LUNAR ANALOGUE MISSION: OVERVIEW OF THE SITE SELECTION AND TRAVERSE PLANNING PROCESS FOR A HUMAN SORTIE MISSION AT THE MISTASTIN LAKE IMPACT STRUCTURE, LABRADOR, CANADA.

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Introduction: A Canadian Space Agency (CSA) funded lunar analogue mission has provided an opportunity to perform science in a simulated human-sortie sample return mission with rover assistance at the Mistastin Lake impact structure (55°53'N; 63°18'W), Labrador, Canada (see [1] and [2] for overview). In August 2011, two astronauts conducted two separate human sortie missions at two different sites. In week 1 (Site 1), the astronauts had rover assistance. In week two, the astronauts were at Site 2 and the rover remained behind at Site 1 to complete follow-up tasks. Importantly, data was available for both sites from a robotic precursor mission conducted in 2010 where sites representing crater rim materials and preserved possible impact melt rock were surveyed by the rover (see [2] and [3]).

Site Selection Process: Prior to deployment, the Mission Control (MC) team and astronauts reviewed remote sensing and precursor rover data, formulated scientific questions that addressed mission goals, identified outcrop-scale sites for the astronauts and rover to further investigate, and planned traverses (see [4] for setup of MC; [5] for details about the instruments available). During deployment, MC (located in London, ON) reviewed new data acquired in the field, made scientific interpretations, gave additional directions to the rover, and facilitated the direction of science carried out by the astronauts.

Methods: The two landing areas (Sites 1 and 2), or large-scale sites of interest to revisit during this deployment were determined using precursor data and logistical constraints (Fig. 1). Candidate Sites of Interest (SOIs) and outcrop-scale Regions of Interest (ROIs) were grouped based on science goals. SOIs were selected based on indicating possible variability of target rock and appearance of structural and/or alteration features as observed within the remote sensing and precursor data.

Multispectral VNIR and TIR data from ASTER and Landsat were processed and fused together to generate RGB composite maps to highlight spectral characteristics of geologic surfaces and assist in data interpretation and planning (Fig. 2a). Spectral maps using ASTER band ratio combinations enhanced Fe^{2+} vs. Fe^{3+} content and vegetation detail (Fig. 2b). MC observed spectral diversity throughout the crater (see [6] for an example of use of remote sensing data in the site selection and science interpretation processes). MC was able to identify sites with the potential for sampling rocks and soils with minimal vegetation coverage.

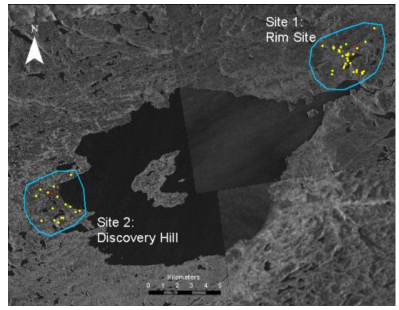

Figure 1: Radarsat (1,2) image of Mistastin Lake impact structure and surrounding area, showing (1) SOI - yellow dots, (2) Regions of Interest, based on groupings of SOI's – blue polygons, and (3) Deployment landing Sites - red letters.

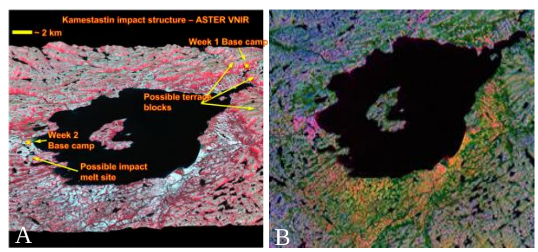

Figure 2: A) 3-D RGB composite map combining ASTER data with DTM (with 3x vertical exaggeration). B) 15m RGB colour composite map (ASTER; Landsat) Red=Fe^{2+} content; Green= Vegetation content; Blue=Fe^{3+} content. Vegetation coverage is evident in this view, which greatly assisted MC in determining hazardous areas.

Following the review of all image data and composite maps MC placed structural mapping, ground-truthing spectral anomalies, and characterizing target rocks as high priority science objectives for the astronauts during the deployment to Site 1. For details about the Site 2 mission, see [6] and [7].

Traverse Planning Methods: Traverse paths were planned and compiled after SOIs and ROIs were determined. Traverse paths were designed keeping in mind SOIs and ROIs of high science priority and, more importantly, routes that met traversibility thresholds defined from the use of hazard maps derived from remote sensing data (e.g. slope, vegetation, water coverage, radar roughness, etc.). Sites of archaeological significance identified by the local Innu community were also included in hazard maps to avoid planning traverse routes that would interfere with these sites. MC determined the best and most effective way of sending astronauts to each of these sites within the allotted time for extra-vehicular activities (EVA) and ultimately achieving all of the scientific objectives of the traverse.

Traverse paths for the rover were selected once deployment commenced to get on-site astronaut assessment regarding terrains that could be traversed by the rover.

Protocols in Site Selection and Traverse Planning: The priorities listed by Mission Control for selecting SOIs and ROIs included: 1) ground-truthing and validating spectral data; 2) characterizing target rocks; and 3) at a broader scale, determining the scientific significance of the site or traverse in regard to location within the crater. Downselecting SOIs involved selecting sites that addressed more than one goal and discarding others.

MC had to keep the following conditions in mind prior to planning traverse paths: 1) astronauts were at each site for only 5 days; 2) there could be only one EVA per day lasting 5 hours; 3) the maximum distance traversable in an EVA was ~5 km; and 4) during the first week, the astronauts also had to teach rover paths for the second week of rover-follow up deployment. Regarding SOIs, MC was responsible for downselecting all sites to a number that astronauts could realistically visit during each EVA and/or within each ROI.

Results: Interestingly, a number of sites with noticeable spectral variation existed at sites of structural interest. Sites were further filtered down to include only prioritized key areas, i.e. specific spots that need to get visited for addressing multiple scientific objectives.

Robotic precursor panoramic images greatly aided MC in identifying outcrops of variable colour suggesting different target lithologies, alteration, or surface coatings, which were of interest to MC in understanding the geologic history of the area. Furthermore, the 2010 precursor panoramas collected from different vantage points facilitated MC's ability to more accurately orient themselves to the terrain and identify SOIs on the ground. This combined with astronaut accounts and geochemical analyses facilitated SOI selection at the sub-outcrop scale during traverses (see [8] for more detail on the geochemical techniques conducted at sub-outcrop scales).

MC recognized that, due to their better situational awareness, the exact paths travelled by the astronauts would differ from the planned traverse paths (see [9] for overview of techniques used by MC to track the astronauts). In total 8 ROIs and 50 SOIs were selected by MC. During week 1, MC designed EVA paths with minimal modifications from the field (i.e. input from the astronauts based on their perspective at the site). During week 2, MC provided the first EVA path but often accommodated astronaut input to modify traverses as necessary and determine future EVAs. "Science" traverses included preceding "reconnaissance" traverses to maximize the science return of site 2 (Fig. 3).

Figure 3: Proposed EVA traverse paths for Discovery Hill (Site 2). Solid line = astronauts must visit all sites along path; Dashed line = astronauts can do recon if time permits.

Lessons Learned: Four major observations from the site-selection and traverse planning process are: 1) all mission participants (MC, astronauts, and field support team) must be involved in the process to understand the rationale and objectives behind each site selection; 2) having a specific testable scientific hypothesis/goal that can be addressed within the confines and restrictions of the mission (e.g. time, resources, instrumentation, etc.) is very critical; 3) early knowledge in identifying the traversibility constraints of the astronauts/rover, determining how much resources is consumed for scientific activities greatly aids in efficiently selecting SOIs and ROIs and successful planning and execution of traverses; and finally, 4) access to robotic precursor data, particularly panoramic images, greatly helps MC in planning traverses for this human sortie mission.

References: [1] Marion, C. *et al*. (2012) *LPS XXXXIII* (this meeting). [2] Osinski, G. R. *et al* (2010) *LEAG*, Abstract #3047. [3] Shankar, B. *et al* (2011) *LPS XXXXII*, Abstract# 2594. [4] Moores, J. *et al*. (2012) *LPS XXXXIII* (this meeting). [5] Pickersgill, A. *et al*. (2012) *LPS XXXXIII* (this meeting). [6] Tornabene, L. L. *et al*. (2012) *LPS XXXXIII* (this meeting). [7] Chanou, A. *et al*. (2012) *LPS XXXXIII* (this meeting). [8] Pontefract, A. *et al*. (2012) *LPS XXXXIII* (this meeting). [9] Kerrigan, M. *et al*. (2012) *LPS XXXXIII* (this meeting).

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