EXPLORING DE GERLACHE CRATER. P. M. Umansky[1], S. J. Lawrence[2], and J. A. Hamilton[2], [1]University of California, Berkeley, Berkeley, CA, USA (paulinaumansky@berkeley.edu), [2]Astromaterials Research and Exploration Science, NASA Lyndon B. Johnson Space Center, Houston, TX, USA.

Introduction: The campaign of Artemis missions will result in the first crewed missions to the surface of the Moon in the 21st Century. As outlined by the Lunar Exploration Analysis Group (LEAG) United States Lunar Exploration Roadmap (US-LER), human missions to the Moon will result in significant advances across a wide variety of scientific and engineering disciplines [1] contributing significantly to scientific discovery, economic prosperity, and world security. A significant focus is exploring lunar Permanently Shadowed Regions (PSRs). PSRs can contain volatiles, including water ice, which makes them high priority for scientific investigation and economic activity.

Rationale: The NASA Artemis III Science Definition Team Report is NASA's science plan for the Artemis III mission, outlining a candidate science plan for the first crewed mission and a summary of how the first mission fits into subsequent missions to the Artemis Base Camp. One of the seven major goals in the report addresses understanding the character and origin of lunar polar volatiles, which involves exploration within a PSR [2]. Furthermore, understanding the economic potential of these regions has been identified for two decades as a high priority by numerous LEAG Special Action Teams. Crewed exploration of a PSR is necessary for the progression of the Artemis program, in-situ utilization of lunar resources, and overall advancement of planetary science.

Purpose and Scope: *Reference PSR Selection: de Gerlache Crater*. De Gerlache crater on the lunar South Pole contains an extensive PSR at its center [3], and multiple smaller PSRs around the crater rim [4]. At 3.9 +/- .1 Ga, the de Gerlache crater may be covered by surface water ice on 2.3% of the surface [5], though the water ice may only be present as grains in the regolith [6]. The PSR within de Gerlache was chosen for this case study due to 1) its proximity to PSR regions identified as being of strong interest for Exploration planning [7], 2) its proximity to one of the most illuminated locations on the lunar surface [3], and 3) the slope surrounding its PSR being relatively shallow compared to craters such as Shackleton, whose slope exceeding 20 degrees everywhere renders wheeled vehicle ingress infeasible [8]. The highly illuminated points on the rim of de Gerlache are logical locations to emplace solar powerplants and associated infrastructure to enable future lunar surface activities such as lunar habitation.

Previous work on traverses near de Gerlache has examined landing on the most illuminated part of the de Gerlache crater rim and exploring small PSRs, including small craters that are 250-390m in diameter [9, 10]. In this effort, we consider exploration scenarios for the larger PSR within de Gerlache.

Study Architecture Assumptions. It is presently contemplated that an unpressurized rover (the Lunar Terrain Vehicle, or LTV) will be available for Artemis missions that follow the Artemis III mission. Since the vehicle is unpressurized, this study assumes that the crew will be wearing NASA's Exploration Extravehicular Mobility Unit (xEMU) spacesuit. For the purposes of this study, we assumed that any notional mobility system would be limited to slopes no greater than 20 degrees. The duration of time that a crewmember can be in the xEMU was constrained for study purposes to 8 hours.

Methods: *Data:* The traverse model used topography data from LOLA and solar visibility derived from the Lunar Reconnaissance Orbiter's Wide-Angle Camera [11], all of which are publicly available in the Planetary Data System.

Nomenclature: The de Gerlache PSR has a distinct crater floor that will be referred to as the inner PSR. The region surrounding the floor, but still permanently shadowed, will be referred to as the outer PSR. We generated traverses from each of the six landing sites both to the inner and outer PSR regions, resulting in twelve optimized traverses.

Traverse Initial Starting Points: As part of this study, we explored scenarios with different starting positions for the traverses descending into the crater. We selected reference starting positions for each traverse along the de Gerlache crater rim. For the purposes of this exercise, we assumed that each of the reference sites could be a plausible landing location to ensure compatibility with future plans.

The basic requirements for each starting site were defined as follows: a starting site must be a circle 100m in diameter; slopes must be less than 8 degrees everywhere within the site; and average Terrain Ruggedness Index (TRI) [12] must be less than .3. The latter two requirements came from statistics on previous successful lunar landings, which were used to create enveloping constraints for the values used [13].

Initially, we examined the most illuminated points on the lunar South Pole that are near the rim of de Gerlache. There were six of these points from [3], including points numbered #11, #16, #24, #34, and #40 in a ranking of best illuminated points on the South Pole. Many of the TRI values from these sites were close to meeting the < .3 average TRI requirement, but some of the sites contained areas with slopes exceeding 8 degrees. There are potentially feasible landing sites close to each well-illuminated point. We then considered sites in completely different parts of the crater rim that are less

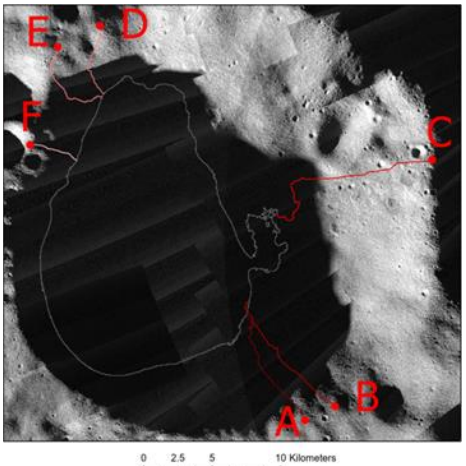

Figure 1. Traverses to the outer PSR.

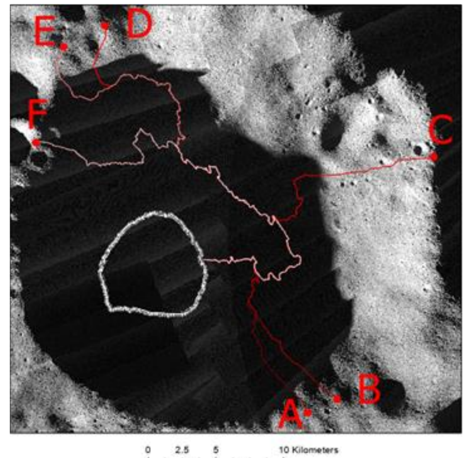

Figure 2. Traverses to the inner PSR.

illuminated, but offered potentially more accessible slopes for crater ingress, lower TRI values, or are closer to the PSR. These candidate reference starting sites were initially selected using standard techniques of geospatial analysis. Candidate sites were then examined for other desired features, such as illumination percent [11] and average illumination [3], Earth visibility [3], proximity to illuminated regions [3], and existence of Lunar Reconnaissance Orbiter Camera imagery of the site [14]. Ultimately, six different initial positions were selected at different locations along the de Gerlache rim.

Traverse Optimization. The boundary of the de Gerlache PSR was determined by the shape file provided by [15] and based on [3]. The only constraint for the traverse was the 20-degree slope limitation on the mobility system.

Results: The shortest traverse to the outer PSR is from Site F with 4.005km one way (8.010km round trip – Figure 1). The second shortest traverse to the outer PSR is from Site D with 6.119km each way (12.238km round trip – Figure 1). The shortest traverse to the inner PSR is from Site B with 24.429km one way (48.858km round trip – Figure 2). However, all the traverses to the inner PSR converge. We note that on this common path, using the presently available data, slopes exceed the requirement in two points (values of 21.28 and 25.11 degrees).

A Reference Traverse. We derived requirements for sampling and/or instrument placement sites that could meet most US-LER objectives. These include samples in regions with: varying ice depth stability (Artemis III investigations 2a-1 through 2a-6); low subsurface temperatures (volatiles) (Artemis III investigations 2b-1, 2c-2, 2c-3), and high H concentrations in the PSR (Artemis III investigations 2c-3, 2d-1). We selected the traverse from Site D to the outer PSR (second shortest traverse) as a reference traverse for which subsurface drilling stops were added, because this traverse passed through a wider variety of ice depth stability regions than the traverse from Site F, the shortest traverse to the outer PSR.

Implications: Based on this analysis, a traverse to the outer floor of the de Gerlache PSR is feasible and would address a significant amount of the Artemis III Science Objectives relating to volatiles. Such a traverse will, minimally, require for the LTV to travel faster than 1.53km/hr for a round trip distance of 6.119km traverse each way (12.238km round trip). A traverse to the inner floor of the de Gerlache PSR would require travel across regions with slopes reaching 25.11 degrees, exceeding the 20-degree slope limitation. The slope constraint on the intended exploration mobility system should be reevaluated to determine if slopes can exceed 20 degrees for short periods, as this would enable entry into the inner PSR. Future analysis should address illumination along the traverse depending on the landing date and include more stopping locations along the route for additional spatial measurements.

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