**CANMARS 2016 MSR ANALOGUE MISSION: MISSION CONTROL TEAM STRUCTURE, TRAINING, AND OPERATIONS.**

M.M Battler[1], M. C. Kerrigan[1], R. Francis[2], and G. R. Osinski[1, 3], [1]Centre for Planetary Science & Exploration/Dept. of Earth Sciences, Western University, London ON, Canada. mbattle@uwo.ca. [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, USA. [3]Dept. of Physics and Astronomy, University of Western Ontario, London ON, Canada.

**Introduction:** The CanMars 2016 Mars Sample Return (MSR) analogue mission followed on the success of the 2015 CanMars mission [1, 2], and was a partnership between the Canadian Space Agency (CSA) and the Centre for Planetary Science and Exploration (CPSX) at Western University as part of the NSERC CREATE project "Technologies and Techniques for Earth and Space Exploration" (http://create.uwo.ca). The 2016 mission control (MC) team structure and operations were modelled after CanMars 2015 [3], with modifications made to simulate possible scenarios for NASA's Mars 2020 mission.

The CanMars 2016 mission was conducted by > 60 people from 11 organizations (academia, government, and industry). Just as in 2015, mission personnel were divided into three teams: 1. The MC team, located at Western University, which analyzed data from the rover and determined daily rover traverses and data collection; 2. The CSA team, which received instructions from the MC team, programmed rover instructions, and relayed to the rover/field team (FT); and 3. The rover/FT, which was co-located with the CSA's Mars Exploration and Science Rover (MESR) in Utah. MESR and the human FT were equipped with instruments (some rover-mounted and some hand-held) that simulated Mars 2020 instruments as closely as possible both in instrument specifications, and through implementing flight-rules to mimic Mars 2020 instrument and rover power, data, and time constraints. The mission ran for three weeks during November 2016, and was subdivided into two operational phases, discussed in Osinski et al. [2], which included testing the feasibility of continuous 3-sol command cycles and rover autonomy [4, 5] during a Fast Motion Field Test (FMFT).

**Mission control team structure:** The MC team was primarily staffed by students and postdoctoral fellows in the NSERC CREATE program with additional participants from CPSX, McGill University, and Canadensys, and mentors and visitors from Stony Brook University, NASA JPL, and the UK Space Agency.

Based on lessons from CanMars 2015 [3] and preceding analogue missions [6, 7], the MC Team was divided into the Science Team (20 people), and the Planning Team (8 people). These teams were located across the hall from each other and were in contact via WebEx, and through the Planning Team Lead, who moved between the rooms. The CanMars 2015 team structure was re-evaluated based on anticipated workflow to streamline roles and team function [3].

*Science Team roles.* The Science Team Lead led the Science team to a consensus on daily and long-term science goals, adjusted the long term (weekly) requested Science plan relative to daily progress, and kept the team working toward mission goals. The Science Team was divided into the following teams, largely based on rover instruments, which simulated Mars 2020 instruments: 1. Imaging (Mastcam, RMI, and WATSON imagers); 2. SuperCam LIBS; 3. SuperCam VISIR; 4. SuperCam Raman/SHERLOC; 5. PIXL (XRF); 6. GIS and Localization; and 7. Documentarians (split between Science Team and Planning team). The instrument teams (#1–5) were responsible for overseeing the operation of their instrument on the rover and the processing and interpretation of the received data products. The GIS and Localization team was responsible for processing remote sensing data, mapping rover traverses, and integrating data from the rover into site maps. The Documentarians were responsible for recording team discussions (decisions made and rationale) and taking notes on activities related to the science and operational goals of the mission.

*Planning Team roles.* The Planning Team Lead monitored progression of daily and long term plans with consideration of overall Mission goals, monitored the health and performance of the rover, and approved all commands sent to rover. The Planning Team was comprised of: 1. Data Manager (uplinked daily operational sequences to the rover, downlinked data products received from the rover and made them available to Science; archived mission data; ensured remote participants were connected); 2. Daily Activity Planner (ensured daily requested Science plan was in line with available time, power, bandwidth budgets); 3. Sequencing Integrator (integrated instrument sequences received from Science to be uplinked to the rover); 4. Autonomy Specialist (guided the team on use of autonomy, and trained the image classifier [5]); 5. Environment and Localization Specialist (advised Science on feasibility of potential routes and localization based on LIDAR); and 6. Rover Planner (developed rover sequences to be uplinked to the rover).

*Mission management roles:* Two Mission Operations Managers (MOM) with previous analogue mission leadership experience coordinated high-level mission activities and oversaw daily operations. Responsibilities included pre-mission planning, (with CSA), staffing MC roles, organizing team training, managing logistics, maintaining communications with the FT, assisting with media events, and collecting final reports from MC members. 2016 featured the addition of a Simulation Assurance Manager (SAM), with previous leadership experience on analogue missions and MSL mission operations experience. SAM played an integral role in guiding the MC team, through teaching mission operations principals and clarifying flight rules and rover capabilities, with an emphasis on rover autonomy [4]. The Education and Public Outreach (EPO) Lead was responsible for developing a social media campaign and organizing media and public events [2]. CanMars 2016 featured experts with significant Mars mission operations experience to fill the role of Long Term Planner (LTP). This role was added to support testing of a new operational mode which made use of periodic “strategic days”, to help maximize scientific return [8]. LTP led big-picture discussions of the scientific results to-date, and long term mission planning.

**MC team training:** An intensive week of training for all MC personnel was held one month before the mission. Training included: 1. An introduction to Apogy – the environmental simulation software designed by CSA (previously called Symphony [9]), and used to visualize MESR – led by CSA, as a day-long training session; 2. A review of the CanMars 2015 mission, led by the Science Team Lead; 3. A half-day dry-run, for MC members to practice their roles and the daily workflow; and 4. A science workshop for all MC members and stakeholders, to cover mission rationale, scientific and operational goals, mission schedule and daily timelines, and discuss approaches to sample collection, rover autonomy, and the use of a strategic traverse route to facilitate strategic days [8]. Additionally, the MC team met for 3 weekly training sessions. The FT trained on science instruments as they arrived.

**Mission operations:** Operational goals were introduced in 2016 and required implementation of new operational modes, additional personnel, and more data collection. Operational objectives included: (i) Testing the accuracy of remote sample selection using the partial context available to mission scientists during rover-based field operations, compared to the more complete context available to a traditional human field party [10]; and (ii) Testing the efficiency of remote science operations with periodic pre-planned strategic observations compared to including strategic *and* tactical considerations in the tactical plan [8]. Workflow during CanMars 2016 was similar to 2015 [3] and varied slightly during the FMFT [11], and significantly on strategic days [8].

**Lessons learned:** 1) The ‘MOM’ role is essential. For a mission of this length and complexity two MOMs may be required. A MOM needs to be readily available to the MC personnel and up-to-the-minute with all operations, at all times. 2) A technical operations manager (TOM) is needed to manage instrument and hardware issues. TOM would work closely with the FT in their instrument training, and be the main point of contact for the FT during operations for issues with the instruments. 3) SAM is an important role for a mission with operational experiment goals. SAM must arbitrate what is realistic (and not) given the technologies assumed to be in play in the mission. 4) All roles and communications protocols need to be fully understood by all team members both in the MC room(s) and the FT, prior to operations. 5) Thorough lab and field testing of all science instruments is essential prior to operations. The FT should understand the mission instruments they’re simulating, and MC members need to understand how their instrument will work in the field, and develop data collection protocols with the FT. 6) It is difficult to run long days and exhausting schedules for more than 2 weeks with the same personnel. A policy of no more than 10 consecutive mission days per individual is advised. 7) Remote participants need to be engaged more effectively. 8) “Lessons learned” need to be implemented for future simulations. A policy of discussing lessons from previous analogue missions at new project kick-off meetings is recommended.

**Acknowledgements:** Thanks to our partners at CSA and guest experts from JPL, Stony Brook U, and UKSA for helping us to run such a high-fidelity mission and excellent training exercise, and to the tireless work of the CanMars team for making the mission a success! Thanks to CREATE partners at U British Columbia, U Winnipeg, and York U, and to collaborators from McGill U and Canadensys for taking part in the mission, and to U Winnipeg, CSA, UKSA, and MDA for instrument contributions. This work was funded by the NSERC CREATE program and the CSA.

**References:** [1] Osinski G. R. et al. (2016) *LPSC XLVII*, Abstract #2616. [2] Osinski G. R. et al. (2017) *LPS XLVIII*, *(this conf*). [3] Kerrigan M.C., & Osinski, G.R. (2016) *LPSX XLVII*, Abstract #1596. [4] Francis, R. et al. (2017) *LPSC XLVIII, (this conf).* [5] Kissi, J. et al. (2017) *LPSC XLVIII, (this conf.).* [6] Moores J., et al. (2012) *Adv Space Res* 10.1016/j.asr. 2012.05.008 [7] Francis R., et al. (2012) *Global Space Expl Conf*. [8] Pilles, E. et al. (2017) *LPSC XLVIII (this conf).* [9] Sapers, H. et al. (2016) *LPSC XLVII*, Abstract #2469. [10] Hipkin, V. et al. (2017) *LPSC XLVIII (this conf).* [11] Pilles, E. et al. (2017) *LPSC XLVIII (this conf).*