NASA-requested input for the Artemis III Science Definition Team, delivered September 8, 2020.

Artemis III EVA Opportunities on Malapert and Leibnitz β Massifs

David A. Kring*, John E. Gruener, and Dean B. Eppler

Introduction. Large mountains ring the margin of the immense 2,400 km-diameter South Pole-Aitken basin in the south polar region of the Moon. Two of those mountains are the Malapert and Leibnitz β massifs (Fig. 1 & 2). Malapert massif is also called Mons Malapert to be distinguished from the adjacent Malapert crater.

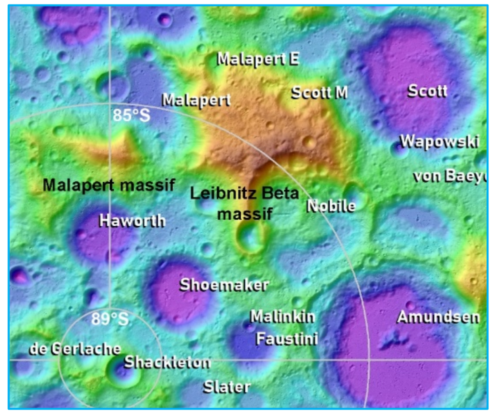

Figure 1. Topography from the south pole to the Malapert and Leibnitz Beta massifs. Both massifs occur within 6° of the south pole, which is the study domain for the Artemis III landing. Detail from [8].

Exploration strategies – past and present. During the Constellation Program the strategy was to construct a base for human exploration at the south pole and Shackleton crater. From there, assets would be re-deployed to other locations where crews would land to temporarily utilize those assets. We and our colleagues were asked by Constellation's Lunar Surface Systems for two products: (i) a traverse from Shackleton to Malapert massif over which assets could be teleoperated and (ii) two 14-day-long traverses that a crew of four could explore with two small pressurized rovers [1]. That exercise led, in turn, to a proposed expansion of the Black Point analogue test site [2] and a dual rover lunar mission simulation in northern Arizona as part of the Desert Research and Technology Studies (DRATS) program [3].

The engineering and architectural rationales for choosing Malapert massif as the first relocation destination were due to its relative proximity to Shackleton and the chosen south pole base. It is an area of scientific interest that can provide a first test of robotic caravan driving and exploring capability which may then be used extensively throughout the architecture. Other considerations such as solar illumination and communication also made the Malapert region a favorable first relocation site. The massifs command tremendously high elevations (Fig. 3), on the nearside, that can provide line-of-site communication links with Earth. Said simply, Malapert and Leibnitz β massifs are the top of the world at the bottom of the world.

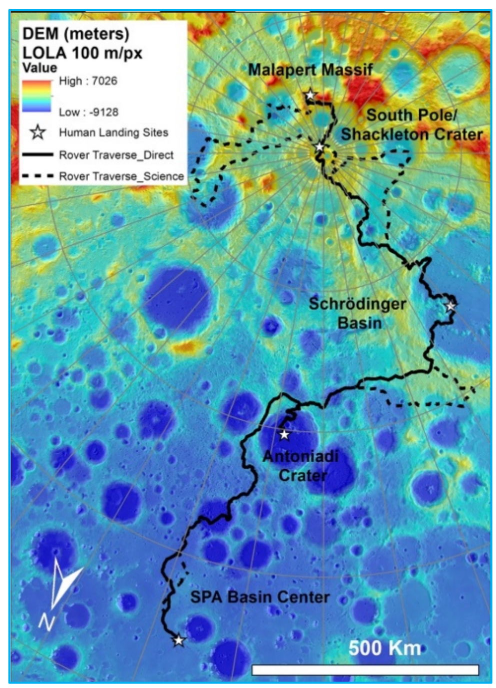

Figure 2. Five human landing sequence in the design reference mission (DRM) scenario developed by the International Space Exploration Coordination Group (ISECG) [5]. Figure extracted from the traverse study of [6].

Those engineering and architectural rationales could be complemented by a reasonable set of science objectives. The Malapert massif and nearby areas provided an opportunity to (a) study cross-sections of the lunar crust that are exposed in the massifs, (b) potentially expanding the diversity of crustal lithologies in our collections, while (c) simultaneously allowing us to test models of massif formation. These massifs are affiliated with the South Pole-Aitken Basin, which is the largest and oldest impact basin on the Moon. Impact melt generated by that impact may be available in the region, which

*corresponding author: kring@lpi.usra.edu

would allow us to (d) anchor the age of the basin-forming epoch on the Moon. Nearby impact craters (e) excavated and exposed additional components of the lunar crust for sampling. Impact melts and breccias associated with those craters can also be used to (f) better calibrate the impact flux to the Moon after the formation of the South Pole-Aitken Basin. The traverses designed contained a series of stations whose science objectives were mapped to those defined by the National Research Council in its report *The Scientific Context for Exploration of the Moon* [4].

As part of a Global Exploration Roadmap (GER), the International Space Exploration Coordination Group (ISECG) used a similar philosophy when designing a five-landing-site sequence (Fig. 2) [5]. In that case, however, Malapert massif was the initial landing point and Shackleton crater at the south pole was the second landing site. A study of the traverses between landing sites, plus traverses for crew at each landing site, was completed [6]. An independent study that proposes a base be establish on Mons Malapert also recently appeared [7].

If Artemis III astronauts land on Malapert or Leibnitz β, the exploration and science rationales developed previously apply. If, however, they are limited to a 2 km walking EVA, the breadth of the science to be addressed will be considerably smaller. In the Constellation Lunar Surface Systems study, communication relay, solar power, and seismometer stations were to be deployed and a heat probe inserted into the regolith. The same can occur at an Artemis III landing site. In a walking EVA mission, samples of massif material could be extracted from the regolith and/or from craters that excavated material from older units. The nature of massifs is sufficiently poor that it is not clear whether those components will be wholly derived from the crystalline crust of the Moon, impact melts and other debris deposited by the South Pole-Aitken impact event and younger events, or both. Depending on the location of the landing site, crew may also have access to secondary craters on the massif. Sampling would involve rocks, scooped regolith, raked regolith, trenching, and cores, either via drive tubes or a drill.

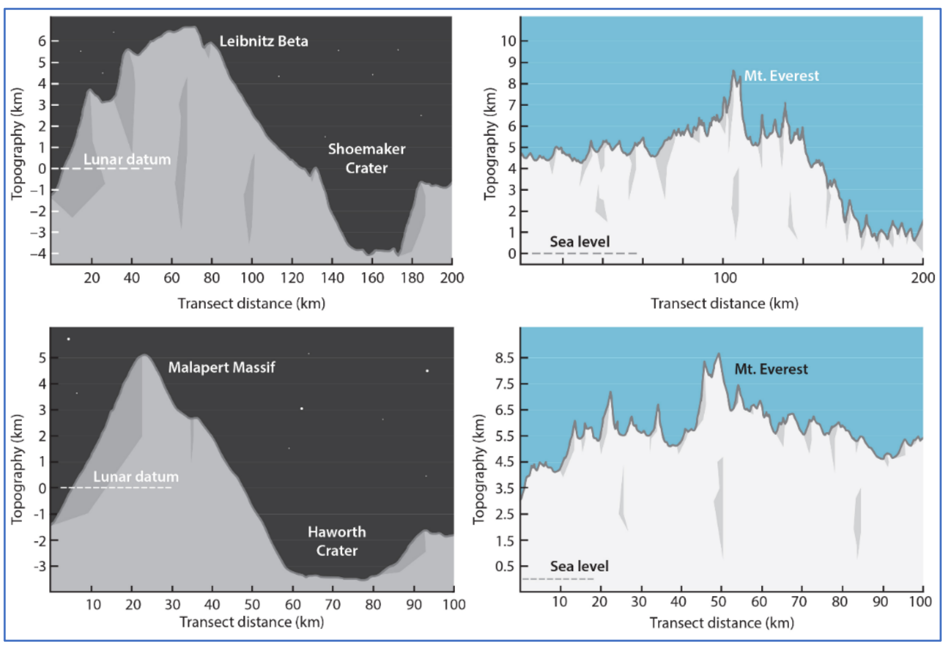

Figure 3. Topographic transects across the Moon's Leibnitz Beta massif and Shoemaker crater (top) and Malapert massif and Haworth crater (bottom) are compared with transects over Mt. Everest on Earth. The horizontal scales are 200 km (top) and 100 km (bottom). The change in elevation in the Leibnitz Beta transect exceeds 10 km and the elevation of Earth's Mt. Everest above sea level. The change in elevation in the Malapert transect exceeds 8 km, a value very close to the elevation of Earth's Mt. Everest. Illustration credit: LPI/CLSE.

References. [1] https://www.lpi.usra.edu/science/kring/lunar_exploration/Shackleton-Malapert.pdf. [2] https://www.lpi.usra.edu/science/kring/lunar_exploration/ExpandingBPLF.pdf. [3] Abercromby, A. F. J. et al. (2013) *Acta Astronautica 190*, 203–214. [4] National Research Council (2007) *The Scientific Context for Exploration of the Moon*. National Academies Press, Washington D.C. [5] Hufenbach, B. et al. (2015) *Internat'l. Astronaut. Congr.* 66th, 11p., Paper IAC-15-A5-1-1-X30756. [6] Allender, E. J. et al. (2019) *Adv. Space Research 63*, 692–727. [7] Basilevsky, A. T. et al. (2019) *Sol. Sys. Res. 53*, 383–398. [8] Stopar, J. & Meyer, H. (2019) *Topographic Map of the Moon's South Pole (80°S to Pole),* LPI Contribution 2169.

*corresponding author: kring@lpi.usra.edu