Moon & Mars Sample Return Analogue Deployment Validation

V. Hipkin[1*]

[1]*Canadian Space Agency, St Hubert, Canada,*

1. Introduction

The Canadian Space Agency (CSA) has been investing in science and technology development to position Canadian scientists and industry for a role in Mars Sample Return and human exploration of the Moon. The Canadian Space Agency's prototype Mars Exploration and Science Rover (MESR) was deployed in Utah in 2016 [3] under CSA's leadership with the intent of demonstrating technologies and advancing operational strategies for the international Mars Sample Return campaign [4]. The CSA also plans a future Lunar Exploration Analogue Deployment (nominally in 2019) related to Lunar Sample Return. These deployments are conducted in collaboration with academia and industry, and with other agencies, notably the NASA Mars program and NASA Mars 2020 Project, and ESA's Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science *(*HERACLES) project [5].

Figure 1: The Canadian Space Agency's prototype MESR Rover returning samples to a Mars Ascent Vehicle mock up during the 2016 Utah MSR Analogue Deployment.

The focus of this paper is a discussion of the use of analogue deployments to explore and validate rover mission requirements, and particularly the new requirements of the upcoming generation of Mars and Moon sample return missions. The objectives, implementation and results from the 2016 Canadian Mars Sample Return Analogue Deployment will be presented and discussed, as well as current status of the planned 2019 Lunar Exploration Analogue Deployment.

2. Definitions and Needs

Analogues are sites or facilities on Earth that resemble planetary environments: ie. typically extreme environments on Earth with challenging logistics and permit access. Deployments at analogue sites or 'analogue deployments' take many forms, ranging from a focussed technology test to end-to-end mission scenario, and have a mission engineering aspect that goes beyond scientific fieldwork.
Analogue deployments at scientifically relevant analogue field sites are key to developing and validating *science operations* requirements for planetary rover and astronaut missions. The purpose of validation efforts is to ensure that mission requirements will meet the intended mission objectives. Analogue deployments can also provide additional benefits such as demonstrating capabilities to potential partners and decision-makers, training students and mission teams, and engaging the public.

For the upcoming generation of Moon and Mars sample return mission concepts, the scientific community desires targeted samples acquired with geological context, with mobility for regional exploration, rather than the simpler landed mission or grab bag approaches, placing requirements on the scientific payload and mobility and sample handling systems. This generation of sample return missions remains highly constrained by mission duration, such that the new requirements on science operations need new highly efficient science operations approaches. Public engagement in the eventual missions is also expected to be high, with pressure on mission teams for rapid reporting of mission success and new levels of public participation during operations.

3. The 2016 Canadian Mars Sample Return Analogue Deployment (MSRAD)

MSRAD took place near Hanksville, Utah, from October 22nd to November 19th 2016, as a two phase deployment. Requirements for site selection included road access for a truck, reliable fair weather, 500m of unvegetated land for rover navigation testing, and geological features relevant to Mars science operations testing. A review of many potential sites in Canada and US resulted in the selection of a site around 4km NW of Hanksville, Utah, with a distinct inverted ancient fluvial channel feature.

In phase 1, CSA's prototype rover 'MESR', built by MDA [6], was successfully deployed as a Cache rover, testing science operations capabilities and approaches, with a payload simulating NASA's Mars 2020 sample cache mission. In phase 2, MESR was deployed as a Fetch rover technology demonstration after a change in payload, while science operations continued using hand held instruments with humans simulating rover mobility. Science operations were conducted by a largely student team led by Western University [8]. International collaboration was sought to develop and strengthen future partnerships. Collaboration with the NASA Mars Program and Mars 2020 [7] project team helped enhance the validation effort and value of research outcomes. The design of the validation approach was a significant part of mission planning and has resulted in an extensive and comprehensive data set consisting of targeted samples in the context of type samples from all stratigraphic units at the site, instrument data acquired by the mission, documentation of the decision-making process by remote science operations and field geology teams [1], and geological field mapping by two separate university teams. A special journal issue is in preparation.

The MSRAD fetch rover mission technology demonstration will also be described. A new solution was developed and successfully demonstrated to locate, acquire and transfer Mars 2020-like sample tubes. Six tubes were transfered over 6 sols under 47 hours of operations including 613m of autonomous navigation.

4. Lunar Exploration Analogue Deployment (LEAD)

Since 2009, the Canadian Space Agency has funded several studies related to lunar surface exploration, from small rovers designed for scientific exploration to 'moon buggy' systems for human exploration, building Canadian expertise in surface mobility systems, drilling and in analogue mission deployments using prototype systems [2]. Requirements for compact rovers were developed in the context of NASA's Resource Prospector and ESA's HERACLES mission concepts. A major technology development study that has recently completed is the Lunar Rover Platform and Drivetrain Prototype (LRPDP), a TRL-6 prototype derived from the CSA's Artemis Jr platform [9] tested under lunar-representative environmental conditions of 'dirty' T-VAC using CHENOBI regolith simulant. A TRL-4 Small Planetary Rover Prototype (SPRP) was also developed in 2016 to advance low cost solutions to surface exploration. Weighing in at 95kg it uses the same drivetrain as the LRPDP to ensure portability of the TRL-6 solution.
CSA remains an active partner in ESA's HERACLES mission concept development, leading the lunar surface rover component, with interest in using HERACLES to demonstrate technology solutions which could be scaled to a potential lunar surface human pressurized rover chassis contribution. Current CSA studies include twin industry studies that will each develop a detailed Lunar surface mobility concept for two main assets: (1) Precursor to Human And Scientific Rover (PHASR) (2) Lunar Pressurized Rover Core (LPRC).

In parallel with these technology efforts, CSA is funding a Lunar Demonstrator Mission Science Maturation Study to provide input to a science instrument payload for PHASR and a science operations scenario for the 2019 LEAD. HERACLES will present significant opportunities for science. While the primary objective of the HERACLES Lunar Demonstrator Mission is to demonstrate key precursor technologies, its design reference mission includes landing at a site of high scientific interest, nominally Schrödinder crater, and return of lunar samples of high scientific value, before conducting a long distance traverse and providing further opportunities for science and exploration.

5. References

[1] Beaty et al, LPSC *XLVII*, Abstract #2750, 2017 [2] Dupuis, E. and Picard, *Proceedings of i-SAIRIS 2016.* [3] Hipkin, V.J. et al, *LPS XLVIII, Abstract* #2666. 2017. [4] iMARS working group, Preliminary Planning for an International Mars Sample Return Mission, 2008. [5] Landgraf, M. et al, *LEAG 2015*, Abstract #1863, 2015. [6] Langley, C. et al, *i-SAIRIS 2012*, 2A-02, 2012. [7] Mustard J. et al., Report of the Mars 2020 SDT, 2013. [8] Osinski G. R., *LPS XLVII, Abstract* #2616. 2017. [9] Reid E. et al, *Advances in Space Research* 55(10)2472-2483, 2015

Short Summary

Discussion of use of analogue deployments to explore and validate rover mission requirements, particularly the new requirements of the upcoming generation of Mars and Moon sample return missions. The 2016 Canadian Mars Sample Return Analogue Deployment is presented and discussed, and current status of the planned Lunar Exploration Analogue Deployment.