PROOF OF CONCEPT OF A BIO-CONTAINMENT SYSTEM FOR MARS SAMPLE RETURN MISSION

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Introduction

In the frame of the Mars Sample Return Mission an important amount of Mars surface/subsurface samples are envisaged for return to Earth

To avoid any possible biological (Earth) contamination a bio-sealing barrier is needed capable to duly contain the samples throughout the return and the re-entry phases. The most stringent requirement:

the bio-container shall ensure that the probability that a single unsterilized particle of > 10 nanometers in diameter is released into the terrestrial biosphere shall be < $10^{-6}$

Triple redundancy, or better, shall be used for the functional elements affecting the containment
Characterizing features:

- Two containment vessels
- Chain Breaking Lid (to support Mars chain breaking)
- Two lids (each equipped with gasketing system)
- Monitoring system (pressurization, pressure and temperature monitoring)
Vessels

Outer vessel: in titanium also to allow ‘wireless’ power and data transfer (D= 360 mm)

Inner vessel: in aluminum (D= 260 mm)

Designed for re-entry loads

No feed throughs utilized
Biocontainer System Configuration

Lids main features

- Lids equipped with three gaskets sealing
- Gaskets of different material and working principle to limit common cause failures
- Locking mechanism

Schematics of Lid (both internal and external)

Schematics of seal (gasket shown are schematics only)
Biocontainer System Configuration

Lids closure mechanism

- Three clamps for final stroke and tightening
- Management of the lids (with different size)
- Actuator based on Motor-Reduced
- Ball screw for output stage

Schematics of Lid (both internal and external)
Main features

- Made by two detachable halves
- Separation interface sterilized during integration
- Outer rims sterilized while in operation by thermal wave

Biocontainer System Configuration

Configuration of CBL (Chain Breaking Lid)
Main requirements:

*Power/Data transfer* through a solid metallic wall

*Transfer* power from the *external* environment *inside the metallic container* sufficient to keep charged the internal energy storage system (some tens of milliwatts, minutes per day)

*Transfer* data from the *internal* sensors and devices to the *external environment* (hundreds bit/s bandwidth)

*Manage* the internal sensors and actuator and operate the correct operations sequence

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**Schematics of the Biocontainer and location of the coupling transformers**
Main elements of the system:

- Coupling transformers
- Rectifier Regulator
- Power Storage
- Data Tx (OOK logic)
- Smart Logic Controller
- Voltage regulator, Voltage monitor, Bus monitor
- Motor and Hall sensors
- P-T sensors
For safety and reliability aspects, the monitoring system is presently foreseen in *triple redundancy*.

**Some General Issues on the Monitoring System**

- **Preliminary layout of the complete redounded system**
- **Schematics of the single pressurization device**

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**Preliminary layout of internal and external ‘wireless’ interfaces**

- Titanium shell
- External Coupling Interfaces (# 3) (schematics only)
- Internal Coupling Interfaces (# 3)
**Biocontainer parts**

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<th>Container test Lid BB</th>
<th>Lid BB</th>
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**Monitoring System**

- Pressurization device
- Wireless I/F
- Inner electronics
- Outer Electronic (for test purposes)
- Separatior Ti plate
Biocontainer BB parts

Location area for gaskets (I/F to lid)

Location area of wireless interface

Complete inner container
End Effector for lid closure

EE mounted on the positioner TE
For Lid closure

Biocontainer BB parts
Breadboards Models (wireless System)

- Coupling transformers (internal)
- External electronics
- Pressurizing system (Argon reservoir, Motor-puncher)
- Internal electronics
- "Separation wall (Ti)"
- "External" parts
- "Internal" parts
- P/T sensor type 1
- P/T sensor type 1
Some General Issues on the Monitoring System

Pressurization is achieved by perforating a miniaturized argon container so to create a pressure of some of hundreds of milli-bars. Dedicated mechanism shown in essence composed by the argon container, the perforating actuator and a position sensor

Basic transducers: digital P-T sensor from Honeywell (left), analogue P sensor from Kulite (right)
Measurement of the leak rate on the:
- Calibrated Hole
- Gaskets of the different types
- Vessel-Gasket combinations
Lid-Vessel closure by using the developed effector (with misalignments) with the different gaskets
‘Escaping of particles’ test (by using nanometers class particles e.g. d= 20 – 100 nm) through both calibrated hole and gaskets
CBL verification and rim sterilization
Pressure and temperature sensors characterization
Wireless I/F test for power transmission, data transmission, misalignment robustness
BB System integrated test
Testing of lid closure and preparation for leak testing
Breadboards – Testing Issues

Some issues on particle test (preliminary)
 APPROACH FOR BIO-CONTAINMENT PERFORMANCE PROJECTION

The starting point are the mathematical model developed (for gas and particles escape) and the specific leak tests for gas and particle. The following steps are covered:

- **Model verification – Gas leak rate calibration (using 9 \( \mu \)m calibrated hole)**
  - Model/True gas leak comparison for validation

- **Model calibration- Particle rate calibration through calibrated holes (9\( \mu \) and 20\( \mu \)m)**
  - Model/True particles leak comparison for validation

- **Gaskets characterization (using measured He data leak rate and measured particles leak)**
  - Viton gaskets
  - Silicon gaskets
  - Metal gaskets

- **Complete BCS simulation with 10 nm particle size and argon gas in the intermediate container**
Complete BCS simulation with 10 nm particle size and argon gas in the intermediate container

**Overall scheme:**

Type of motion: *molecular plus viscous* for gas, *molecular* for particles

**Note:** particles not with self locomotion, type of motion Brownian
Overview a possible configuration of complete Orbiting Sample Handling System
Conclusions

An important design and development activity is presently being concluded on the Bio-Containment system for the possible future Mars Sample Return Mission.

Several parts have been detail designed, manufactured and tested and the results so far achieved seems compatible with the overall objectives. Some more development is being planned.

The final key requirement related to ‘very low particle escape probability’ is coped with by making use of the test results achieved in terms of gas leak and particle escape rates and propagating them via a mathematical model of the complete bio-container.