DWI: Double Walled Isolator, a Potential Solution for MSR & CAT V Sample Handling

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Introduction

A key challenges of Mars Sample Return is to develop the technologies that will enable the safe handling/movement, analysis and curation of Planetary Protection Category V, restricted samples from Mars [1]. A Mars Sample Receiving Facility (MSRF) has often been envisaged for this purpose [2, 3]. However, that is a major cost and challenge for a MSRF, both in its implementation and running cost, and potentially could hinder some of the more complex analyses of samples. Unlike current technologies and industry specific isolators (e.g. pharmaceutical or bio-safety cabinets), the planetary science community requires both isolation and containment along with analytical capability inside the cabinet. To meet this need, a new type of double walled isolator technology has been developed.

Double Walled Isolator (DWI)?

Working with Thales Alenia Space (UK) and the European Space Agency, the University of Leicester have developed a breadboard (prototype) isolator that facilitates testing, de-risking and end-user assessment of "commercial off the shelf" (COTS) technologies. In terms of enabling MSR science, the DWI breadboard (BB) is a flexible platform that can be configured to operate over a range of containment levels, pressure regimes, tested with analogue samples and instrumentation to inform engineering/procedural solutions to planetary protection requirements in the handling of future Mars material.

Figure 1: right; shows the DWI BB (Feb 2019) in a class 1000 aseptically managed cleanroom at the University of Leicester. Key features are identified (see description below) as is the direction of system gas flow in the unit.

In the context of DWI, we broadly define isolation as the means by which a sample (inside DWI) is separated from sources of contamination and by which a sample is kept separate from our biosphere. For example, particulate, organic or biological, that may exist in the terrestrial/laboratory environment, the construction and infrastructure of the isolator itself, instrumentation used for analysis and potentially other samples. Containment refers to the mechanism of isolation and the techniques that ensure that degree of isolation during sample transfer, manipulation and storage with a DWI.

Current testing with a geo-technics instrument, called SPLIT [4], and a dust generator that cuts a 10 mm diameter analogue rock core, has enabled demonstration of a negative pressure isolator environment under worst case "dirty" operations. In the case of this initial testing an analogue rock was spalled (using a percussive technique) and a commercial diamond circular saw used to cut a calcite rock core with the intention of generating small quantities of dust debris that can be tracked with UV light. While it is not expected that such extreme operations would ever be conducted inside a Mars DWI, it serves to provide a baseline to demonstrate cleanability, operations and recovery times.

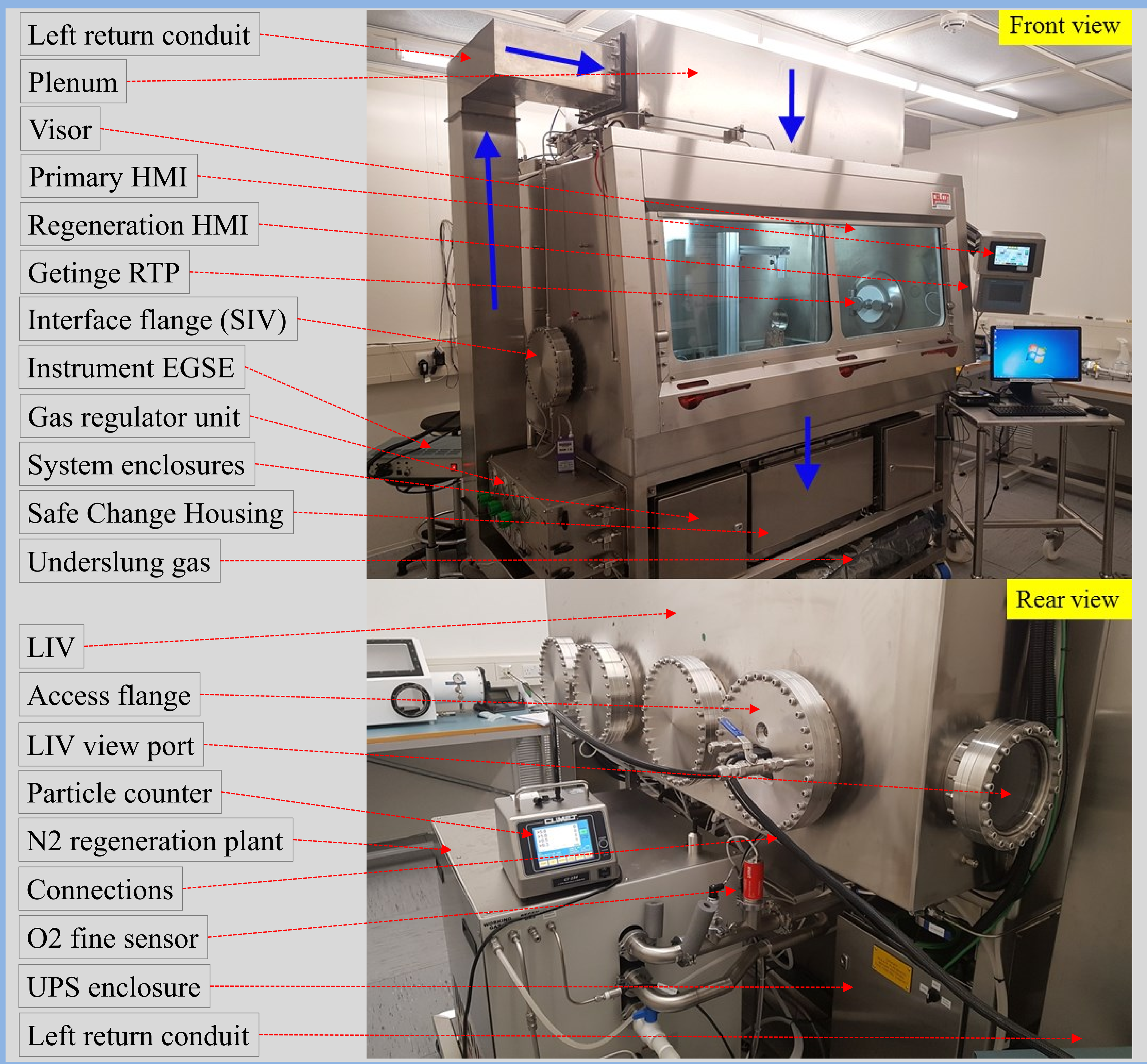

Figure 1. Double Walled Isolator Breadboard at the Class 1000 Aseptically Managed Planetary cleanroom of the University of Leicester. The DWI is c. 2.4 m wide & 1500 kg.

DWI Breadboard Technical Description

See Fig 1; designed to operate in an ISO 6 (or better) positive pressure clean-room environment, DWI is a static operation (movable on castors), 316 stainless steel construction (3 mm thick solid wall with welded seams) , with external dimensions of 2540 mm high, 2400 mm wide and a physical depth of 1300 mm (internal surface finish is better than <0.8 µRa with ground and polished radius edges and corners to support cleaning). The main interfaces to the building are; single and 3 phase power, Ethernet for control, gases (supply & venting), 2 bar cooling/heating water, smooth load-bearing floor and a stable temperature environment.

The Pressure regime is critical to operations, see Fig 2, where the main working volume is maintained at negative pressure (wrt atmosphere) and all interfaces pass through a double seal with an intermediate positive pressure of inert gas (LIV). In the event of a leak, the risk of forward contamination of the sample is mitigated because only inert gas (pure argon in the DWI BB) can pass into the working volume and the pressure difference maintains isolation in terms of backward contamination. In the event of power failure, the DWI BB is equipped with a battery back up UPS that will maintain the negative pressure and underslung gas bottles permit stand-alone operation in the event that a DWI needs to be moved while containing a sample.

The DWI BB is leak decay tested to an ISO 14644 class 1 standard where preliminary tests have demonstrated 25.3 and 16.9 Pa/hr for the isolator working volume and LIV respectively (NB: Class 1 limit is 51 Pa/hr). Operating at -250 Pa of 99.9998% nitrogen (BB range permits -1000 Pa), two fans in the plenum push gas across the primary HEPA filter, providing variable velocity, uni-directional flow (UDF) over the working area, which accommodates a sample and analytical instruments designed to work in the DWI. Gas is recirculated through a secondary H14 filter in the lower safe-change housing (SCH) where system temperature is typically maintained between 18 to 22ºC +/- 1 degree and recycled through a nitrogen regeneration plant to remove oxygen and water vapour to <10 ppm (<1 ppm target); flow direction indicated by blue arrows in Fig 2.

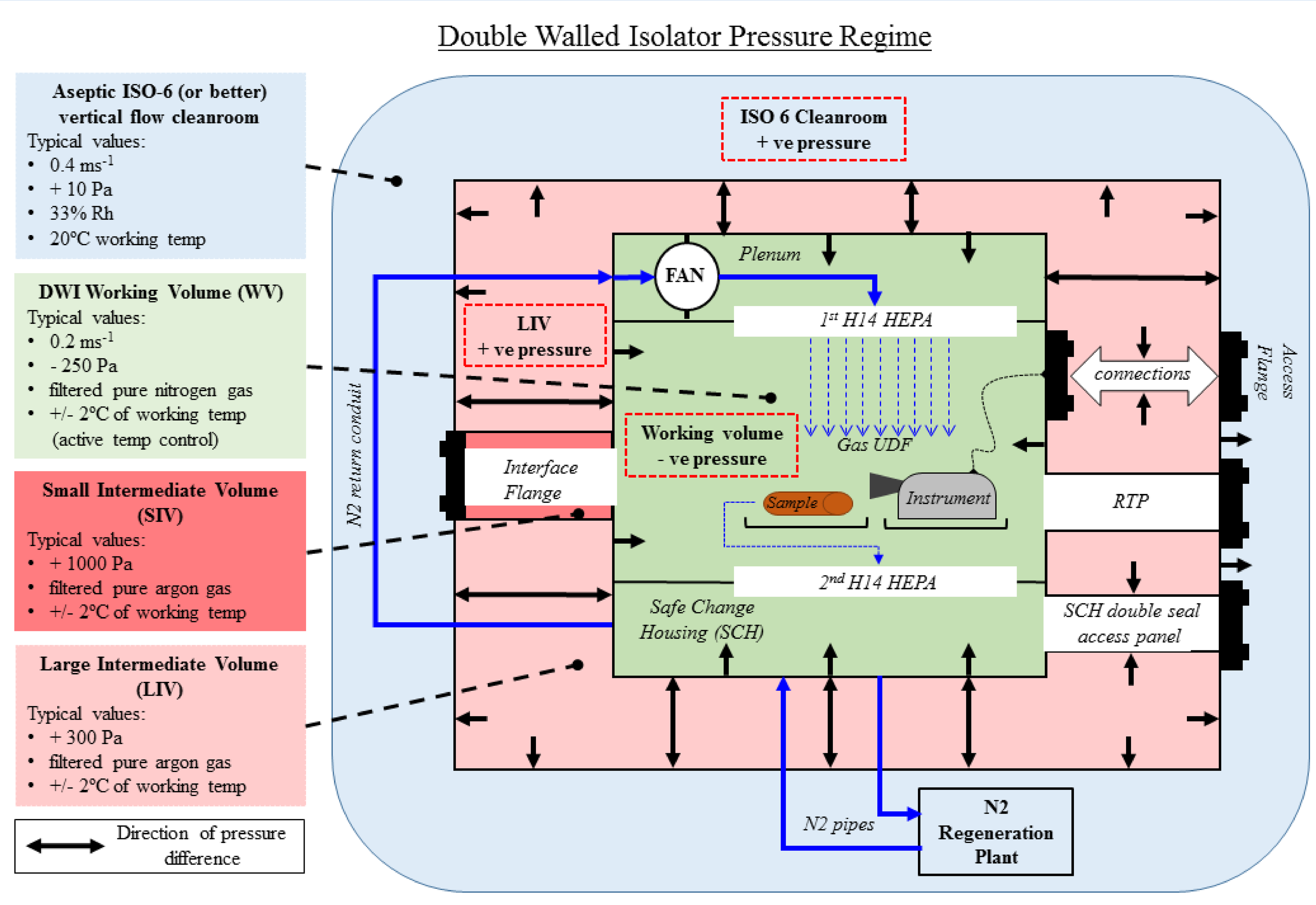

Figure 2. Double Walled Isolator Pressure Regime & System Overview.

DWI Breadboard Key Features

Fig 2 depicts the pressure technique by which isolation is maintained, but in terms of eventual user capability, several key enabling features are included in the breadboard to facilitate scientific analysis of a sample.

Operating Trays – this is a compromise approach between maintaining uniform gas flow for clean operations and the risk of loosing precious samples through a perforated base.

Access Flange – adopting con-flat flange technology from the field of vacuum engineering, the technique allows almost any interface (eg. low and high power electrical, signal, digital, gas, liquid, electromagnetic, windows) to pass through the high pressure LIV to the lower pressure WV).

Interface Flange - similar to the "Access Flange" this is designed to facilitate specialist instrument interfaces like an SEM, XRF or X-ray CT. A Small Intermediate Volume (SIV) is built into the flange and future iterations of the DWI will use this solution to accommodate an instrument box (that can be maintained at negative pressure) so that larger instruments can be partially accommodated (half in and half out of the DWI) without compromising isolation integrity. The interface could also be used to connect multiple DWI's with cascading cleanliness for specific operations, for example.

RTP – as with all Rapid Transfer Ports (RTP), the Getinge XO system is dependent on both the Alpha port (mounted in the wall of the DWI Breadboard with a compressed EPDM gasket body seal) and a Beta port on the transfer vessel. An interlock system prevents the operator from disconnecting the Beta vessel when the Alpha door is open and the new port provides rotation-free docking. One external operation actuates leak-tight transfer without rotation of the Beta part, thus maintaining lateral position of the sample tube/holder and reducing the risk of particle generation. The current DWI accommodates one RTP and it is anticipated that two ports could be used with a pass box that can be purged and sterilised.

Safe Change Housing – the SCH contains the secondary HEPA filter that pre-filters the closed loop circulating nitrogen gas before it is returned to the primary HEPA in the plenum. This housing and change process enables filter replacement without exposure of the operator to the filter or the inside of the isolator (using a double bag technique). Furthermore, a two filter approach is intended to extend the operating life of the primary and allow the safe removal and change of the secondary. The plenum fan that circulates gas may be stopped for some sample preparations.

Summary

Operating as a no-glove (remote manipulator) negative pressure isolator means that a seal failure will only pass inert argon (from the LIV or SIV) into the working volume and thus, maintain sample cleanliness and isolation. The DWI Breadboard should not be seen as a typical microbiological safety cabinet or BSL3/4 facility isolator but rather a flexible breadboard that can be configured to function over a range of containment levels; meeting the needs of a MSRF as analysis technology advances. Modularity, provided by the "Interface flange" and RTP could enable multiple DWI's to be connected to form a sample analysis chain with cascading cleanliness or built up to a "Super" DWI facility.

Acknowledgments:
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Conclusions

The current DWI BB is a flexible platform that has been used to demonstrate the pressure regime, described here, over a range of pressures. Analogue processing was conducted and controlled through LIV interfaces. Leak testing shows that the DWI system can operate as an ISO 14644 class 1 cabinet with particle cleanliness levels, comparable to an ISO 2 cleanroom (particulate range: 5.0, 1.0, 0.5 & 0.3 µm). DWI operations were also conducted under low oxygen and water content with values of 372 and 26 ppm respectively. Current testing has demonstrated a biologically clean facility with surface swabs returning no spore forming colonies.

In the next phase of development, the DWI BB will be combined with high fidelity instrument interfaces and the concept of a pass box with accommodation of analytical instruments, notably a high resolution microscope, will be tested. In terms of molecular cleanliness (inside the working volume), the DWI BB will be assessed for compatibility with MSR Tier 1 and 2 contamination requirements.

References: [1] COSPAR/IAU, COSPAR "Planetary Protection Policy (As amended)". 2011. [2] Committee on Planetary & Lunar Exploration, N. A. P, Washington, DC (2002). "The Quarantine and Certification of Martian Samples.". [3] . Beaty, D. W., et al. (2009). "Planning Considerations for a Mars Sample Receiving Facility: Summary & Interpretation of Three Design Studies." Astrobiology 9(8): 745-758. [4] Subsurface scientific exploration of extra-terrestrial environments (MINAR 5): analogue science, technology and education in the Boulby Mine, UK (2018) International Journal of Astrobiology; DOI: 10.1017/S1473550418000186