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SpaceQ chamber: the environment simulator for planetary exploration instrumentation and research

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Abstract

This work describes the new SpaceQ (Space Qualification) chamber at Luleå University of Technology, Sweden, and its performance. This chamber is designed to operate instrumentation in representative space conditions (vacuum, Mars atmosphere, Earth stratosphere, lunar environment, etc.) and to validate their performance by acquiring real-time data in a simulated environment. It is also designed to test and qualify the behaviour of certain components when exposed to thermal vacuum, outgassing, baking, low temperatures and dry heat microbial reduction procedures. As an example of operation, we present the validation of the instrument HabitAbility Brines Irradiation Temperature (HABIT), that will be part of the ESA/IKI´s ExoMars 2020 mission.

1. Introduction

Over the last decade, multiple countries, space agencies and companies have demonstrated their interest on designing instrumentation for the exploration of the Moon, for orbiters around the Earth or for Mars exploration. However, these missions require hardware and scientific instruments that can operate under extreme conditions. To facilitate the design, testing and calibration phases of instrumentation for exploration we have designed the SpaceQ chamber. The purpose of this chamber is to test the behavior of certain components when exposed to space thermal and pressure changes. It is also devoted to recreating locally certain conditions of the Martian or Lunar surface for research purposes.

An specific application of this chamber is the recreation of the environmental conditions that will be experienced by the HABIT instrument of the ExoMars mission to Mars. One of the goals of this instrument is to observe the diurnal water cycle and its interaction with deliquescent salts [1].

The SpaceQ chamber can operate at temperatures (T) between -80°C to + 150 °C and pressures from ambient to < 10^{-5}mbar, allowing for injection of atmospheres of different gaseous composition, it is compatible with CO_2 which is the main constituent of the Martian atmosphere. The SpaceQ chamber (Figure 1) is a 30-cm edges (27000 cm^3 = 27 l) cubical stainless-steel chamber that includes two quartz window viewports, thermocouple feedthroughs, a port for a UV lamp that can irradiate inside under vacuum or Martian or Earth pressures, pirani gauges for pressure monitoring, gas inlets, ports for a rotary and a turbo molecular pump, connections of USB, DB25 to read the data from the instrumentation while being tested inside as well as ports for an infrared spectrometer. The chamber also has a working table that can be cooled down to -50°C using liquid nitrogen. An external, adapted, heating jacket is used to heat to a desired temperature, for outgassing, thermal vacuum cycle or other tests. Finally, the chamber also includes a relative humidity (RH) sensor that can work within the thermal range -70°C to +180°C, and the pressure range vacuum to 100bar. The specifications are summarized in Table 1.

Table 1: Specifications of the SpaceQ chamber.

Parameter	Characteristics
Chamber dimensions	30 cm x 30 cm x30cm
Operating temperature	-80°C to + 150 °C
Operating pressure	1000 mbar to < 10^{-5} mbar
Viewport	Fused silica quartz
UV lamp	115-400 nm
Data output	USB and DB 25
RH and Temperature	0-100% and -70°C to +180°C

Gas inlet	CO_2 and water
VNIR spectrometer	200-1100 nm

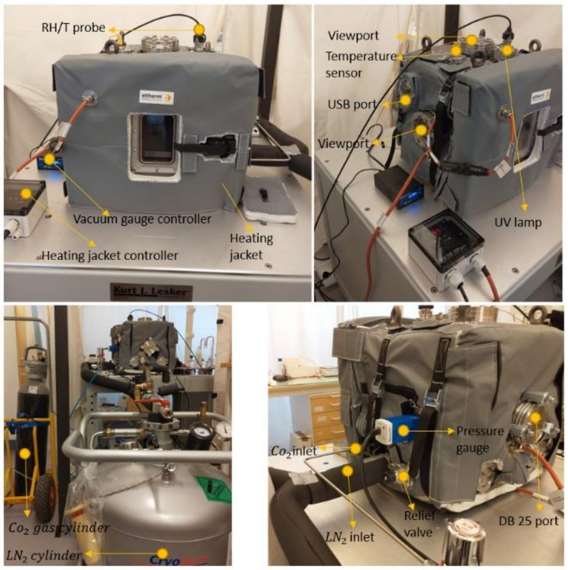

Figure 1: SpaceQ chamber fitted with external heating jacket

2. Preliminary tests and results

As an example, the SpaceQ has been used to test the response to depressurisation of certain products, like the salts+ super absorbent polymer (SAP) mixture that will be stored in HABIT. The mixture was subjected to depressurisation, and then it was left outdoors with a RH/T sensor to demonstrate that they can deliquesce again after the launch/cruise phases to Mars.

Additionally, the HABIT Engineering Model (EM) (Figure 2b) was placed inside the Space Q, to acquire measurements in real time including the Brine Observation Transition To Liquid Experiment (BOTTLE), the Ground Temperature Sensor (GTS) and the Ultra Violet Sensor (UVS) (Figure 2c and 2d). We have validated its nominal response during an accelerated cycle that mimics the launch, cruise and Mars surface operation in dry conditions. The chamber was first depressurized to vacuum, while maintaining certain level of frozen water as on the stratosphere of the Earth, the RH increased to 24% when this ice sublimated, then a CO_2 atmosphere at 6-8 mbar was injected (Figure 2a), and the RH decreased to 1,35%. The T of the mounting plate was reduced down to 240 K, while recording the instrument data.

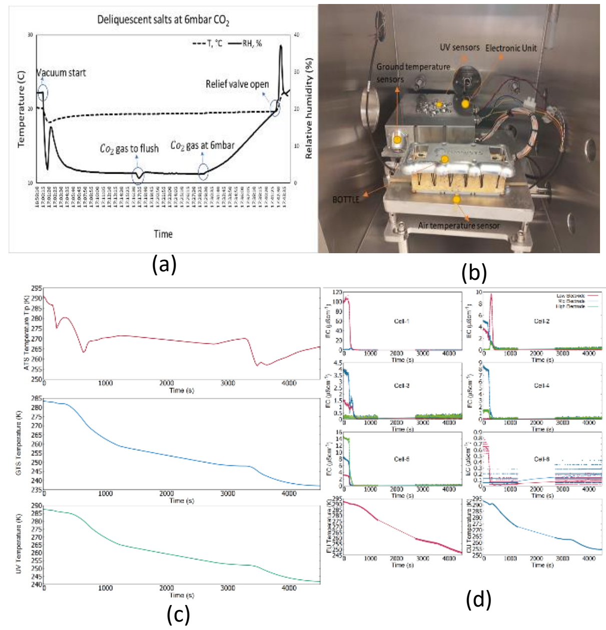

Figure 2: (a) RH% changes during vacuum and CO_2 injection (b) HABIT inside the SpaceQ (c) Retrieved T from ATS, GTS and UVS (d) Electrical conductivity from each cell of BOTTLE and hardware T.

3. Summary and Conclusions

The SpaceQ Chamber is a high "Quality", versatile, chamber for space exploration. A unique feature of this chamber is that it includes USB and DB25 connectors to acquire the instrumentation data while being tested inside. This facility can operate instrumentation in representative space conditions and validate their performance in a simulated environment. Additionally, the chamber can mimic the Martian diurnal/seasonal T and RH% variation within an atmosphere of CO_2 at Martian pressures. The initial HABIT tests of the launch, cruise and dry surface phases have been successful. In particular, it has shown the transient water absorption of $CaCl_2$ through a sudden increment in electrical conductivity. This new technological facility will be of interest for the Mars, Earth atmosphere and Moon exploration community, as well as for the future prototype design and validation of space exploration instruments.

References

[1] MARTIN-TORRES et al. Transient liquid water and water activity at Gale crater on Mars. Nature Geoscience 8, 357-361, 2015