SHACKLETON-DE GERLACHE RIDGE AND SHACKLETON-SLATER PEAK, LUNAR SOUTH POLE: PRELIMINARY ROVER TRAVERSE PLANNING TO SCIENTIFIC REGIONS OF INTEREST FROM CANDIDATE NASA ARTEMIS BASE CAMP SITES.

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Summary: Preliminary rover traverses from candidate Artemis Base Camp sites at Shackleton-de Gerlache Ridge and Shackleton-Slater Peak to local science targets are presented. Both areas, which are NASA candidate landing regions for Artemis III, offer promising science opportunities for long-term exploration.

Introduction: Candidate sites for a future NASA Artemis Base Camp (ABC) in the lunar south polar region have been proposed and ranked [1-4], and studies of rover traverse concepts from these sites to local science regions of interest (SROIs) have begun [e.g., 1-5]. NASA's list of 13 candidate landing regions for the Artemis 3 mission, released in August 2022 [6], matches the highest priority candidate ABC sites identified [7].

In this study, we examine rover science traverse opportunities from the two highest ranked candidate ABC site clusters closest to the Lunar South Pole: the Shackleton-deGerlache Ridge (location "001" in [8]) with its three candidate ABC sites (SGα, β and γ), and the Shackleton-Slater Peak (location "007" in [8]), with its two candidate ABC sites (SSα and β).

Methodology: The criteria we applied for long-range traverse planning build on the goal of accessing the highest priority science targets identified in the lunar science and exploration reference documents used by NASA [e.g., 8-10], and rest on several assumptions regarding the capabilities, performance, and operational constraints of future crewed rovers available to Artemis. Based on our experience with the Lunar Roving Vehicle (LRV) during Apollo [11], the Lunar Electric Rover (LER) at Desert-RATS field tests [12], ATVs and Humvees on the NASA Haughton-Mars Project in the Arctic [13], and snowmobiles in the Antarctic Search for Meteorites (ANSMET) Program, our traverse planning criteria are:

1. Solar Illumination: Traverse paths shall prioritize areas illuminated more than 50% of the time in static illumination maps at 60 m/pxl [14]. Although lidar-assisted navigation might enable safe traversing even in darkness, photovoltaics may need > 50% illumination.

2. Direct-To-Earth Visibility: DTE visibility > 50% of the time on static DTE visibility maps at 60 m/pxl [14] is required, limiting reliance on orbital relay assets.

3. Surface Slope: Surface slopes shall not exceed 20º. as shown on 10 m/pxl maps.

4. Surface Roughness: Surface roughness shall not exceed 3 RMS meters [15], as mapped at 60 m/pxl.

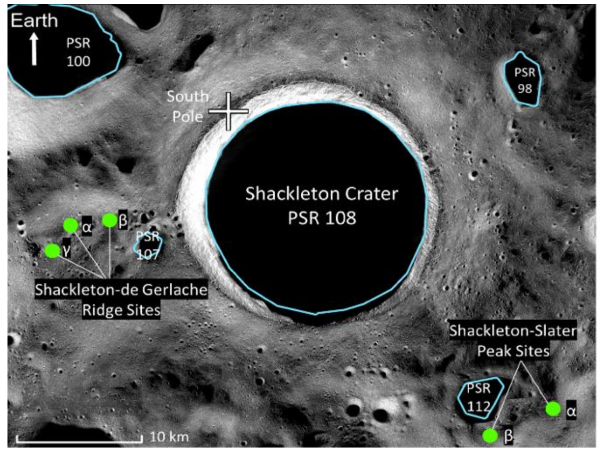

Figure 1: Context Map of Candidate Artemis Base Camp (ABC) Sites Considered in this Study. *Green Dots: Candidate ABC sites [1]. Blue Outlines: H_2O ice-bearing Permanently Shadowed Regions (PSR) [5].*

5. Science Targets: Science targets visited shall include at least one H_2O ice-bearing Permanently Shadowed Region (PSR) identified in [16], two H_2O terrain classes as defined in [17], and large boulders as in [18]. Class 3 terrain presents hydrogen signatures within the top 1 m of the regolith and yet is outside PSRs, which is optimal SROI for early exploration [17].

To minimize time spent in cold, shadowed, out of DTE communication areas, each PSR shall be accessed via a specific "Entry Point" chosen, via GIS Python analysis, to minimize traversing over terrain with <25% illumination, <25% DTE, >5° slope, and >1 RMS m surface roughness.

To map a preliminary traverse route with the criteria presented above, a least cost path analysis from ArcGIS Pro was utilized. Using this tool, we reclassified and overlaid datasets with different costs. With different costs, the traverses reflect a minimization of a maximization of solar illumination exposure and steep slopes.

Case studies with Static Datasets: While dynamic data sets, in which solar illumination and DTE visibility may change significantly with time over the course of a long-range traverse, must ultimately be used for realistic traverse planning, we consider in this study the approximate but much simpler case of traverses using static datasets, to establish a preliminary set of reference traverses from candidate ABC sites to SROIs.

Shackleton-Slater α to PSR-112: Shackleton-Slater α (SSα) is a candidate ABC site with a solar illumination average of 78% and an average DTE of 61% [1,3-7]. SSα is located at the boundary between Class 3 and 8 terrain [17], allowing the frequent exploration of both. PSR-112 is the closest H_2O ice-bearing PSR (Class 1 terrain [17]) to SSα [1,3-7,16]. Our traverse path from SSα to PSR-112 passes through SSβ, the other candidate ABC site on the Shackleton-Slater Peak **(Fig. 2).** Total traverse distance from SSα to the Entry Point of PSR-112, located on the far side of the PSR as viewed from SSα, is 12 km, which at 8 km/h (5 mph) typical of the Apollo LRV [11], can be driven in 1.5 hours once a route is established. If stops are made along the way, traverse time will be adjusted accordingly. **Figure 2** shows stops, or "stations", along the traverse for lunar science observations and sample collection. Station locations were chosen based on terrain roughness [15], terrain class [17], and the opportunity presented by small craters and other PSRs.

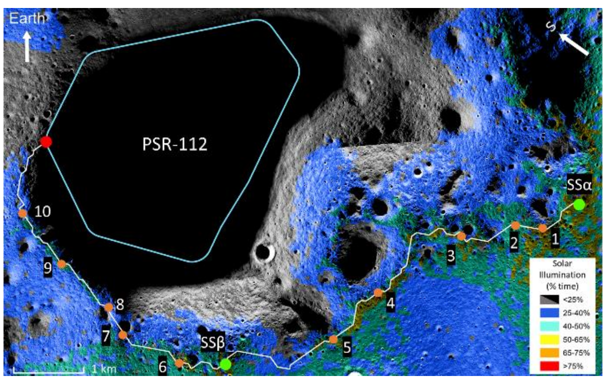

Figure 2: Traverse from Shackleton-Slater α (SSα) to PSR-112 with Static Solar Illumination. *Traverse route (white line) from SSα to the closest H_2O ice-bearing PSR, PSR-112 (outlined in light blue), via Shackleton-Slater β (SSβ). Green dots: Candidate ABC sites. Red dot: PSR Entry Point. Orange dots: Main science/sampling stops at locations of increased terrain roughness [15], small craters, and other PSRs.*

Shackleton-de Gerlache α to Lunar South Pole: Shackleton-deGerlache α (SGα) is a candidate ABC site with an average solar illumination of 85% and an average DTE of 58% [1,3-7]. Our traverse route passes through SGβ, another candidate ABC site on the SG Ridge **(Fig. 3)**. SGα and SGβ are located on Class 3 terrain [17]. The traverse also goes through the "Least Rough Rim" section of Shackleton Crater's rim, which might be a good location for a remote science outpost or a major cache of supplies. The total traverse distance is 22 km, which can be driven via a known route in 2.75 hours at 8 kph (5 mph) [11]. Science stations include the science target categories of the previous traverse, but also large boulders identified in [18].

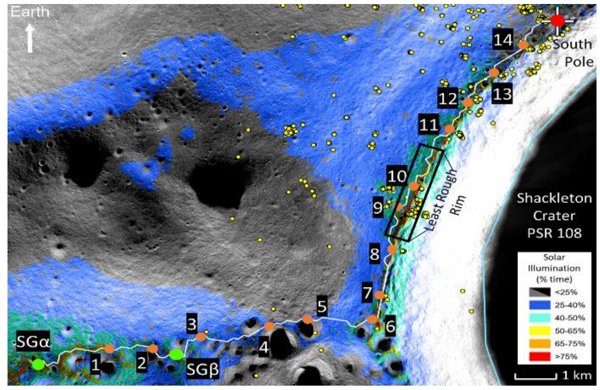

Figure 3: Traverse from Shackleton-de Gerlache α (SGα) to Lunar South Pole with Static Solar Illumination. *Traverse route (white line) from SGα to the lunar South Pole (red dot) following the ridge of Shackleton Crater via Shackleton-de Gerlache β (SGβ). Green dots: Candidate ABC sites. Yellow dots: Identified lunar boulders [4]. Orange dots: Main science/sampling stops based on terrain class, surface roughness, small craters, other PSRs, and boulder data.*

Conclusion: Our study identifies, on the basis of static datasets, potential long-range traverse paths from candidate ABC sites to exciting SROIs at two locations also identified by NASA as candidate Artemis III landing regions. With the recent availability of new dynamic and 3D traverse planning tools, our preliminary traverses will be revisited using dynamic datasets to investigate the feasibility of the proposed traverse paths and best strategies to travel them. We also recommend that NASA consider a candidate ABC site for the Artemis III landing, so that long-term use of a site would be an option following its short-term exploration by Artemis III, and to use upcoming CLPS mission opportunities to recon candidate Artemis III and ABC sites.

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References: [1] Willard et al. 2021. *LSSW XII*, 8035; [2] Pimentel et al. 2021. *LSSW XII*, 8032; [3] Lee et al. 2021. bit.ly/3VZ37Io; [4] Willard et al. 2022. *LPSC 53*, 2742; [5] Lee et al. 2022. bit.ly/3IU7Dp1; [6] NASA 2022. go.nasa.gov/3ZmPGoH; [7] Lee et al. 2022. 6th Global Moon Wkshp & Symp, bit.ly/3Xi9pEd, 2:00:00-2:30:00; [8] *NASA Lunar Exploration Program Overview*; [9] NASA 2020. *Artemis III Science Definition Report*; [10] National Academies 2022. *Planetary Science & Astrobiology Decadal Survey 2023-2032*; [11] NASA 2016. *Apollo Lunar Roving Vehicle*; [12] bit.ly/3ixcl16; [13] Lee 2001. LSSW 2021, 3033; [14] Mazarico et al. 2011. *Icarus*, 211, 1066-1081; [15] Mikhail et al. 2013, *Icarus*, 226, 52-66; [16] Lemelin et al. 2021 *Planet. Sci. J.* 2:103; [17] Moye & Lee 2020. *LPSC 2020*, 2594; [18] Kawashima et al. 2022. *Icarus*, 378, 114938.