DEVELOPMENT OF A GEOSPATIAL MODEL TO IDENTIFY POTENTIAL LANDING SITES, HIBERNATION SITE, AND TRAVERSES FOR UPCOMING ROBOTIC MISSIONS. S. Bouffard[1], S. Gagnon[1] M. Lemelin[1], Josh Newman[2], Perry Edmundson[2], Nadeem Ghafoor[3], [1]University of Sherbrooke, Sherbrooke, QC, Canada. [2]Canadensys Aerospace Corporation, Bolton, ON, Canada. [3]Avalon Space Inc, Toronto, ON, Canada (samuel.bouffard2@usherbrooke.ca) Département de Géomatique appliquée, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, Qc, Canada, J1K 2R1

Introduction: In the coming years, a variety of robotic missions will reach the lunar surface. These missions will visit different parts of the Moon, including the south polar region. The Canadian Space Agency's (CSA) Lunar Rover Mission (LRM), for example, will go to the south polar region no earlier than 2026 in collaboration with NASA through the Commercial Lunar Payload Services initiative in the search for water ice [1]. While the different missions will each have their specific engineering constraints and scientific objectives, they will have to consider both to identify potential landing sites, traverses, and hibernation sites (in the case of missions aiming to survive the lunar night).

Here we present a multicriteria decision model that could help identify potential landing sites for future lunar missions, using the context of the LRM as an example. Our model consists of a Python code that merges solar illumination and Earth visibility products acquired from the Lunar QuickMap Terrain Shadows (2D Cartographic Mode) and other geospatial datasets into ArcGIS, and (1) determines the most suitable landing sites, (2) hibernation site, and (3) traverses given engineering and scientific constraints. Our model is developed to be usable in any region of interest. Here we apply it to the 13 potential landing areas identified by NASA for the Artemis III mission, see Figure 1 [2]. The landing window considered for this analysis is October 1 to November 30, 2026.

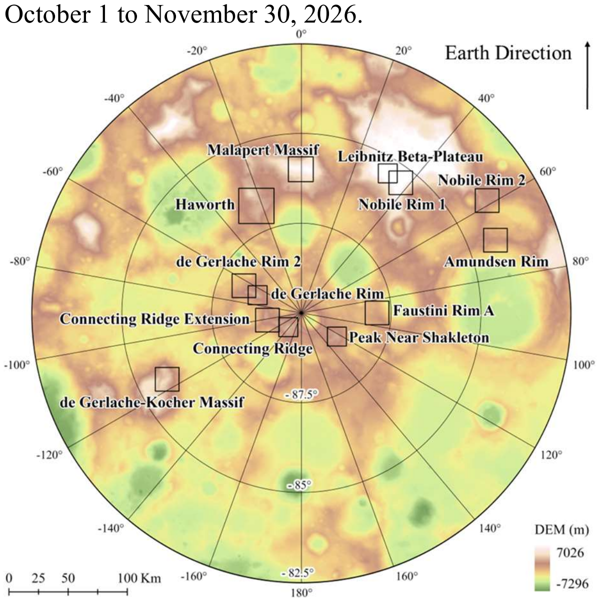

Figure 1 : Regions of interest of the Artemis program

Datasets and method: For our analysis, we acquire solar illumination and Earth visibility products at 60 m/pixel from the Lunar QuickMap Terrain Shadows (2D Cartographic Mode) [3], Digital Elevation Model (DEM) used by QuickMap [3] for illumination and visibility with a 60 m/pixel and a map of *Permanently Shadowed Regions* (PSRs) at 60 m/pixel from the LOLA PDS Data Node [4]. We perform our analysis using a Python model and the ArcPy module of ArcGIS and consider the scientific criteria of the mission and the engineering constraints of the rover. The methodology is based on the work of [5,6] and was developed during an internship with Canadensys Aerospace Corporation [7,8], the company designated to build the rover.

First, the model identifies one or more potential lunar landing sites over the regions of interest shown in Figure 1, as well as over the same period. To do this, the model identifies the locations in the region of interest with the longest continuous periods of solar illumination, as well as terrestrial visibility. Then, the areas with a maximum slope of 5° are identified. Finally, the PSRs located within 1500 meters of a landing site are identified, as a first order estimate of the distance that the rover may be able to travel within a single lunar day.

Second, when the sun will go down, there will be no remaining sunlight to power the solar panel. The rover will shut down his system and wait until the sun is back, the rover will hibernate. The hibernation sites must have an overlap of solar illumination and terrestrial visibility on the last 48 hours of the first exploration period, as well as the first 48 hours of the second exploration period. This ensures that the rover will be in a place where it can continue its activities on the next lunar day as the hibernation site becomes re-illuminated by the sun and visible from Earth, given that it is unknown if the lander will be equipped to survive the lunar night.

Third, the different routes between the potential landing sites and the areas the rover will explore must be identified using a cost raster composed of three geospatial layers: slope, visibility, and solar illumination. The values of the cost raster are integers ranging between 0 and 2001. Values of 0 mean that one or more criteria for rover traverse is not met, making passage impossible. Values between 1 and 2001 mean that passage is possible, with values closer to 1 being the most desirable due to an easier passage. The analysis finds an optimal route for the rover between a given location to a given destination. It favors pixels with a low value (values close to 1), hence avoiding, but using if necessary pixels of greater value (values > 1). Topography should not exceed 20° of slope. The value of the pixels in this layer will increase linearly in proportion to the increase in slope. Pixels with a slope greater than 20° will be assigned the value zero. Next, the terrain must always be visible from either the Earth, the lander, or both. Visibility from both is preferred for redundancy. Moreover, the speed-made-good of the rover depends on the type of visibility. When the rover is visible from the Lander, the higher data rate link available via the Lander's high-gain antenna allows it to travel more quickly than when the rover must communicate directly to Earth. Pixels that permit a high speed are more desirable than pixels that permit a low speed only. Pixels that are not visible will be assigned a zero value. Finally, the terrain must be illuminated by the sun. The illuminated pixels will have a low weight, while the non-illuminated pixels will have a null value.

Routes are plotted using the Least Cost Path tool in the ArcPy module using the cost raster. This allows us to identify all the routes between each landing site and each PSR, then between each PSR and each hibernation site. Then, all the routes with a distance greater than 1500 meters are removed. The remaining routes are the routes considered operationally.

Preliminary Results: The scenarios are located on the Faustini Rim A site, see Figure 1, between October 22 and November 1, 2026, see Figure 2.

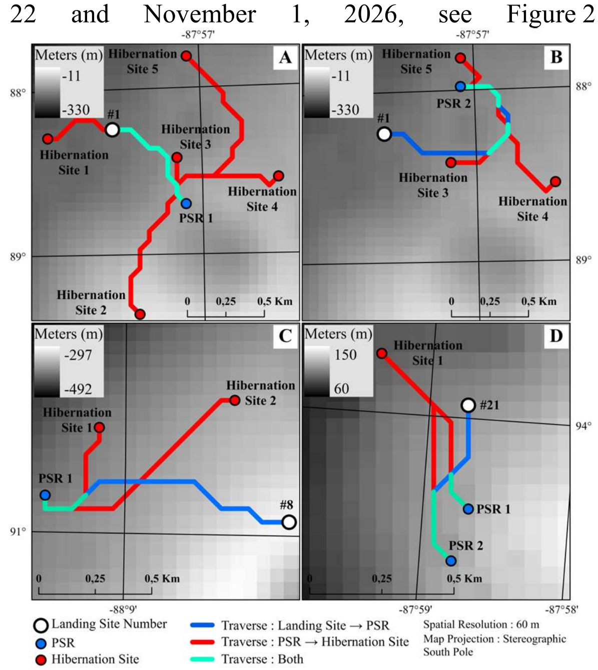

Figure 2: (A & B) Scenario showing Landing Site #1. (C) Scenario showing Landing Site #8. (D) Scenario showing Landing Site #21. The map showing Site #1 has been illustrated using two maps to minimize confusion of the multiple features.

The spatial analyses produced on the LM7 site allowed the identification of 22 lunar landing sites. In addition, 13 PSRs have been identified as potential locations to visit from the lunar landing sites. Each of the identified traverses are no more than 1500 meters apart. Figure 2 shows three possible scenarios. Some scenarios have more options than others, and some crossings are shorter than others. For example, Figure 2A and 2B show a scenario with two PSRs and then five hibernation sites. The shortest exploration route would be to visit PSR #1 then to drive to hibernation site #3 with a distance of approximately 1,110 meters. Figure 2C shows a scenario with one PSR, then two possible hibernation sites. The shortest exploration route would be to visit PSR #1, then hibernation site #1 with a distance of approximately 1,854 meters. Figure 2D shows a scenario with two PSRs, then a hibernation site. The shortest exploration route would be to visit PSR #1, then hibernation site #1 with a distance of approximately 1,073 meters. Among the three scenarios presented, only the lunar landing sites #1 and #21 allow routes lower than 1500 meters. On the contrary, the shortest distance of site #8 is greater than 1500 meters. This analysis considers 1500 meters as the highest distance the rover can travel. The real constraint is time and the distance that may be travelled vary with the type of communication.

Discussion and conclusion: The analyses in Figure 2 illustrate what different scenarios generated by the Python model might look like. The results presented illustrate that some scenarios meet the total distance criteria of 1500 meters, while others do not. However, two other datasets, such as water ice detections [9] and ice stability, will be added on top of the results to identify which scenario would have the best chance of exploring an icy region. Additional operational parameters will also be added to produce a higher fidelity model of the rover's capabilities for route weighting. The PSRs located near a water ice detection, as well as the PSRs located in a region conducive to water ice stability, will be privileged. It should be mentioned that the resolution of these data is not fine enough to be added in the Python analysis.

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References: [1] Osinski et al., 2023 LPSC. [2] Barker, M.K. *Planet. Space Sci.*, **2021**, *203*, 105119. [3] ACT (accessed Apr 4, 2022). [4] Washington University, LOLA PDS Data Node (accessed Nov 26, 2022). [5] Lemelin, M. *Planetary and Space Science*, **2014**, *101*, 149–161. [6] Lemelin, M. *The Planetary Science Journal*, **2021**, *2*, 103. [7] Gagnon, S. LPI #4017, **2023**. [8] Bouffard, S. LPI #4018, **2023**. [9] Li, S. *Proceedings of the National Academy of Sciences*, **2018**, *115*, 8907–8912.