DOUBLE WALLED ISOLATOR TECHNOLOGY FOR MARS SAMPLE RETURN FACILITIES.

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Introduction: A key challenges of Mars Sample Return is to develop the technologies which will allow the safe handling/movement, analysis and curation of Planetary Protection Category V, restricted samples from Mars [1]. A 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 sample analyses. 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. Double walled isolation refers to an internal (where the sample is handled) negative pressure working environment *wrt* atmosphere of the cleanroom, with interfaces passing through a "double wall" that maintains an inert, intermediate positive pressure (*wrt* the positive pressure of the cleanroom).Thus, the primary function of a Double Walled Isolator (DWI) is to maintain separation between the sample and the external (Earth) environment. To address planetary protection requirements [2,3] we have developed a DWI Breadboard (BB) to demonstrate how COTS technology can be used to achieve containment and cleanliness.

Based on a high performance, commercially available single walled, class III isolator [2], the Leicester facility is a flexible BB that mimics different safety containment levels and pressure regimes to inform the detailed engineering design of a MSRF, all within the constraining requirements of planetary protection and the handling needs of Category V restricted materials [2, 3, 4]. A class III design means that an operator is separated from the 'work' by a physical gas tight barrier. Primary design features of the BB support an aseptic, low particle, vertical uni-directional flow (UDF), self-supporting, multiple gas type (argon and nitrogen), pressure tracking, temperature controlled, closed loop primary gas recirculation system with automatic ppm (O_2 & H_2O) regeneration capability and a power failsafe containment facility (pressure regime is maintained). This unique flexibility and its anticipated performance exceeds many isolator cabinets with a configurable interface that permits various scientific instruments to be added for sample analysis. Ongoing testing and sample trials with the DWI BB will demonstrate the principles and operation of a full DWI system; in order to reduce technological, operation and financial risk in the final design of a MSR receiving facility and its isolators.

Here we describe the DWI BB that has been developed at the University of Leicester with Thales Alenia Space and outline future development pathways.

DWI Breadboard Design: See Fig 1; designed to operate in an ISO 6 (or better) positive pressure cleanroom environment, DWI is a 1500 kg static operation (movable on castors), 316 stainless steel (3 mm thick solid wall with welded seams) construction, with external dimensions of 2540 mm high, 2400 mm wide and a physical depth of 1300 mm. The main interfaces to the building are; single and 3 phase power, ethernet for control, gases (supply & venting), 2 bar cooling water, smooth load-bearing floor and a stable temperature environment.

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), the working volume directs user variable velocity, UDF filtered gas from a primary H14 HEPA filter mounted in the upper plenum over the working area that accommodates a user sample (internal surface finish is better than <0.8 µRa with ground and polished radius edges and corners). Gas is recirculated through a secondary H14 filter in the lower safe-change housing where temperature is typically maintained between 18 to 22ºC +/- 1 degree and recycled through a nitrogen regeneration plant to remove oxygen and water vapor to <1 ppm.

In terms of a "double wall" there are two key features; a Large Intermediate Volume (LIV) and the Small Intermediate Volume (SIV, including the visor and IF flange seal) (Fig. 1), which are operated at +250 Pa of inert 99.998% argon (BB range permits +1000 Pa). The LIV is a sealed 316 stainless steel box welded to the rear wall of the main Isolator Working Volume. Its main function is the failsafe "access" of isolated interfaces (electrical, optical or fluidic) through a double seal, positive to negative pressure regime, such that external interaction and control of ancillary devices inside the DWI working volume is possible, via inner and outer "Access flanges" on the LIV walls. The SIV operates in conjunction with the LIV and supports the double seal integrity of the visor and "Interface Flange" (IF). Mounted on the left-hand side of the working volume, the IF flange enables future user interface to scientific instruments that maybe fully or partially accommodated inside DWI (eg. SEM, X-ray CT or sterilization equipment). Flange sealing is achieved with an oxygen-free annealed copper gasket and an inner EPDM O-ring. This configuration of the pressure regime, with different gasses, is such that the direction of a subsequent leak (very small leaks are inevitable) can be identified (particularly if a TOF spectrometer was incorporated in a future design). Furthermore, the positive pressure environment of the cleanroom adds a further layer of cleanliness in the event of a major failure of the LIV or SIV integrity.

Another key feature of the DWI BB is an externally operated, 190 mm Getinge Rapid Transfer Port (RTP) that enables samples to be moved in and out of the isolator via a special interlock door (leak-tight, non-rotation transfer).

Operations: Initial operation of the DWI BB requires extensive decontamination and cleaning of the internal surfaces to remove hydrocarbon, chemical, biological and particulate contamination from the manufacturing process. Particulate monitoring is achieved with a Climet CI-154 counter where typical post-cleaning measurements inside the working volume are zero across the 0.3, 0.5, 1.0 and 5.0 µm range. Larger particles >5 µm can be monitored at the top of the secondary HEPA filter during a “dirty” operation like sample preparation (eg. rock cutting). Initial results from cutting an analogue rock core (10 mm diameter) inside the DWI show that debris distribution is less than previously assumed. Biological contamination is currently monitored using the 3M PetriFilm surface culture swab system to establish typical spore counts (yeast, mould and *E.coli* as a human commensurate species) and this is correlated with *ATP swabs such that contamination can be easily and rapidly monitored when testing (*NB: only possible when the visor is open during test/maintenance). Monitoring of volatiles is possible during normal operations (visor closed) via 6 mm, valved Swagelok ports and universal thermal desorption (TD) tubes that are subsequently measured with a GCMS.

Modular Design: In common with standard isolator practice, adjacent compartments of a future DWI (including pass-boxes or instrument boxes, accessible by the IF flange or RTP, would be held at pressure differentials of ~100 Pa to prevent cross-over contamination between different samples. Furthermore, such compartments would likely be purged and decontaminated with processes such as vapor hydrogen peroxide. This level of flexibility in DWI design allows for modularity and the IF flange technology developed during the BB programme could enable modular connectivity between “standard” DWI’s with cascading levels of cleanliness in the sample analysis chain. Modular flexibility allows DWI assembly to be relatively simple or built up in to a “Super” DWI facility.

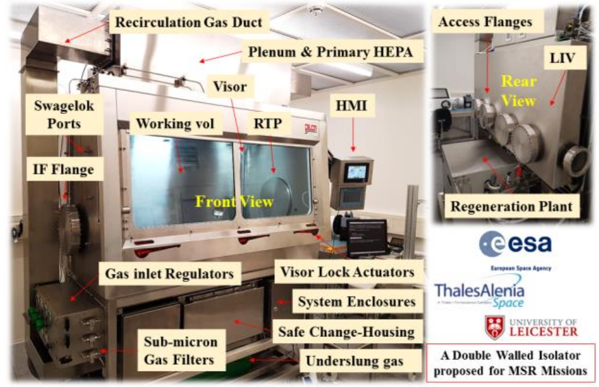

Figure 1. *Double Walled Isolator Breadboard at the Class 1000 Aseptically Managed Planetary cleanroom of the University of Leicester. The DWI is c. 2.4 m wide.*

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) in to 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. DWI instrument integration studies are underway and a future DWI variant, could service the wider scientific community when Mars or other high value planetary samples are returned and released. Similarly other sectors (eg. pre-clinical research, bio-tech, forensics, ice core or ancient DNA) could use an instrumented DWI.

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References: **[1]** COSPAR/IAU, COSPAR “Planetary Protection Policy (As amended)”. 2011 **[2]** Committee on Planetary and 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 and Interpretation of Three Design Studies." Astrobiology 9(8): 745-758. **[4]** J. C. Bridges and M. Guest, “Planetary Protection and Mars Sample Return,” Journal of Aerospace Engineering, vol. 225, no. 2, pp. 239-246, 2011. **[5]** Centers for Disease Control and Prevention 2nd edition 2000 “Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets”