IASI: a Review of Instrument Performance and Characterizations

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Corporate Communications

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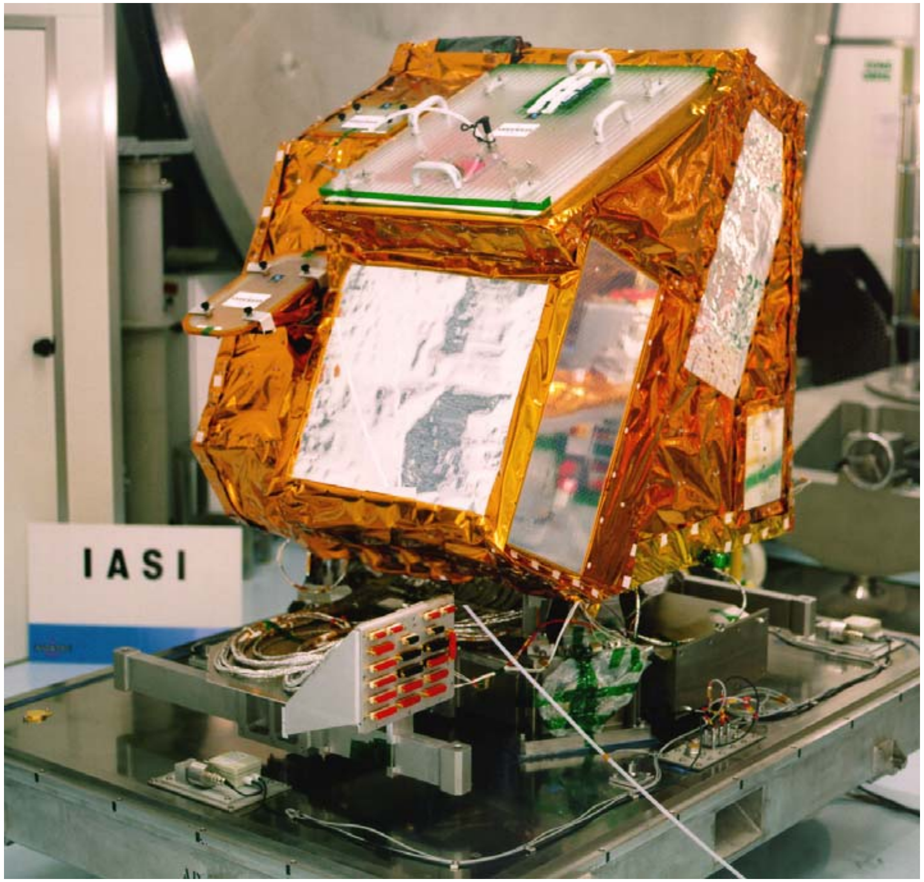
IASI Payload of the European Meteorological Polar-Orbit Satellites METOP

Mains missions: weather predictions and climate studies.

Program led by the French National Space Agency CNES in association with the European Meteorological Satellite Organization EUMETSAT.

Prime Contractor: Thales Alenia Space

Dimensions of sounder : 1.1x1.1x1.2 m^3
Mass sounder < 200 Kg
Stiffness > 55Hz during launch
Power consumption < 200 Watt
Reliability > 0.8
Availability > 97.5 % over 5 years



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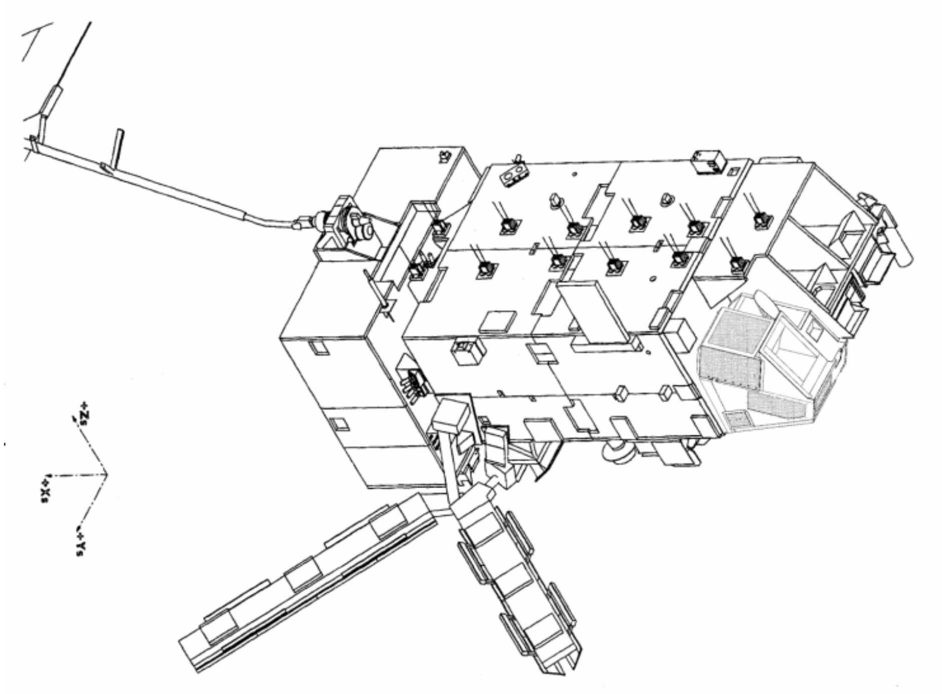

Status :
- EM delivered in Dec 2001
- PFM delivered in July 2003
- FM2 delivered in Dec 2004
- FM3 delivered in Jan 2005
- PFM refurb & delivered in Dec 2006

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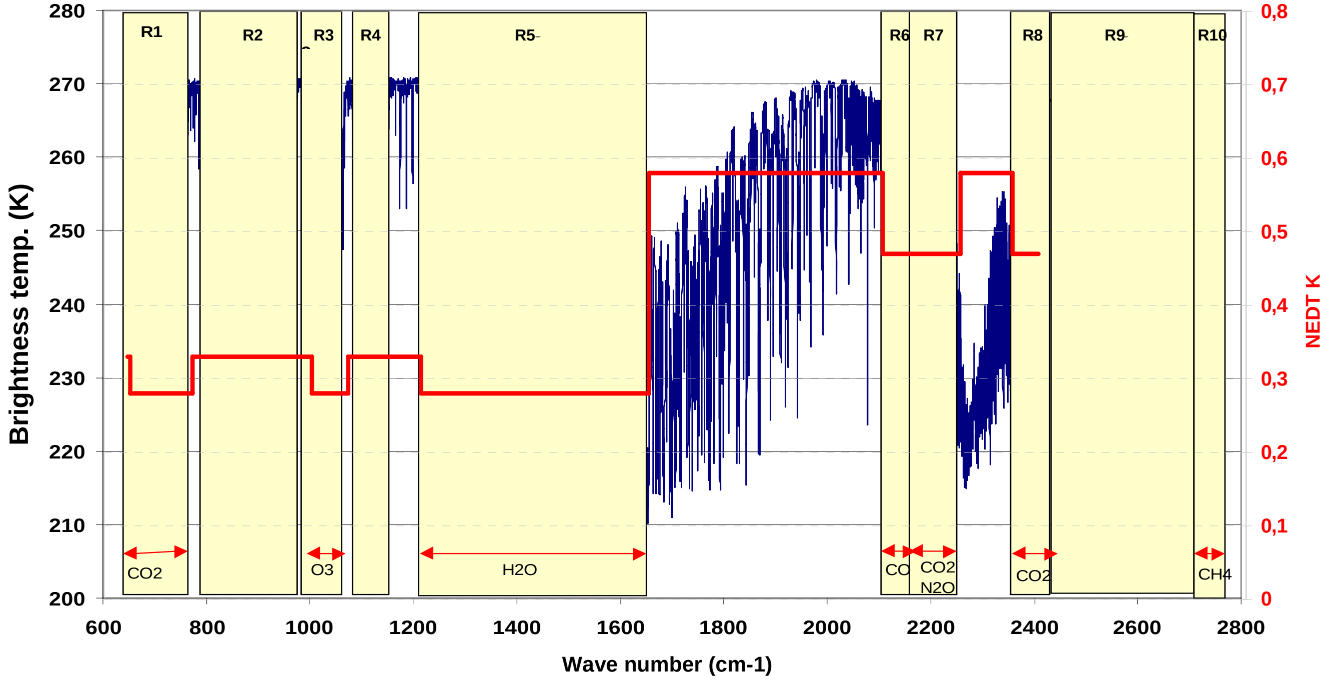
Spectral and Radiometric Requirements

- **Spectral range continuous from 650 cm^{-1} to 2760 cm^{-1}**
  - Spectral resolution 0.35 to 0.5 cm^{-1}
  - Sampling 0.25 cm^{-1} (8461 samples)
  - Spectral calibration : 10^{-6} (stability during calibration period)
  - Spectral response knowledge 2-5 % (error < 0.1 K in modelled atmospheric spectra)
- **Radiometric resolution NedT**



- **Absolute radiometric calibration : 0.5 K**

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Field Of View Requirements

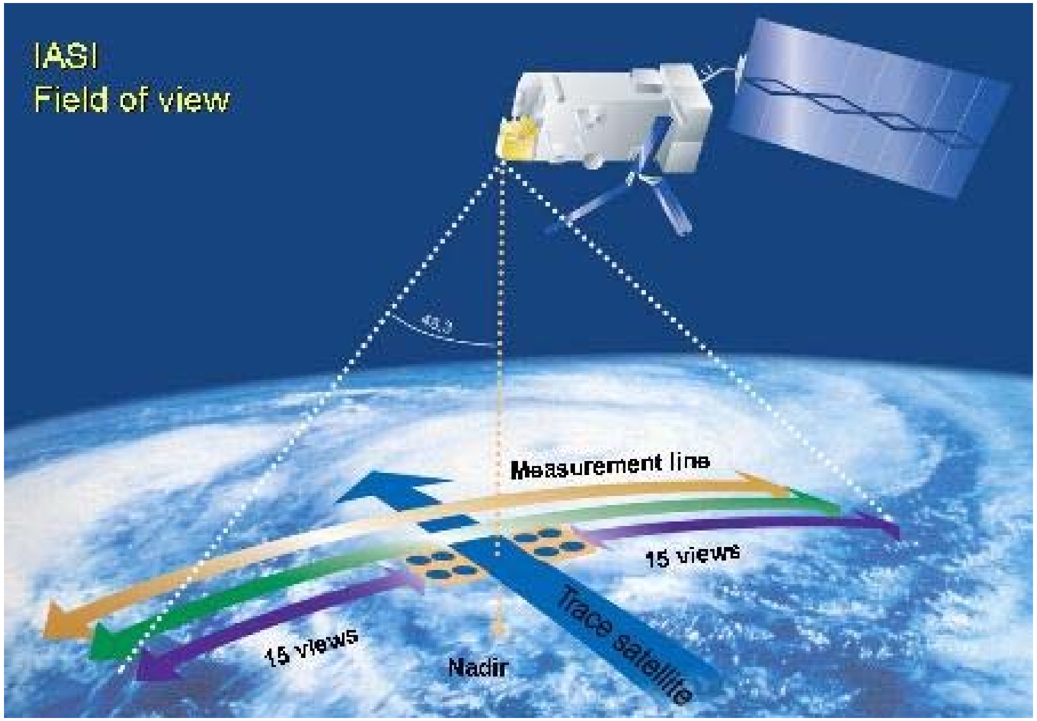
Step by step scanning

Swath

- 30 earth views every 8 seconds cycle
- +/- 50 degrees wrt nadir position
  - Ground swath = 2400 km
- Stop for measurement period (151 ms)
- Field motion compensation device

Field Of View

- Conical: vertex angle = 3.3 °
- 4 pixels (12 km on ground at nadir)



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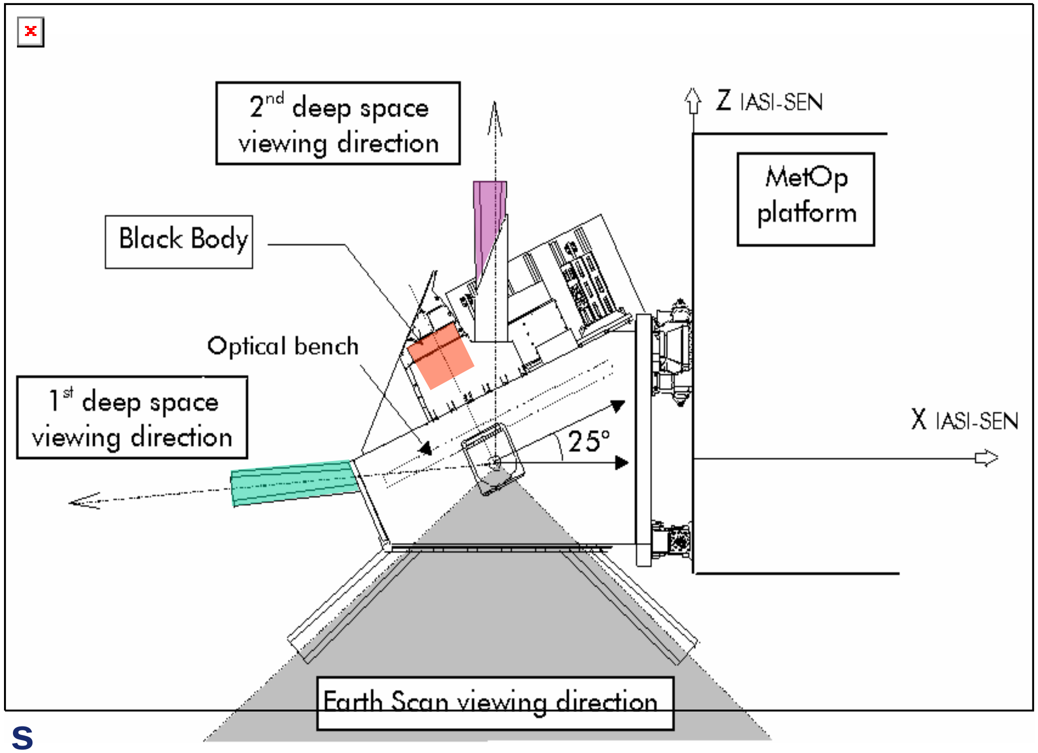
Field Of View Requirements

Step by step scanning



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Field Of View

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Calibration views looked at every 8 s

- **Internal Reference Blackbody view**
- **Cold Space view**

NADIR and 2nd deep space views in External Calibration mode

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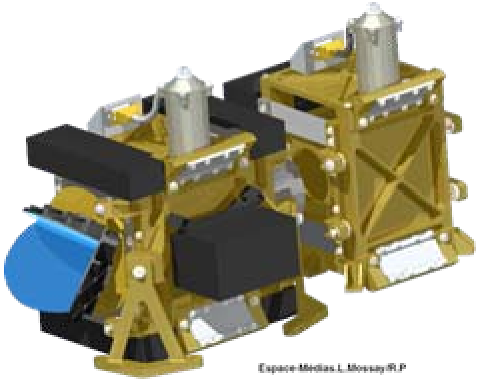
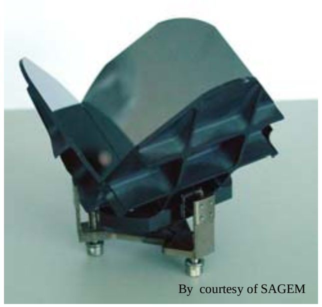
Michelson Interferometer Variant

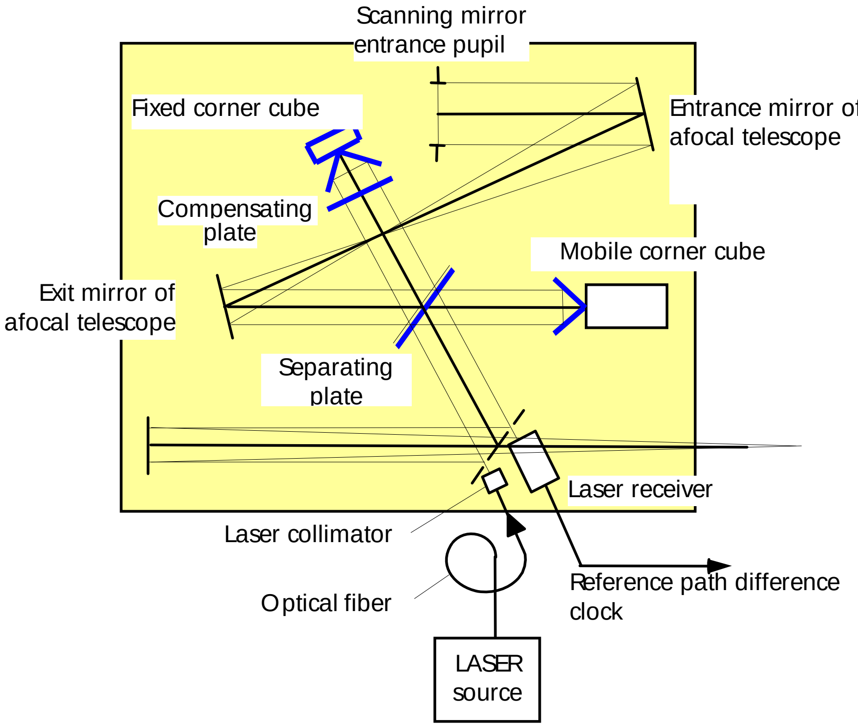
- High performance equipment
- **Cube corner driving mechanism**
  ±1 cm stroke
  423 ms period



- **Hollow cube-corner reflectors in Silicon Carbide (170 g)**



- **Beam splitter 5 mm thickness in ZnSe, compensating plate in the fixed arm**



- **High stability wavelength reference LASER source $\Delta\lambda/\lambda < 10^{-7}$ over 5 years (frequency emission locked on a molecular absorption line of an acetylene gas in 1.54 µm region.)**

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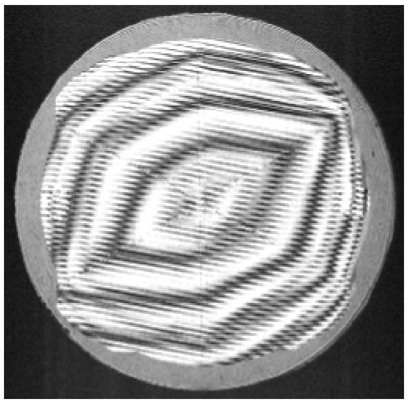
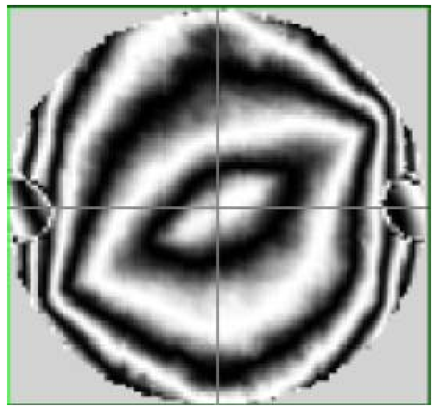
Optimised for Performance in Orbit

- **INTERFEROMETER ARMS PAIR UP TO OPTIMIZE FTS CONTRAST IN ORBIT**

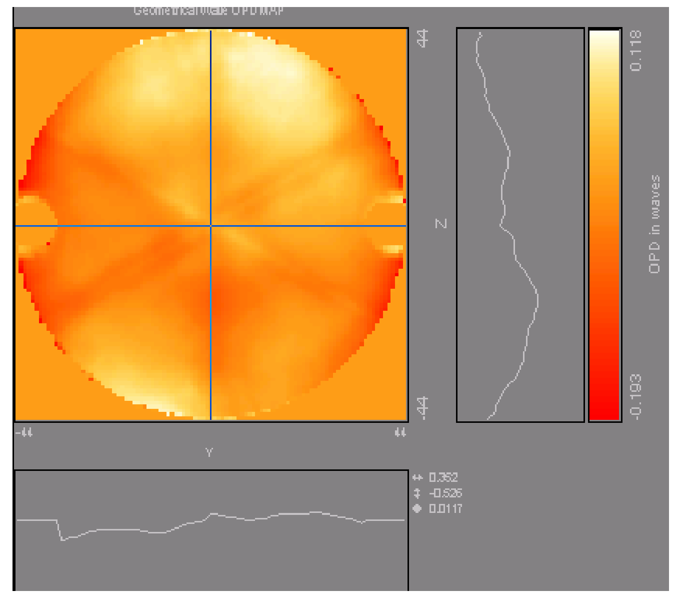
Global ambient measurement on one arm



Orbital Model prediction including component elementary WFE



WFE difference between arms optimised by selection of CC and beamsplitter



157nm RMS
1.2µm PTV
WFE contrast: 95%

- **CUBE CORNER SHEAR GRAVITY RELEASE WITHIN 2 µm ACCURACY PREDICTION**

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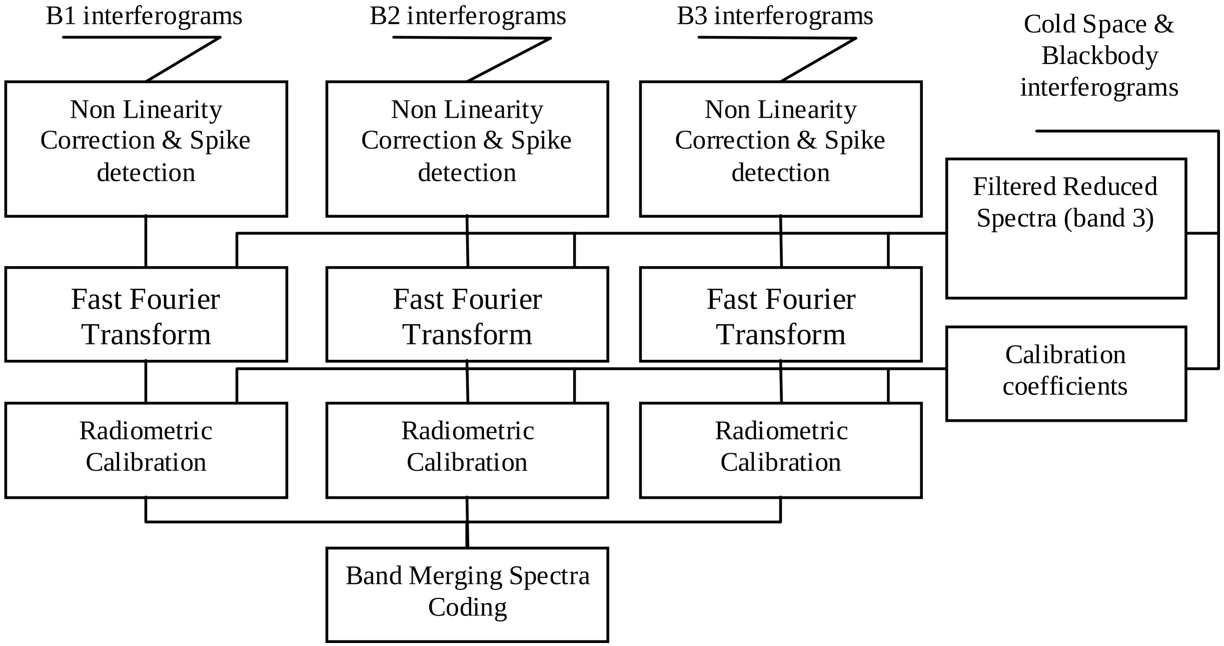
On Board Processing

Output data: Corrected Calibrated Spectrum + Image (1.5 Mb/s)

Data compression factor : 40

- LF Non Linearity, Filtered Reduced Spectra & Calibration Coefficients from Cold Space and Blackbody views
- Ground Filtered Reduced Spectra Initialization & NL determination
- Algorithms include quality index computation for processing monitoring.



- DPS performs corrective action such as interruption of processing or non up-date of the calibration coefficients according to severity error.

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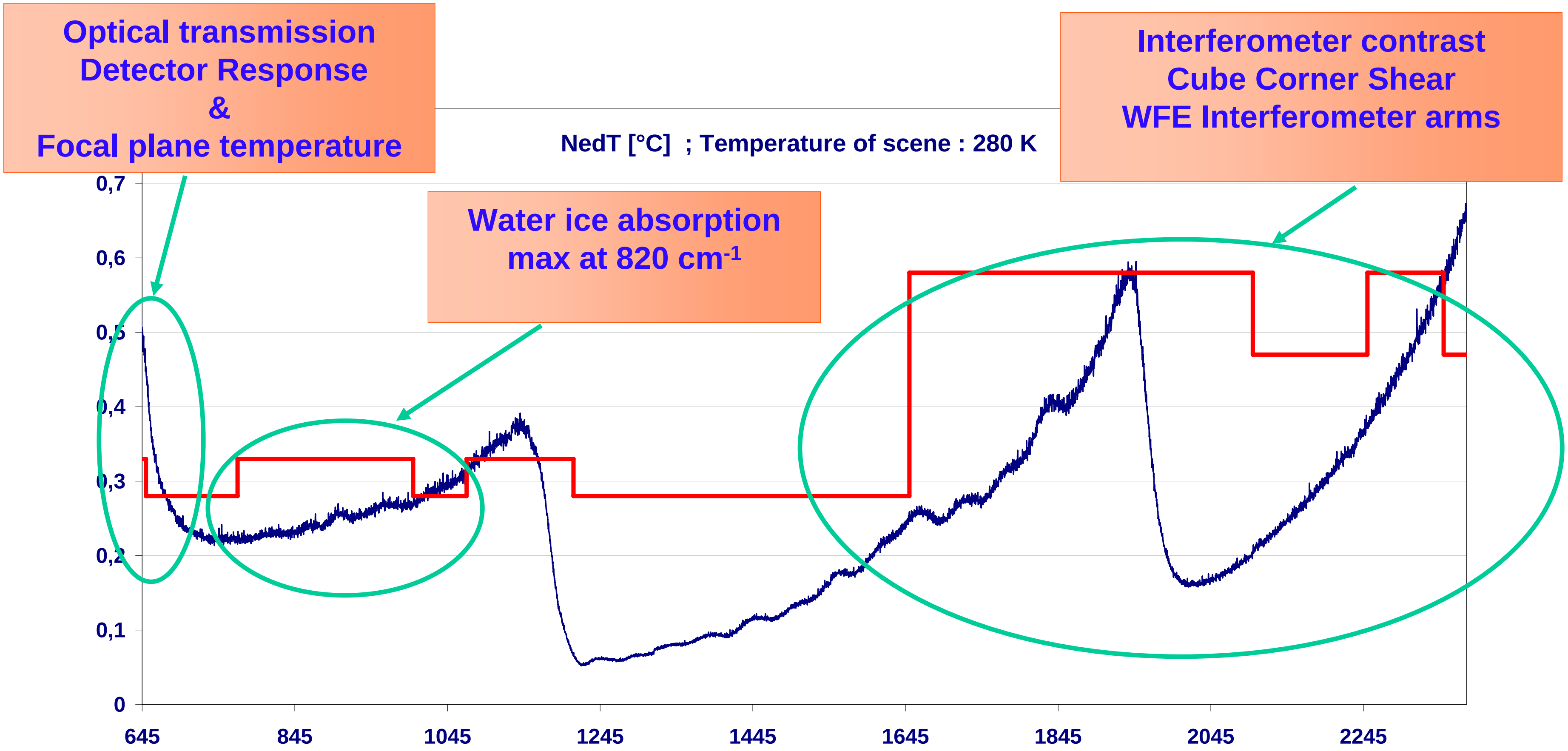
The Challenges of the Radiometric Resolution



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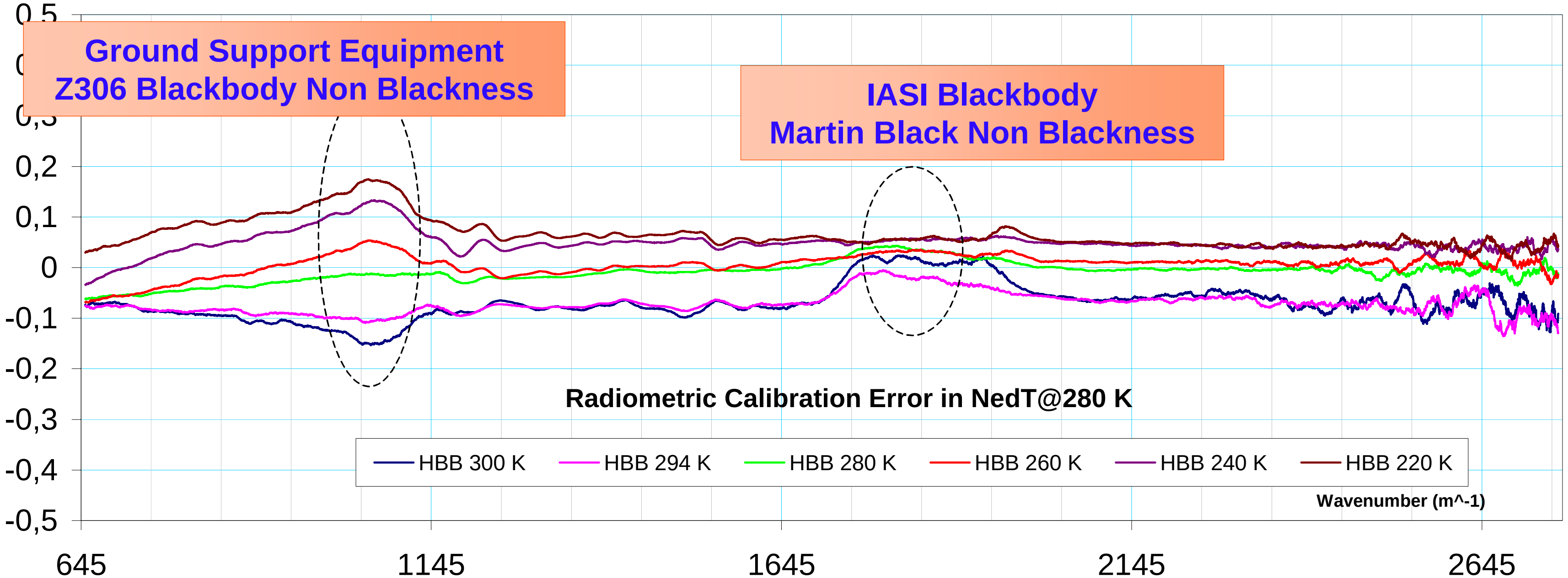
Radiometric Calibration

- Radiometric calibration measured with OGSE Blackbody using Z306 paint
- Impact of Z306 Non Blackness on Radiometric Calibration measurements deduced from Equipment Characterization and Environmental Data



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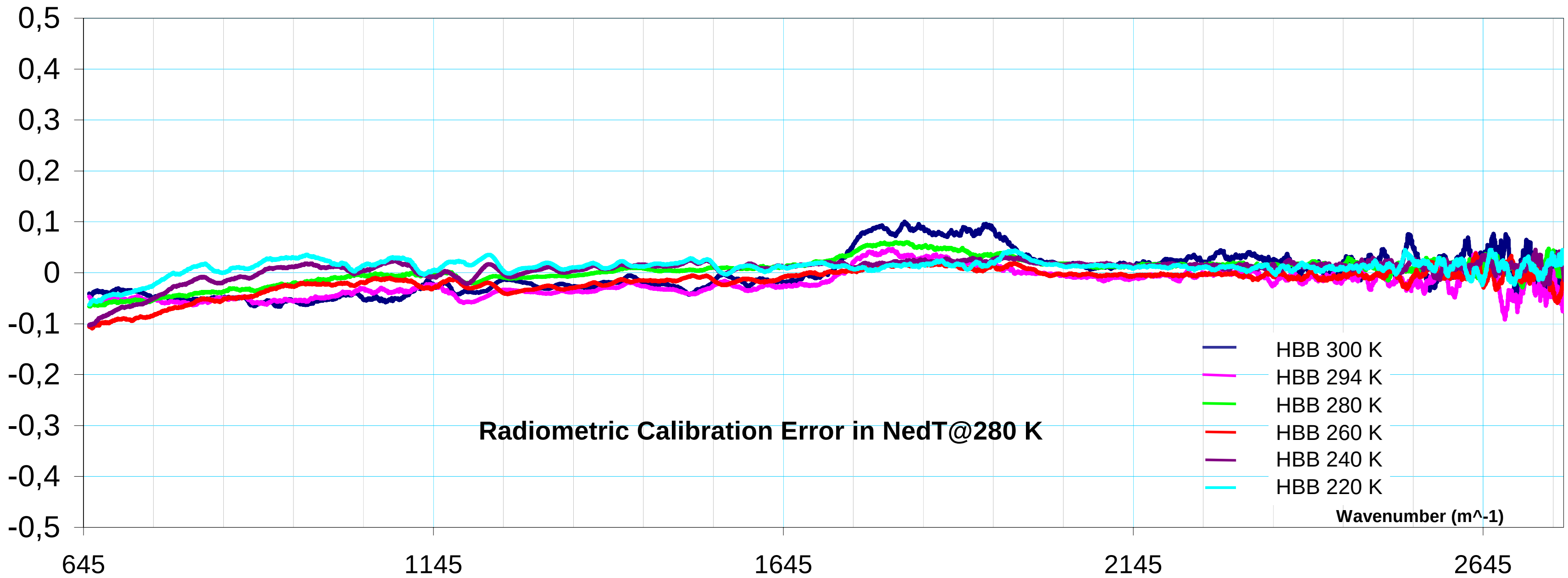
Radiometric Calibration

- Radiometric calibration measured with OGSE Blackbody using Z306 paint
- Impact of Z306 Non Blackness on Radiometric Calibration measurements deduced from Equipment Characterization and Environmental Data
- ± 100 mK Temperature Accuracy
  After Correction of Ground Support Blackbody Non Blackness



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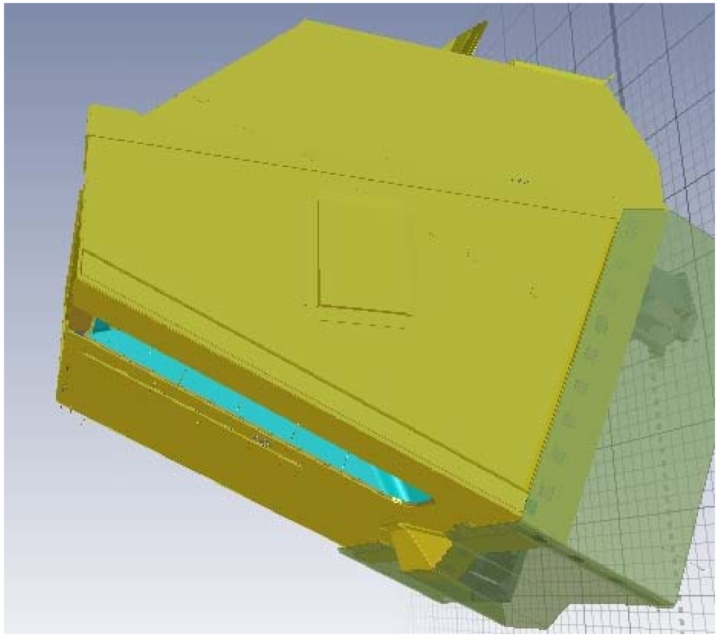
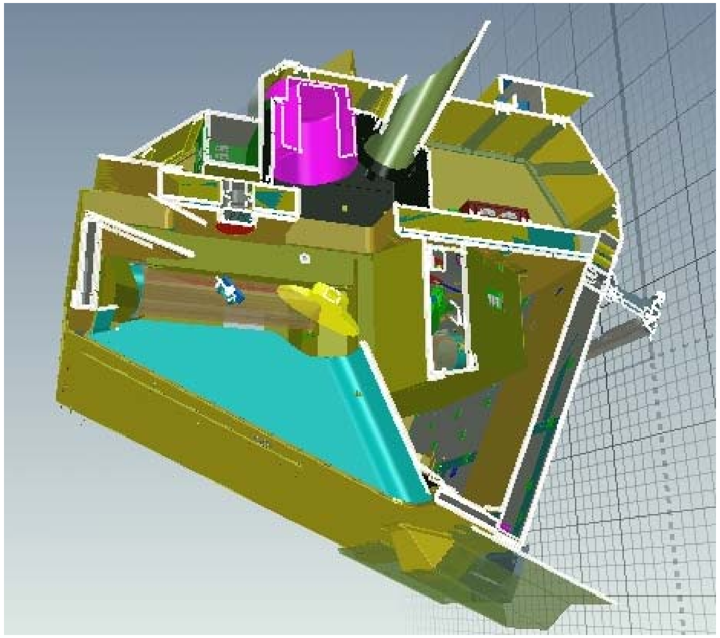
Radiometric Calibration

- Absolute calibration error almost insensitive to environmental variations such as input and output eclipse





▶ **IASI blackbody protected by Design against solar illumination of input and output eclipse**

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Radiometric Calibration

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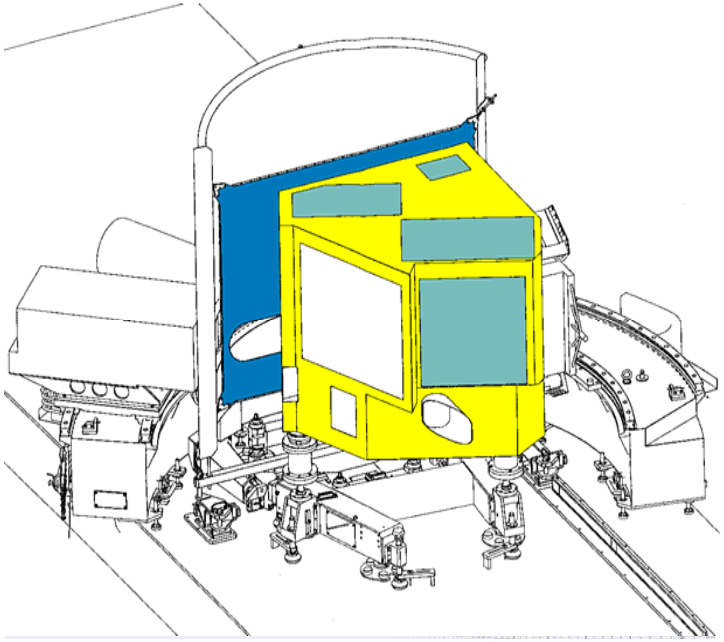

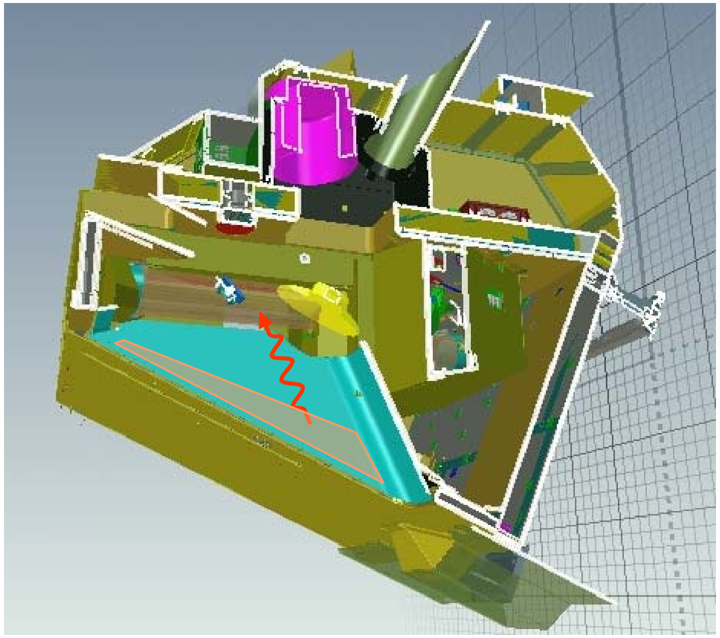

▶ **Dedicated testing on ground (Earth and Sun Entrance simulation)**

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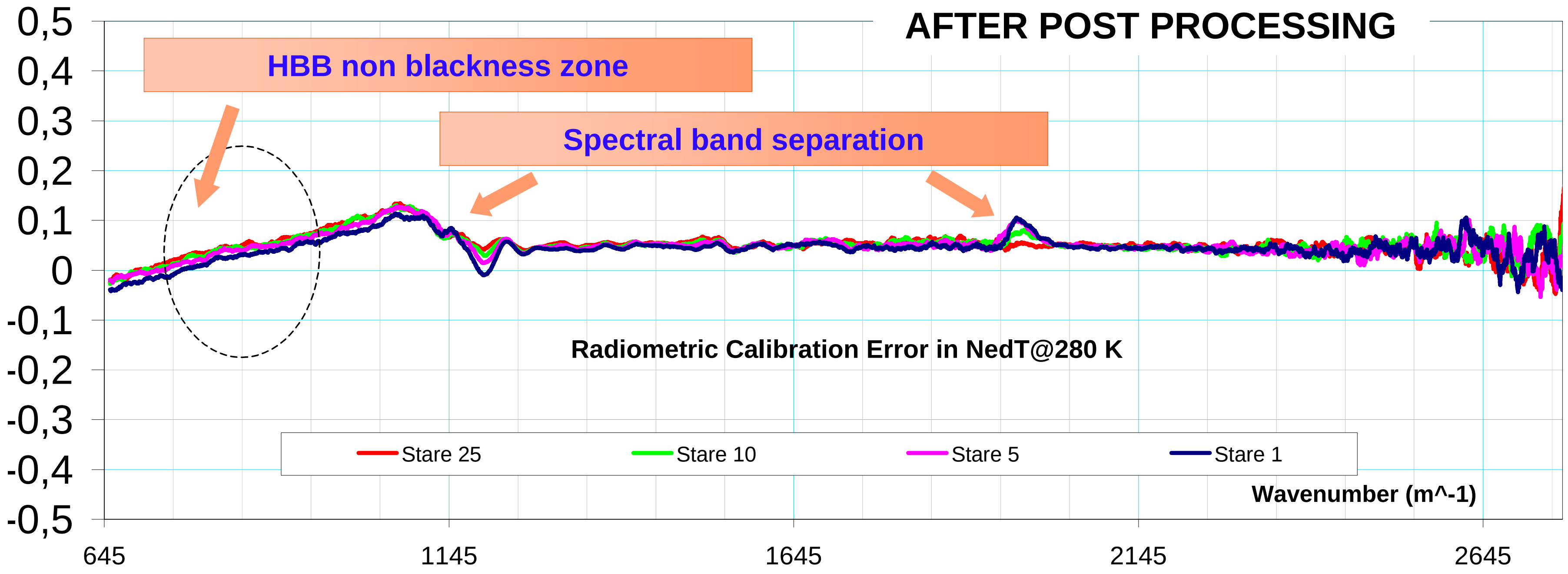
Radiometric Calibration

- Scan mirror reflectivity variation versus incidence angle almost totally corrected in the frame of the IASI Post Processing



▶ IASI + : the 2nd deep space views allows a flight monitoring of scan mirror reflectivity variations from BoL to EoL

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Radiometric Calibration

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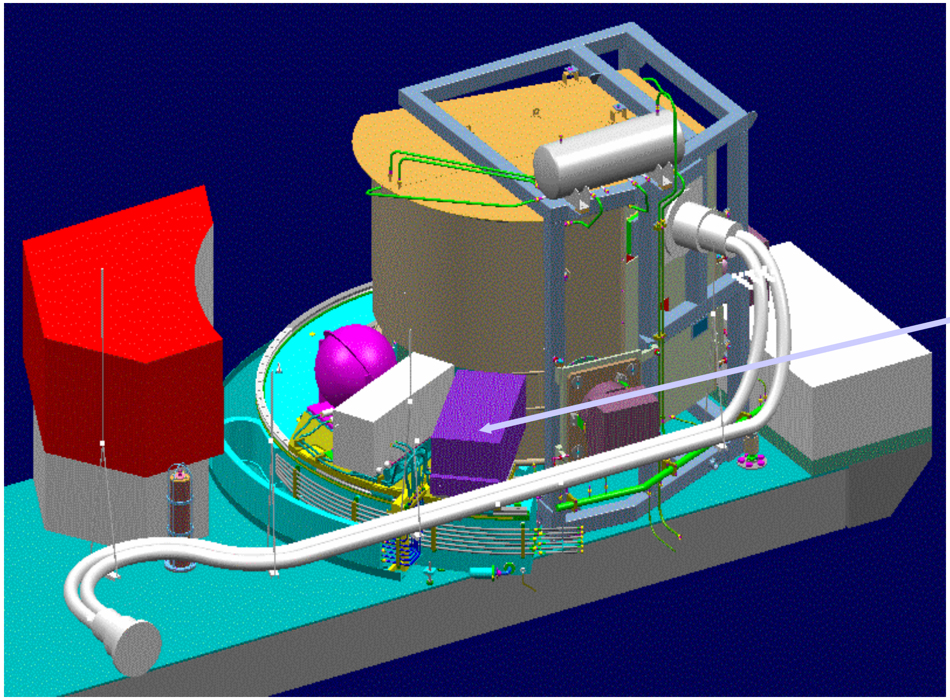

Thermally regulated 80-300 K Blackbody mounting on moving carriage

❑ Measurements of Scan Mirror Reflectivity Law versus Incidence Angle

❑ Validation of Scan Mirror Reflectivity correction

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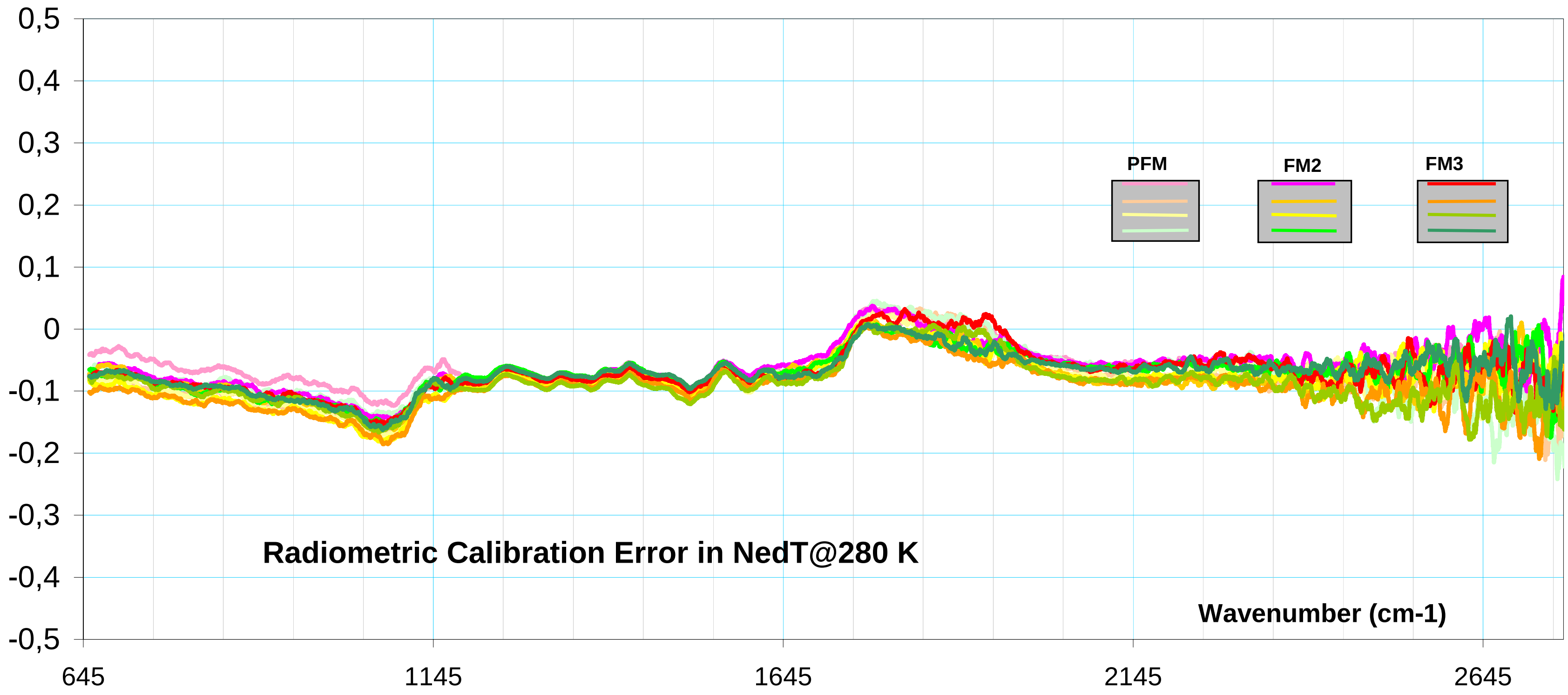
50 mK Calibration Performance Repeatability : 3 IASI flight models

(12 tested chains , 3 x 4 pixels)



- Radiometric Performance from DPS output without Post Processing

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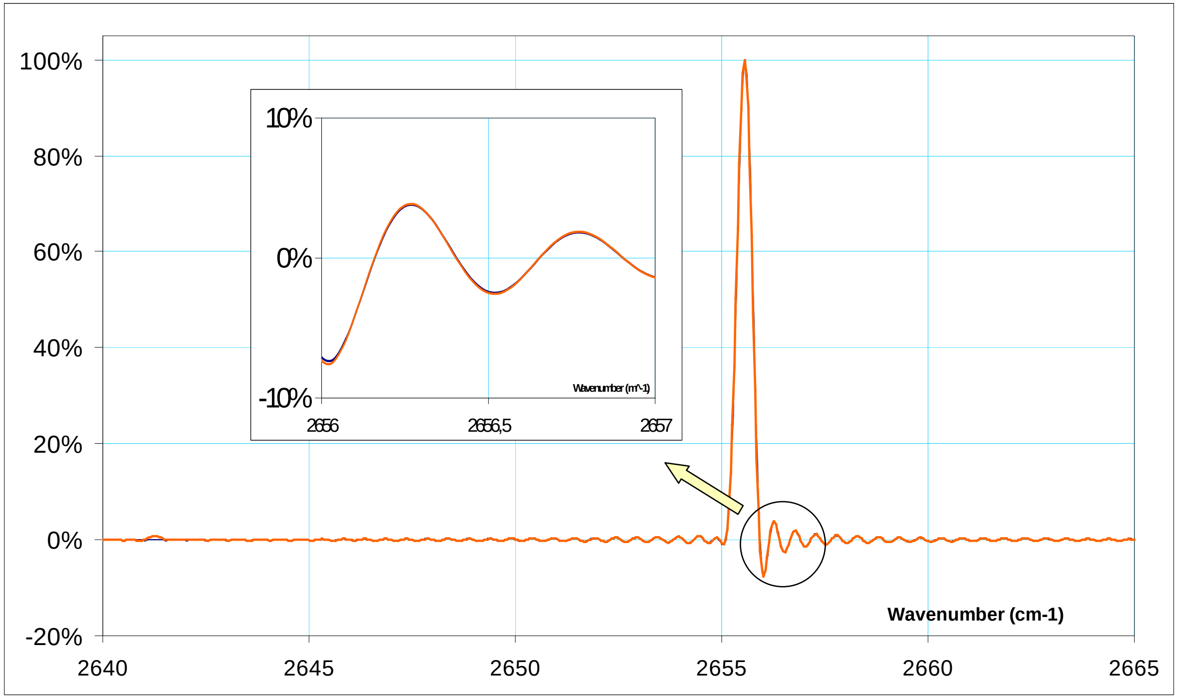
ISRF influenced by Pixel Position in the FTS's Field of Views



- Outstanding matching between ISRF model and ISRF measurements
- Measurements at:

2655.83 cm^{-1}
(Deuterium Fluoride LASER)

944.2 cm^{-1} (CO_2 LASER)

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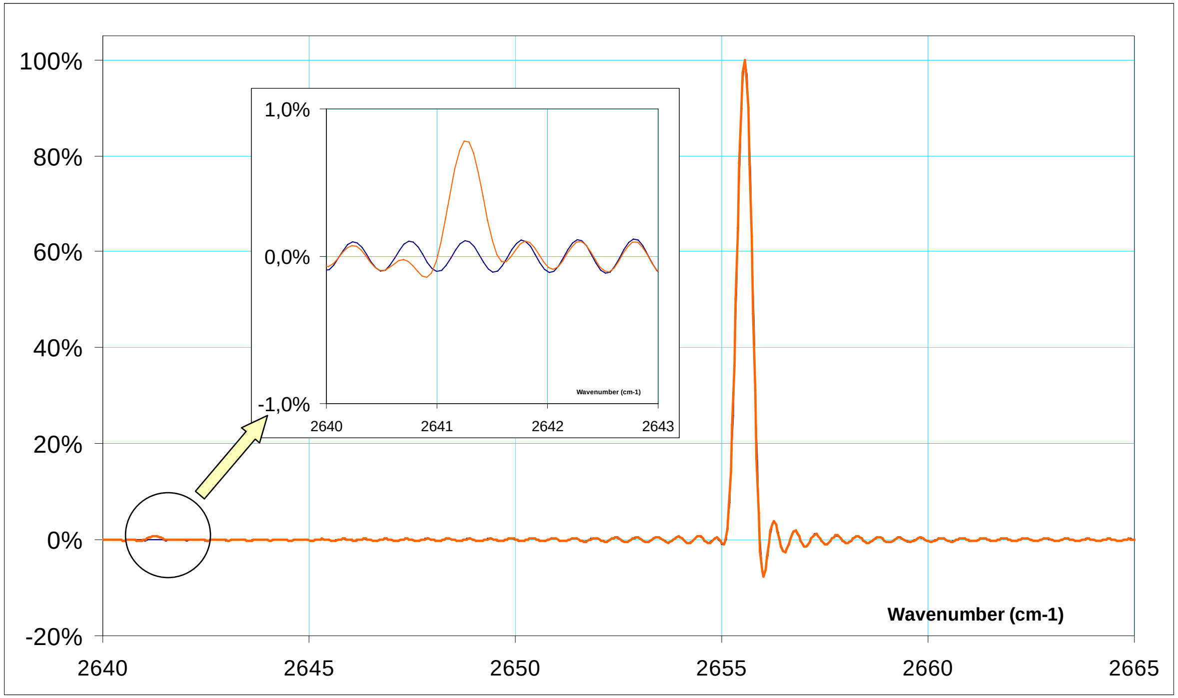
ISRF Ghost due to harmonic jitter at 378 Hz



- ISRF Ghost Work Plan
  - Ghost characterization
  - Explanation of Ghost origin
  - Identification of Flight Worst Case

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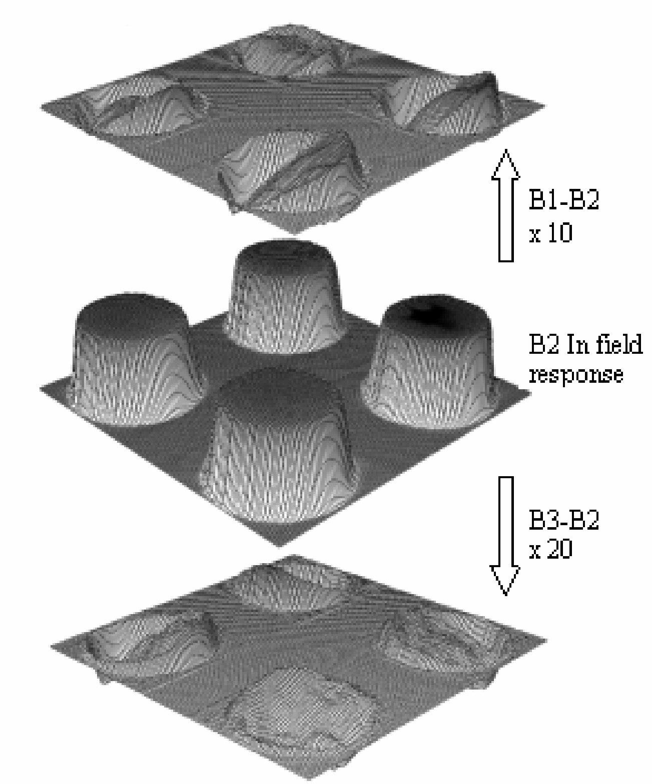
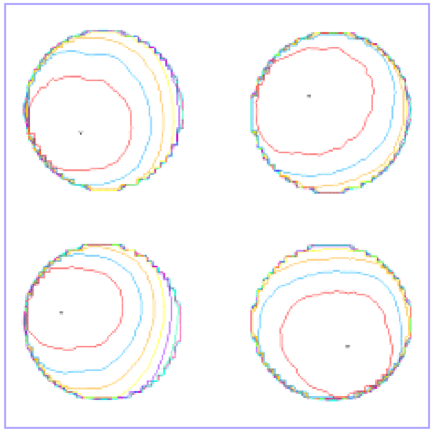
Field Response Characterization

- IASI PIXELS : 4 pixels of 12 km at Nadir
- LOW FIELD RESPONSE DIFFERENCE BETWEEN BANDS

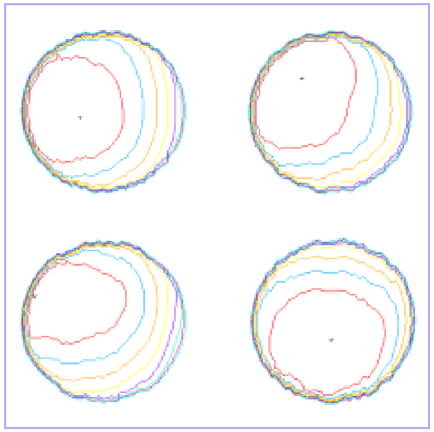


❑ Simulations and measurements are very closed

Field response **predictions**



Field response **measurements (FM3, band 1)**



▶ **Simulations include detector response NU & alignment defaults**

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Conclusions

IASI has been designed to meet IR sounding mission objectives:

- Outstanding spectral and radiometric performance
- Complete and accurate characterization of Instrument Transfer Function

Performances have been optimized for flight conditions based on accurate predictions

IASI achievement: an outcome of a close cooperation with CNES and EUMETSAT

Special thanks to to all people involved in IASI program from industries and space agencies, and in particular to F. Cayla from CNES.

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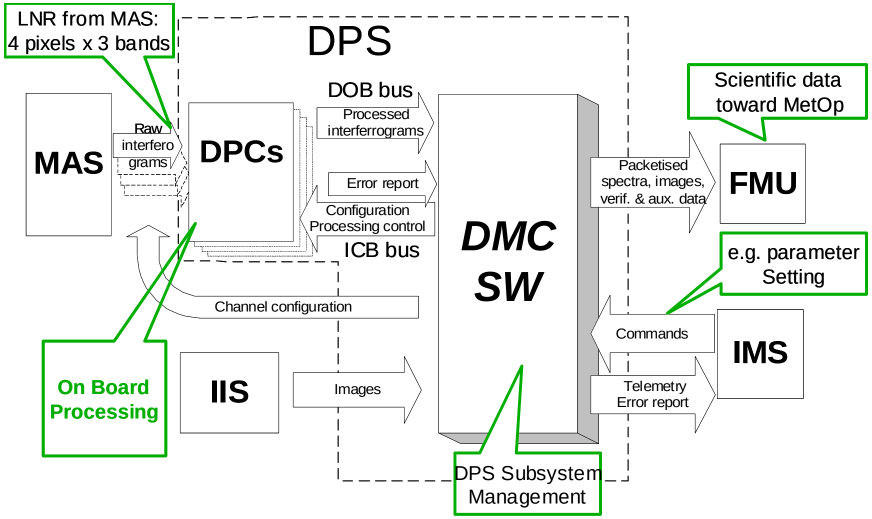
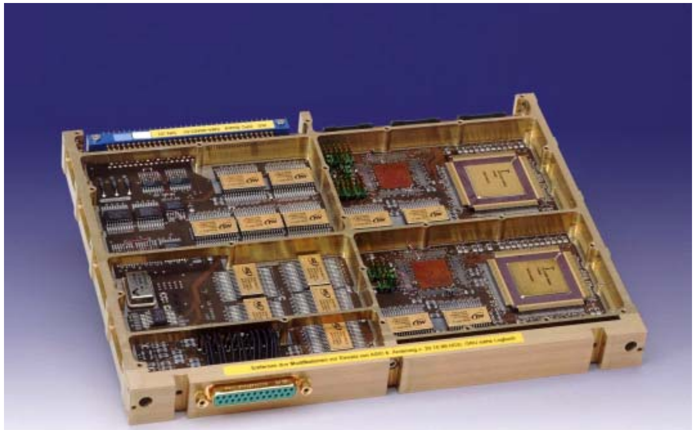
Digital Processing Subsystem

A Master Slave System

- **The master is the Data Management Chain. DMC is in charge of interfaces with:**
  - Instrument Management (TMTC)
  - Imaging Subsystem (image data)
  - METOP (processing data)
- **In operation DMC controls 8 Processing Chains (DPC)**
- **One DPCs performs processing of interferograms of 3 spectral bands of one pixel.**
- **DPC and DMC boards are based on TSC21020F µprocessors.**





By courtesy of SAAB Ericsson Space

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High performance blackbody (manufactured by AEA).

Controlled in temperature through its mechanical interface (around 20°C).

Designed and accommodated with care in order to achieve an absolute temperature knowledge better than 0.12 K.

Blackbody cavity design: cylinder with a conical base internally painted with Lockeed Martin's enhanced black finish.

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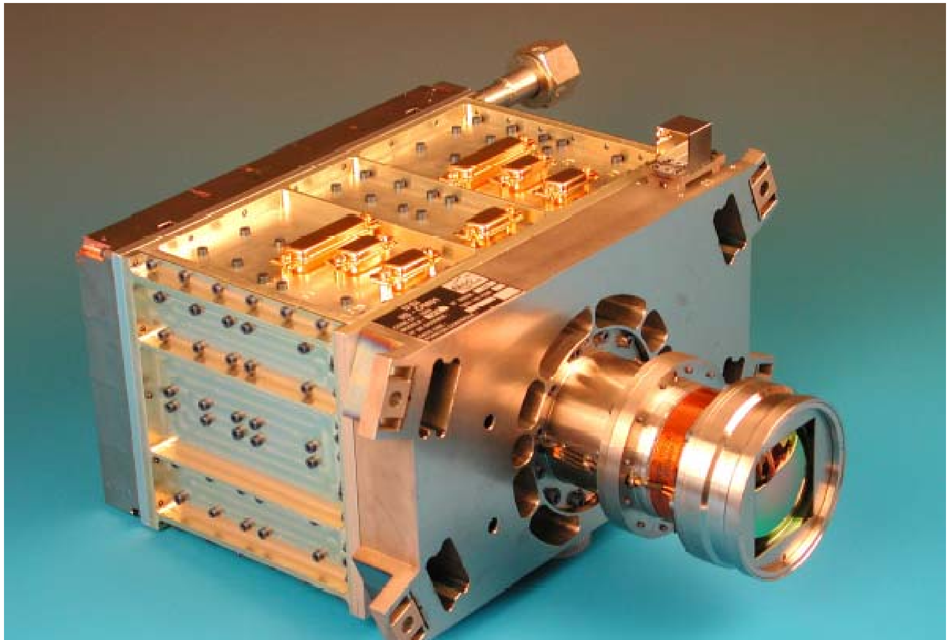
Imaging subsystem [10.3 to 12.5 µm] (manufactured by EADS-SODERN)

Co-aligned with the interferometer optical axis, to perform co-registration of IASI sounder with AVHRR

- Objectives including spectral filter designed to minimize straylight
- Microbolometer array U30000A manufactured by BOEING
- 12 bit video processing chain including offset correction
- 64x64 images in a 60x60 mrd FOV.
- Noise Equivalent Temperature Difference 0.5 K (for a scene temperature of 280 K).
- Mass : 5.2 Kg / Power 5.2 W



By courtesy of EADS-SODERN

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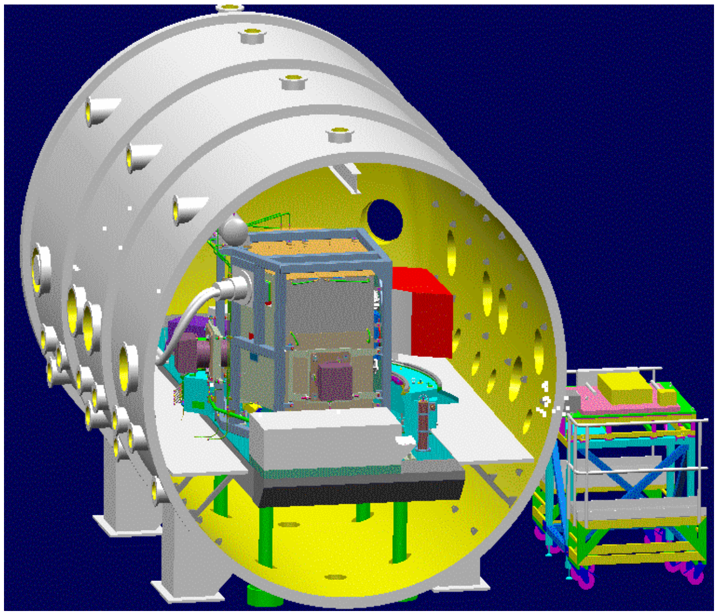
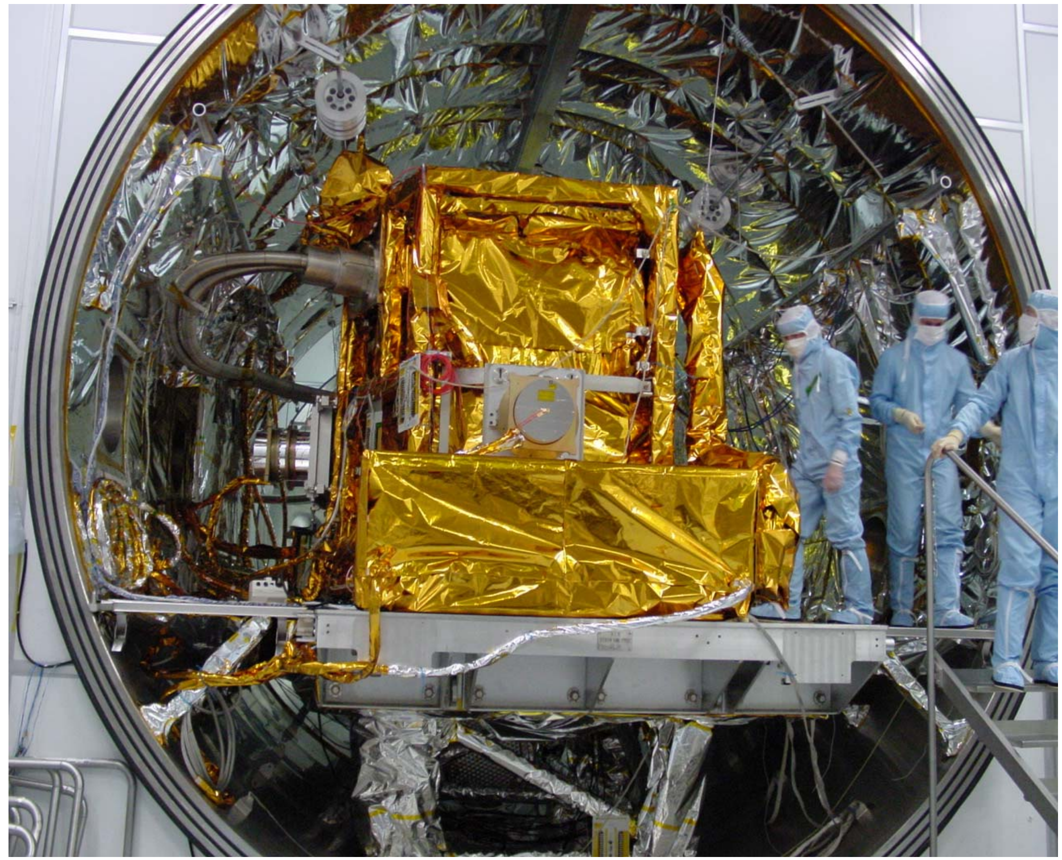
VACUUM CHAMBER CONFIGURATION





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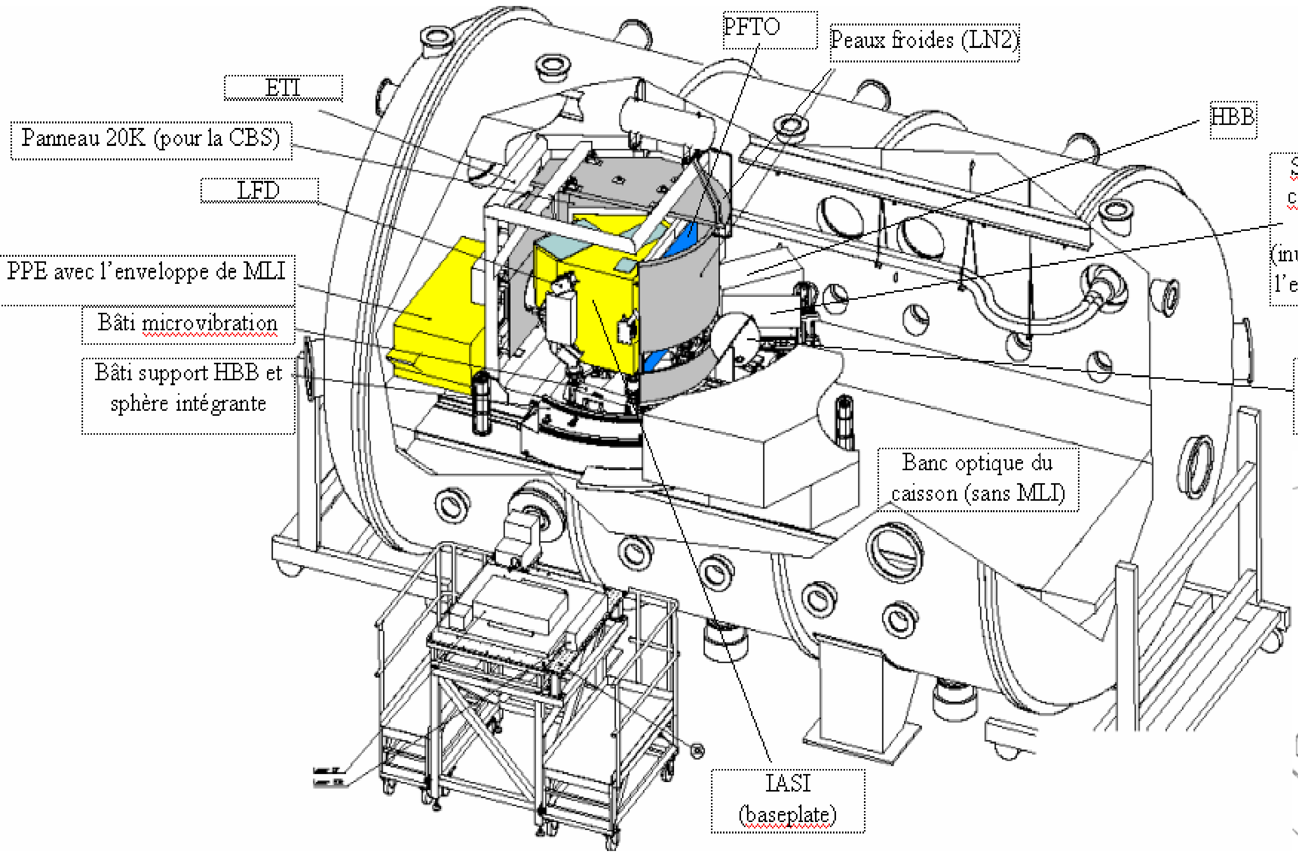
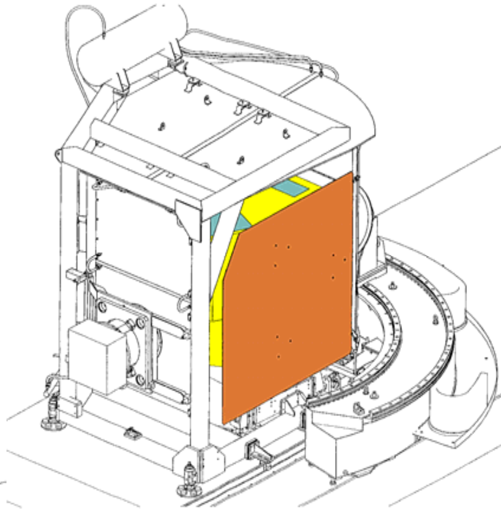
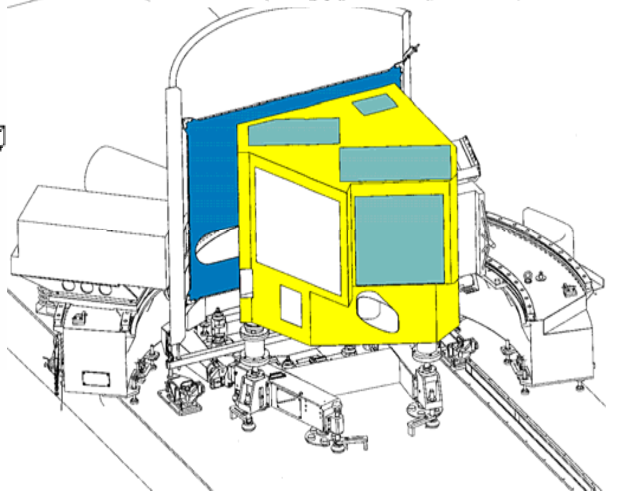
OPTICAL VACUUM TEST CONFIGURATION







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