A modular rack for shared thermo-fluid dynamics experiments in reduced gravity environment

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Abstract Parabolic flights represent an important tool for short space-related experiments under reduced gravity conditions. During the ballistic flight manoeuvres, the investigators have the possibility to operate their experiments, in a laboratory-like environment, where the level of gravity subjected to the experiments repetitively in a series of periods of reduced gravity, preceded and followed by periods of hypergravity. Aboard large aircraft, the duration of this phases varies from approximately 20 s for a 0g flight up to up to 32 s for a Martian g level. A parabolic flight rack able to host experiments concerning thermo-fluid dynamics, has been designed, realized and qualified during the ESA 66th Parabolic Flight Campaign. This microgravity research platform, is the first UK facility available for such investigations, providing a data acquisition system, cooling system and heating system compliant with Novespace requirements.

Keywords: Parabolic Flight, ESA, Microgravity, Thermo-fluid dynamics investigation

1. Introduction

Parabolic Flights (PFs) are one of the most common tool for performing short-duration reduced gravity investigations. Other microgravity platforms are available, with different extensions in the available gravity reduction: Drop Tower (4-9s), Sounding Rockets (6-12min), Satellites (<1 month) and the International Space Station (>1 month).
During orbital flights and atmospheric manoeuvres, the gravity level is only slightly reduced compared to gravity level on Earth ($9.37 m/s^2$ rather than $9.81 m/s^2$). What is taking place aboard, is a continued falling toward the Earth under the action of the gravity force. The result is a weightlessness perception, caused by the absence of reaction forces by the aircraft on the "parabonauts" and on experiments aboard. What is null during the freefall is the net *g* level, not the gravity field.

Parabolic Flights are used by many space agencies (ESA, CNES, DLR) to conduct space-related research and to prepare for human space flights. The main objective of scientific PF campaigns is to provide a laboratory environment (electrical power, vent ports, constant ambient temperature), with varying gravity level, where experimenter can change parameters during the flight, observe phenomena during constant gravity levels and during transitions from hyper to micro g and collect quantitative and qualitative data. This platform is frequently adopted to improve reliability and chance of success of experiments that need a validation test prior to long-duration reduced gravity investigations aboard of the International Space Station (ISS).

Investigations of thermo-fluid dynamics for space-related projects can achieve valuable on-ground experimental data but, given the complexity of the phenomena involved, correlations that can be extended to other conditions may not be valid, particularly when is the gravity being reduced.

Due to the demand of low gravity, ad-hoc experimentations, a modular parabolic flight experimental rack has been designed, realised and qualified during the ESA 66th Parabolic Flight Campaign from the University of Brighton, with the aim of hosting experiments quantitative and qualitative investigations. This facility, the first available for the UK scientific community, is the result of a long series of experimental activities carried out by this research team in passive two-phase systems on parabolic flights and sounding rockets:

- ESA, 58th Parabolic Flight Campaign May/June 2013;
- ESA, Spin Your Thesis, September 2013;
- ESA, 59th Parabolic Flight Campaign October 2013;
- ESA 60th Parabolic Flight Campaign, April 2014;
- ESA 61st Parabolic Flight Campaign, September 2014;
- ESA REXUS 18 Sounding rockets, June 2015;
- ESA REXUS 21 Sounding rockets, January 2016;
- ESA 63rd Parabolic Flight Campaign, April 2016;
- ESA 65th Parabolic Flight Campaign, November 2016;
- ESA 66th Parabolic Flight Campaign, May 2017.

2. Experimental rack

In order to perform investigations in reduced gravity conditions, an experimental rack has been designed and realised according to strict aviation criteria. This platform has been designed and realized with the aim of hosting experiments of thermo-fluid dynamics; any research team should be able to participate to a specific campaign by just adapting their experiments to size and power consumption constrains provided by the owner of the rack. The volume available is 800x600x800mm, with a maximum weight allowance of 60kg. The rack is already equipped with:

-Liquid cooling loop driven by thermo-electric cooling stages, designed with a maximum cooling capacity of 300W. The system can operate between -5°C and 60°C;

-Two-channels electrical input to provide a variable 3A@28Vdc power source throughout two individual PWM;

-Water heating system, a shell-and-tube like heat exchanger with 2x120W@36Vdc cartridges;

-NI C-Rio unit for FPGA and real time data acquisition of the most common sensors;

-Double containment enclosing to prevent accidental contamination of the aircraft.

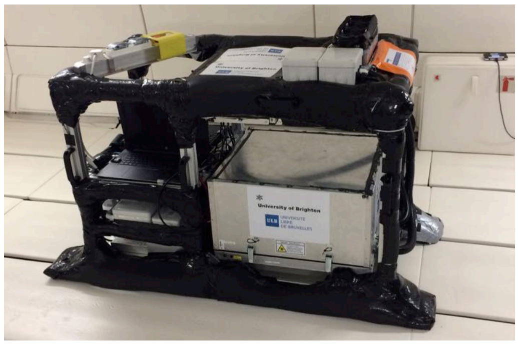

Figure 1 Rack onboard ESA 66th PFC

3 Conclusions

A tool for microgravity thermo- and fluid-dynamics related experiments is available for the UK science community. A modular parabolic flight rack has been designed and realised and a first campaign has highlighted the high adaptability of the system to third parts payload and suggested improvement for future flights.

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