VISIBILITY OPPORTUNITIES ON THE SHACKLETON-HENSON CONNECTING RIDGE FROM THE SPACEX ARTEMIS III HUMAN LANDING SYSTEM. E. Peña-Asensio[1,2], P. Tripathi[3], J. Sutherland[4,5], K. Mason[6], A. Goodwin[7], V. T. Bickel[8], and D. A. Kring[9]. [1]Autonomous University of Barcelona (eloy.pena@uab.cat), [2]Institute of Space Science (IEEC-CSIC), [3]Indian Institute of Technology Roorkee, [4]Institut Laue-Langevin, [5]TU Berlin, [6]Texas A&M University, [7]The University of Manchester, [8]Center for Space and Habitability, [9]Lunar and Planetary Institute.

Introduction: The Artemis III mission is designed to land astronauts in the south polar region of the Moon [1]. The selected Human Landing System (HLS), being developed by SpaceX, has a remarkable vertical height of ~50 m (**Fig. 1**) [2]. This height will allow for intravehicular activities (IVAs), provide a prominent reference to assist astronaut surface navigation, access additional solar energy, and improve direct communication with Earth. We explore these opportunities within the Artemis exploration zone at potential landing sites 001 and 004, and a nearby location, 001(6), that meets HLS landing requirements [3,4].

Methods: To compute the HLS-to-surface line of sight, we use an enhanced Lunar Orbiter Laser Altimeter (LOLA) 5 m/pixel digital elevation map (DEM) [5] to generate the viewshed from the HLS windows (~40 m) for site 001, 001(6), and 004. All three locations are within the Artemis III candidate landing region called 'Connecting Ridge'. The topography in this region can be dramatic: within 2 km of the three landing sites, elevation changes by 504 m, 540 m, and 1,125 m, respectively, and can reach 3 km within line of sight. We implement a viewshed algorithm using reference planes rather than ray tracing sightlines, requiring fewer computations per grid element [6]. Lunar surface curvature is accounted for by assuming the Moon is a perfect sphere with a radius of 1,727.5 km.

In addition, we compare direct-to-Earth (DTE) communication from the HLS windows and a point two meters above the lunar surface. We use the JPL Horizons ephemerides to locate the Earth at the required local lunar reference frame and ray trace the line of sight. As a case study, we evaluate direct communication during December 2025 at one-minute intervals.

Results and discussion: The estimated height of windows from the HLS concept design suggests a viewing opportunity from ~40 m above the lunar surface (**Fig. 1**), offering potential for geological IVAs that can be used to evaluate the geology of the region, or assess modification of regolith by the landing. It can also provide a platform for imaging, including ultra-high-resolution time-lapse cameras to study the distribution and diurnal evolution of cold traps, monitoring the horizon for dust glow analyzes, long exposure imaging of permanently shadowed regions (PSRs), and enhanced guidance during astronaut extravehicular activities (EVAs). These insights might be especially

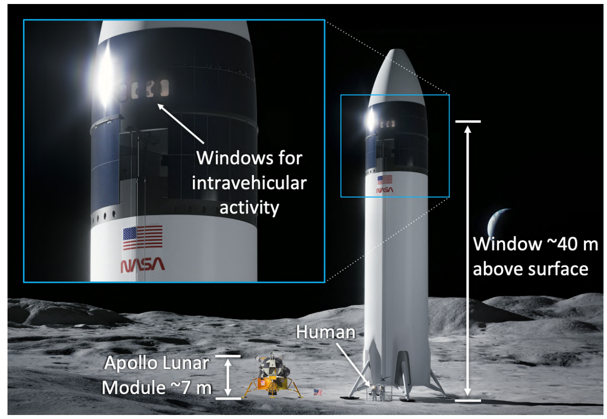

Figure 1. Illustration of the Artemis III SpaceX Human Landing System in comparison with an astronaut and the Apollo Lunar Module. Figure adapted from SpaceX.

relevant given the lack of easily distinguishable features (navigation landmarks) for EVA routes and no geolocation system planned for EVA operations.

Fig. 2 shows the visible areas (masked and colored with DEM elevation data) and the non-visible area (in grayscale) for each considered potential landing site. Because astronauts may conduct walking EVAs to a radial distance of ~2 km, the reciprocal HLS visibility during EVAs is also depicted ('near-field') to illustrate how the height of the HLS may enhance surface navigation. An additional 10 m above the windows would slightly extend the visibility. The computed visible area is 698.7 km^2, 1,062.9 km^2, and 934.1 km^2, and the surface visibility within a 2 km radius is 19%, 15%, and 6% for 001, 001(6), and 004, respectively. Direct line of sight from the window reaches as far as 60 km distance. From 001 and 001(6), only the rims of Shackleton and de Gerlache craters are visible. From 004 it is possible to see the far wall of Shackleton crater. The latter may be useful to observe layered deposits seen within the crater walls within NAC imagery [7]. If HLS windows are limited to one side of the vehicle, then visible coverage in **Fig. 2** will be correspondingly limited.

The capability for DTE communication changes monthly and is sensitive to the height of the vehicle relative to the topography around each landing site. DTE time can be increased by ~6 days (from ~13 to ~19 days) during December 2025 owing to the height of HLS above potential landing sites 001 and 004. Location 001(6) already exhibits exceptionally good

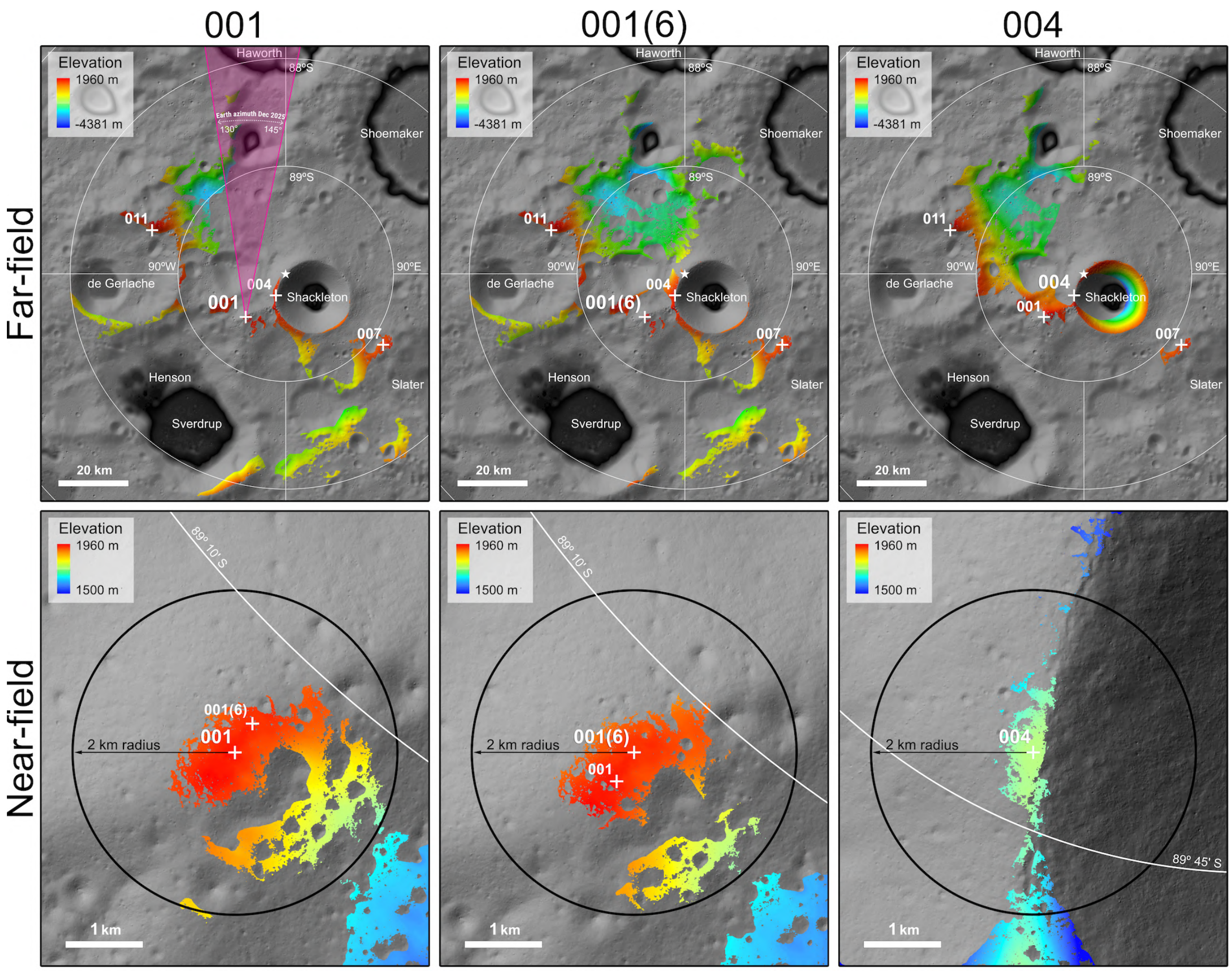

Figure 2. Far-field and near-field viewshed from HLS windows for site 001, 004, and 001(6) using 5 m/pixel LOLA DEM and accounting for the Moon's curvature. Visible area is colored with DEM data and non-visible zones are in grayscale. The total visible area is recorded above each map. Far-field from 001 shows in pink the Earth local azimuthal range for December 2025.

DTE communication from two meters above the surface due to its geographical location (~18.4 days), so the increase in coverage is not so pronounced from the HLS windows (~18.8 days).

Conclusions: The far-field visibility of the lunar surface is noticeably greater from 001(6) than the other sites, as it is closer to a decreasing flank and, therefore, has a lower local horizon toward that side. It also coincides in direction with the azimuthal range of the Earth for Dec. 2025, featuring an excellent DTE communication (pink area in **Fig. 2**). However, site 001 displays the best visibility within a ~2 km radial perimeter where EVAs could take place.

Astronauts on the surface should be able to see and, thus, use the HLS for surface navigation if they remain on the crest of the 'Connecting Ridge' or the rim of Shackleton crater, at least to ~1 km from the lander, and if the HLS is in sunlight or has a beacon light. Beyond 1 km, however, even a tall HLS may be hidden beneath the horizon along the ridge crests.

The height of the HLS can enhance DTE communication at sites 001 and 004 but does not provide significant improvement at 001(6).

In summary, the height of the Artemis III SpaceX HLS may assist astronaut operations on the lunar surface. The opportunity of terrain visibility for IVA and improvement of DTE are interesting HLS design capabilities for the Artemis III mission.

Acknowledgments: This work is supported by the USRA-LPI, CLSE, and NASA SSERVI.

References: [1] NASA (2020) *Plan for Sustained Lunar Exploration and Development*, 13p. [2] Hawkins, L. (2022) *73rd IAC* (No. IAC-22, B3, 1, 9, x71658). [3] NASA (2020) *The Artemis III Science Definition Team Report*. [4] Kring D. A. et al (2020) *Sci. Def. Team for Artemis*, 2042. [5] Barker M. K. et al. (2021) *P&SS*, 203,105–119. [6] Wang, J., Robinson, G. J., & White, K. (2000) PERS, *66*(1), 87–90. [7] Gawronska A. J. et al. (2020) *Adv. Space Res*, 66, 1247–1264.