LANDING SITE ASSESSMENT FOR PHASE 2 OF EDSH-ENABLED LUNAR MISSIONS BEING EXAMINED AS AN ISECG–GER MISSION SCENARIO. J.J. Ende[1] (jende@vols.utk.edu), E.J. Allender[2], N.V. Almeida[3,4], J. Cook[5], O. Kamps[6], S. Mazrouei[7], C. Orgel[8], T. J. Slezak[9], A.J. Soini[10], D.A. Kring[11]. [1]University of Tennessee, Department of Earth and Planetary Sciences, 1412 Circle Drive, Knoxville, TN, 37902 [2]University of Cincinnati, [3]Natural History Museum, London, [4]Birkbeck College, London, [5]University of Houston, [6]University of Twente, [7]University of Toronto, [8]Freie Universitat Berlin, [9]Brigham Young University, [10]University of Helsinki [11]USRA-Lunar and Planetary Institute

Introduction: The International Space Exploration Coordination Group (ISECG) has been examining the architectural requirements of its Global Exploration Roadmap [1]. For humans to the lunar surface, beginning in 2028, a five-year campaign with five landing sites was designed by Hufenbach et al. [2]. To further evaluate that type of initiative, they proposed five sites of potential scientific interests: Malapert Massif (85.9°S, 2.9°W), South Pole/Shackleton Crater (89.3°S, 130.0°W), Schrödinger Basin (75.4°S, 159.9°W), Antoniadi Crater (69.7°S, 172.0°W), and the South Pole-Aitken Basin center (60.0°S, 159.9°W). Here we examine those landing sites and evaluate the science that can be accomplished by crew at them.

Mission architecture: In the design reference mission (DRM) of [2], a crew of four lands at each site and traverses a 200 km-diameter exploration zone in a pair of Lunar Electric Rovers (LERs). Surface activities are composed of two 14-day-long traverse loops that return to the lander. Those can be done in a 28-day mission, if the LERs can operate at night. If not, then they can be done in a 42-day-long mission, with a limited range of activities around the lander during darkness. Mission hardware includes: NASA's Space Launch System (SLS), the Orion vehicle, an evolvable Deep Space Habitat (eDSH) developed by ESA, a reusable ascent/descent stage, and two Lunar Electric Rovers (LER) with notional instrumentation packages (APXS, GPR, and Gigapan). A companion abstract [3] details the inter-landing site traverse; LERs will be tele-robotically driven over the course of a year from one landing site to another. The eDSH will be positioned in a large southern halo orbital configuration around Earth-Moon LaGrange point 2 (EM-L2) to enable communications support to the lunar farside.

Methodology: To determine if crew in LERs could effectively explore the landing sites and to evaluate potential science, landing site traverses were developed using ArcGIS 10.1. Trafficability was determined via slope maps and digital elevation models derived from Lunar Orbiter Laser Altimeter (LOLA) data at resolutions from 5 to 100 m depending on latitude. Terrain was also visualized using Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) mosaics of 100 m/pix and LROC Narrow Angle Camera (NAC) images of 1 m/pix to provide detailed information for sample collection. Such fine resolution imagery enables specific targets, such as boulders or geologic contacts, to be pinpointed for examination. The design of the intra-site traverses also builds upon the previous studies of [4-10] to ensure the maximal number of NRC scientific concepts are addressed.

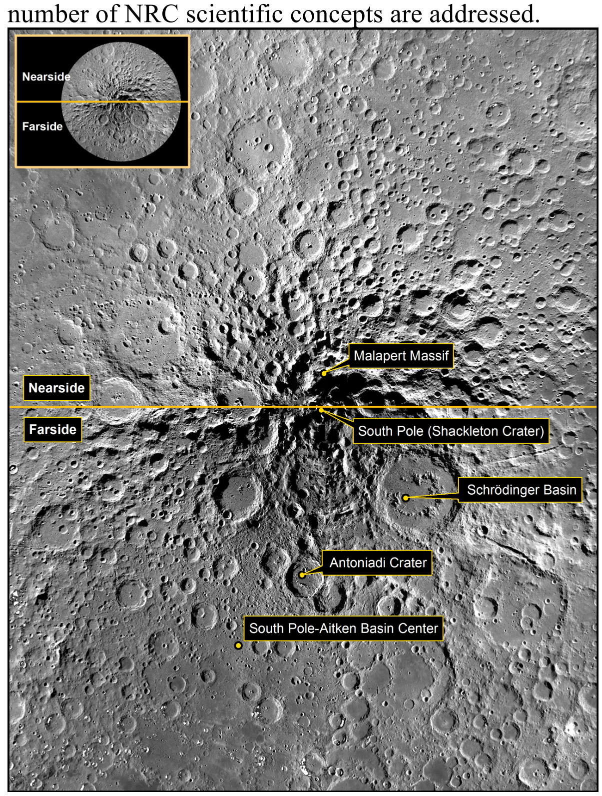

Figure 1: Site overview. Base image LROC WAC mosaic 100 m/pix.

Concept of Operations: This study utilized LER capabilities and conops consistent with past lunar mission simulations [11-15]. Sample masses are consistent with CAPTEM recommendations [16]. The crew of four are capable of working 8.5 hrs per day [11]. The use of an orbital asset at EM-L2 using the eDSH as a relay is necessary as radio-based E-M-E communications are insufficient. A large southern halo orbit can provide greater than 80% coverage per orbital pass at each landing site [17]. Communication dropout times are considered.

Malapert Massif: The first human landing site is particularly notable because of its potential for direct-to-Earth communication, and the study of Permanently Shaded Regions (PSR) and highly illuminated regions, which experience constant illumination 74% of the lunar year [18]. These regions provide a multitude of In Situ Resource Utilization (ISRU) potential. Massif material samples provide an ideal opportunity to study cross-sections of the lunar crust. Six of seven NRC (1-4, 6, 7) concepts can be addressed.

South Pole/Shackleton Crater: Exploration of the second human landing site is unique due to its proximity to many PSRs. The study of such features is a high priority for [19] and sustainable exploration. Crew in LERs can explore regions of both H_2O and CO_2 stable subsurface temperatures [20]. Traverses are designed such that PSRs on the floor of Faustini Crater and in the vicinity of de Gerlache and Shoemaker craters will be explored. In situ observations and sample collection can help address six of the seven NRC concepts (1-4, 6, 7) and provide ISRU potential.

Schrödinger Basin: This basin is recognized as the highest priority landing site for addressing NRC objectives [6]. It hosts a large central pyroclastic deposit – a key target for both scientific and ISRU exploration. Sampling other geologic sites provide ample opportunities to test the lunar cataclysm and lunar magma ocean hypotheses, constrain lunar volatile cycling, and provide insight into the thermal evolution of the Moon. Samples of impact melt from the margins of the South Pole-Aitken (SPA) basin, the oldest, largest basin on the Moon, may also be available to determine its age. All NRC concepts can be addressed. While this study determined that the floor of Schrödinger is accessible to LERs, contingency extra-basin EVAs have been planned. Extra-basin exploration is limited in geologic context and lacking notable features such as: young mare, pyroclastics, feldspathic primary crust and impact melt products with geologic context.

Antoniadi Crater: Exploration of Antoniadi Crater, may serve to test the lunar cataclysm hypothesis, as it is the youngest impact from that epoch. Additionally, Antoniadi offers an opportunity to sample the central SPA basin impact melt sheet as well as some of the youngest volcanic rocks on the Moon. With over 40 different volcanic constructs, selective sampling can further enhance an understanding of material of ISRU interest. All NRC concepts can be addressed. Although it appears the floor of the crater is accessible to LERs, a contingency extra-basin traverse was designed, but it has less scientific potential.

South Pole-Aitken Basin Center: Exploration of the SPA provides an opportunity to sample fragments of the SPA impact melt sheet, mare and cryptomare, and some of the oldest regolith on the farside of the Moon. Sampling the diverse geology will elucidate regolith formation and provide insight into the thermal evolution of the Moon. Six NRC concepts can be addressed (1-3, 5-7). Discrepancies in existing geologic maps require updated mapping using new data before detailed traverse assessment can be made. As this is the last landing site, there is sufficient time to conduct such studies.

Discussion and Conclusion: Almost all of the NRC concepts can be addressed at Malapert Massif, South Pole/Shackleton Crater and SPA Basin center and all concepts can be addressed at Schrödinger Basin and Antoniadi Crater. Schrödinger Basin has been more thoroughly characterized by previous studies [3,5,6], provides a better location for ISRU, and has more entry and exit locations than Antoniadi Crater. Thus, it is the highest priority landing site. Robust characterization of PSRs for both ISRU and composition analysis require exploration of the South Pole/Shackleton Crater landing site. Therefore, if the mission were to be limited in the number of human landing sites that could be explored, the highest priority locations to address all NRC concepts most thoroughly would be the interior of Schrödinger Basin and South Pole/Shackleton Crater. However, exploration of only these two landing sites would prohibit the study of massif formation and ancient regolith that can be conducted at Malapert Massif and SPA Basin center respectively. Furthermore, while Schrödinger Basin provides the opportunity to test the lunar cataclysm hypothesis and thermal evolution models of the Moon, such concepts would be greatly enhanced by further study at Antoniadi Crater and SPA Basin center.

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