OVERVIEW OF THE CANMOON LUNAR SAMPLE RETURN ANALOGUE MISSION. C. L. Marion[1], G. R. Osinski[1], M. Bourassa[1], C. M. Caudill[1], E. A. Cloutis[2], P. Christofferson[1], P. J. A. Hill [1,3], Z. R. Morse[1], J. D. Newman[1], E. A. Pilles[1], S. L. Simpson[1], L. L. Tornabene[1], T. Xie[1] and the 2019 CanMoon Team. [1]Department of Earth Sciences / Institute for Earth and Space Exploration, University of Western Ontario, London, ON, Canada. [2]Department of Geography, University of Winnipeg, Winnipeg, MB, Canada. [3]Department of Earth and Atmosphere, University of Alberta, Edmonton, AB, Canada (cmarion3@uwo.ca, gosinski@uwo.ca)

Introduction: In preparation for the expanded robotic exploration of the Moon and Mars and the near-term return of humans to the lunar surface, our group has been conducting a campaign of analogue missions at terrestrial analogue sites around the world. Terrestrial analogues are places on Earth that approximate, in some respect, the geological, environmental and putative biological conditions and/or setting(s) on a particular planetary body, either at the present-day or sometime in the past [1]. In addition to enabling comparative planetology studies, terrestrial analogues allow for the development and testing of technologies, software and operations architectures, the training of personnel for future missions, and opportunities to engage and educate children and the general public. Analogue missions represent integrated, interdisciplinary field campaigns conducted in terrestrial analogue environments and provide a critical pathway in preparing to return to the Moon.

In this contribution, we provide an overview of the most recent CanMoon analogue mission that sought to simulate a robotic lunar sample return mission. This builds upon the CanMars Mars Sample Return analogue mission conducted in 2015 and 2016 [2–8].

Mission Overview: The CanMoon lunar sample return analogue mission was funded by the Canadian Space Agency (CSA) as part of its Lunar Exploration Analogue Deployment (LEAD) through a contract and grants to the University of Western Ontario (Western) and the University of Winnipeg. It was conducted over 2 weeks on the volcanic island of Lanzarote, Spain, in the Canary Island group, in August of 2019. Lanzarote hosts several geologically young lava flows that date to the 1700’s [9]. Two field sites were used: “Janubio” in week 1 and “Nuevo Ortiz” in week 2. CanMoon 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 scientific objectives of CanMoon were:

1) Determine the geochemical and lithological diversity of rocks in the landing site region;
2) Identify and collect the best samples for radiometric age dating;
3) Identify and collect the most volatile-rich rocks;
4) Explore for crustal and mantle xenoliths in the landing site region.

The operations objectives of CanMoon were to:

1) Explore the mission control operations structure for 24/7 lunar science operations;
2) Compare the accuracy of selecting lunar samples remotely from mission control versus a traditional human field party;
3) Test the efficiency of remote science operations including the use of pre-planned strategic traverses;
4) Evaluate the utility of real-time automated data analysis approaches for lunar missions;
5) Test how Virtual Reality (VR) technology can be used to help with enhancing the situational awareness in mission control.

Pre-mission Characterization and Traverse Planning: Prior to the start of the CanMoon mission, the only information made available to the Mission Control team was a set of remote sensing datasets selected to be analogous to datasets currently available for studying the lunar surface. This remote sensing data was used to create detailed traverse plans for both of the two field sites (see Morse et al. [10] for overview).

Mission Operations: The CanMoon Mission Control was located at Western in London, Canada. Personnel were divided between the *Planning Team* – responsible for composing and sending specific commands to the analogue rover (see Newman et al. [11] for overview) – and a *Science Team*. The Science Team was broken down into two sub teams, a *Tactical Science Team* responsible for targeting the individual instruments onboard the analogue rover (see Morse et al. [12] for overview), and a *Science Interpretation* team responsible for analyzing the constant flow of data being generated and downlinked from the rover platform (see Hill et al. [13] for overview).

Science Instrumentation: The CanMoon analogue rover platform included a suite of scientific instruments for analyzing the composition and morphology of site. The instrument suite included 3 different visible light cameras: a 360˚ panoramic camera represented by a Cannon T3i DSLR camera mounted on a static tripod, a zoom camera represented by the same cannon DSLR with the addition of a telephoto lens, and an analogue remote micro imager for detailed close up images represented by an iPhone equipped with a specialized macro lens. In addition to the three still image cameras, a real time color video camera was included in the instrument suite with the intention of providing near real time streaming video during rover traverses or while the rover was stationary. The camera used was a Reolink Keen live streaming camera mounted to the main tripod on the analogue rover body.

Three compositional instruments were included in the analogue mission scenario including a Laser-Induced Breakdown Spectrometer (LIBS), a Visual-Near Infrared (VIS-NIR) spectrometer, and a RAMAN Spectrometer. The LIBS was represented by a Sci Aps Z500 GEOChem unit that used a 1064 nm, 5mJ laser with a 50 µm diameter beam. The VIR-NIR spectrometer was represented by an ASD FieldSpec4 which collected spectral acquisitions from 350 to 2500 nm and had a spectral resolution of between 3 and 10 nm. The RAMAN spectrometer was represented by a DeltaNu Rockhound RAMAN which used a 785 nm laser with ~ 8cm^{-1} resolution.

The instrument suite also included four analogue sampling devices. A scoop tool was included for collecting loose regolith samples or a collection of small unconsolidated rock samples. A sieve option was included should the Tactical Science team decide to sample only small rock fragments from a loose unconsolidated surface. A claw tool was included for collecting small rock samples from hard surfaces where the scoop or sieve would be ineffective. Finally a chisel tool, an analogue representation of a percussive drill was included.

Mission Results: The first in-situ images returned by the rover at the field site dubbed "Janubio" revealed the presences of numerous boulders that were below the size detectable from pre-mission remote sensing images, but large enough to be significant obstacles to rover traverses. As a result, the rover was only able to traverse ~100 m rather than completing the pre-planned 650–720 m traverse [8]. Rover data quickly led the team to identify numerous vesicular, xenolith-bearing, glassy basalts at the landing site. The Science Team were able to collect 2 representative samples from this site which met all four main science objectives. For additional detail on the analysis of this site and the collected samples see Hill et al. [13].

Week 2. The second site ("Nuevo Ortiz") had far fewer obstacles allowing for a greater amount of rover movement (~300 m) mostly along a portion of the pre-planned traverse path. Five samples were collected from this site that collectively met all 4 of the main science objectives (see Hill et al. [13]).

Use of VR and Immersive Technologies: Oculus Rift Virtual Reality (VR) headsets were employed to provide members of the Science and Planning teams with a more immersive view of the analogue terrain. The two mission datasets integrated into the immersive VR system were the panoramic images obtained by the rover and a digital terrain model generated using pre-mission remote sensing data [see 10]. The models were uploaded to a 3D visualization website to provide easy fast access to the whole crew. Post mission field observations showed the VR to be an incredibly advantageous tool for orientation and interpretation of the terrain.

Shift Handovers: To address the 24/7 real-time lunar mission operations objective, shift work was scheduled and shift handover documentation and procedures were developed for the Mission Control crew (see Marion et al. [14] for overview). Week 1 Mission Control worked on a single 10 hour shift for training purposes. During Week 2, operations were divided into two separate but overlapping shifts of 5.5 hours. Two types of handovers were explored: a document-only and an in-person handover.

Conclusions: Overall lessons learned from CanMoon include the need for dynamic collaboration between science and planning teams, the benefit of walkabout traverse strategies, the advantages of stand-off versus contact instruments, the application of autonomous geological targeting, and the benefit of VR technology for enhancing the situational awareness in mission control.

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