IASI: a Review of Instrument Performance and Characterizations

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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 m³
- 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
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**
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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Calibration views looked at every 8 s
- Internal Reference Blackbody view
- Cold Space view

NADIR and 2nd deep space views in External Calibration mode
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.)
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
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.
Radiometric Resolution

The Challenges of the Radiometric Resolution

Optical transmission
Detector Response &
Focal plane temperature

Water ice absorption
max at 820 cm\(^{-1}\)

Interferometer contrast
Cube Corner Shear
WFE Interferometer arms

NedT [°C] ; Temperature of scene : 280 K
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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± 100 mK Temperature Accuracy
After Correction of Ground Support Blackbody Non Blackness
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
Radiometric Calibration

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

Dedicated testing on ground (Earth and Sun Entrance simulation)
Scan mirror reflectivity variation versus incidence angle almost totally corrected in the frame of the IASI Post Processing

HBB non blackness zone
Spectral band separation

Radiometric Calibration Error in NedT@280 K

IASI +: the 2nd deep space views allows a flight monitoring of scan mirror reflectivity variations from BoL to EoL
Scan mirror reflectivity variation versus incidence angle almost totally corrected in the frame of the IASI Post Processing

- 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
50 mK Calibration Performance Repeatability : 3 IASI flight models
(12 tested chains, 3 x 4 pixels)

Radiometric Calibration Error in NedT@280 K

Radiometric Performance from DPS output without Post Processing
ISRF influenced by Pixel Position in the FTS’s Field of Views

- Outstanding matching between ISRF model and ISRF measurements

- Measurements at:
  - $2655.83 \text{ cm}^{-1}$ (Deuterium Fluoride LASER)
  - $944.2 \text{ cm}^{-1}$ (CO$_2$ LASER)
ISRF Ghost due to harmonic jitter at 378 Hz

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

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

- Simulations and measurements are very closed

Simulations include detector response NU & alignment defaults
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 all people involved in IASI program from industries and space agencies, and in particular to F. Cayla from CNES.
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.
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 Lockheed Martin’s enhanced black finish.
Integrated Imaging subsystem

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
OPTICAL VACUUM TEST CONFIGURATION

Thales Alenia Space

OPTICAL VACUUM TEST CONFIGURATION

Various labels and annotations on the diagram, indicating different components and labels such as "Peaux froides (LN2)", "Straylight collimator support (utilisé pour l'essai FTI)", "Sphère intégrante", "Base optique de caisson (sans MLI)", "LED", "FPE avec l'enveloppe de MLI", "PTEO".