A LONG DURATION HUMAN-ASSISTED ROBOTIC SAMPLE RETURN MISSION TO THE SCHRÖDINGER BASIN PART 1: TRAVERSING THE BASIN CENTER.

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Introduction: Situated on the lunar farside and approximately 500 km from the south pole, the Schrödinger peak-ring basin is the second youngest and one of the best preserved impact basins on the Moon. With a diverse geology and potential for *in situ* resource utilization (ISRU), Schrödinger is a prime target location for a long duration sample return mission [1-5]. With no current infrastructure at the lunar surface to support humans, a human-assisted robotic sample return mission is proposed and two long duration rover traverses have been developed. The traverses were designed to collect samples that can address most of the 31 remaining lunar scientific and exploration objectives defined in the 2007 report by the National Research Council (NRC) [6] and agreed upon by the international lunar science community (e.g., [7]).

HERACLES: The traverses have been planned in parallel with an ESA-led HERACLES multi-mission concept being studied for the International Space Exploration Coordination Group (ISECG) and Global Exploration Roadmap (GER). The mission architecture utilizes NASA's Orion crew vehicle and an Exploration Augmentation Module (EAM). The EAM is a crewed facility situated at the Earth-Moon L2 Lagrange point enabling a continuous communication relay between the lunar farside and the Earth to aid teleoperation of a rover. A lander with a reusable ascent vehicle deploys a rover at the first landing site and rendezvous with the rover at 2 additional locations along the traverse. At each landing site, robotically sampled material is transported by the ascent vehicle from the surface to the EAM for subsequent return to Earth by crew in Orion.

Method: A traverse was designed to meet a driving limit of 100 to 300 km imposed on the concept study. The traverse builds upon the ~14 day (1 lunar day) traverse of Potts et al. [8] by extending it for a 3 year mission. A second traverse option is described elsewhere [9]. LOLA-derived slope maps, an interpreted geologic map [4], M^3 spectral data, and an FeO map derived from Clementine multispectral data [4] were overlain onto LROC-WAC (100 m/pixel) and NAC imagery (0.5 m/pixel). Detailed analysis of these data enabled identification of scientifically interesting target sites (for which a notional rover payload was designed to carry out *in situ* analysis that can support interpretation of the returned samples), specific sample collection points, and landing sites for the reusable ascent vehicle.

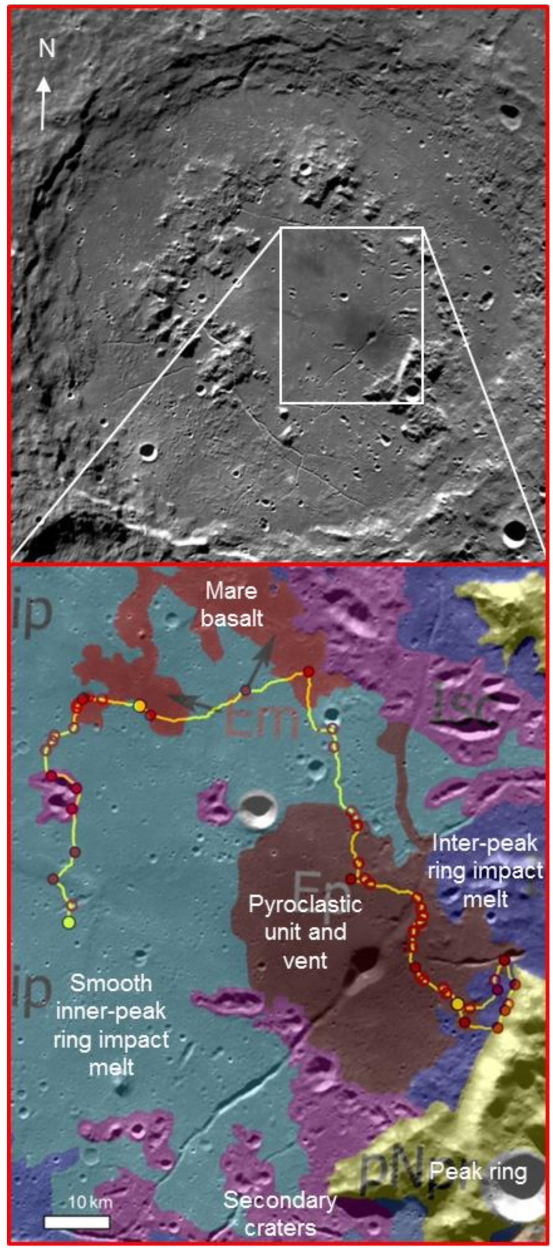

Figure 1: *WAC mosaic of the Schrödinger basin (top; diameter ~320 km) with an overlain geologic map [4] showing the traverse route (bottom).*

Traversing the Basin Center: The rover traverses 207 km, encountering 6 geologic units (and far more lithologies) within the central peak ring (Fig. 1). The traverse is separated into 3 sections defined by 3 landing sites (yellow closed circles). Fifty sites of interest (red circles) are identified of which 18 are prioritized as sample collection points (closed red circles). A baseline sample mass of 30 kg (3 times 10 kg per section) is to be collected and returned to Earth.

Sampling capabilities. A minimum science return can be accommodated with 30 kg of returned samples [8, 10], but additional mass would increase mission productivity. A study of volume to mass ratios for a spherical sample transfer container of varying internal diameter was conducted, in conjunction with an engineering study that determines if the lunar escape velocity can be exceeded with increased ascent vehicle payload. The results suggest a total sample return mass greater than 30 kg may be reasonably accommodated (subject to the payload of the EAM and Orion).

Traverse Section 1: A 35 km loop returns peak ring samples, pyroclastic material, and inter-peak ring impact melt breccias to the first landing site. This loop is the shortest section of the traverse designed to address the most science objectives within a small area [8], minimizing risk of no sample return. The pyroclastic unit (associated with the vent) is targeted first, in part because it has been a site previously identified as having ISRU potential [1-4].

The peak ring (~2 km high) is composed of uplifted crust and has 3 mineralogically distinct units determined from M^3 spectra (anorthositic, olivine-bearing, and orthopyroxene-bearing lithologies) [4]. Boulders accessible to the rover have identifiable tracks tracing back to outcrops of the peak ring, providing access to the first in-context samples of lunar mid- and lower-crust. Combined *in situ* measurements and subsequent laboratory analyses can test peak ring formation models and the lunar magma ocean hypothesis, with broad application to crater-forming and planetary differentiation processes throughout the solar system.

Traverse Section 2: A 112 km section en route to the second landing site crosses both the pyroclastic unit and mare basalts. Determining the ages and chemical compositions of these first in-context farside volcanic units can provide information on their different mantle sources and mechanisms of delivery to the surface. The samples can test mantle chemical stratification models, while providing critical measures of the thermal and magmatic evolution of the Moon (and other small rocky planetary bodies).

Section 2 also crosses smooth inner-peak ring melt sheet. Several sample locations across the basin will investigate optically different types of melt present and any melt sheet heterogeneity. The top of the melt sheet has a dominantly noritic composition (inferred from M^3 spectra [4]) and may represent a quenched surface layer. Determining the age of this layer constrains Schrödinger's formation age and, hence, the end of the basin-forming epoch. This, in turn, can be applied to models testing the lunar cataclysm hypothesis (a proposed spike in the inner solar system impact flux at 3.9 Ga). Further *in situ* and laboratory analyses of the melt sheet, its surface layer, and excavated clasts in melt breccias will provide a chemical and lithological cross-section of that portion of the Moon.

Traverse Section 3: The final ~59 km section provides *in situ* analyses and outcrop mare samples from the wall of a ~4 m deep sinuous rille that can be used to evaluate how it was formed. Asymmetrical secondary craters formed by ejecta from the Antoniadi crater (~505 km away [4]) may have retained up to 18% of extra-basinal material (using a ballistic model calculation [11]). Analysis of the secondary crater ejecta blankets may constrain the age of the Antoniadi impact and provide lunar crust samples from closer to the interior of the South Pole-Aitken basin. An intriguing iron-rich ridge is the final target of interest. It is suspected to be associated with the volcanism, but may be attributable to some tectonic activity [12, 13]. Finally, intermittent regolith sampling along the traverse also addresses impact cratering and regolith gardening processes.

Conclusions: A long duration human-assisted robotic mission to the central region of the Schrödinger basin can return a minimum of 30 kg of sample. The material would include the first samples of lunar farside volcanic units, unaltered basin melt sheet, and in-context crustal lithologies. Subsequent analysis would address at least 20 of the 31 remaining lunar science goals, including 5 of the top 10 prioritized goals [7]. The potential for ISRU also provides an important step toward using the Moon as a platform for onward space exploration.

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