Basic Characterisation of Returned Mars Samples under Containment L. F. Adam, J. M. C. Holt, J. C. Bridges, *Space Park Leicester, School of Physics and Astronomy, University of Leicester, UK (lfa7@leicester.ac.uk)*.

Introduction: All Mars material retrieved by a Mars Sample Return (MSR) mission must be kept under stringent containment and contamination control until assessed safe for release to the wider community. This poses significant challenges to the Basic Characterisation (BC) of samples that will have to be carried out in this environment [1]. We are investigating BC of returned Mars2020 samples using a Double Walled Isolator (DWI), a viable containment solution for MSR [2]. Specifically, we are investigating visible light optical characterisation of samples inside a DWI or an Instrument Box with the aim of informing early geological classification.

Basic Characterisation: Basic Characterisation is the initial phase of Mars Sample Return analysis, performed on each sample and consisting of passive and non-invasive measurements of their physical characteristics. Visible light imaging is one of the primary investigative methods. Sample properties to be measured are sample shape, surface topography, reflectance, and colour. These data, combined with rover data, enable early analysis of the lithology, petrology, and mineralogy; this informs the sample catalogue and the science priorities of each sample for the Preliminary Examination process. [1]

Double Walled Isolator: A DWI is a controlled pristine environment for BC and PE operations within containment. With ESA and Thales Alenia Space UK, Leicester has designed, developed, built and demonstrated a DWI breadboard (BB). DWI is an ultra-clean, class III bio-safety cabinet offering BSL-4 containment and supporting a wide variety of analytical techniques and their requisite instrumentation. The Mars Science Planning Group workshop 2 (pre-decisional) found that the DWI BB demonstrates the feasibility of cabinet isolation as the primary contamination control method [3]. DWI is designed to be operated in a BSL-4 style cabinet room (likely a UDF ISO 5) An Interface Flange (IF) allows scientific instruments (e.g. SEM, optical instruments, spectrometers or sterilisation equipment) access to the working volume; with larger instruments partially outside the DWI while the IF seal maintains double seal isolation. An industry standard Rapid Transfer Port enables contained safe transfer of samples and smaller equipment in and out of DWI [4].

Instrument Box: The Instrument Box's purpose is to enable co-location of a variety of instrumentation to perform measurements on Mars samples inside a smaller, flexible, and mobile volume compared to a full Double Walled Isolator, while maintaining containment to prevent forward or backward contamination [4]. Our design enables flexible swap in/out of different analytically themed IBs during "hot" running operations of the DWI due to a dual door design (between the IB and DWI). A BC imager may be accommodated in the instrument box and/or the DWI. [5]

Optical Imaging: We are investigating the science and instrument requirements for successful BC using optical imaging, and developing a prototype of an imager optimised for geological measurements. To that end we propose a set of minimum measurement goals to fulfil BC's aims:

TABLE 1: Proposed imaging requirements

Sample feature	**Minimum imaging requirement**
Loose dust	Resolving loose particles down to 10 μm on high contrast backgrounds (e.g. sample tube surface)
Grain size	Resolution of very fine sand grains (62.5 μm) and larger
Grain shape, layering, and diagenetic features	Resolving detail of fine sand scale (125 μm) and larger
Composition	Full visible colour

Therefore, an appropriate BC imager would consist of a non-contact zoom camera with variable optics capable of micrometry over scales from 10 mm down to 10 microns. This range would cover the features most important to BC. Higher and lower magnification could be covered by commercial microscopes and the DWI's utility cameras.

The DWI environment places constraints on the size, materials, and other properties of instrumentation used inside (such as imager working distance). For this reason we are investigating performing BC on samples inside the IB through a window, which allows much greater design freedom for imager customisation.

BC Imager Breadboard: A modular BC Imager Breadboard (BCIB) has been assembled to allow test imaging while remaining easy to modify. The BCIB enables testing of different configurations to optimise lenses, filters, sensors, and illumination geometries. Important optical characteristics of the breadboard, such as spatial resolution, are measured for each design iteration to quantify image quality changes.

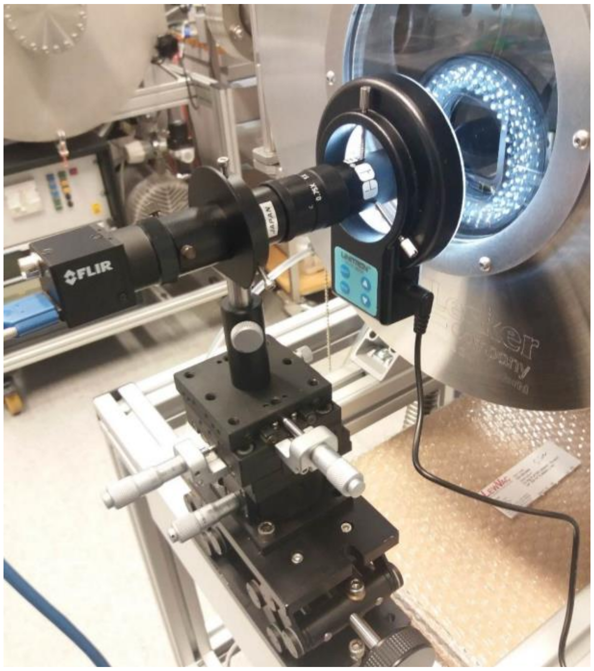

FIGURE 1: Basic Characterisation Imager Breadboard imaging into the Instrument Box

The first version of the BCIB incorporates a 2/3", 2448 × 2048 pixel, Sharp RJ32S3AA0DT sensor. A VZM 300i zoom lens provides 0.75× to 3× optical magnification with 62 mm working distance, 6–0.5 mm depth of field, and 15.3–2.8 mm diagonal field of view. The BCIB's spatial resolution and contrast has been characterised through Modulation Transfer Function (MTF) measurements derived from imaging a 1951 USAF resolution target. MTF ranges from 44 to 147 lp/mm in the imager's zoom range. Geometric distortion has been measured with a chessboard target, and is below one pixel at all magnifications. Brightness is calibrated continually through flat- and dark-field correction, and colour reproduction is calibrated using a Spectralon white balance target and X-rite ColorChecker chart.

A set of sample analogues representative of the Mars2020 science objectives and the expected breadth of sample features has been assembled. A subset of these have had drill cores prepared analogous to those of Perseverance. Several analogue Mars2020 sample tubes have also been manufactured to aid investigations of BC procedure. These are 60 mm long, 13.4 mm inner diameter, 14.1 mm outer diameter, Ti-6Al-4V alloy tubes. These analogues have been imaged using the BCIB to test optical sample characterisation and inform imager design, measurement procedure improvements, and device articulation. Similar to recent Mars rover cameras, focus stacking is required for most imaging to counteract insufficient depth of field. The images were used to characterise several of the sample analogue rocks, including a conglomerate, tuff, sandstone, and basalt. Our experimental findings demonstrate the analytical viability of BC of returned Mars samples using visible light imaging on a variety of Mars sample analogues. They also demonstrate that BCIB version 1 can meet the minimum BC requirements. Data gathered from this testing has been used to identify changes for an upgraded imager design.

Preliminary testing of BC through a window into the Instrument Box (see Fig. 1) has been carried out. The BC requirements were met and successful BC carried out, but the experiments highlighted the need to control vibration and minimise reflection from interior surfaces and the window. Different solutions , such as anti-reflection coatings, internal wall coating, window masks, and incorporation of the imager lens into the IB are being considered and implemented.

Imager Breadboard upgrade: Following the experimentation, a larger zoom range, and longer working distance were identified as desirable for BC imaging. A new lens arrangement has been designed and is currently being assembled. This includes an option of (currently two) lower lenses: a 1× and a 1.67×. The new imager optics will have an extended magnification range of 0.28× to 3.5× or 0.47× to 5.8×, and 190 or 110 mm working distance, respectively. This enables imaging the full width of a 10 mm core.

Future Work: The capabilities of the upgraded BCIB will be characterised to quantify the changes in image quality. Blind and remote BC trials of sample analogues, unknown to the tester, are also planned in Q2 2022, which will more reliably verify the imager design and procedure.

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