DEFINING ANALYTICAL STRATEGIES FOR MARS SAMPLE RETURN WITH THE CanMars ANALOGUE MISSION. H. M. Sapers1,2,†, G. R. Osinski1,2,†, M. Battler4,†, R. Francis1,2, C. Caudill1,2,†, A. Pontefract1,4, and L. L Tornabene1,†. Centre for Planetary Science and Exploration/ Dept. of Earth Sciences, University of Western Ontario, 2Jet Propulsion Laboratory, California Institute of Technology, 3Dept. of Physics and Astronomy, University of Western Ontario 4Dept. of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, †Current affiliation: Div. of Geological and Planetary Sciences, California Institute of Technology/ Dept. of Earth Sciences, University of Southern California/ Planetary Chemistry & Astrobiology Group, Jet Propulsion Laboratory (gosinski@uwo.ca)

Introduction: One of the highest priority goals for the international planetary science community is Mars Sample Return (MSR) [1, 2]. The top three science objectives identified by MEPAG [2] are:

1) Identify habitable environments;
2) Assess the potential for preservation;
3) Determination of biosignatures

Successful selection of a habitable environment, acquisition of samples with a high probability of biosignature preservation, and detection and characterization of putative Martian biosignatures, will require a rigorous integrated analytical pipeline across instrumental platforms and observational scales. Analogue environments and full-scale analogue missions provide context for implementation and assessment of such technologies and methodologies.

In November 2015 and 2016, in partnership with the Canadian Space Agency (CSA) and MacDonald Dettwiler and Associates Ltd. (MDA), the Centre for Planetary Science and Exploration (CPSX) at the University of Western Ontario designed and conducted one of the highest fidelity Mars Sample Return (MSR) mission simulations to date (see [3] and [4] for overviews of the 2015 and 2016 deployments). The 2015 and 2016 “CanMars” missions (#CanMars on Twitter) used a suite of integrated instruments onboard the CSA Mars Exploration Science Rover (MESR), built by MDA. The deployment site, near Hanksville, Utah, in the area known informally as Kissing Camel Ridge, was chosen based on an extensive assessment of its suitability from both scientific and engineering perspectives. The landing site region consists of a variety of clastic and chemical precipitates comprising potential samples corresponding to the three highest priority MSR sample suites: sedimentary, hydrothermal, and low temperature [2].

Defining Science Analysis Needs for MSR: The primary focus for this aspect of the CanMars analogue mission is the science analysis needs for MSR, the development of systematic protocols to be performed on samples selected and returned from a MSR mission, and an analytical pipeline specifically designed to achieve the 3 main MSR science Objectives. We assume that the Mars 2020 (M2020) will commence the MSR mission sequence with adaptive caching of samples. The overall Aim, broken into 4 goals (below) is to determine the optimum approaches (methodology) and requirements (instrumentation) during deployment (science operations and sample acquisition on Mars) and subsequent laboratory investigations (after the sample has been returned to a sample receiving facility on Earth). The 4 main goals are to:

1) Determine the optimal approach to using the M2020 instruments to select a sample site and acquire a sample. This goal seeks to understand the process by which remote imaging, remote spectroscopy, and contact instruments of the types available on M2020 allow identification and triage of potential sampling sites, and further, understand the dependencies and redundancies between those types of scientific data. This was done by integrating measurements at decreasing scales of observation. The instrument suite used for the analogue mission included a number of technologies that when combined complement and simulate the planned M2020 payload instruments (see [4]). In the field, we used a 532 nm Delta Nu Rockhound in addition to a handheld ASD FieldSpec Pro spectrometer to collect VIS-NIR (0.35-2.5 μm) spectra to complement the Raman analyses. A field LIBS with a 500 μm beam diameter was used to acquire quantitative in situ elemental compositions complemented by a field XRF spectrometer. Three camera systems were integrated into MESR including PanCam, a high-resolution, multispectral, stereoscopic mast-mounted camera, ZoomCam and TEMMI, a three dimensional multispectral microscopic imager. This field phase of the analogue mission is complete (see [4] and references therein). Laboratory-based methods are currently being used to assess the fidelity of field analyses.

2) Determine what measurements need to be taken with the M2020 instruments in order to adequately characterize the sample in preparation for eventual Earth-based analysis including potential sample prioritization and down selection. This goal investigates the extent to which in-situ remote and contact science can support eventual Earthbound analysis of samples, and the degree to which characterization of the sample site is possible and necessary with a M2020-like instrument suite. Mars 2020 has remote and contact instru-
ments, but very little for in-situ analysis of the sample itself. Analyses are now in the process of being repeated for both the full sample suite and down selected sample suite to identify the capability of M2020 instruments to adequately down sample.

Additional Raman analyses of returned field samples is being carried out at multiple institutions that will provide quantitative ground truth measurements at additional wavelengths. A fully characterized and field tested contact Raman sapphire ballprobe lens, developed for liquid, solid, and powdered samples will be utilized to mitigate the optical variability challenges of Raman spectroscopy.

Bulk chemistry and trace element concentration is being measured via inductively coupled plasma mass spectrometry (ICP-MS). XRD and ICP-MS will serve to ground truth the mineralogy and chemistry determined in situ by the LIBS, Raman, and XRF field instruments. Powder XRD is being used to confirm mineralogy assignments established with TEMMI, Raman measurements and XRF with bulk power XRD analysis conducted on a Rigaku Powder diffractometer and µ-XRD on a Bruker D8 Discover microdiffactometer. The Bruker M4 Micro-XRF will produce elemental maps on rough sample surfaces to spatial resolution of 25 um providing a laboratory reference for PIXEL-simulated field data.

3) Determine the extent that autonomous geological feature detection be used to identify potential sampling sites faster. The science team will make use of advanced image analysis techniques, which have recently been developed and tested for the automated interpretation of geological scenes. The team will test their utility in the analogue terrain, assess their value to the science team, and quantify their suitability for guiding M2020-like instruments as inputs to autonomous target selection, with an aim to speeding the progress of exploration tasks and reducing command cycles.

During the analogue mission an Autonomous Geochemical Instrument Reconnaissance (AGIR) experiment was run using returned imagery. Each suitable outcrop and terrain image returned by the field team was subjected to autonomous scene classification (described in [5] and [6]). These tools were used to produce automatically-generated maps of geological materials in each scene. Maps were provided to the remote science team as a data analysis and scene interpolation tool; their use by and utility to the science team will be assessed over the course of the deployment. In addition, in post-deployment experiments, the maps are being used to perform autonomous instrument targeting simulation experiments, wherein locations for narrow-field instrument observations (such as SuperCam LIBS/Raman) will be selected by a computer program using the geological scene classification data. These experiments will be used to quantify the performance of MDA and TextureCam (on real field imagery of an analogue terrain as acquired during robotic operations) as inputs to autonomous targeting software. Such software is currently in use on the Mars Science Laboratory mission [7], using an edge-detection system as the input [8], but enhancements using advanced geological scene classifiers are highly desirable. In addition to verifying the accuracy of the geological scene classification, the specific targets selected by the computer algorithm will be compared to those chosen by the science team in the Utah deployment on the same images, allowing an assessment of the algorithms’ overall suitability as a basis for autonomous instrument targeting.

4) Determine how best to optimize the detection of organic molecules and other potential biosignatures. In addition to the ground-truthing of field in situ techniques conducted in goal 2, subsequence high-resolution analyses are now being performed on ‘returned’ samples. These analyses utilize Earth-based techniques that cannot, as of yet, be modified for flight. Mineralogical, organic, and elemental information collected in Goal 2 will be used to select high priority (i.e., biologically interesting) samples for further high-resolution analyses. The mineralogical identification of field samples will further be refined with Micro-XRD of discrete mineral grains, conducted on areas as small as 50–500 µm and integrated with a microscope-camera system, will provide a structural control on mineralogy at a sub-mm scale that will supplement high-resolution spectroscopic analyses including light microscopy, microscope-based Fourier Transform Infrared spectroscopy, confocal Raman spectroscopy and electron-beam based microscopy analyses.

Biological investigations involving high-resolution secondary electron imaging of fixed samples in addition to nucleic acid extraction and genomic analyses will correlate potential geochemical biosignatures and organic molecule detection with microbial colonization.