IN SITU RESOURCE UTILIZATION INVESTIGATIONS OF POTENTIAL ARTEMIS LANDING SITE 105, LUNAR SOUTH POLE. R.V. Patterson1, K. R. Frizzell2, G. R. L. Kodikara3, M. A. Kopp4, K. M. Luchsinger5, A. Madera5, M. L. Meier6, T. G. Paladino7, C. J. Tai Udovicic8, F. B. Wróblewski9, and D. A. Kring10, 1University of Houston (rvpatter@cougarnet.uh.edu), 2Rutgers University, 3University of Wisconsin- Milwaukee, 4Boston College, 5University of New Mexico, 6University of Idaho, 7Idaho State University, 8Arizona State University, 9Lunar and Planetary Institute.

Introduction: Human and robotic missions supporting NASA’s Artemis Plan [1] will initially target the lunar south pole and assess the nature and availability of ices for in situ resource utilization (ISRU) to facilitate a sustained exploration program [2]. Here we augment previous studies of potential Artemis landing sites [3-5] with an analysis of Site 105 (87.18° S, 62.84° E) and potential water- and dry-ice deposits in that area [6,7].

Methodology: Eight concepts for landing site selection were outlined by the National Research Council [8] and served as guiding principles in our study. Mapping boundaries reflect a 20 km radial exploration zone relative to the nominal landing site.

Data information. A MoonTrek NAC mosaic with >1.25 m/pixel resolution (https://trek.nasa.gov) was used with seamless stitching as the base map for visual analysis. Shoemaker and Faustini craters contain large NAC-shadowed regions. Several areas of high albedo exist within crater rims, but the surface of Site 105 has near-constant albedo. Boulders were identified in NAC images with a minimum detectable size of 0.5 to 1.5 m depending on the resolution of individual images. Digital elevation models (DEMs) in 5 m and 30 m resolutions were used to map positive-relief boulders and negative-relief permanently shadowed regions (PSRs). Surface roughness and slope were calculated from the DEMs. Potential ISRU locations were determined using LOLA data in 120 m/pixel resolution as described in [9]. Those data were collated to produce illumination and permanently shadowed region (PSR) maps. The Diviner data portal (www.diviner. ucla.edu) provided temperature data at a resolution of 240 m/pixel [10]. Hydrogen abundance data was obtained from NASA PDS Geosci-ence Node (https://pds-geosciences.wustl.edu/mis-sions/lunarp/reduced_special. html) in a spatial resolution of 0.5° by 0.5°/pixel bin size [11]. ISRU maps were resampled for a final map resolution of 240 m/pixel. Finished map products were created using ArcGIS Pro Version 2.6.0. Regions where the summer and winter maximum temperature did not exceed 110 K were mapped as zones where water-ice may be stable at the surface; 55 K was the temperature threshold for dry-ice stability [12]. These regions were further examined to determine the areas within them belonging to PSRs.

Geologic Analysis: Site 105 occurs at the end of a funnel-shaped, gently sloping (<15°) ridgeline separating Faustini (43.5 km diameter) and Shoemaker (51.8 km diameter) craters (Fig. 1). The slope increases

Figure 1. Left: Slope map of Site 105. Warm colors are steeper, cool colors are less steep/flat areas. Shoemaker and Faustini craters are outlined with dashed lines. Right: ISRU map of Site 105. Blue and red lines are regions of water ice stability in winter and summer, respectively, white triangles are $M^9$ detections of water ice, light blue polygons represent carbon dioxide ice stability during winter, basemap is illumination. Both: Concentric circles represent 2, 10, and 20 km radial exploration zones.
considerably with increasing distance from the ridge, toward the centers of Faustini and Shoemaker. Within a 2 km radial distance of Site 105, the elevation change does not exceed 200 m. A 10 km radial distance includes the beginning of the aforementioned ridge and is well-illuminated (Fig. 1). A 20 km radial traverse limit contains 1300 m of elevation change that dips into Shoemaker and Faustini craters.

Craters. The terrain is dominated by Shoemaker and Faustini, but is also covered with ~39,000 craters (~0.20 km to >50 km diameter) within a 10 km radius of the landing site. The majority of craters are less than 0.20 km in diameter, while only eleven are larger than 2 km. Within a 10 km radial exploration zone, eight craters exist that are comparable in size to Meteor Crater (~1.2 km diameter), an astronaut training site. Two major secondary craters exist, one of which was linked to the Orientale impact event [13] and could provide fragments of crust from the Moon’s western limb should Site 105 be selected for Artemis missions.

Rock identification. Dozens of boulders from 1.5 m to 9 m in diameter were identified and occur in groups within and around large craters (Fig. 2). They may be crater ejecta, or possibly dislodged boulders from massifs that rolled downhill to their present locations, although no boulder tracks were detected.

If a crew were limited to a 20 km radial exploration zone, then sample age diversity would include pre-Nectarian terra, Nectarian crater materials (surrounding Shoemaker and Faustini), and Orientale basin ejecta. Regolith samples may provide fragments of original highland crust and cryptomare from the South Pole-Aitken region. Impact melts for determining crater chronologies and large hand samples chipped from boulders for studying crustal evolution could also be harvested readily.

Results: At the spatial resolution (240 m/pixel) of our study, no regions exist within a 2 km radius of Site 105 where water- and dry-ice are stable in both summer and winter. Within 10 km, 14.77 km² (4.70% of radial zone) may possibly contain seasonal water-ice. Of that area, 7.05 km² (2.24%) fell within PSRs. The 20 km zone contains 196.25 km² (15.61%) of area suitable for water-ice stability and 0.95 km² for dry-ice (Fig. 1). Water-ice stability within PSRs account for 120.24 km² (9.56%) of the 20 km zone. A small area of dry-ice stability is located just inside the rim of Faustini crater, is far from high illumination areas, and is only accessible through steeply sloping and rugged terrain. However, if exploration occurs during the winter, potential areas of water- and dry-ice stability within the 20 km exploration zone increases to 701.75 km² and 93.94 km², respectively, and becomes easily accessible. The seasonal nature of the potential deposits suggests any trapped volatiles will be dominated by solar wind and micrometeorite impacts.

Potential Landing Site Considerations:

Hazardous terrain. Terrain of Site 105 has low surface roughness along ridges and plains, except for punctuated occurrences where craters cause steep elevation change. These areas are the major trafficability hazards at Site 105. The ridges appear safe for traversing due to the smooth and gently-sloping surface.

Sites of interest and trafficability. Ample ISRU and sample collection potential exist at Site 105. Water-ice and boulders exist in easily accessible locations within a 20 km radius. Despite the region containing abundant boulders suitable for sampling, it has lower overall surface roughness than a notional 13 km VIPER traverse to take place within a ~3 km radius of Site 102 in [2]. The low surface roughness between the outer rims of Shoemaker and Faustini make this site apt for both rover and human traverses up to 20 km from the prospective landing site. Inter-site traverses will bear the most extreme elevation changes. For example, a traverse path from Site 102 to 105 will require precise movement along the narrow rim of Nobile crater, with a smaller (~18 km diameter and ~4,000 m deep), unnamed crater existing directly in the traverse path.