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Analyses of robotic traverses and sample sites in the Schrödinger basin for the HERACLES human-assisted sample return mission concept

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Abstract

The International Space Exploration Coordination Group (ISECG) developed an integrated Global Exploration Roadmap (GER) that outlines plans for human-assisted sample return from the lunar surface in ~2024 and for human presence on the lunar surface in ~2028. Previous studies have identified the Schrödinger basin, situated on the far side of the Moon, as a prime target for lunar science and exploration where a significant number of the scientific concepts reviewed by the National Research Council (NRC, 2007) can be addressed. In this study, two robotic mission traverses within the Schrödinger basin are proposed based on a 3 year mission plan in support of the HERACLES human-assisted sample return mission concept. A comprehensive set of modern remote sensing data (LROC imagery, LOLA topography, M^3 and Clementine spectral data) has been integrated to provide high-resolution coverage of the traverses

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and to facilitate identification of specific sample localities. We also present a preliminary Concept of Operations (ConOps) study based on a set of notional rover capabilities and instrumental payload. An extended robotic mission to the Schrödinger basin will allow for significant sample return opportunities from multiple distinct geologic terrains and will address multiple high-priority NRC (2007) scientific objectives. Both traverses will offer the first opportunity to (i) sample pyroclastic material from the lunar farside, (ii) sample Schrödinger impact melt and test the lunar cataclysm hypothesis, (iii) sample deep crustal lithologies in an uplifted peak ring and test the lunar magma ocean hypothesis and (iv) explore the top of an impact melt sheet, enhancing our ability to interpret Apollo samples. The shorter traverse will provide the first opportunity to sample farside mare deposits, whereas the longer traverse has significant potential to collect SPA impact melt, which can be used to constrain the basin-forming epoch. These robotic missions will revalidate existing lunar surface capabilities and pioneer new ones and, thus, provide important precursor results for subsequent human missions to the lunar surface.

Keywords: Schrödinger; Moon; Exploration; Lunar; Sample return mission

1. Introduction

The international community agrees (e.g. NRC (2007), Crawford et al. (2012)) that exploration of the Moon can address fundamentally important scientific questions, while providing a credible path for human exploration into the Solar System. The International Space Exploration Coordination Group (ISECG) developed an integrated Global Exploration Roadmap (GER) that outlines plans for human-assisted sample return from the lunar surface in ~2024 and for human presence on the lunar surface in ~2028. The ISCEG is currently exploring the first phase of that sequence with a human-assisted robotic sample return mission concept (HERACLES; Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science). This mission concept involves a series of landings that would expand access to the lunar surface. The first landing would deploy a rover. Two additional landings of a reusable ascent vehicle at other sites along the traverse would deploy a suite of experimental packages. The rover collects samples and performs in situ analyses during each section of the traverse for a number of months, and rendezvous with the ascent vehicle to transfer the collected samples. A crew in the Orion capsule or an exploration Deep Space Habitat (eDSH) could tele-operate the rover while orbiting at the Earth-Moon L2 Lagrange point above the farside of the Moon (Burns et al., 2013; Pratt et al., 2014). The samples for each section would then be transferred from the ascent vehicle to the eDSH, which would allow for transfer of the samples to the Orion crew vehicle for return to Earth.

One of the most comprehensive studies of lunar science objectives conducted by the US National Research Council produced a report that outlined eight scientific concepts and thirty-five prioritized investigations (NRC, 2007). A large number of studies were then conducted to determine the locations on the lunar surface where those investigations could be addressed (Kring and Durda, 2012). This work showed that the Schrödinger basin, situated within the South Pole–Aitken (SPA) basin, is the best location on the Moon for addressing the highest priority and largest number of objectives.

For example, a robotic sample return mission to the Schrödinger basin would test the lunar cataclysm hypothesis (NRC Goal 1), would provide insights into the the petrologic structure of the lunar interior (NRC Goals 2 and 3), would assess the thermal and compositional evolution of the Moon (NRC Goals 3 and 5), would provide insights into basin forming processes (NRC Goal 6) and would investigate regolith processes and surface weathering (NRC Goal 7). A recent study of Kumar et al. (2016) suggests that the Schrödinger basin is also an interesting locality for studying local seismic events and could be tied into a tetrahedral seismic array for global lunar coverage (Tian et al., 2013). In addition, several targets within the peak ring structure are likely to receive no or little illumination year-round and are therefore believed to be targets suitable for in situ resource utilization (ISRU) (Kring et al., 2014; NRC Goal 4). The pyroclastic vent is believed to be a prominent source of volatiles and, therefore, also has a significant ISRU potential (Kring, 2014). Previous studies have referenced these benefits to justify a range of sites and traverses that are located within the Schrödinger basin. However, these mission designs involved either human exploration on the lunar surface (Bunte et al., 2011; O'Sullivan et al., 2011) or a robotic exploration mission that does not exceed a lunar day (Potts et al., 2015).

In this study, two possible traverses for long-term (~3 year) robotic exploration in the Schrödinger basin are investigated by integrating a wide range of remote sensing datasets that include topography, compositional spectra, and high-resolution imagery (Martin et al., 2016; McDonald et al., 2016). The proposed traverses are based on previously identified key targets within the Schrödinger basin (O'Sullivan et al., 2011; Potts et al., 2015; Hurwitz and Kring, 2015) and are designed to address the key science and exploration objectives that are prevalent throughout the international lunar science community (NRC, 2007; Crawford et al., 2012).

2. The Schrödinger basin

The Schrödinger impact basin (Figs. 1 and 2) is located on the lunar farside (−75°, 132.5°) and is the