OVERVIEW OF THE 3-U MANITOBASAT-1 CUBESAT PAYLOAD TO STUDY THE EFFECTS OF SPACE WEATHERING ON GEOLOGICAL SAMPLES.

S. A. Connell[1*], E. A. Cloutis[1], D. M. Applin[1], N. N. Turenne[1], P. Mann[1], M. Ramirez[1], C. Kiddell[1], A. E. Parkinson[1], K. Kubanek[1], J.C. Kuik[1], E. Stanish[1], P. Ferguson[2], M. Driedger[2], J. Campos[2], V. Platero[2], and H. Umar-Lawal[2]; [1]Department of Geography, University of Winnipeg, 515 Portage Avenue, Winnipeg, Manitoba, R3B 2E9, Canada; [2]Faculty of Engineering, University of Manitoba, 66 Chancellors Cir, Winnipeg, Manitoba, R3T 5V6, Canada; [*]connell-s@webmail.uwinnipeg.ca.

Introduction: Space weathering is the modification of materials that takes place in space over a long period of time [1]. Lunar samples, meteorites, and other returned materials have provided some insight into our understanding of space weathering processes [1]. Specific effects are dependent on the materials and heliocentric distances. For example, hydrous vs. anhydrous minerals, near-Earth vs. main belt asteroids, or S-type vs. C-type asteroids [1]. As such, there is the need to continue research on the products of space weathering [1]. Understanding space weathering processes on asteroids is important because it could provide information that better links meteorite and specific asteroids [2].

A team of student engineers from the Space Technologies and Advanced Research Laboratory (STARLab), at the University of Manitoba, are designing and building the 3-U CubeSat that will be launched into near-Earth orbit sometime in 2020-2021. A total of 39 meteorites and airless body analogue material candidates were selected for the 3-U ManitobaSat-1 CubeSat payload (Table 1). The payload is being fabricated at the University of Winnipeg's Centre for Terrestrial and Planetary Exploration (C-TAPE). A maximum of 24 samples that have been vacuum sintered and passed testing will make it onto the CubeSat for launch. As per mission requirements, the payload shall include a minimum of 10 geological samples in order to acquire sufficient scientific data to meet the mission's science goal.

The science goal is to study the effects of space weathering on planetary surfaces by exposing meteorites, minerals, and simulants to the space environment and observing their visible spectral reflectance properties. This experiment will lead to a better understanding of the spectral changes expected to occur on the surfaces of airless bodies (Moon and asteroids) in response to space weathering. The samples will be exposed to solar wind irradiation, some cosmic rays, and vacuum desiccation. The samples will also be exposed to micrometeorite bombardment and thermal cycling, as the satellite moves in and out of Earth's shadow. The CubeSat will acquire spectral reflectance data of the samples using commercial RGB cameras to see if any spectral changes are exhibited over the course of the ~1 year mission and will also monitor illumination exposure conditions with a sundial (gnomon) to allow corrections for viewing geometries.

Table 1: The following samples are candidates for launch.

Sample ID	Sample Type	Relevance
Chergach-VR	H chondrite	Asteroid
Mbale-VR	L chondrite	Asteroid
Murchison MS	CM carbonaceous chondrite	Asteroid
Tatahouine-VR	Diogenite	Asteroid
MET01	Iron meteorite	Asteroid
NWA 7059	Ureilite	Asteroid
NWA 974	E chondrite	Asteroid
OLV003	Olivine	Lunar/asteroid
NWA 11444	Lunar highland	Lunar
BAS600	Lunar mare simulant	Lunar
PYX023	Pyroxene	Lunar/asteroid
Admire olivine	Pallasitic olivine	Asteroid
CA-4	Oil shale	Asteroid
TRO203	Troilite	Asteroid
OOH003	Goethite	Asteroid
I-OBR-007	Obsidian	Lunar
MET01+PYX023	Mesosiderite simulant	Asteroid
Chelyabinsk-VR	Ordinary chondrite	Asteroid
I-MID-001	Pillow basalt w/ glass	Lunar
Allende-VR	CV carbonaceous chondrite	Asteroid
NWA801	CR carbonaceous chondrite	Asteroid
SAP105	Saponite	Asteroid
GRP102	Graphite	Asteroid
CRB417	Carbonate	Asteroid
CRB413	Carbonate	Asteroid
ALB101	Albertite	Asteroid
GIL101	Gilsonite	Asteroid
SHU102	Shungite	Asteroid

The production of samples for this project replicates the methods used for some of the Mars2020 standards, which are at a high technology readiness level. Most importantly, this is the first space weathering experiment done with geological samples in a space environment. Sample preparation was done at

CIRIMAT, which is the same establishment that produced space-qualified pellets for SuperCam. Sample preparation details are outlined in Turenne et. al. [3] at this conference.

Payload Overview: The CubeSat will include 24 geological samples clamped down onto the sample plate, including three Lucideon and Avian standards: Aluwhite 98, grey33, and cyan (large variation in red, green, blue values). All samples have been analyzed at <45 µm particle size and as vacuum sintered pellets, by X-ray Diffraction (XRD), Raman spectroscopy, and Visible and near-infrared (VNIR) reflectance spectroscopy [3]. All sample chemical compositions are known via bulk X-Ray Fluorescence (XRF) to detect major and minor elements [3].

CIRIMAT vacuum sintered 10 mm diameter by 2 mm thick pellets, which was performed at low atmospheric pressure and at temperatures suitable for sintering but not melting the sample, to ensure structural stability of the samples to remove any volatiles so that collected volatile condensable material (CVCM) and total mass loss (TML) risks are low [3]. Graphite coating used in the sintering process, was removed from both sides and edges of the samples to avoid unwanted spectral contributions [3].

Several tests have and will be performed on the sintered pellets by C-TAPE, such as friction testing [3], and measurements for pellet diameter and thickness to ensure the pellets fit within the stipulated parameters of the sample plate. The samples will also undergo vibration testing by Magellan Aerospace, and thermal-vacuum (TVAC) testing performed by STARLab.

Discussion: The samples were sintered to ensure that they are structurally resilient to survive launch and operations. Current testing and results have shown that likely due to sample compositions, some of the samples did not survive the vacuum sintering process or vibration testing, such as organics and some clay minerals. During the vacuum sintering process, there was slight alteration of a few of the sintered pellets as shown by Raman and XRD analysis [3]. This is likely due to the rock samples containing several mineral types with different melting temperatures making it difficult to determine their appropriate melting temperatures.

As shown in Table 1, each sample was selected for possible inclusion in the payload based on its relevance to the Moon and/or asteroids.

Sample testing and verification are imperative as the success of the mission depends on the resilience of the pellets to stay secure during launch and operations. Any failure of the samples during launch could cause concern for the astronauts in the International Space Station (ISS) (e.g., respirable dust), and will not provide sufficient scientific data on the effects of space weathering. All sample compositions for flight pellets and their candidates will be known; vibration testing and TVAC testing will also be performed to ensure that CVCM and TML risks are low, as sample outgassing has been identified as a potential hazard; however, is considered low risk by the science team, as the sintering process involves elevated temperatures and hence devolatilization.

OSIRIS-Rex and HAYBUSA-2 are active sample return missions that will bring back material from the surfaces of C-group asteroids and will allow direct comparison to the results found by the ManitobaSat-1 mission [4].

Conclusions and future work: This study will acquire space weathering results after the spacecraft has launched. The CubeSat will first be launched to the ISS where the astronauts on board will deploy the CubeSat into Earth's low orbit. This study will enhance our understanding of space weathering processes on airless planetary bodies. Not only will this mission execute the first space weathering experiment with geological samples in a space environment to provide valuable scientific data, but it also allows for the exploration of new technologies to emerge that can prove to be more streamlined and dependable for small space programs beneficial to the engineering industry [5], thus, allowing science to take advantage of space technology innovation.

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