CANMOON ANALOGUE MISSION OPERATIONS: GIS, LOCALIZATION, AND ROVER TRAVERSE PLANNING AND MONITORING.

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Introduction: CanMoon [1] is a Canadian Space Agency-funded lunar sample return analogue mission with a focus on lunar science objectives and mission operations [2] training undertaken jointly by the University of Western Ontario (Western) and the University of Winnipeg. Rover operations were located in Lanzarote, Spain, while Mission Control operated at Western in Canada. The mission was intended to test operational practices for lunar rover missions. This included rover traverse and localization operations carried out by a sub-team known as the *GIS team*. The purpose of this team was to plan and monitor rover traverses, maintain a rover localization map with hazards and features of interest, and then combine this map with pre-geologic maps to identify new science targets.

The members of the *GIS team* were distributed across both the Planning [3] and Science [4, 5] mission control teams, located in separate rooms. More specifically, the *GIS team* consisted of the following roles:

1. **GIS/Localization Lead *(Planning Team)***: mapped rover-collected data (including hazards as more ground-based imagery was acquired for navigation and science), localized the rover position, incorporated nomenclature of samples, sites, features of interests (as acquired from the Science Team), and updated traverse maps by obtaining traverse data from the Traverse Plan Monitor.
2. **Traverse Plan Monitor *(Planning Team):*** added new rover waypoints used by the Planning Team during traverses, tracked distance and heading changes when the rover was in motion or arrived at a waypoint, and documented how closely the rover followed the pre-planned traverse route. The Traverse Plan Monitor and GIS/Localization Lead worked closely to maintain an updated traverse map.
3. **Remote Sensing/GIS Interpretation Team *(Science Team):*** interpreted and correlated remote sensing datasets with the updated traverse paths in order to suggest a more diversified group of potential targets.

The general outline of the team workflow is depicted in **Figure 1**.

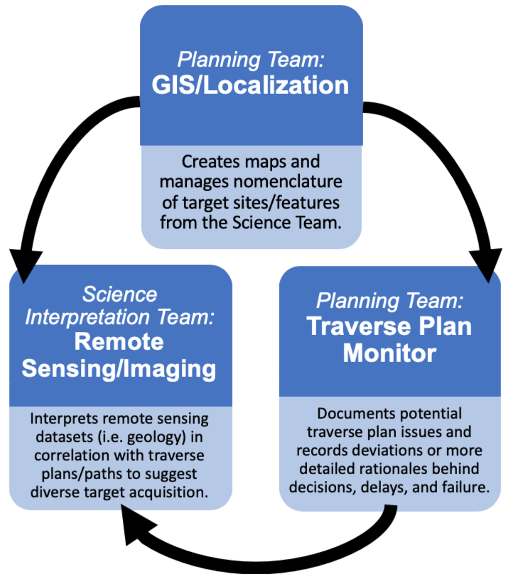

Figure 1: Workflow showing basic *GIS Team* operations.

Methods: In order to successfully map, plan, and execute rover traverses, initial reference and access to pre-mission remote sensing data [6] were integral to the *GIS team*. This pre-mission dataset [6] was the basis for detailed, preliminary traverse mapping of potential hazards, geologically diverse targets, and traverse distances, which were calculated and mapped using ArcGIS 10.7. In order to organize the mission datasets, a standard protocol was followed for displaying descriptive data specifically for traverse waypoints (successful, proposed, collision) and features of interest (**Fig. 2**).

During the mission, the *GIS team* was responsible for keeping track of the waypoint name(s), coordinates, and science/sample collection details for respective sites (**Table 1**). This allowed for detailed and consistent documentation for not only the planning team, but for the Tactical Science [4] and Science Interpretation [5] teams. The Remote Sensing/GIS Interpretation team was then responsible for further analyzing these science measurements in correlation with GIS data to suggest a wider range of possible targets.

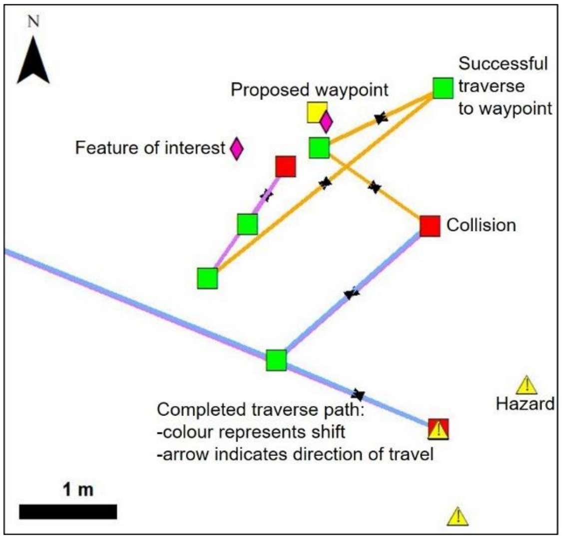

Figure 2: Mapping symbology used on ArcGIS.

Table 1: Documentation of waypoint details with respect to GIS and localization of rover targets and regions of interest (target names are italicized).

Label	Type	Science Notes	Lat (DD)	Long (DD)
Tobermory	Landing Site	Pano, supercam *Broom-sticks*	28.952569	-13.817653
Cowichan	Proposed	-	28.951932	-13.817673
Fairview	Collison	-	28.952058	-13.817997
Espanola	Waypoint	Pano, zooms, RMI	28.952090	-13.817996
Kingston	Waypoint	Pano, supercam *Chernabog*, RMI, sample *Dancing flowers*	28.952072	-13.818021

Typical rover commands sequenced and utilized for GIS purposes can be grouped into two main categories namely: (1) planning/localization commands and (2) moving commands [7]. The goal of localization commands was to assess the rover's surrounding environment as well as plan future traverses by taking hazards, rover headings, and nearby potential targets into consideration. For example, planning/localization commands consisted of *Panorama Image, Blind Targeting, Zoom Image, Rover Heading, and Distance to Target*, all of which contributed to hazard assessment and successful traverse plans. Moreover, commands to move the rover were widely used for traversing with the goal of travelling towards a specific target or region of interest. Some examples of moving commands are *Traverse (direct; waypoint; precise return), Reverse Rover, Nudge, and Turn Rover.*

Results: Two final traverse maps were generated for *Lunar Day 1*/*Site 1: Janubio* and *Lunar Day 2*/*Site 2: Nuevo Ortiz*. These summary maps show the traverse path, total number of waypoints, and other key features that were identified during the entire mission. In total, the final traverse distance of the rover for *Site 1: Janubio* was 86.68 m and *Site 2: Nuevo Ortiz* was 418.89 m. In Site 2, the rover travelled almost five times the distance in comparison to Site 1 as a result of fewer rover hazards and an improved efficiency in traverse planning and mission operations in general.

Discussion: Due to the three different GIS-oriented roles (which made up the *GIS team*), communication played a critical role in traverse planning. We encourage the *GIS team* to establish mapping and communication protocols before the commencement of mission operations for effective collaboration. For example, establishing the appropriate use of legends, GIS labelling, and relaying map changes to other team members require more attention especially for mission control training and preparation. Some of the mapping protocols used during this mission are outlined in **Fig.2** and a separate GIS channel on Slack was created for constant communication. Slack, an instant messaging platform, was used by the entire mission control team.

One of the challenges the *GIS team* encountered was the transfer of ArcMap data from one role to another. For this, we recommend an integrated GIS interface that allows multiple users to be logged into the same interface and edit collaboratively. This would give the whole team access to a real-time/live map with constant updates about traverse paths, new target names, etc.); this would be especially helpful if the planning and science teams have separate designated rooms. In addition, live map updates would also be useful for efficient selection of new science targets. Moreover, this will further promote an open line of inter-team communication during mission operations and should be an area targeted for improvement upon in future studies.

References: [1] Osinski G. R. et al. (2020) *LPSC LI*, this conf. [2] Marion C. L. et al. (2020) *LPSC LI*, this conf. [3] Newman J. D. et al. (2020) *LPSC LI*, this conf. [4] Morse Z. R. et al. (2020) *LPSC LI*, Abstract #1253. [5] Hill P. et al. (2020) *LPSC LI*, this conf. [6] Morse Z. R. et al. (2020) *LPSC LI*, Abstract #1254. [7] Andres C. N. et al. (2020) *LPSC LI*, this conf.