HIGH-VALUE SCIENCE TARGETS IN THE MALAPERT MASSIF ARTEMIS III LANDING REGION.

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Introduction: For the first time since 1972, all of the elements needed to return to the Moon are in active development [1]. The SLS rocket, the Orion spacecraft, the Starship lander, and the AxEMU spacesuit are fully-funded and are tracking towards an initial crewed landing as early as 2025 during the Artemis III mission. NASA has identified 13 candidate landing zones for Artemis III in the vicinity of the lunar south pole [2]. Each region measures 25 by 25 kilometers and contains multiple accessible landing sites. As Artemis III will not have access to a Lunar Terrain Vehicle, all traverses must be accomplished on foot. For planning purposes, it is assumed that the astronauts will not venture more than two kilometers from their lander [3].

An ideal Artemis III landing site should meet three requirements. Most importantly, it must satisfy the mission's engineering constraints in order to guarantee crew safety. Starship must land in a 100-meter zone with slopes less than 8 degrees, and the landing site must remain illuminated throughout the six-day surface mission [4]. The leading scientific priority for Artemis III is the availability of a Permanently Shadowed Region (PSR). PSRs can be reservoirs for water ice and other volatiles [5]. In addition to their value as a potential resource, core samples from these regions could improve our understanding of water delivery to Earth and lunar volcanism [6]. However, PSRs only satisfy one of the seven science goals described in the Artemis III Science Definition Team report [7]. Therefore, the Artemis III landing site should contain a variety of targets to maximize the mission's scientific return.

Malapert Massif Overview: Malapert Massif is a 50-kilometer-long ridge situated 120 kilometers north of the lunar south pole [8]. The peak of the mountain is elevated eight kilometers above the floor of nearby Haworth Crater. Malapert lies on the rim of the South Pole-Aitken (SPA) Basin, and it is interpreted to be a block of crustal material exhumed by the impact [9]. It is an advantageous site from an engineering perspective. The ridge at the crest of the mountain features benign (<10 degree) slopes which can facilitate safe landings and traverses. Additionally, it is illuminated for 75% of the lunar year [10]. If it were selected as a landing site, Malapert's high mission availability would allow the astronauts and their support teams to optimize their training for one particular site.

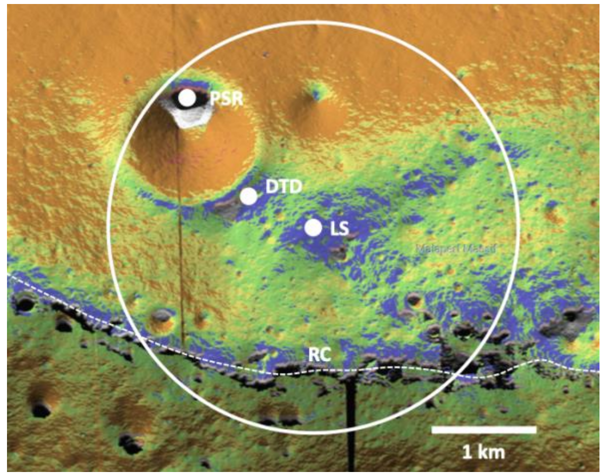

Figure 1. Context map of the proposed Artemis III landing site on Malapert Massif. The locations of the proposed science targets are marked. The basemap is an LROC Digital Elevation Model (DEM). LS = landing site; PSR = Permanently Shadowed Region; DTD = Dark-Toned Deposit; RC = Ridge Crest (traced by the dashed line).

However, prior studies have not identified PSRs on Malapert Massif. This site describes several potential science regions of interest, including a newly-discovered PSR, within the Malapert landing region. All of the targets described in this abstract are located within two kilometers of a safe landing site (Figure 1).

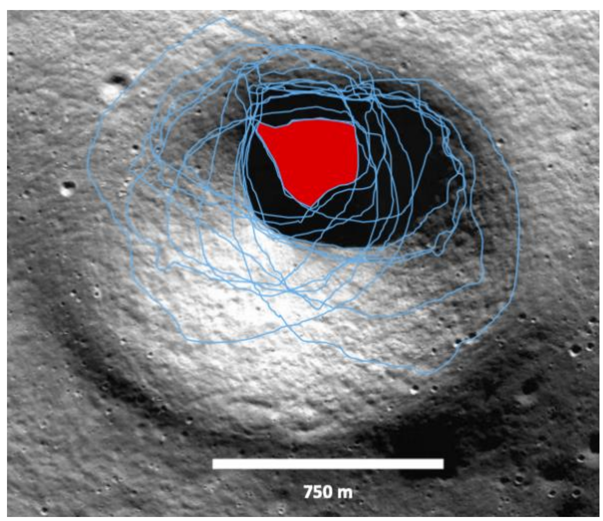

Figure 2. PSR on Malapert Massif. The extent of the shadowed area in each analyzed LROC frame is traced in blue; the PSR is shaded red.

Permanently Shadowed Region: A candidate PSR was identified using Lunar Reconnaissance Orbiter Camera (LROC) imagery. The PSR is located on the northern wall of an unnamed 1.5-km crater. The northern rim of the crater and the peak of Malapert Massif appear to shield it from sunlight at all angles. The candidate PSR remains shaded in all 30 LROC images of the site. The changing illumination of the crater in a subset of these images, which encompass the boundary conditions, is illustrated by Figure 2. The PSR has an estimated area of 5,000 m^2, and it is comparable to similar features on the Shackleton-de Gerlache ridge [11]. Notably, the slope of the northern rim of the host crater appears to be less than 15 degrees, so the PSR itself is likely accessible on foot. The host crater appears to be relatively fresh, with blocks of ejecta on its floor. Therefore, any ice within the PSR was likely emplaced by micrometeorite impacts rather than by the Late Heavy Bombardment or volcanic outgassing [12].

Potential Dark Impact Deposit: An enigmatic low-albedo feature is located adjacent to the basin which contains the PSR. A bright five-meter-wide feature is visible at its center. The feature appears to be situated on level terrain in an LROC DEM. In some LROC frames, the structure of the low-albedo feature resembles the rays of an impact ejecta blanket. If this interpretation is correct, sampling a dark, potentially carbon-rich ejecta deposit could allow us to understand which meteoritic organic compounds can survive a high-velocity impact. This, in turn, can inform origins of life studies [13].

One counterargument is that the position of the largest ray may shift with the solar illumination angle (Figure 3). It is unclear whether this behavior is due to discrepancies in the orientations of LROC images in the JMARS GIS program, or if it is an actual feature of the site. Alternatively, the dark-toned feature could be a shadowed area with a tall boulder at its center casting a shadow.

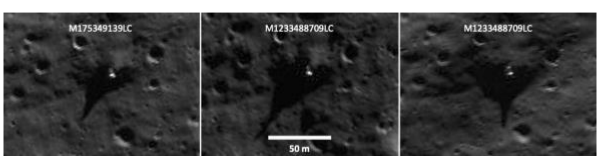

Figure 3. Potential dark-toned feature with an unknown origin on Malapert Massif.

Ridge Crest: The nature of the regolith which mantles Malapert Massif remains unknown. Prior studies have speculated that the mountain's surface is dominated by feldspathic highlands material and/or SPA impact melt [14]. Both types of samples are not represented in the Apollo sample suite and represent major lunar terranes [15]. The floor of the PSR host crater contains several large boulders. These may be intact samples from the massif itself. The southern slope of Malapert Massif faces several well-studied polar craters, including Shackleton, Haworth, Shoemaker, and Schrödinger. The mountain likely intercepted ejecta from these impact events as it traveled north. Sieve samples taken from just beyond the ridge crest could potentially contain breccia and impact melt from one or more of these basins. Dating these craters would help refine the lunar cratering chronology and place an upper bound on the ages of the ice deposits in the respective basins' PSRs.

Conclusions: Malapert Massif is often identified as a promising lunar landing site due to its flat ridge crest and its persistent illumination. This study demonstrates that it also contains multiple enticing scientific targets. A permanently shadowed region could contain water ice. The origin of an anomalous low-albedo feature is unclear, but it may be an impact crater formed by a carbon-rich bolide. Finally, the site provides access to boulders of crystalline massif material and ejecta from the craters surrounding the lunar south pole. Notably, all of these regions of interest are accessible by suited astronauts during a single mission. Malapert Massif can address several of our most pressing questions about the Moon, and it deserves consideration as a high-priority landing site for Artemis III.

References: [1] Creech S. et al. (2022) *IEEE Aerospace Conference*, 1-7. [2] Mishra A. and Kumar P. S. (2022) *Geophys. Res. Lett.*, 49, e2022GLO98505. [3] Scoville Z. (2022) *LPS LIII*, Abstract #1079. [4] Kumari N. et al. (2022) *Planetary Science Journal*, 3 (9), 224-257. [5] Bickel B. T. et al. (2022) *Geophys. Res. Lett.*, 49, e2022GLO99530. [6] Kring D. A. et al. (2021) *Adv. Space Research*, 68 (11), 4691-4701. [7] Artemis III Science Definition Team Report (2021). [8] Basilevsky A. T. et al. (2019) *Sol. Sys. Res.*, 53, 383-398. [9] Garrick-Bethell I. and Zuber M. T. (2009) *Icarus*, 204, 399-408. [10] Bussey D. B. J. et al. (2010) *Icarus*, 208, 558-564. [11] Gawronska A. J. et al. (2020) *Adv. Space Research*, 66 (6), 1247-1264. [12] Hendrix J. R. et al. (2019) *J. Geophys. Res.*, 46, 2417-2424. [13] Damer B. and Deamer D. (2020) *Astrobiology*, 20 (4), 429-452. [14] Spudis P. D. et al. (2008) *Geophys. Res. Lett.*, 35, L14201. [15] Jolliff B. L. et al. (2000) *J. Geophys. Res.*, 105, 4197-4216.