OPTIMIZING LUNAR SURFACE SCIENCE: COMPARISON OF SHACKLETON BASE SCENARIO AND SORTIE SURFACE SCENARIOS AT THE NECTARIS BASIN, MARIUS HILLS, AND OLIVINE HILL.

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Introduction: The work reported here responds to the need to provide the Constellation Program Office Lunar Surface Systems Project with science requirements for a lunar surface system architecture and metrics for lunar surface system operations. The Surface Science Scenarios Working Group of the NASA HQ Outpost Science and Exploration Working Group (OSEWG) has developed science-driven lunar surface activity scenarios. This group has created multiple lunar field studies on scales ranging from tens to hundreds of kilometers in a way that addresses lunar science goals, as most recently stated by the Lunar Exploration Working Group (LEAG). Here we compare surface scenarios performed at an outpost (Shackleton Crater) and at three sortie sites (in the Nectaris Basin, at Marius Hills, and at Olivine Hill). The detailed plans for the each of the two scenarios (base versus sortie) are described in detail in companion abstracts [1,2].

Here we briefly describe then compare the two scenarios and address the limitations/strengths of each approach with regards to the expected science return of each site.

Surface Operations Assumptions: Initially we follow these assumptions: the four person astronaut crew is on the surface for a total of seven days, there are simultaneous traverses with two teams of two astronauts, there will be four total EVA's per team, and there is a 10km walk back distance from a central lander. One exception is that we allow for the possibility of longer EVA's (15km walk back distance) when the two teams work together.

Outpost at Shackleton Crater: In a companion abstract [1] the surface scenarios capable from the outpost at Shackleton Crater are described. For such an outpost scenario with the above assumptions, the science return is regarded [1] as being minimal when restricted to 10km distance from the outpost site. Therefore, longer duration (~2 weeks) and larger distances (10-100's of km) are required in order to maximize science return.

Extending both the time and duration of surface traverses allows for multiple science questions to be addressed. For example, exploration into the large South Pole-Aitken Basin (SPA) and several of the larger craters within it near the south pole would allow for the sampling of SPA-derived material as well as other geochemically unique rocktypes. Furthermore, exploration of the several additional Hydrogen anomalies in the south pole region are possible with extended traverses (Figure 1).

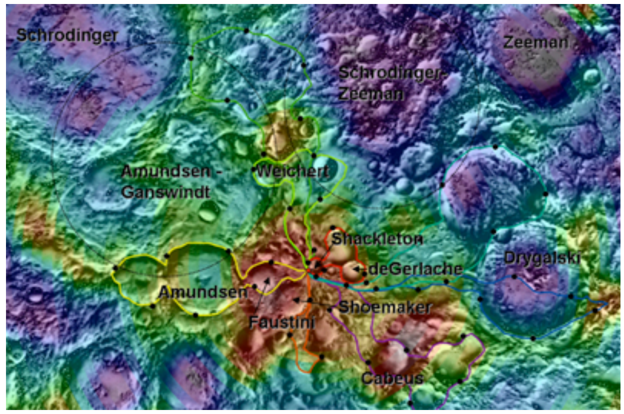

Figure 1. Example extended traverses from Shackleton Crater Outpost site [1]. These example traverses focus on exploring Hydrogen anomalies and range in distance from ~75km to Faustini to ~340km to Drygalski.

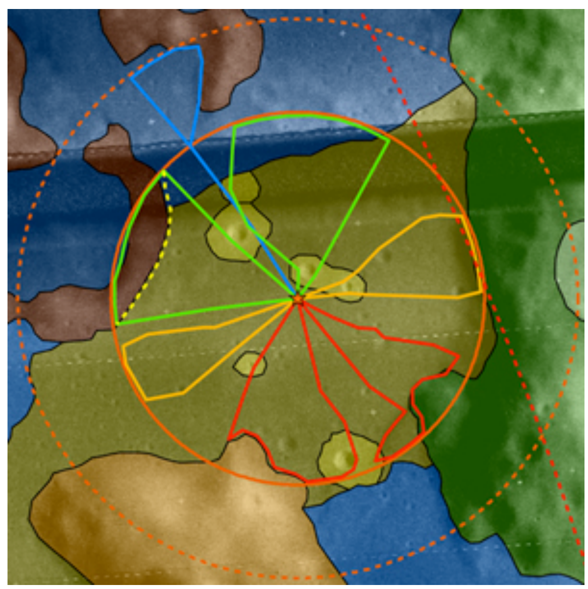

Figure 2. Example traverses in eastern Nectaris basin. Red dashed line marks main ring of the basin, with the orange circles marking the 10 and 15km distances from the landing site.

Sortie Sites: Sortie surface scenarios have been constructed for three example sites that include the Nectaris Basin, Marius Hills, and Olivine Hill [2]. These three sites were selected in order to address various lunar science goals outlined by the Lunar Exploration Analysis Group (LEAG) as well as the NRC Scientific Context for the Exploration of the Moon [3]. In all three cases, landing sites were selected to maximize the compositional diversity and number of structures (e.g., massifs, rilles, fresh craters) where bedrock or unweathered material can be sampled. Additionally, at each site, the deployment of geophysical stations is given high priority to support the deployment of a widespread geophysical network.

Nectaris Basin Interior (13.2ºS,3.98ºE): The landing site was selected in northeastern Nectaris with the primary objective to determine, unequivocally, the age of the basin. Sampling sites include several small fresh craters within the mare as well as exposures of basin massif material in the 10km walk back boundary. A longer traverse is utilized to sample *in situ* the Gaudibert pyroclastic deposit [4].

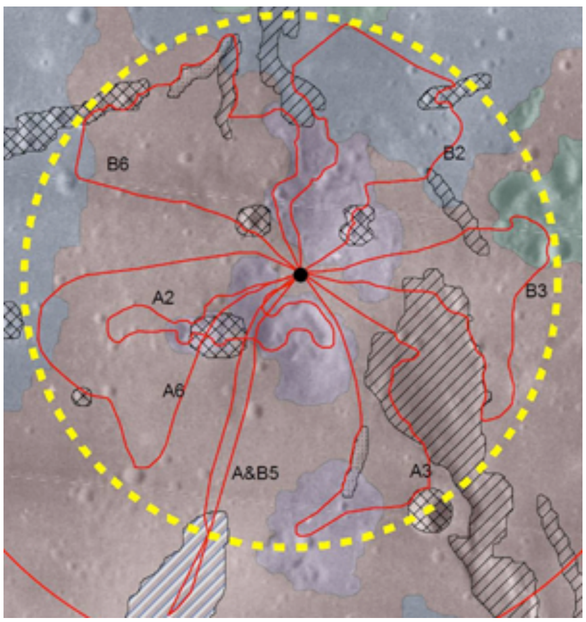

Figure 3. Marius Hills landing site. The yellow dashed line marks the 10km walk back limit, while the red curve marks the 15km walk back limit for the joint traverse.

Marius Hills (11.5N,54.8W): The Marius Hills landing site is surrounded by unique volcanic landforms (e.g., domes, a rille) with varying estimated TiO_2 contents [5], structural features (e.g., wrinkle ridges), and portions of the Riener Gamma formation [2] (Figure 3). The focus of the traverses is on sampling the multiple volcanic and structural features/compositions as well as measuring and sampling from the "swirl material" possibly associated with the magnetic anomalies in the area [6].

Olivine Hill in Central SPA(57.7S,162.2W): The Olivine Hill landing site is located on the northern portion of the "hill". Olivine Hill's location within the central SPA and potential abundance of olivine [7] make this site unique in that sampling SPA-derived as well as mantle-derived material is possible (Figure 4).

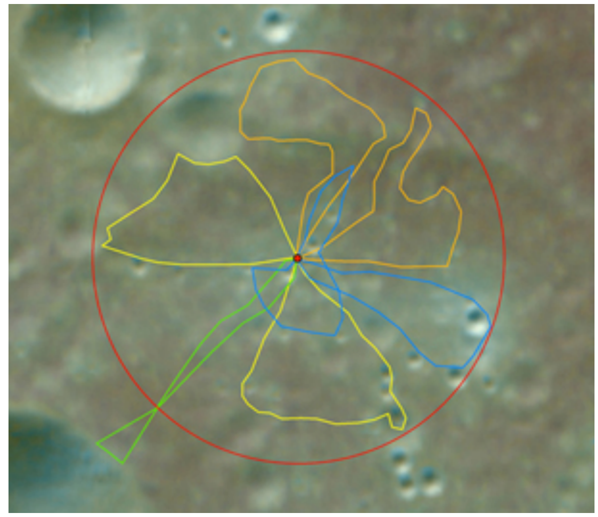

Figure 4. Olivine Hill landing site traverse plans. Red circle marks the 10km walk back limit.

Comparison of Scenarios: In the described scenarios, we show [see 1,2] that well-planned traverses address multiple science questions and goals. At the three example sortie sites, working within the defined scenario assumptions results in the sampling of multiple rocktypes and unique geologic features. However, the limitation of a 10-15km radius for surface operations limits the ability to fully characterize geologically complex regions. At each of the three example sortie sites, the 15km traverses are to sample key units no represented within the 10km walk back limits. Increasing the radial distance of surface capabilities significantly increases the science return from each site. Similarly, at the outpost site, only after the addition of long-range surface capabilities are the science goals unequivocally met [1]. This is not to say that comparable science would not be accomplished at a Shackleton site as there are a number of science questions that may be addressable there [8].

Data from current [Chandrayaan-1, Kaguya, Chang'e] and upcoming missions [LRO] will reveal much more about the geology of the Shackleton region (i.e., demonstrate a geochemical diversity of the region and place it in better context with SPA) that may increase the science return for more localized surface sampling. Ultimately, selecting widespread sortie sites (to enable broader geophysical station deployment), each with a diversity of materials similar to the three sites illustrated here, will increase the science output of lunar surface exploration.

References: [1] Clark, P.E, et al. (2009) these abstracts. [2] Bleacher, J.E. et al. (2009) these abstracts. [3] Committee on the Scientific Context for Exploration of the Moon (2007), 120pp. [4] Gaddis L. et al. (2003), *Icarus*. [5] Weitz, C. and Head J. (1999), *JGR*. [6] Hood, L. et al. (2001), *JGR*. [7] Pieters, C., et al. (2001), *JGR*. [8] Spudis, P. et al. (2008), *GRL*.