N91-19142

IAL SPACE : A TEST LABORATORY FOR THE ISO CRYOGENIC PAYLOAD.

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1) INTRODUCTION

The ESA Infrared Space Observatory (ISO) satellite is a 3 axes pointed plateform designed to make accurate pointed observations of astronomical objects and sources in the wavelength range between 2.5 and 200 microns.

ISO is composed of a service module and a payload module which is a large cylindrical vacuum vessel. The vessel is in fact a cryostat (capacity of 2250 l of liquid He II) which containts the telescope and the four focal scientific instruments. The latters being cooled up to a temperature less than 4K.

The qualification of the payload requires to measure respectively :

- the image quality of the telescope through WFE (wave front error) measurements,
- the optical alignment of the scientific instruments with respect to the telescope axis and the telescope focus,

and this under cryogenic conditions (typically 5K). Consequently, since 1988, the FOCAL 5 IAL Space facility (see the paper of M. HENRIST et al. in the same proceedings) has been upgraded in order to perform the cryogenic optical tests of the ISO optical subsystem.

2) EXPERIMENTAL CONSTRAINTS

Optical testing under cryogenic conditions represents a certain number of constraints, the main ones being :

- the cool down and the warm-up phases of the experimental set up components (optics, thermal shrouds, thermal baffles, telescope assembly...) must be actieved in a way which avoids excessive stresses in the different materials,

- the alignment between the different optical elements (telescope, OGSE, baffles,...) must be kept inside severe margins between 300K and 5K,
- the WFE measurements for image quality evaluation are achieved through interferometric methods which need high mechanical stability even in cryogenic conditions,
- the thermal control, the monitoring and the thermal measurements require to acquire, store and analyse in real time (high frequency scanning) data of about 150 sensors with a high accuracy,
- the thermal losses must be minimized in order to avoid thermal overgradients between the different components of the tested device and to reduce the consumption of cryogenic fluid.

Consequently, a dedicated experimental set-up has been designed, manufactured and installed in FOCAL 5 in order to fulfil the test objectives taking into account this above-mentionned constraints.

3) CRYOGENIC EXPERIMENTAL SET-UP

3.1. Cryogenic box.

The experimental set-up which has been developped allows to perform the cryogenic optical tests for the single optical components as well as for the overall telescope assembly of the ISO payload. The configuration for the complete telescope assembly is shrown on figure 1.

The basis was to create a cryogenic environment to cool and warm up the experimental components as fast as possible without introducing excessive stresses in/or between the different materials. One way was to use only the radiative transfer by enclosing the specimens within cold boxes, but the cooling time has been estimated of about 6 months which was unacceptable in terms of time schedule.
Another way was to fill the cold enclosure with a conductive gas (e.g. gazeous helium). This solution led also to an excessive cooling time (2 weeks).

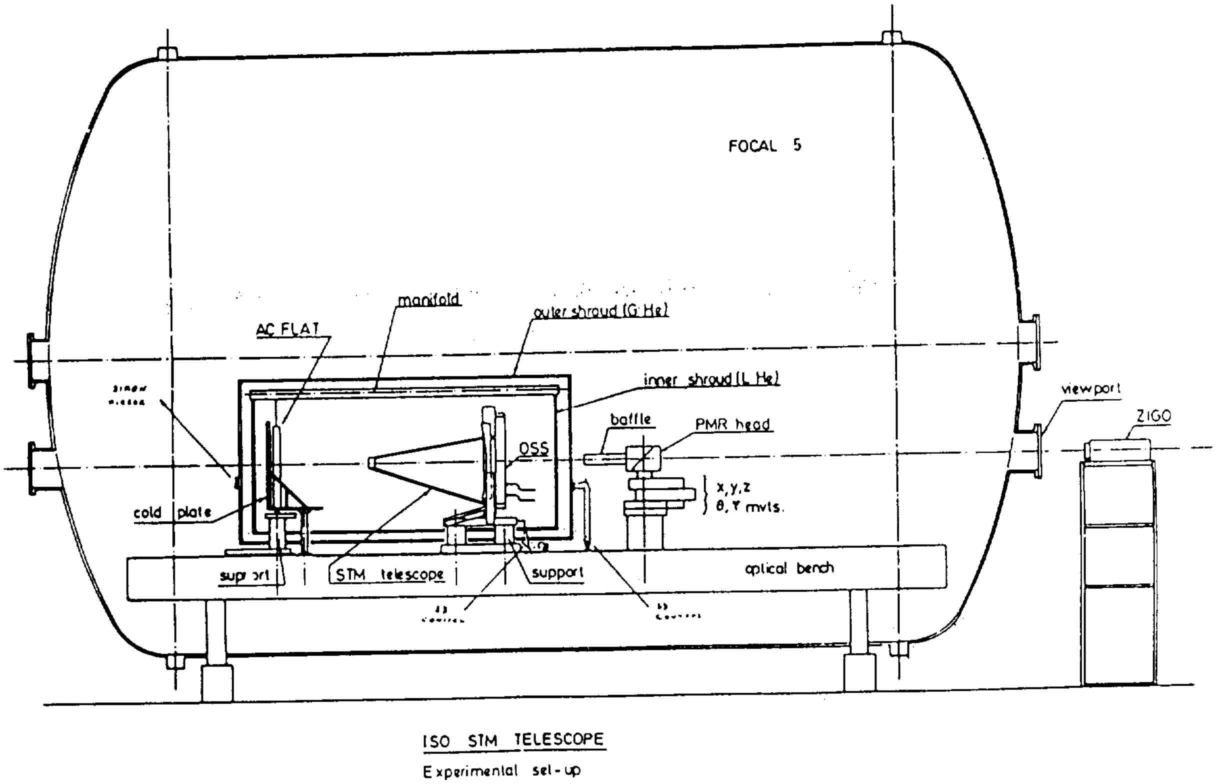

Figure 1 : Experimental set-up configuration.

The solution closen combines the radiative transfer effect which reduces the thermal gradients and consequently the stesses, with a conductive coupling through straps. This allows to reduce the thermal cycle (cool down and warm up) to about 6 days.

As shown on fig 1, the cold enclosure is a double wall cryobox fed by liquid helium (at 4.6K). The guard wall is fed by liquid nitrogen (77K). Inside, the specimens and their supports are cooled in conductive mode though flexible copper straps (see fig 2) attached to cold plates where circulates refrigerated gazeous helium. As the optics of the specimens are mechanically coupled to the cold plates, it has been found that the induced vibrations were lower using gazeous helium rather than liquid. By this way, the warming sequence and the subsequent baking is also easier using hot gazeous helium.

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Figure 2 : Strapping of calibration minor.

3.2. Optical supports.

A critical problem encountered concerns the supports of the optical devices. Indeed :

a) the optics and the different mechanical structures must be cooled up to 5K whereas the optical bench which supports the overall system must stay at 300K.

b) for WFE measurements, the optical alignment must be kept during the cool down and warm up phases and this without induced low frequency vibrations.

The solution adopted to face these problems is represented on fig 3.
- The bottom part of the support, the one comprising the different movements (tilt, rotation) allowing initial alignment and which is interfaced with the optical bench is manufactured in invar for thermal expansion reasons.
- The central part is composed by two quartz tubes and an intermediate invar plate. The quartz tubes present the advantages that the material have :

- a thermal expansion coefficient close to zero
- a very low thermal conductivity
- a good strengh under heavy loads.

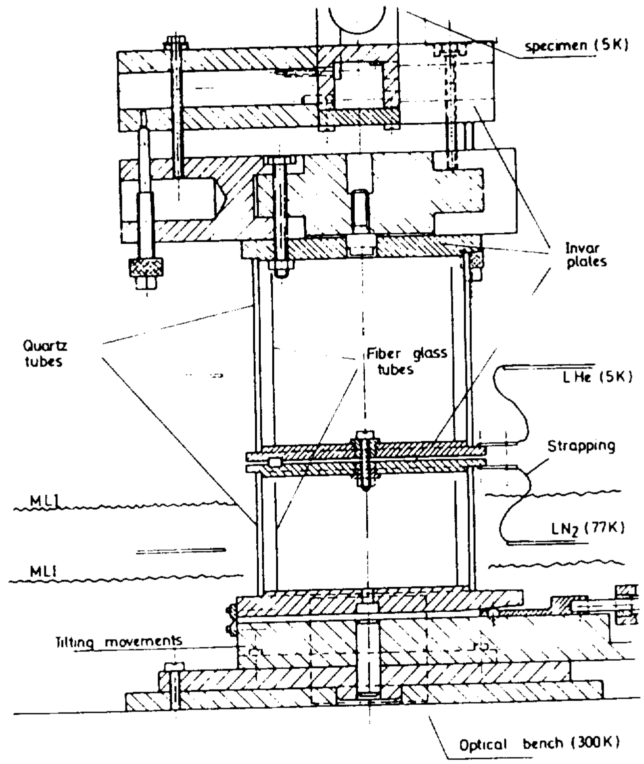

Figure 3 : Typical cryogenic support.

The intermediate invar plate is connected by copper straps to the double wall cryo-box and constitute a thermal barrier for the heat flux coming from the bench.
- The upper part has also been realized in invar.

The risks of quartz breakage are warranted by a fiber glass tube inside the quartz one and does contribute neither to the thermal conductivity nor to the mechanical properties of the support.
The overall structure of the support is completely decoupled from the rest of the cryo-box in order to keep the required vibrational stability.

3.3. Liquefier.

As previously mentionned, the cryogenic box as well as the cold plates are respectively fed with liquid and refrigerated helium. In fact, to perform the cryo-test, there were

two solutions : - to use helium dewars
- to produce cold helium with a liquefier.

The liquefier option has been chosen because :

a) it allows to use at the same time liquid and gazeous helium which is very important at the level of the cold plates vibration problem.
b) the number and the duration of the cryo test justify the investment.

c) the driving of the thermal cycles is more flexible and the liquefier allows continuous operation.
The model installed in the IAL Space facilities is the KPS model 1630 which provides liquid helium at 4.6K and gazeous refrigerated helium at a minimum of 4.6K with a total capacity of 40 l/h or equivalent in refrigerated gas.

3.4. Instrumentation of the experimental set-up.

The thermal control of the overall experimental set-up requires to manage in real time,high accuracy data in the temperature range from 4K to 50K.
The number of sensors is close to 150 and have been homemade and calibrated. They are diodes fed by DC at 10 microamps. The temperature is given by the electrical resistance of the diode.

The sensors are calibrated in a cryostat by comparison with a standard sensor delivered by Lake Shore (California). The junctions are encapsulated in small copper cylinders. The wires are thermalized by many loops around the diode inside the copper cylinder which is screwed on the surface to be measured.
The accuracy obtained is +/- 0.1K between 4K and 50K.

3.5. Control and monitoring system.

The control of the overall experimental set-up is achieved through thermal data acquired by a 3497 data logger and managed by a HP 9000, serie 370, working station.
A dedicated software (home made), working under Unix, X windows and NFS, allows multitasking programs. The users can define easily in real time :

- sensors groups
- gradient groups
- scanning speed
- drawings
- temperature curves
- histograms
- synopses
- alarms and warmings.

Examples of such displays can be found on fig 4, 5 and 6. These synopses shows the performances of the cryogenic box as well as the ones of the control and monitoring system.

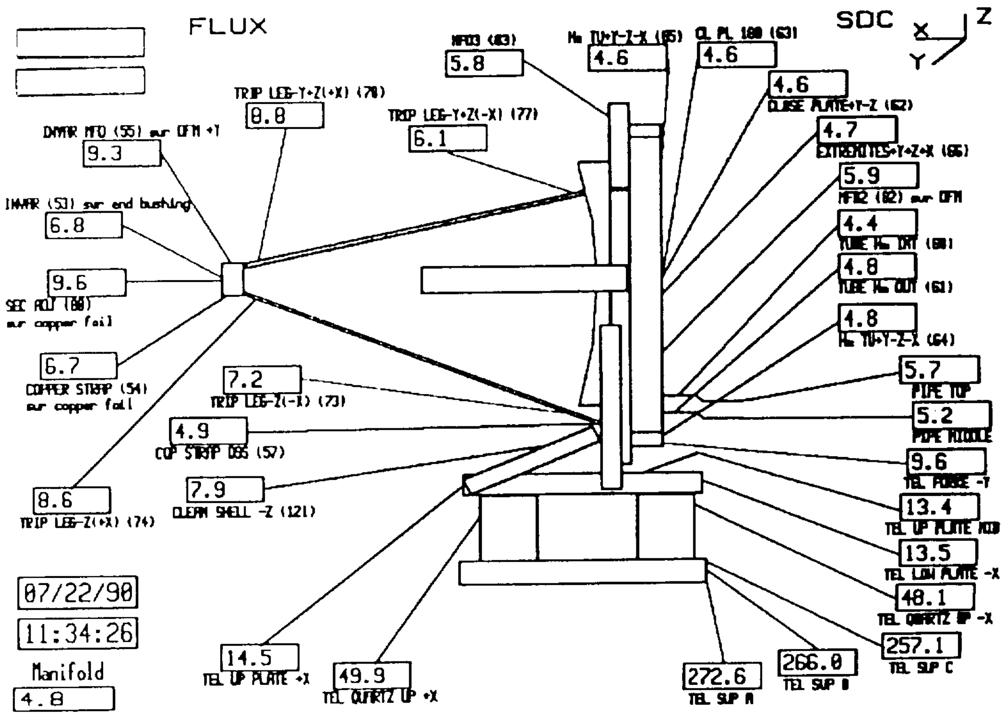

Figure 4

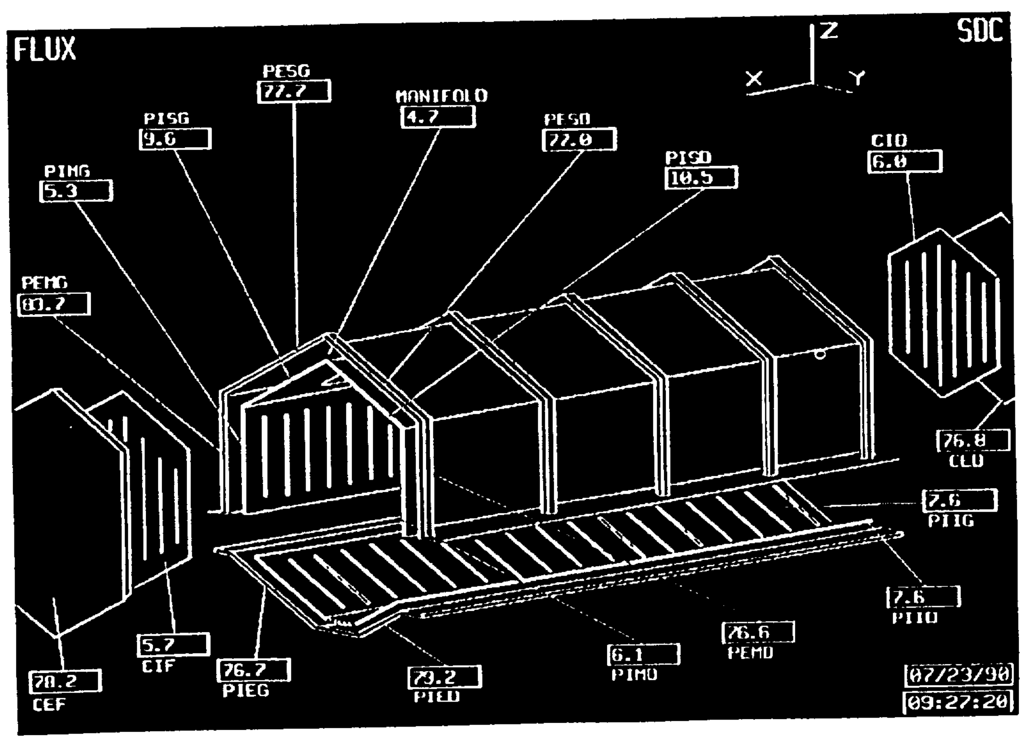

Figure 5

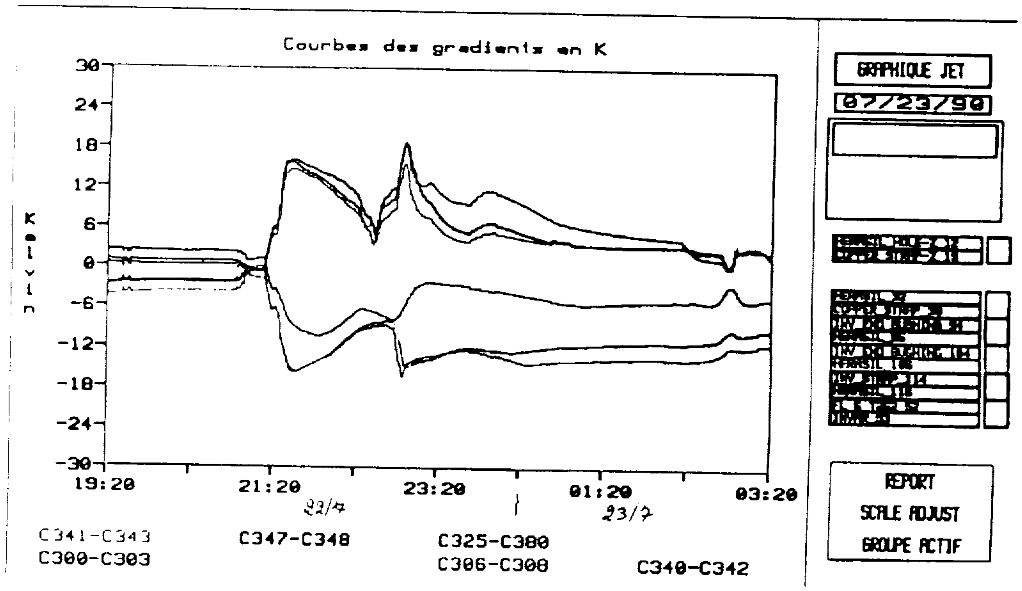

Figure 6

4) PERFORMANCES AND RESULTS

Up to now, the cryogenic tests performed in IAL Space facility concern the structural and thermal model of the ISO optical subsystem. The concerned items tested have been :

the primary mirror
the Calibration autocallimation flat mirror
the telescope (see fig 7)

After a cool down sequence of about 80 hours, a thermal equilibrium between the different parts of each specimen has been reached. The temperatures were comprised everywhere between 4.6K and 10K. This being good enough to allow a close estimation of the thermomechanical behaviour of each specimen tested. The warm-up sequence has needed a equivalent time duration (3.5 days).

The optical quality of the individual mirrors or of the overall telescope was performed through interferograms taken from an interferometer Zygo MARK IV working in phase mode.

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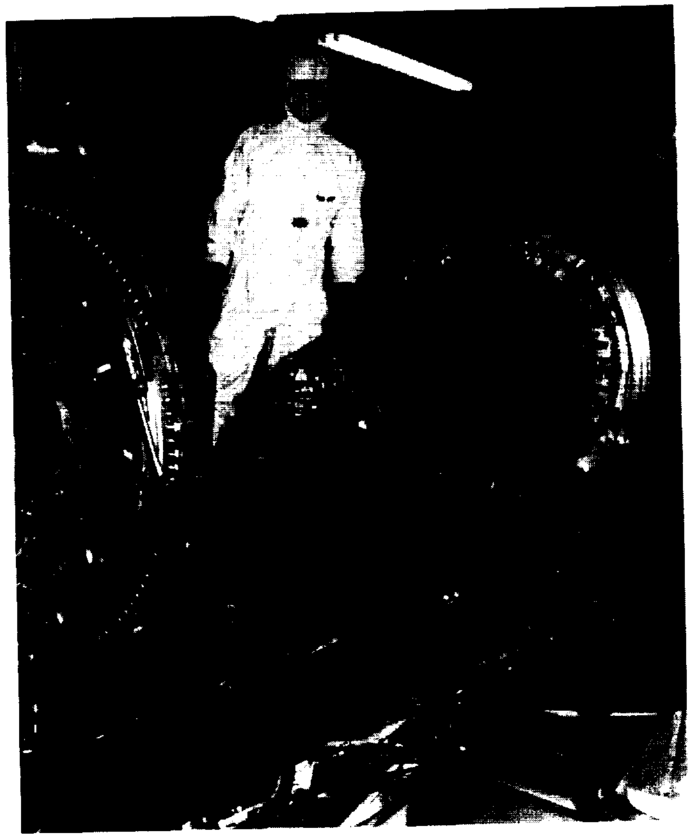

Figure 7 : ISO STM TELESCOPE

This method implies a very good position stability of the optics to be measured with regards to the reference optical cavity which is situated outside the cryogenic box (see fig 1). A typical example of interferogram taken at cryotemperature of about 5K can be found on fig 8. It concerns the overall STM Telescope.

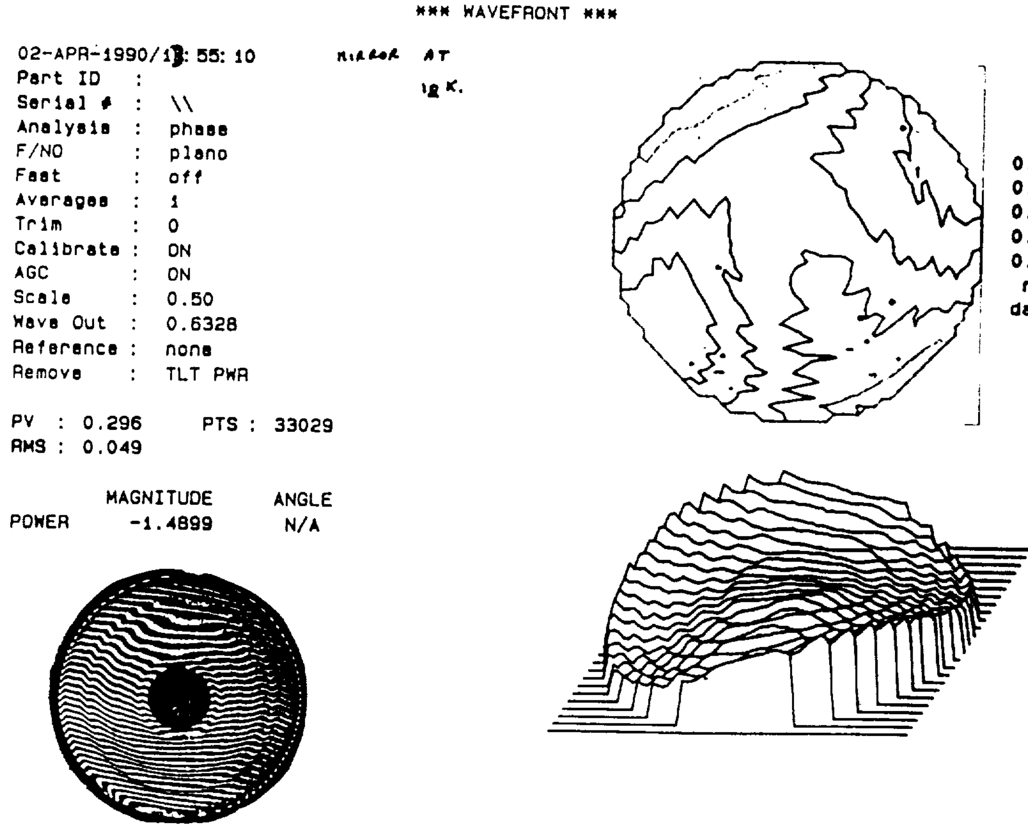

Figure 8

The future tests will be dedicated to the Flight models of all the items which have been mentionned. For these, in addition, to the constraints already described, the particular contamination will constitute a major problem one will be faced with. Indeed a specification of 1.5 ppm/per day is hard to reach with the experimental conditions hereabove presented.

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SESSION V

DYNAMIC TESTING

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