Introduction: In mid-November 2015, the Centre for Planetary Science and Exploration (CPSX) at the University of Western Ontario (hereinafter referred to as Western University) served as mission control for the 2015 CanMars MSR Analogue Mission. This was a Mars Sample Return Analogue Mission carried out in partnership between the Canadian Space Agency and MacDonald, Dettwiler and Associates Ltd. (MDA), as part of the NSERC CREATE project “Technologies and Techniques for Earth and Space Exploration” [1]. The 2015 CanMars MSR Analogue Mission involved researchers, postdoctoral fellows and both undergraduate and graduate students from Western University, York University, Saint Mary’s University and the University of British Columbia. The analogue mission consisted of two main components: (i) the field operations, led by the Engineering Team and (ii) mission control, led by the Science, Planning and Tactical Teams.

The field operations took place in a remote site in Utah, USA, which served as a Martian analogue for the robotic exploration mission. The Mars Exploration Science Rover (MESR), built by MDA, was equipped with a range of remote sensing instruments [1]. Mission control consisted of scientists and engineers who were responsible for day-to-day mission operations (e.g., planning, scientific data interpretation, communication with the Engineering Team and other processing functions) [2]. Due to space limitations, mission control was divided into two rooms. The Science Room was used primarily by the Science Team, while the Planning Room was used by the Planning and Tactical Teams. However, there were instances which required both Planning and Tactical Teams to perform their operations in the Science Room. This will be further discussed below.

While the actual Martian robotic mission simulation took place over the two week period (November 16–27, 2015), the pre-planning and post-mission activities required several months of careful planning and organization. One of the essential components necessary to carry out a successful analogue mission is assigning specific function roles to each team member and determining how these will be carried out throughout the mission. This report describes the primary function and operational framework of the Tactical Team and offers a concise overview of the responsibilities associated with each role within the Tactical Team.

Tactical Team Structure and Responsibilities: The Tactical Team consisted of four main roles: (i) Team Lead, (ii) Uplink and Sequencing Integrator, (iii) Downlink and Data Management, and (iv) Tactical Documentarian. The core responsibilities of Tactical Team Lead included managing the activities of the Tactical Team, monitoring health and performance of the MESR and approving all commands sent to the MESR, and participate in daily teleconferencing communication with the Engineering Team at the CSA. The tasks of the Uplink and Sequencing Integrator role were to integrate all instrument sequences received from the Science Team to be uplinked to MESR, as well as uplink complete daily operational sequences to the MESR [3]. The Downlink and Data Management team member was responsible for all downlink data products and ensuring that these are available to the Science Team. The specific tasks associated with this role included managing file structures, ensuring smooth data flow between Teams, and ensuring proper archiving of all Mission data. The primary tasks of the Tactical Documentarian were to document all the activities of the team, record Team discussions (decisions made and rationale), and work closely with the Team Lead.

Day-to-day Operations of the Tactical Team During the Mission: During the mission, all the teams would typically meet twice a day, once in the morning, and then again in the evening. In summary, the evenings were dedicated to examining the current sol downlink data from the Engineering Team, drafting the plan for the next day and devising the MESR operations sequencing plan, also ensuring that the MESR operations are within the data and energy budget. The morning planning consisted of two main phases. The first phase involved authorizing the MESR sequencing plan and operations, making any last minute modifications or updates if needed, ensuring that the uplink contains the latest version of the final sequencing plan and any other necessary data products for the Engineering Team and finally, discussing the plan with the Engineering Team via teleconference. The second phase was focused on establishing the scientific rationale and drafting a provisional plan for the next Sol and onward.
For the duration of the 2015 CanMars MSR Analogue Mission, however, not all Tactical Team roles were always staffed. For example, the Sequencing Integrator and Downlink and Data Management roles were not staffed on Sols 6-9 and Sol 7, respectively. The Tactical Lead role was staffed during week 1 of the mission (Sol 0-5), but not during week 2. All of these roles were interactively filled as needed by other team members with sufficient skills. In fact, previous analogue missions led by CPSX have used a two-team structure (Science and Planning) [4], except when the simulation included real-time communications with astronauts, for which a Tactical process is added [5]. The two-team structure was also used in the precursor test to this deployment, the CREATE-CSA 2014 exercise, which used a nearly identical rover system and payload suite, but explored a constructed analogue terrain at CSA headquarters in St-Hubert, Quebec, ahead of this field trial at a genuine analogue site.

During the second week of operations for this 2015 deployment, the mission returned to that successful structure – a transition effected by merging of the Tactical team into the Planning team, a process which had already begun, in a practical sense, in the first week. This transition was further eased by the fact that senior ops personnel had significant experience in previous analogue mission simulations. This is an important lesson that multi-dimensional and cross training of mission personnel is crucial for a successful mission (real or analogue), and speaks to the success and flexibility of the process developed for remote robotic science in [4] and extended for human and joint human-robotic exploration in [5], and reported extensively in LPSC XLIV ([6],[7],[8], and others).

**Modes of Communication Between the Mission Control Rooms and Teams:** As noted above, the Tactical and Planning teams were separated from Science. Several applications were tested and subsequently implemented to aid communication between the two mission control rooms. Slack [www.slack.com], the messaging system, proved to be a very efficient and fast way to exchange information and data and engage in discussions. An important and beneficial aspect of Slack is that it retained the history of all conversations and shared documents, thus enabling the team members to tune in at any given time, whether they were on site or off-site. WebEx [www.webex.com], a video conferencing interface, was used for real-time live discussions. Google Hangouts [hangouts.google.com] was also tested on several occasions; but was not used for the general every-day communication. It was found that the fact that mission control had to be divided into two rooms was an impeding factor in facilitating effective exchange of ideas and participation in discussions. Therefore, the circumstances often necessitated the Tactical and Planning Team members to join the Science Team in the Science Room.

**General Communication and Planning:** Outside of usual mission control hours, and during pre-planning and post-mission operations, all pertinent notifications and mission relevant communication were carried out via e-mail. The pros of using e-mail are the rapid communication, instant dissemination of information and record keeping. However, the cons of standard e-mail use are numerous e-mail exchanges, and long threads which become more cumbersome and difficult to sift through over time. During the 2015 CanMars MSR Analogue Mission, other than e-mail communication, there was no set day-to-day calendar. While embarking on an endeavor to prepare and maintain the calendar is time consuming, potential future benefits should be further investigated.

**Recommendations:** For future analogue missions, the following recommendations for improvement should be taken into consideration:

- Review co-location requirements, assessing which personnel can/should be accommodated in a single Mission Control room, and providing adequate tools for dial-in remote personnel.
- Return to the established two-team process, with roles called ‘Tactical’ here returned to the Planning team, and a Tactical team used only for real-time operations.
- Use lessons learned and experience gained through past missions, as well as this one, to prepare a “how-to” manual for each role (even the reports prepared for this analogue mission can be used as future how-to manuals).
- Revisit data management and record-keeping tools, potentially reviving the ‘wiki’ system used in previous deployments.


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