GIS-BASED MISSION PLANNING FOR PLANETARY SURFACE MISSIONS: SIMULATING EXTENDED ROVER OPERATIONS IN HOSTILE ENVIRONMENTS. J. M. Burley¹, N. Jackson¹, B. DesRochers¹, C. Morisset¹, D. Gingras¹. ¹Canadian Space Agency

Introduction: In our attempt to explore the remote regions of our universe, robotic missions face great environmental and technical challenges. As global objectives become more ambitious regarding exploration of the Moon and Mars, attention has focused on some of the most difficult areas to study in situ like permanently shadowed regions, and the terrains that surround them where volatiles might be stable in near-surface substrates [1-5]. Prior rover-based missions have focused on regions where solar insolation and communications with Earth are relatively stable geographically [5-7]. This strategy allowed for a large portion of decision making regarding traverse path-planning, scientific targets of interest, and night survival locations to be made after the rover had touched down on the target surface. Similar assumptions cannot be made for upcoming lunar South Pole missions. They require detailed traverse planning prior to landing. This pre-planning is necessary to account for temporally specific conditions of variable operability (following patches of illumination and Earth visibility for direct communication across the terrain), as well as the evaluation of scientific interests and standard engineering/terrain constraints (slope, obstacles, etc.,). Pre-landing scheduling of all rover’s functions from first signal to its demise, will be the safest way to guarantee success in meeting stated mission objectives.

In order to plan a traverse path prior to arrival, we have created an adaptable high-resolution simulated environment within which various scientific value criterion layers can be evaluated in a geographically and temporally precise manner. As an initial case study, we have applied the environment as a planning tool for the upcoming Canadian Lunar Rover Mission (LRM)[4].

Methods – Development of Environment: ArcPro v3.0.2 was used to assemble a 3d lunar surface model from elevation data sourced via publicly available LOLA (Lunar Orbiter Laser Altimeter) mosaics (5 m/px) and high resolution DEMs (Digital Elevation Models) produced in-house (1 m/px). The latter DEMs were built from LOLA mosaics enhanced with the SFS (Shape From Shading) method and NAC (Near-Angle Camera aboard LOLA) images [8]. All further layers are draped over this baseline terrain. SFS high resolution elevation data was used to create high-resolution slope models (rover slope constraints for accessible terrain) and hill shades to provide real-time local illumination conditions (highly oblique sun angles lead to rugged terrains being occluded by shadow etc.,). Operational visibility layers for solar power and direct-to-Earth communications were computed in 1 hour time steps from LOLA 20m DEMs [9-12] and integrated as a time-logged mosaic to display relevant conditions within the simulated environment. High resolution SFS-DEM based hill shades were produced within Arc at intervals of ≤12 hours based on orbital geometry values provided alongside the 20m/px operational modelling data. Scientific value layers and manually mapped specific SOIs (Sites of Interest) were then added to the environment to provide potential traverse targets [13].

Methods - Using the Environment: Once an appropriate landing area, landing ellipse and landing time were determined [13-15], the planning environment was set to that time and operational layers updated to provide users with information on where it is safe to traverse and what might be of interest (SOIs) in that area. After receiving mission objectives and rover functionality constraints (speed made good, slope limits, hibernation limits, etc.), a traverse was scheduled and digitized in order to meet as many scientific and engineering objectives as possible, maximizing both operational hours/days as well as distance travelled. Traverses were then subjected to resiliency testing in order to determine the magnitude of consequences should a landing time be delayed.

Observations: Results were recorded as timestamped 3d path and waypoints shapefiles, as well as a series of excel-based data tables, which can be interpreted or manipulated outside of the GIS-based environment.

Discussion and Future Works: Despite the 20m/px solar illumination modelling providing data at a lower spatial resolution than the in-house 1-meter hill shades, the coarser data accounts for distal terrain feature shadowing (shadows cast from topography more than 5km away) as well as lunar surface curvature. These two parameters are not accounted for by Arc’s Hill shade tool. Utilizing two resolution levels, allows for high confidence shadow prediction at very small spatial scales while integrating the impact of the distant terrain on local illumination. Apart from disruptive obstacles below the resolution of the hill shade (such as small boulders), this method allows for high-confidence planning at relevant mission scales.

Planned traverses are resilient to schedule changes within the same operational period (e.g., staying longer at one site or interest within the same “lunar day”), however they are less resilient to delays.
spanning multiple operational periods (e.g., arriving a month late).

Most traversal decisions (e.g., directional changes, operational hours spent traversing) were associated with reaching and exploring SOIs, not rover survival, suggesting effective landing site selection [13-15]. As such, strict hierarchies of operational priorities/mission objectives are necessary in order to meaningfully compare traversal opportunities objectively.