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THE SPACE SIMULATION FACILITIES AT IAL SPACE

M. HENRIST, A. CUCCHIARO, I. DOMKEN and J.P. MACAU

Centre de Recherches IAL SPACE - Université de Liège
ANGLEUR - LIEGE (Belgium)

ABSTRACT

The thermal vacuum facilities of IAL SPACE have been tailored for testing of the ESA payloads. They have been progressively upgraded for cryogenic payloads including 4K (liquid helium temperature) experiments.

A detailed review of the three vacuum chambers, ranging from 1.5 meter to 5 meter diameter, is presented including the corresponding capabilities in the vacuum, thermal and optical fields.

The various aspects of cleanliness, product assurance and quality control are also presented.

INTRODUCTION

IAL SPACE is a research center of the University of Liege, Belgium, which has been devoted since 1962 to space research, in close cooperation with the European Space Agency (ESA) from the beginning. After a series of sounding rocket payload development, IAL SPACE has been involved mainly in the thermal vacuum testing of optical payloads for satellites. Some major steps of this activity are listed hereafter :

- ultraviolet telescope (S2/68 experiment) aboard the TD1 satellite, launched in 1962 by a THOR DELTA vehicle;
- infrared radiometer of the weather forecast METEOSAT satellite;
- Hubble Space Telescope : detectors of the European experiment, called Faint Object Camera (FOC);
- imaging camera of the GIOTTO probe, launched at the encounter of the Halley comet;
- complete payload of the HIPPARCOS astrometry satellite;
- infrared telescope of the Infrared Space Observatory (ISO) satellite, to be launched from 1992 by an ARIANE vehicle.

The latter payload is quite ambitious. It is composed of a 600 mm diameter telescope, placed into a cryostat with 2200 liter of liquid helium in order to keep the experiment at around 4K during 18 months. All necessary tests have to be carried out in this temperature range.

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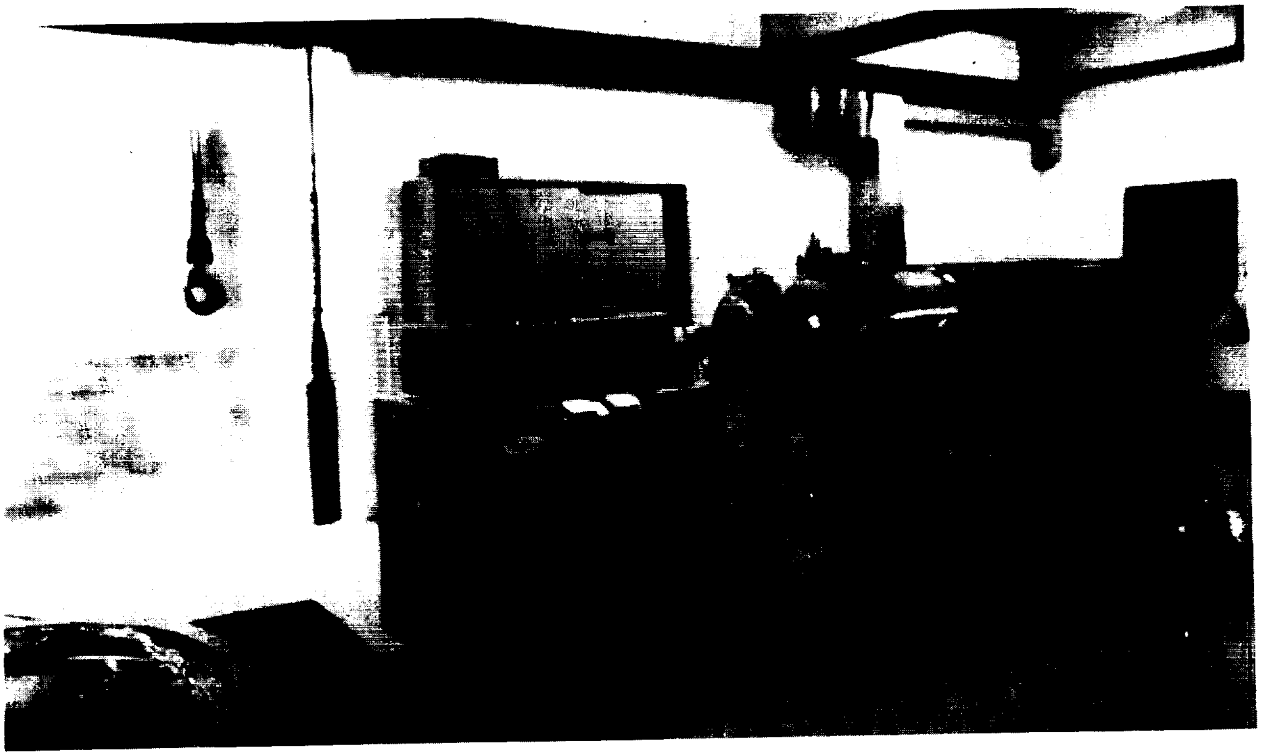

Figure 1 : view of FOCAL 1.5 From left to right : monochromator, imaging telescope, vacuum chamber.

The pumping system is composed of a mechanical roughing pump, a turbomolecular pump and, when necessary, a cryopump. The ultimate vacuum is better than 10-5 mbar in the whole temperature range.

2) FOCAL 2

This chamber is made of stainless steel with an horizontal axis; the diameter is 2 meter and the length is 5 meter without lids. It is equipped with and optical bench (1.3 X 4.7 meter), the feet of which are resting on an external seismic block. The optical bench does not touch either the chamber or the ground of the clean room. The resulting stability is quite good (vibration level in the 10-6 g range), so that interferometric measurements can be carried out under vacuum.

For thermal regulation, FOCAL 2 had been completely lined with thermal shrouds for the TD and METEOSAT test campaigns. In order to get more flexibility to install viewports, feedthroughs, ..., the shrouds have been removed and replaced by a railway system, which allows dedicated shroud assemblies to be attached and moved along. The modification enhances the available space, and greatly improves the flexibility of the facility. In particular, the modified chamber can accomodate experimental setups coming from the large chamber FOCAL 5 (see next paragraph)and vice-versa,

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provided the overall dimensions are compatible. This was purposely designed in the case of the ISO project, in order to have a backup test facility in case of planning problems.

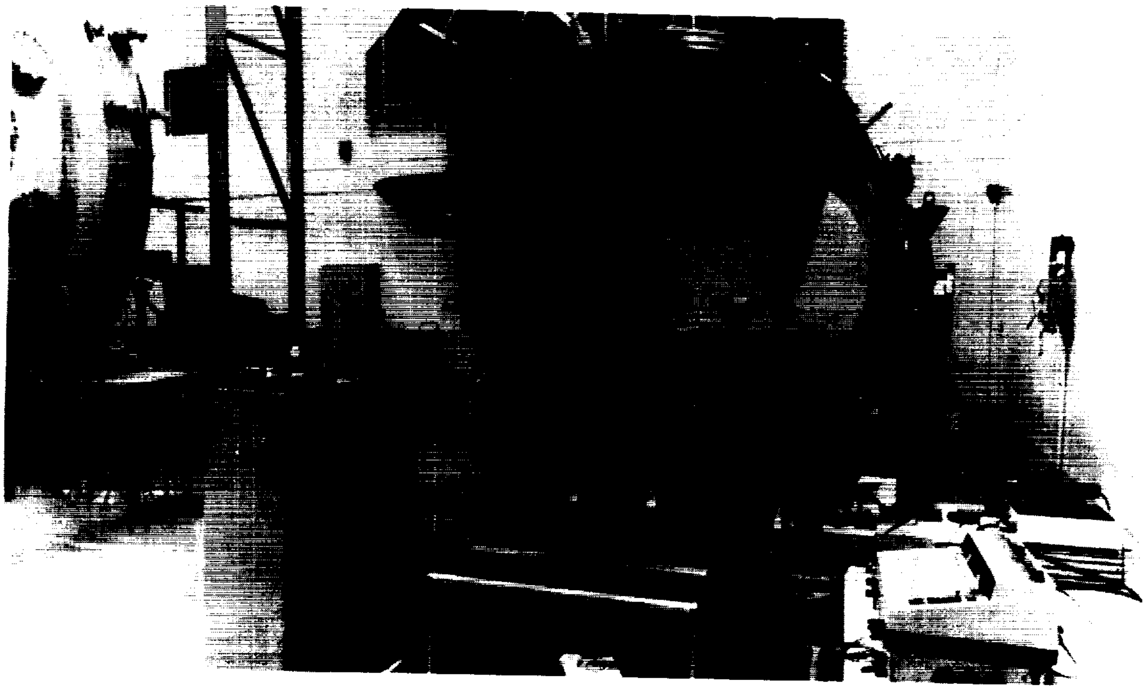

Figure 2 : view of FOCAL 2 (lids removed). The optical bench (below) and the railway system (top) are clearly visible.

The thermal connections of FOCAL 2 are fixed on interchangeable flanges of a standard type. They are able to feed the shroud assemblies in the range -190C to +80C, by using nitrogen which is prepared in a thermal group with an automated valve assembly.

The pumping system is able to reach a vacuum of 10-5 to 10-6 mbar, depending on the outgassing of the test setup. It is composed of a mechanical roughing group, a turbomolecular pump and two cryopumps with large vacuum valves. This configuration authorizes long vacuum sequences on experiments with significant outgassing rates, by using the cryopumps in alternance, while enabling fast returns to the atmospheric pressure since the cryopumps can be isolated from the chamber.

3) FOCAL 5

This chamber is one of the largest in Europe. It has a diameter of 5 meter and a length of 6 meter without the lids, with an horizontal axis. It is equipped with a large optical table

(1.8 X 6 meter) which is mechanically insulated from the chamber and rests on a separate 350 ton seismic block. The resulting

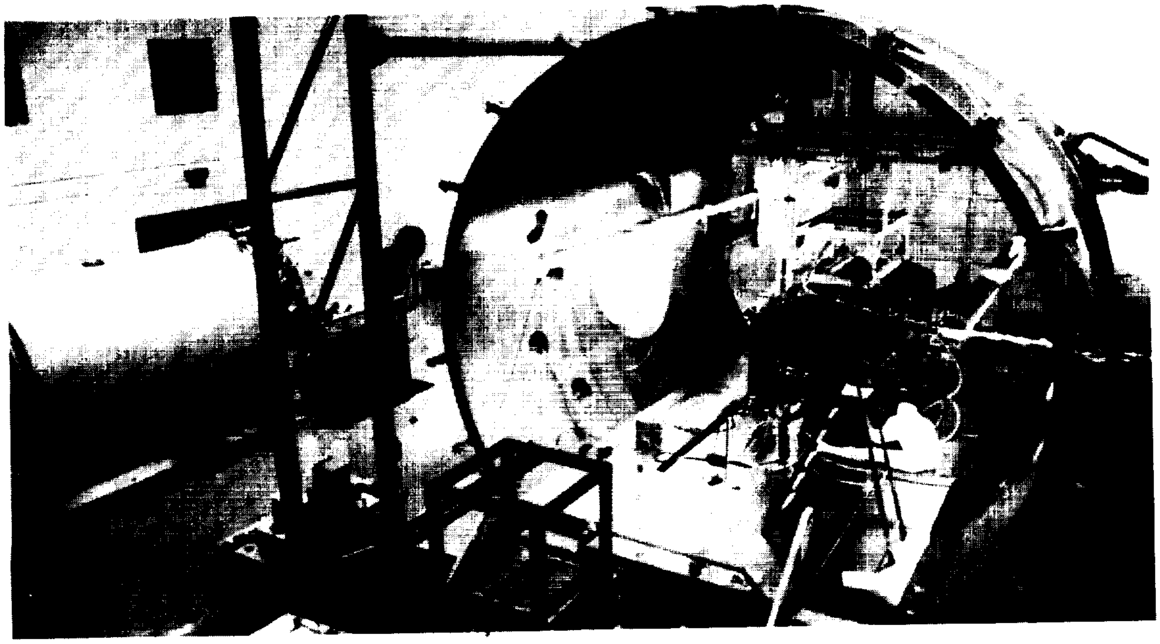

Figure 3 : view of FOCAL 5 (lids removed) with a part of the ISO shroud assembly attached on the trolley.

vibration level is between 2 and 4.10-6 g, with a first resonant frequency around 16 Hz, giving access to the interferometric measurements on tall payloads. The seismic block has the shape of a cross, the arms of which can support the external optical equipment needed for the optical measurements (interferometers, theodolites,...).

The pumping system is able to achieve a vacuum of 10-6 mbar within 3 hours, depending on the setup. It is composed of a mechanical roughing group, one turbomolecular pump and a large duplex cryopump fed by a helium liquefier.

A number of flanges, the diameters of which vary between 350 and 2000 mm, are distributed over the chamber with a comprehensive set of electrical and fluid feedthroughs, and of optical windows.

The payloads can be handled throughout the length of the chamber by means of a monorail crane of 1000 kg capacity, one section of the rail being permanently attached inside the chamber and the other section being fixed to a movable trolley outside the chamber. In case of need, an extra length of rail enables an unloading at any end of the chamber.

The thermal shroud system has been designed in an original way, in order to accommodate various payload shapes while keeping the fluid rates to a minimum. To achieve that, no permanent shrouds are installed. Instead, a trolley is rolling on two bars under the "ceiling" of the chamber. The trolley can be equipped with dedicated thermal shrouds which can surround the test payload without touching neither the optical bench nor the payload (in order to avoid vibration caused by the fluid circulation). All fluid feedthroughs are located in the bottom of the chamber, so that the piping is also decoupled from the optical bench.

Presently, FOCAL 5 has 10 independent thermal loops, each one being able to control the temperature of a shroud between -190C and +60C by means of a mixture of hot and cold nitrogen. For each, loop, the process control software can achieve either a stable temperature (to 0.1C in the whole range) or temperature changes with preset speeds. Additionally, two loops can deliver liquid nitrogen without temperature regulation, for simple cold space simulations.

In order to fulfill the ISO test requirements, three cold helium loops have been installed, which are able to cool the shrouds and the experiment either with a gaseous or a liquid phase helium, supplied by the liquefier system. The results indicate that a effective temperature of less than 5K has been obtained in the whole test setup, the total weight of which exceeds 500 kg.

The data handling and command system is based on a data logger, several HEWLETT-PACKARD 9000 workstations and a home-made process control software based on MONITROL. It can handle up to 500 thermal channels, record them and give realtime displays as well as historical graphs, temperature and gradients automatic control,...

4) CLEAN ROOM

All the above facilities are located in a controlled environment area of 650 square meter and 10 meter high, with two airlocks in series (each one being 10 meter high and 80 square meter area). The temperature and humidity are regulated, and the cleanliness class is 10000 (Fed.Std. 209). An external room (100 square meter) can receive the customer's payload checkout equipment. The air cleanliness is obtained by a bank of filters, installed under the clean room; filtered air is injected from the ceiling of the room through a distribution of diffusers and taken back at the ground level, along the walls.

Around FOCAL 5, a class 100 enclosure of 500 cubic meter has been built inside the clean room with a laminar flux bench which blows HEPA-filtered air throughout the vacuum chamber (horizontal air flux). The class 100 assembly also comprises a double airlock for personnel (GORETEX garments are extensively used) and a preparation/cleaning/storage area, also of class 100, which serves as an equipment airlock.

Figure 4 : general view of the clean room. From left to right : class 100 enclosure, FOCAL 5 chamber, FOCAL 2 chamber.

In the course of a test, all equipments (apart from the main air circulation in class 10000) are connected to a no-break power supply, in order not to loose data or stop the activities in case of mains breakdown. Anemergency fuel generator can take the relay of external mains within 30 seconds.

5) CONTAMINATION CONTROL

5.1. Dust particles.

In the frame of the ISO activities, very stringent cleanliness requirements were asked and lead to a careful monitoring of dust particles. Indeed, the optical surfaces are gold coated and no cleaning process has been considered; moreover, several tests have

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been scheduled on the same optical components at various levels of integration (bare mirror, mounted mirror, assembled optical combination, whole telescope with experiments). This testing philosophy leads to a maximum required contamination level of 15 ppm per test (fallout obscuration factor, expressed in parts per million). In order to achieve this requirement, the air dust contents is regularly measured by means of a HIAC/ROYCO dust counter, in order to ensure that the class 100 airborne level is kept at all times. In addition, a number of particle fallout samples (PFO) are distributed all over the working area and measured every day by a PFO photometer (URAMEC, Netherlands, under ESA license).

The theoretical PFO rate is 1.5 ppm/day for a class 100 zone, but this equivalence refers only to a normal distribution of dust. When a large amount of equipment is handled by several people, the above correspondance is lost and our actual results are around 3 ppm/day. Even to achieve this result, a stringent discipline is mandatory in the clean room and during the test :

- frequent vacuum cleaning of most equipment;
- limited use of wipers, which all produce fibers during the cleaning of machined surfaces;
- use of GORETEX garments with a strict clothing procedure (other garments produce small fibers and are not leak tight enough);
- frequent inspection of the hardware with ultraviolet light in order to actually see the dust particles;
- during the vacuum sequence of the test, a very slow pumpdown is mandatory, in order to avoid turbulences inside the chamber which could move the remaining dust particles;
- at the end of the test, the return to ambient pressure is allowed through an HEPA filter, at a speed similar to that of the pumpdown for the same reason.

A number of further actions are constantly taken for still improving the cleanliness levels towards the limit.

5.2. Molecular contamination.

Since the tests at IAL SPACE are mostly vacuum optical tests, a number of equipment items have to be designed in order not to outgas when in vacuum. In the case of ISO, the situation is still more complicated, because the test specimen is cooled to cryogenic temperatures and it can trap any released contaminants.
The requirement is down to 2.10-8 g/cm2 for a complete test sequence, as measured by witness samples which follow the temperature cycle of the telescope.

Nevertheless, the requirement has been fulfilled, mainly by means of the following precautions :

- preliminary chemical cleaning of the cleanroom plastic walls, in order to remove the volatile plasticizers;
- severe selection of all the vacumm-used materials;
- no paint except black CHEMGLAZE Z306 without primer;
- no lubrication except FOMBLIN Z25 grease and oil;
- in-depth analysis of the cool down and warm-up sequences, in order to ensure that the test specimen is never the coldest point in the setup;
- use of a cold trap which catches most of the released contaminants;
- repressurization of the chamber only with clean gaseous nitrogen (taken from the main nitrogen tank and filtered).

6) PRODUCT ASSURANCE AND QUALITY CONTROL

Since IAL SPACE is a coordinated facility of ESA, all testing activities are managed under a product assurance organisation which is compliant with the ESA system (PSS : Procedures, Standards and Specifications). The administrative position of IAL SPACE within of expertise (chemical analysis,...), whereas its autonomy can cope with the management and planning aspects of space programs.

7) CONCLUSION

The IAL SPACE facilities represent a major tool for thermal vacuum testing of satellite payloads. They are able to cope with simultaneous requirements regarding temperature, optical stability, experiment volume, vacuum and cleanliness. The necessary ground support equipment is essentially designed and manufactured, either in-house, or in a series of neighbouring companies with a high expertise.

The experimental test setup is presented elsewhere in this conference. The purpose of the present paper is to give a review of the main test facilities at IAL SPACE.

Three vacuum simulation chambers are currently operated at IAL SPACE, with a regular upgrading to high performances. Their uniqueness is due to the integrated optical benches with a very low vibration level (in the 10-6 g range), giving access to interferometric measurements under vacuum. Thanks to a Memorandum of Understanding with ESA, all the facilities are continuously kept to the state-of-the-art by a highly experienced team.

All the chambers bear the name of FOCAL (acromym of "Facility for Optical Calibration"), with a figure corresponding to their diameter. Depending on the required volume and specifications, a given test can be run with the optimum cost and duration by choosing the appropriate chamber. A strong effort has been made on the modularity and flexibility of the chamber systems, together with the standardization of components.

FOCAL 1.5

This small chamber (1.5 meter diameter; 0.7 meter height; horizontal axis) has been extensively used for HST-related activities. It is made of stainless steel in 3 parts : a baseplate, a main cylinder and a lid, giving a very high transportability. The chamber is connected to a vacuum monochromator (range : 120 to 650 nm) by means of an imaging telescope assembly. Hence it is possible to project the monochromatic images of a test pattern inside the chamber, or to supply a flat field illumination.

Inside the chamber, specimens up to 100 kg can be remotely aligned by means of 3 crossed-axis translators and 1 rotator. The whole test setup in the chamber can rest directly on one of the existing seismic blocks, by means of columns which pass through the baseplate via bellows without touching anything else.

The temperature regulation can be ensured between -40C and + 60C, both at the specimen level by means of fluid feedthroughs, and around the specimen by a set of removable shrouds which cover the inner skin of the chamber. Within the temperature range, stable values or programmed cycles can be controlled by a process software, together with the data recording and retrieval. Recently the temperature range has been extended by a liquid nitrogen connection and internal heaters, in order to allow fast (15 minutes) cyclings to be applied on specimens between -120C and +200C.