UNDERSTANDING FUTURE LUNAR LANDING SITES ARTEMIS 3 - AREA 007 AND CHANG’E 7: MAPPING THE SOUTH-EASTERN SIDE OF THE SHACKLETON CRATER. A. Van den Neucker1,2, S. Boazman2, R. Bahia2, I. Torres2, 1German Aerospace Center (DLR) – Institute of Planetary Research, Rutherfordstrasse 2, 12489 Berlin, Germany, 2European Space Agency (ESA) – European Space Research & Technology Centre, 299 2200 AG Noordwijk, The Netherlands.

Introduction: After more than 50 years, the future Artemis plans mission to send humans back to the Moon in 2025, highlighting once again the scientific importance to studying this celestial body. Around the same time frame, the CNSA-led Chang’e 7 robotic mission plans to send scientific instruments to perform remote sensing analysis of the Moon from orbit and in-situ measurements with a rover. Both of these missions aim to collect lunar samples and have chosen to target the south polar region due to its geological importance, potentially to find traces of volatile elements and water ice within the Permanently Shadowed Regions (PSR) for in-situ resource utilization (ISRU) [1]. Possible landing sites were determined for both the Artemis III and Chang’e 7 missions near the Shackleton crater, which is a well-preserved impact crater, of around 21 km in diameters and centrally located within the lunar south polar region [2]. Interestingly, this crater is characterized by its high rim, composed of multiple high peaks, creating continuous shadows on the crater floor and several other localized areas, which could serve as “cold traps” and preserve volatiles underneath the surface [3]. This study aims to assist future lunar missions in identifying potential sampling spots near the crater rim by producing a geomorphological map, spanning approximately 8.9 x 7.9 km between the Shackleton crater rim and the Artemis candidate landing site 007 (NASA 2020), which lies within the proposed Chang’e 7 landing site. The generated map represents the distribution of isolated boulders and their sampling potential during Extravehicular Activities (EVAs), which is determined by the boulder size, boulder density, geological potential and sampling safety. This study was performed on an area that has previously not been mapped, based on previous mapping techniques to help astronauts in the near future to determine the most ideal location to perform unassisted and assisted EVAs. [4,5]

Materials and Methods: The Area of Interest (AOI) of approximately 8.9 x 7.9 km large is situated within the south-eastern side of the Shackleton crater. It encompasses the area in between the Shackleton crater rim and the edge of NASA’s Artemis III lunar landing site Area 007 and is situated within Chang’E 7 landing site. A geomorphological map from the AOI was generated using the open-source geographical information system QGIS 3.28.6. For the analysis, we imported a 5 m/pixel digital elevation model (DEM) of the Lunar Orbital Laser Altimeter (LOLA) data on NASA’s Lunar Reconnaissance Orbiter (LRO), to create a south polar topographic map. From this dataset, it was possible to derive hillshade and slope maps. The lunar features were identified and mapped, by using Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) images (~1 m/pixel). The NAC images could be found using the open-source LROC Quickmap map interface and later downloaded from the Planetary Data System (PDS). A digital processing tool Integrated Software for Imagers and Spectrometers 3 (ISIS3) of the United States Geological Survey (USGS) [6,7] was used to process the NAC images and align them with the lunar polar stereographic projection Moon2000_spole. The resolution of the NAC images ranges from 0.62 – 0.93 m/pixel. For this study, isolated boulders and rock exposures were identified as point shapefiles on 10 processed NAC images.

Results and Discussion: Within the AOI it was possible to map a total of 2922 possible sampling features, of which 2857 isolated boulders, and 65 rock exposures. The resulting map reveals the areas where EVAs are preferred, considering safety, accessibility and sampling potential. (Fig.1) Unassisted sampling tasks must be performed on < 15° slopes, and rover-assisted EVAs on < 25° slopes. In total, 857 boulders located on slopes of 25° or less, were identified and were considered as boulders on a safe slope for EVAs. [8] Density maps were generated to determine the areas containing a large number of reachable boulders. These dense areas of boulders were highlighted within the final map as red or blue colored ellipsoids, depending on their surface slope, respectively < 15° and < 25°. The distribution of boulders was determined by comparing the frequency of boulders according to their distance from the rim. For this, boulders were subdivided in three categories according to their surface area: < 5 m², 5-10 m² and > 10 m². Statistical results showed that the boulders were more frequent closer towards the Shackleton crater rim and progressively declined in number further away from the rim. Furthermore, the resulting map also revealed that the size of the boulders plays a role in the density distribution of the features. The distribution map revealed that the larger sized boulders (> 10 m²) are almost exclusively concentrated within 1.5 km radius from the Shackleton crater rim. These large boulders may originate from the deepest parts of Shackleton crater. [9] Small boulders (< 5 m²)
seem to be clustered around smaller impact craters; this suggests that these boulders may originate from secondary impacts from Shackleton crater. Boulder density related to size were taken into account for determining the preferred sampling zones within the AOI. The study also suggests that sampling in a dense boulder field with larger boulders have a higher chance to have PSRs and therefore retain volatiles within their shadows. [10] As a last point, distances between each sampling area were considered. The maximum reach of astronauts performing EVAs is estimated to 2 km. [4] However, rovers or other unmanned retrieval equipment, can travel longer distances (10 km radially), and reach rougher and steeper areas [11]. Considering all different aspects, the preferred sampling areas within the AOI is situated in the Southern part of the generated map and are marked with open ellipsoids.

**Fig1:** Generated map from our AOI within the southeastern side of the Shackleton crater.

**Conclusions:** The focus of the study was to map possible sampling features such as boulders and localize the best areas to perform EVAs. Results showed that the identified boulder fields within the southern part of the AOI were preferred for sampling, due to their relatively flat average surface slope (<25°), the dense areas of potential sampling materials, high illumination and good Earth visibility. Our AOI was chosen to be in between NASA’s Artemis 3 landing site 007 and the Shackleton impact crater to highlight the importance of sampling large boulder areas close to the crater rim. As suggested by previous studies, the large boulders close to the crater rim likely originate from the Shackleton crater itself and also increases the chance to have a PSR. In the search of lunar volatiles, sampling the permanent shadows cast by large boulder is recommended as these are likely to be coldest stable areas in close proximity of the proposed landing zone.