PLANNING TEAM OPERATIONS FOR THE CANMOON LUNAR SAMPLE RETURN ANALOGUE MISSION. J. D. Newman1,2, E. A. Pilles1,2, Z. R. Morse1,2, C. L. Marion1,2, P. A. Christoffersen1,2, P. J. A. Hill1,2,3, G. R. Osinski1,2, E. A. Cloutis4, C. N. Andres1,2, M. Bourassa1,2,3, C. M. Caudill1,2, M. Cross1,3, A. Dicecca2, K. Doerkens1,5, S. Hibbard1,2, R. Hopkins1,6, J. Kollewyn7, A. Pascual1,5, K. Ratcliffe8, A. Roberts9, C. D. Rodriguez Sanchez-Vahamonde1,2, C. Ryan1,2, J. Shah1,2, G. Tolometti1,2, L. L. Tornabene1,2, O. Vlachopoulos9,10, Institute for Earth and Space Exploration, University of Western Ontario, London, ON, Canada. 1Department of Earth Sciences, University of Western Ontario, London, ON, Canada. 2Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada. 3Department of Geography, University of Winnipeg, Winnipeg, MB, Canada. 4Department of Electrical and Computer Engineering, University of Western Ontario, London, ON, Canada. 5Department of Physics and Astronomy, University of Western Ontario, London, ON, Canada. 6Department of Mechanical Engineering, University of Alberta, Edmonton, AB, Canada. 7Department of Mechanical Engineering/Aerospace Mechatronics Laboratory, McGill University, Montreal, QC, Canada. 8School of Earth and Environmental Sciences, University of St. Andrews, St. Andrews, United Kingdom. 9Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, NB, Canada. (jnewma49@uwo.ca)

Introduction: As part of its Lunar Exploration Analogue Deployment (LEAD), the Canadian Space Agency (CSA) is carrying out a series of field tests and analogue missions to test technologies, develop mission operations architectures, and provide training for students and young professionals. The CanMoon lunar sample return analogue mission was a joint endeavor of the University of Western Ontario and the University of Winnipeg that was conducted over two weeks during August 2019. This analogue mission was designed to accurately simulate near real-time communication between an Earth-based Mission Control station and a scientific rover platform operating on the lunar surface. The goal of this analogue mission was to assess the decision-making abilities of the Mission Control Team and to document the approaches undertaken to complete reliable scientific analysis. For a full overview of the 2019 CanMoon analogue mission see [1].

Planning Team: The CanMoon Planning Team was one of three teams stationed in Mission Control during CanMoon operations. The Planning Team operated in a room adjacent to the other two Mission Control Teams, Tactical Science [2] and Science Interpretation [3]. The primary responsibility of the Planning Team was to translate Tactical Science decisions and intended actions into rover readable commands. Commands were sent directly to the rover using “Rover Ops”, a Google Sheet interface, which communicated what activities the rover was to perform. The rover was operated by a Field Team from two field sites in Lanzarote, Spain named “Janubio” and “Nuevo Ortiz” [2]. As the rover completed activities, the Planning Team received the data obtained by the rover and relayed it directly to Tactical Science for validation and processing. Acquired data then guided future science decision making and sample collection opportunities.

During mission operations, data flow between Mission Control and the rover was managed by the Planning Team under the supervision of the Planning Lead. Each member of the Planning Team was essential to ensure there was no interruption to this flow. When issues arose, the team worked quickly to formulate solutions and resume data flow.

Planning Team roles. The Planning Team was comprised of nine different roles: Planning Lead, Data Manager, Documentarian, Long Term Planner, GIS/Localization, Rover Operator, Rover Sequencer, Science/Planning Integrator, and Traverse Plan Monitor. For the two-week duration of the mission there were two people assigned to each role, except for the Documentarian where there was only one. During the first week most roles were double occupied for training purposes. This allowed the team to split into two shifts during the second week as shifts were shortened and handing over duties was tested [4].

The Planning Lead directed the activities of the Planning Team and provided mission planning input such as rover operational constraints while working with the Tactical Science Lead to work toward achieving mission goals and objectives. The Data Manager was responsible for receiving the raw data downlink, ensuring the received data matched requested data, organizing the data archive, notifying Tactical Science when data was ready to be processed, and informing the Planning Team when uplink files were ready to send to the rover. The Documentarian ensured there was a written record of Planning Room activities while capturing the decision making process and rationale for final decisions that were made. GIS/Localization maintained maps and helped manage the nomenclature of samples, sites, and features [5]. The Long Term Planner continually assessed the current rover location and status with respect to mission goals and timeline based on what rover activities could be performed in the remaining mission time. The Rover Operator was the instructional relay between Mission Control and the rover by entering activity parameters into the “Rover Ops” interface. The Rover Sequencer translated rover
activities requested by Tactical Science for the Rover Operator while adding any navigational inputs necessary from the Traverse Plan Monitor into sequencing document templates created for specific rover activities [6]. The Science/Planning Integrator was a dual role that consisted of one person seated in the Planning Room while their counterpart was seated in the Science Room and facilitated communication and decision-making between the Planning and Tactical Science Leads. The Traverse Plan Monitor aided with navigation by determining locations of waypoints for points of interest from Tactical Science as well as calculating distance and direction for rover traverses.

“Rover Ops”: Communication between Mission Control and the rover was made possible by a Google Sheet document called “Rover Ops”. The Google platform was used here for its accessibility over Wi-Fi in the field and the range of apps and functions within Google Drive. Various Google accounts were created to allow different permissions to be set among the Planning Team and Tactical Science Team to access “Rover Ops” that ranged from being able to send commands to the rover to view only. The structure of “Rover Ops” used multiple sheets that included Rover Command, Command History, and list of activities.

Rover Command is where a rover activity was selected from a drop-down menu and parameter fields required for the chosen activity were defined. In total there were 32 possible activities that could be sent to the rover [6]. Parameters were entered based on prepared sequencing documents initiated by either the Tactical Science Team or the Planning Team, depending on the rover activity required, as per instructions from the Science and Planning Leads. Input parameters for traverses included distance travelled (m), heading (deg), and final heading (deg) and image parameters included starting azimuth direction for panoramic images, magnification for zoom images, and elevation angle for blind image targeting. About half of the activities required an attachment, which was provided as a sharable Google Drive link that opened an annotated image (saved in Google Drive) with targeting information indicated for the associated activity. The shared image link was a fast way to connect the rover Field Team with features of interest or targeting information related to activities requested by Mission Control.

Once a command was sent, all input data was populated in corresponding columns in the Command History and saved. Every command had a unique Command ID, e.g. 2.1a.4, which indicated the lunar day, shift, and command number within the shift. Several columns were strictly for input by the rover Field Team and showed when a command was received, when an activity was complete, and actual duration time. The ability to see when the rover acknowledged that a new command had been sent and when it completed an activity was very useful. The duration of an activity always had a set minimum time but could take longer due to issues with instrumentation or communication. Activity duration was linked to a convenient Time until Deadline cell in the Rover Command sheet that counted down in minutes to when the rover would be idle, which the Mission Control Team wanted to avoid as much as possible. The Command History sheet in “Rover Ops” was always projected on the main screen in both the Planning and Science Rooms. This allowed all members of Mission Control to see the current status of the rover at all times while monitoring the progress of commanded rover activities.

Challenges: As per all analogue and real rover missions, including CanMoon, communications remain a principal challenge or bottleneck related to mission timeline, data acquisition, and success.

Precise navigation, including orientation and localization, was often a challenge for the Planning Team. Having a LiDAR-equipped rover would have been extremely beneficial for navigation during the CanMoon analogue mission as discussed by [7,8,9]. LiDAR also has the additional benefit of being able to operate in the dark or shadows, which would be an asset during a real lunar mission [9].

Mission Results: The “Rover Ops” system was a very beneficial tool for the Planning Team that worked well to send commands to the rover and to monitor its progress during the mission. Despite the challenges noted above, the Mission Control Team was able to collect a total of 7 samples and met all four of the main science objectives outlined for this lunar sample return analogue mission [1,2,3].

Acknowledgements: This work was funded by the Canadian Space Agency (CSA) via FAST grants to GRO and EAC and a Science Maturation Study to GRO. We thank the Government of Lanzarote Spain for granting access to the field sites and the Faculty of Science at the University of Western Ontario for providing the location for Mission Control.