CANADIAN SPACE AGENCY OBJECTIVES FOR THE 2016 CANADIAN MARS SAMPLE RETURN ANALOGUE DEPLOYMENT V. J. Hipkin[1], T. Haltigin[1], M. Picard[1], and the MESR team. [1]Canadian Space Agency, 6767 Route de l'Aeroport, St Hubert, J3Y8Y9 (Victoria.Hipkin@Canada.ca),

Introduction: This paper describes the Canadian Space Agency (CSA) objectives for the Canadian Mars Sample Return Analogue Deployment (MSRAD) conducted in Utah from October 22nd to November 19th 2016. MSRAD 2016 includes a cache rover mission simulation, 'CanMars 2016', and a Mars Fetch Rover technology demonstration. This end-to-end analogue simulation will be completed with post-mission sample analysis to validate research outcomes. CSA MSRAD objectives are summarized in **Table 1**. Implementation and results to date are reported elsewhere[eg. 1-4].

Motivation and Preparatory Activities: The road to the 2016 deployment began with Canadian community interest in Mars exploration, leading to CSA participation in the international Mars Architecture for the Return of Samples (iMARS) working group, in order to explore potential contributions from Canada in Mars Sample Return (MSR) missions. The following year, the Canadian 2009 Budget invested in terrestrial prototypes of space robotic vehicles. CSA formed a Mars Sample Return (MSR) Analogue Mission Science Definition Team with 11 members from Canadian universities and participation from NASA, to provide mission requirements [5], for a planned prototype Mars Exploration Science Rover (MESR) based on the cache rover element of iMARS architecture [6], and an associated prototype payload: a mini-corer; microscope [7]; Raman [8]; and, LIBS [9]. A partnership with the NSERC CREATE project 'Technologies and Techniques for Earth and Space Exploration' (PI: G. Osinski, Western) provided access to CSA's analogue deployment program for student training. An analogue geological sample library was competitively contracted in support of prototype instrument testing [10].

MESR was designed and built by MDA [11], to act as a flexible rover testbed with a standardized interface to accommodate different payloads, with CSA managing system testing, integration of payloads, and the development of an Open Source operations and visualization tool called 'Apogy' [12].

Development progressed from the laboratory to CSA's Mars Terrain, with the intent of system testing at a scientifically relevant site necessary to validate requirements for operations and interoperability. A competitive contract was issued in 2014 to investigate potential analogue sites in Canada and beyond, including logistical considerations such as shipping cost and climate. A desert site around 5km NW of Hanskville, Utah, USA, was selected, representing an analogue of an ancient Mars sub-aqueous environment. As a result, the 2015 'CanMars mission' [13] took place in partnership with the UWO CREATE project, as a highly successful dry run for the planned end-to-end mission simulation in 2016.

International collaboration: Building on the international vision developed through iMARS, an invitation to participate in CSA's 2016 deployment was extended to other space agencies through the International Mars Exploration Working Group.

Both NASA and the UK Space Agency (UKSA) contributed to the MSRAD Science Plan. NASA's interest and mission expertise has been key to the success of the deployment in helping CSA focus 2016 resources on tests that could provide initial feedback on science operations design for Mars 2020. NASA has also provided sample tube interface information necessary to support advanced technology demonstration for a potential future Mars Fetch Rover mission.

In addition, parallel 2016 analogue deployment tests were conducted by DLR and the UKSA, taking advantage of site knowledge and infrastruture established by CSA, and with consideration of developing future, more closely co-ordinated, analogue campaigns.

TABLE 1: CSA Objectives for the 2016 Canadian Mars Sample Return Analogue Deployment

Element	Objective	Implementation
International collaboration	Develop and strengthen partnerships + position Canada for future contributions	Invitation to international community
Science / Operations	Advance MSR science operations and sample targeting	Co-ordination through Science Plan and Strategic Operations experiment
Technical Development	Advance selected rover autonomy and arm positioning technologies	Navigate to sample cache locations and return samples to lander
Communications	Attract and inspire the general public in STEM subject matter	Implement Communications Plan
Education / Training	Provide valuable learning opportunities to students	Continued partnership with university Programs

Science and Operations: The 2016 MSRAD Science Plan was developed by CSA as a means to coordinate science and operations research objectives for the 2016 Canadian MSR Analogue Deployment. Science Plan objectives were:

1. *To test the accuracy of selecting samples remotely using the partial context available to mission scientists using rover-based field operations, compared to the full context available to a traditional human field party.*
2. *To test the efficiency of remote science operations with periodic pre-planned strategic observations compared to including strategic and tactical considerations in the tactical plan*
3. *To assess the utility of realistic autonomous science capabilities to the remote science team, to understand how such autonomy improves the effectiveness and rate of progress of the science mission, and to learn which strategies of exploration emerge from the availability of these capabilities, including in a downlink-constrained environment*
4. *To make a preliminary determination of the factors that affect the quality of sample selection decision-making in light of returned sample analysis*

Science plan objectives 1 & 2 were based on agency considerations and recommendations from previous analogue work, eg. [14].

CSA Announcements of Opportunity provided opportunities to incorporate Canadian community research investigations in the deployment. Two CSA Science Definition Study grants were awarded, (PIs: G. Osinski, Western, and L. Whyte, McGill). A CSA Flights and Fieldwork for the Advancement of Science and Technology (FAST) grant was also awarded (PI: E. Cloutis, Winnipeg).

As CSA prototypes for Raman and LIBS were not yet sufficiently advanced for rover integration, a simulated Mars 2020 payload was provided under the Western University grant, designed for their investigation into the application of the instrument suite to Mars 2020 mission science objectives. Because robotic drilling would have been extensively time and resource consuming, a hand-held drill was used to accelerate the process. The McGill team, in collaboration with JPL and the UK Natural History Museum, developed a protocol for hand acquisition of sterile samples, minimizing organic contamination, to support their respective investigations into life detection on returned samples, and organic carbon analyses.

Rover operations were conducted remotely by CSA from its HQ in St Hubert, Quebec. Science operations were conducted from Western University under the CREATE partnership agreement.

Technical Development: Autonomous traverse and detection of sample tubes in a Fetch Rover scenario were successfully demonstrated by CSA in collaboration with MDA. Autonomous acquisition of sample tubes and transfer to a simulated Mars Ascent Vehicle cache was also demonstrated based upon requirements provided by the NASA JPL team and demonstrated the challenges and constraints to the design of a sample collection and transport system.

Communications, Education & Training: These three objectives were important to partners as well as to the CSA. Through the Western University-led CREATE project, students and early career researchers populated key roles in the 'Science' and 'Planning' sub-teams of the Western remote science operations centre. The high fidelity operations environment that was created at Western and CSA HQ, and NASA support for the participation of US Mars scientists, enhanced the training opportunity for all partners. A coordinated communications campaign involved tradiational media engagement, website development, and social media, including #CanMars on Twitter. Details are provided in [1].

Future Work:

CSA is exploring the potential for follow on activities with partners and would be pleased to discuss ideas.

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References: [1] Osinski G. R. et al. (2016) *LPS XLVII this meeting* [2] Caudill C. et al. (2016) *LPS XLVII this meeting* [3] Caudill C. and Pilles E. (2016) *LPS XLVII this meeting* [4] Hipkin V. J. et al. (2016) *LPS XLVII this meeting* [5] Science Definition Team (2009) CSA MSR Analogue Mission report [6] iMARS Working Group (2008) Preliminary Planning for an International Mars Sample Return Mission [7] Ryan C. H. et al (2016) *LPS XLVI, Abstract* #1903 (2016) [8] Eshelmann E et al (2014) *AGU Fall Meeting, Abstract* #P21D-3955 [9] Koujelev A. et al (2009) *Cdn. Aeron. Sp. J.,* 55(2): 97-106 [10] Cloutis E. A. (2015) *Plan. Sp. Sci*,119: 155-172. [11] Langley, C. et al (2012), *i-SAIRIS 2012*, 2A-02
[12] https://bitbucket.org/apogy/ca.gc.asc_csa.apogy
[13] Osinski G. R. (2016) *LPS XLVII, Abstract* #2616.
[14] Yngst A. R. et al (2014) *Asta Astronautica*, 99: 24-36