ARTEMIS III EVA MISSION CAPABILITY FOR DE GERLACHE-SHACKLETION RIDGE

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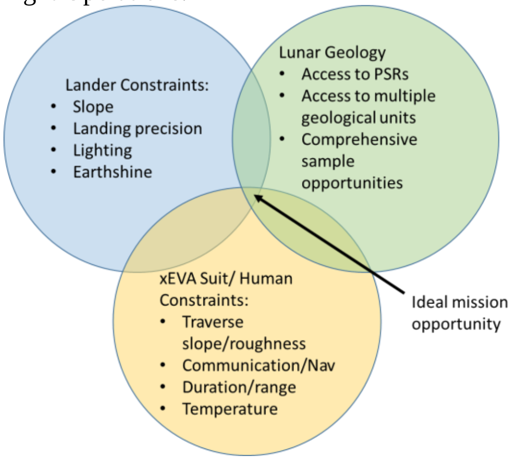
Background: NASA has committed to sending humans to the Moon no earlier than 2025. The Artemis III mission will include scientific, technology demonstrations, commercial, inspirational, and explorational objectives. Achieving these goals will depend upon balancing priorities and mission constraints. A landing location needs to meet terrain conditions suitable for the lander with acceptable thermal and lighting conditions. This location must also allow access to geological areas of interest within traverse range and capability of walking astronauts. A representative EVA timeline is then developed for an example location on the de Gerlache-Shackleton ridge and used to examine the location's acceptability as a candidate site for Artemis III. Similar studies are being conducted to NASA's Science Mission Directorate and Flight Operations.



Approach: Candidate landing locations near the lunar south pole were assessed for compatibility with hardware requirements. Sites were then screened for target areas within walking range which were likely to meet high priority scientific objectives. These factors were assessed as follows:

Terrain acceptability and hardware limitations: Based upon NASA contract requirements, the Human Landing System (HLS) must have a landing site slope tolerance of at least 8 degrees [**1**]. The exploration Extravehicular Activity (xEVA) spacesuit and astronauts must be able to walk up, down, and across a 20-degree slope [**2**]. The xEVA suit shall operate for a minimum of 8 hours [**2**] with nominal excursions of 6 hours [**3**]. At any point during an EVA, astronauts must be able to return to the lander and repressurize the airlock within one hour. This time is driven by reserve suit consumables and limits the distance from the lander to ~1.38 km [**2,4**]. The suit must function after exposure to two hours in permanently shadowed regions (PSRs) [**2**]. Astronaut walking rate is 2km/hr [**4**].

Lunar terrain and geological assessment: The primary science objectives for Artemis III are [**3**]:

- Understanding planetary processes
- Understanding the character and origin of lunar polar volatiles
- Interpreting the impact history of the Earth-Moon system
- Revealing the record of the ancient sun and our astronomical environment
- Observing the universe and the local space environment from a unique location
- Conducting experimental science in the lunar environment
- Investigating and mitigating exploration risks

Lunar Reconnaissance Orbiter Narrow Angle Camera (NAC) 2 m/pixel images and Laser Altimeter (LOLA) 5-meter DTM images were used to assess slope, distance, lighting, terrain, and impact craters for hardware and scientific compatibility.

Results: A candidate landing location was identified at -89.495° latitude, 222.5° E longitude with slope <5° [**5,6**] that meets HLS lander terrain requirements. As a high ridge elevation with unobstructed view toward Earth, this site will provide persistent direct-to-Earth communication with Deep Space Network assets in the event the lunar Gateway communication relay is not yet established. Percentage of time in solar illumination at landing location is 56.1% over a year [**7**]. For a six-day surface mission, this allows sufficient mission windows to provide persistent power generation and illumination of EVA worksites and translation paths.

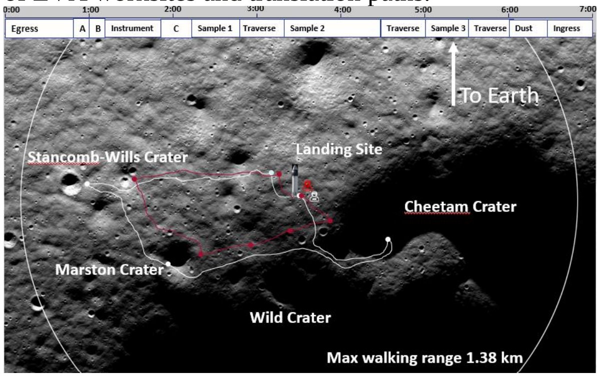


Fig.1: de Gerlache-Shackleton ridge landing site with possible EVA traverse path to explore small 10-350 meter craters and regional geology [**6**].

EVA traverse terrain is generally mild with the majority of slope <10° throughout the distance traveled [**5,6,**]. Local slopes in and around craters does increase and vary by size and age of the crater. Small craters may have some entry routes less than 20° which could allow human access for sample collection. The angle of repose for lunar regolith varies from 32° to measured values at 58° **[8]**, and LOLA measurements show steep slopes greater than 25° on larger crater walls. These slopes will require real-time assessments by astronauts and flight controllers to assess safe access below all crater rims.

Mapping a representative EVA timeline with sample and traverse plans as shown in **Fig. 1** would allow the following objectives to be satisfied at the various locations:

Lander site: contingency sample collection, HLS inspection, public affairs address/flag planting, in-situ instrument deployment.

Stancomb-Wills Crater: sealed core, small clast, and regolith surface sample collection.

Marston Crater: sealed core, small clast, sealed surface sample collection. Deployment of volatile monitor.

Cheetam Crater and approach: Sealed core sample from permanently shadowed region. Small and large clast and surface samples along 700-meter approach to crater rim.

Addition overhead tasks: Airlock egress/ingress, elevator/ladder descent, tool retrieval and stow, dust mitigation, sample stow, photo documentation.

Regions south of the landing site show significant variations in small crater density. This could indicate a possible geological unit boundary for exploration on a second or third EVA.

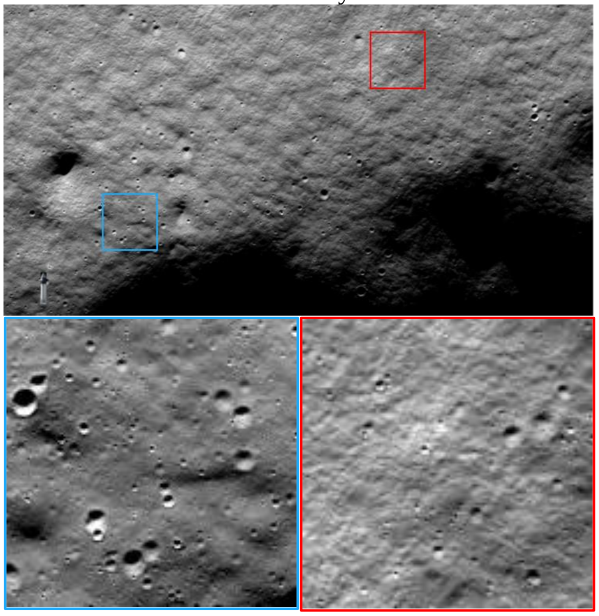


Fig. 2: Crater density change near landing site (lower left in top image) indicates possible geological boundary. Top image 3km x 1.6 km. [**6**]

Discussion: Artemis III will likely not have means for humans to descend into large PSRs greater than ~200 meters due to steep slopes and traverse paths that require extended exposure to extreme thermal environments. It is unknown if smaller craters at the poles have sufficient cold traps to retain volatiles. Robotic exploration of larger PSRs can bridge gap until human capability improves with more advanced rovers and fall protection equipment on later missions. EVA tasks to retrieve samples from potential precursor CLPS missions nearby could prove highly valuable.

Navigation and lighting pose significant challenges to EVA timeline efficiency. Highly shadowed terrain without accurate relative navigation systems on the suit will cause significant time to be lost resolving translation paths with only visual means. As suit designs mature, consideration should be given to adding Inertial Navigation Systems (INS) sensors which could provide telemetered real-time position information with minimal mass/volume cost.

Summary and Conclusions: The de Gerlache Shackleton ridge has areas with very promising conditions for a potential Artemis mission. Low slope terrain is acceptable for landing (<8°) and suited human traverse (20°). The location has proximity to potential geological boundaries and many craters of various size, age, and volatile content. For many mission windows there is persistent sunlight available for lander to generate electricity and maintain moderate thermal conditions. Sufficient lighting exists to provide at least minimally acceptable visual navigation between EVA worksites and photographic imagery. Line of site to Earth provides direct communication capability. The capabilities, objectives, and lunar surface properties are in alignment for a highly successful potential Artemis III mission.

References: [**1**] *Sustained Phase Human Landing System (HLS) Program System Requirements Document* (2021), NASA, HLS-RQMT-006. [**2**] *XEVA System Requirement Document Attachment J-02 80JSC021R0006* (2021), NASA. [**3**] *Artemis III Science Definition Team Report* (2020) NASA/SP-20205009602. [**4**] Del Greco, J., et al. 2021. *Artemis III EVA Distance Trade.* [**5**] LPI 2214, 2019. *Slope Map of the Moon's South Pole Ridge.* [**6**] LROC Team NAC and LOLA layered image, (2021). [**7**] E.J. Speyerer, M.S. Robinson, (2013), Icarus, 222, 122-136. [**8**] Calle C.I. and Buhler C.R. (2020) Lunar Dust 2020, abstract 5030. [**9**] Brown, H., et al., (2021 submitted), ICARUS-D-21-00251.