ries or Sudbury impact structure*. Scenario 2 will be executed over 2 field deployments in 2010 and 2011, with the robotic precursor phase in 2010 and the human sortie mission in 2011. This will be conducted at the *Mistastin impact structure*. These impact structures represent three very unique and complementary sites that fulfill the criteria proposed herein to meet the objectives of this analogue mission. The Mistastin impact structure is one of few terrestrial impact sites that contain significant amounts of anorthosite. Feldspars are also a significant component of the impact melt-bearing breccias of the Ries impact. Other factors that affected site selection included 1) a lack of vegetation, required to conduct lunar-like deployments, 2) accessibility, and 3) preservation of impact structures, required to adequately model lunar crater topography.

Results of the first deployment: The first field deployment to the Mistastin Lake structure was carried out over the course of 4 weeks from mid-August to mid-September 2010. Operations were carried out at 3 main sites, chosen without apriori knowledge of the site through a rigourous site selection process (detailed in [10]). Details of the field procedures and lessons learned for sample return missions are detailed in [11] and overall operational lessons learned in [12]. In addition, this analogue mission also demonstrated the value of conducting real cutting edge science in parallel – scientific results include the discovery and documentation of ejecta deposits and melt-bearing impactite dykes with the central uplift at Mistastin for the first time [13, 14].

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References: [1] Hiesinger H. and Head J.W., III 2006. *Reviews in Mineralogy and Geochemistry* 60:1-81. [2] Neukum G., et al. 2001. *Space Science Reviews* 96:55-86. [3] Alvarez L.W., et al. 1980. *Science* 208:1095-1108. [4]Kring D.A. 2000. *GSA Today* 10:1-7. [5] Grieve R. and Masaitis V. 1994. *International Geology Review* 36:105 - 151. [6] Pieters C.M., et al. 2009. *Science* 326:568-572. [7] Osinski G.R., et al. 2006. *Geoscience Canada* 33:175-188. [8] Farr T.G. 2004. *Planetary and Space Science* 52:3-10. [9] NRC 2007. *The Scientific Context for the Exploration of the Moon*. Washington D.C.: The National Academies Press. 107. [10] Shankar et al. (2011) LPSC XXXXII (this meeting). [11] Mader M. et al. (2011) *The Importance of Solar System Sample Return Missions to the Future of Planetary Sciences Workshop* (abstract #5038). [12] Antonenko I. (2011) (2011) LPSC XXXXII (this meeting). [13] Mader M. et al. (2011) (2011) LPSC XXXXII (this meeting). [14] Singleton A. et al. (2011) (2011) LPSC XXXXII (this meeting).