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*Gérard Cluzet, Benjamin Pouilloux*

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# THREE-STAGE PASSIVE RADIATOR FOR IASI INSTRUMENT

**Gérard CLUZET** - *AEROSPATIALE Cannes, 100 bd du midi 06156, Cannes la bocca*
Tel 04 92 92 30 26 - Fax 04 92 92 62 70

**Benjamin POUILLOUX** - *CNES, 18 av Edouard belin, 31401 Toulouse*
Tel 05 61 28 22 87 Fax 05 61 27 34 46

## ABSTRACT

IASI instrument (Infrared Atmospheric Sounding Interferometer) is an earth observation instrument which will be launched on the METOP meteorological polar platform in order to provide spectrums of the Earth's atmosphere.

To fulfil the required operating temperature of 100K for the infrared detection unit used for this mission, a three-stage passive radiator is under development at AEROSPATIALE under the direction of the French national Agency (CNES).

After a study which had shown that a two-stage radiator was not suitable to cool down to 100K detectors with a dissipation of 56 mW, the concept has been improved by the addition of a third stage and a new suspension system.

This paper describes the final thermal concept, the thermal analysis performed, the heat balance for each stage, and the corresponding needed technological developments.

In order to limit inputs from external environment on the radiator, the three radiating plates are in the same plane in the direction of the Earth limb. They are protected from solar insulation by a sunshield. An earth shield minimises the albedo and infrared earth fluxes on this sunshield. The thermal insulation from the internal instrument is obtained with Multi Layer insulation and three sophisticated low conductive fiberglass fixation blades.

Some technological tests are under development to achieve required performance; among them the specular reflecting coating of the sunshield, mechanical and thermal characterisation of fiberglass fixation blades, the behaviour of different material and coatings at low temperature, and cover mechanism characterisation.

## 1. INTRODUCTION

The three-stage passive radiator described in this paper is part of IASI instrument, an Earth observation instrument which will be launched on the European METOP meteorological platform (figure 1) in 2001 for a 5 years operating period in low earth orbit

IASI mission is to provide emission spectrum of Earth's atmosphere for meteorological application. For this mission detectors have to be cooled below 100 K in operational conditions, with an adequate cooling margin of safety over the entire mission. This performance is achieved by a three-stage passive radiator.

The passive concept has been chosen because it requires no moving parts (no micro-vibration problem) or stored coolant, and has a very limited power consumption, if necessary, for detectors temperature control.

The program is under CNES and EUMETSAT responsibility, and is in the end of phase B. AEROSPATIALE will be the prime of IASI development during phase C/D.

A first study had shown that a two-stage radiator was not suitable to cool down at 100 K the detection unit with a dissipation of 56 mW. The concept has been improved by the addition of a third stage and new suspension system. Those main modifications reduce the effect of heat leaks through MLI which have been characterised by a specific test on a representative mock-up.

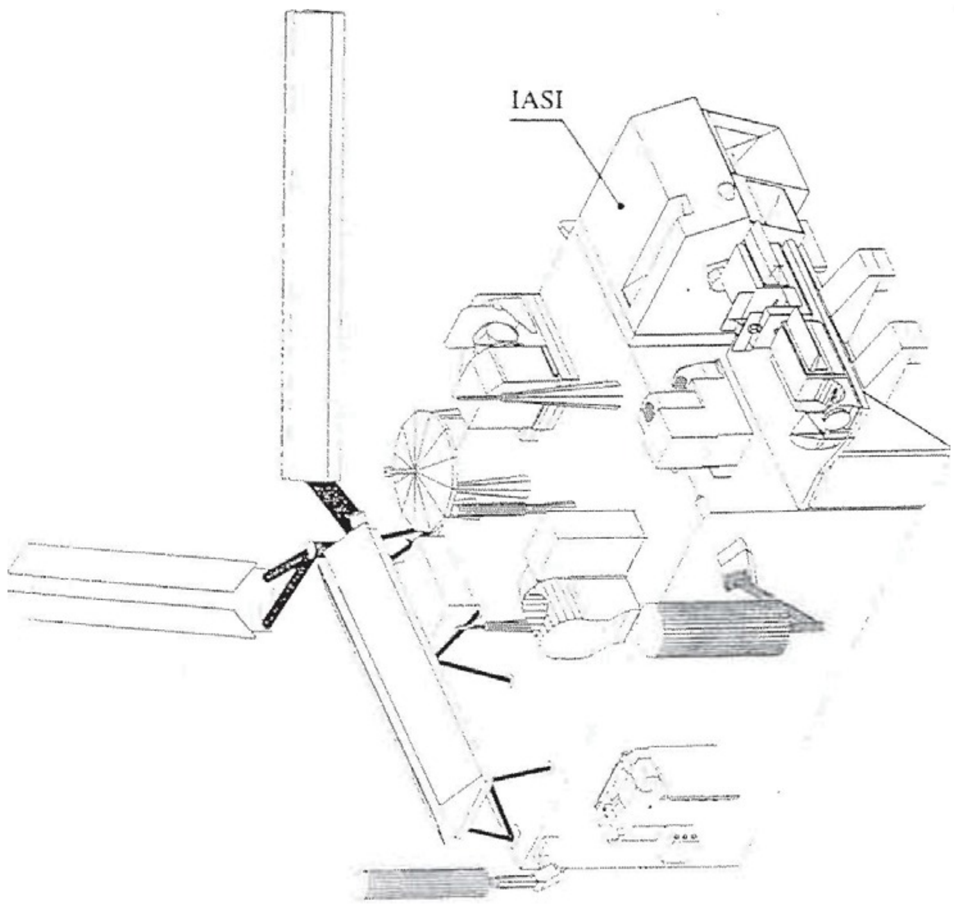


Fig I : METOP platform

## 2. IASI MISSION

IASI mission consists in providing vertical profiles of temperature and humidity, trace gases monitoring, land and sea surface temperature, and cloud radiation.

The instrument measures the emission spectra of atmosphere in the field 3.6 µm to 15.5 µm. It is based on a Fourier Transform Spectrometer based on a Michelson Interferometer coupled with an Integrated Imaging System to provide the characterisation of cloudiness in the field of view.

IASI instrument (figure 2) is composed of a scanning mirror looking toward NADIR, an interferometer and mirrors which focuses the optical beam to the infrared detection unit. Incoming light is spread in three spectral bands inside the detection unit. This element is composed of cold optics and detectors. The heat load on the radiator from the detectors is 56 mW. They are operating at a temperature of 1●● K by a three-stage passive radiator to fulfil the instrument performances.

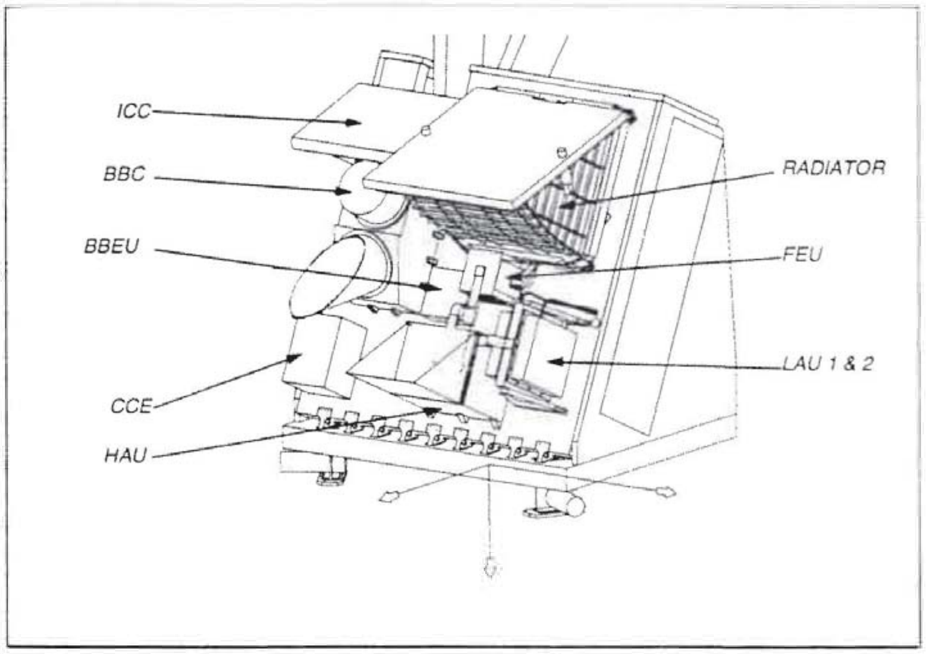


Fig 2 : IASI instrument

IASI passive radiator shall also be defined to guarantee a temperature level lower than 333K on detectors in non-operating conditions (safe mode attitude for instance).

Radiator design and development are made by AEROSPATIALE. A significant effort was made to reduce development risks and to fit with IASI program schedule by the selection of already existing technologies.

## 3. CONCEPT DESCRIPTION

METOP spacecraft is operating in a heliosynchronous low earth orbit at 800 km, with a inclination of 98.7°.

Following spacecraft initial injection at a 10h00 A.M local time, orbit will gradually drift to a final 09h30 A.M local time after 6 to 9 months.

Detection unit thermal performance shall be guaranteed with the initial orbit.

Those parameters define the clear field of view of IASI cooler. The orbit altitude is 800 km, so the earth horizon is about 27° below the local horizontal. Due to the local time, the solar rays approach to within 23° from the local vertical. The horizontal field of view is limited to 180° by warm surfaces of the spacecraft.

Taking into account those two aspects and the precision of orbital parameters, the radiator has a free field of view of 138°.

To achieve required thermal performances, the three-stage radiator is defined to minimise the effects of the external environment (sun and earth) and of the instrument internal environment (300 K).

A global view of the radiator is given in figure 3. External dimensions are 430x430x650 mm. A description of the definition is given in figure 4.

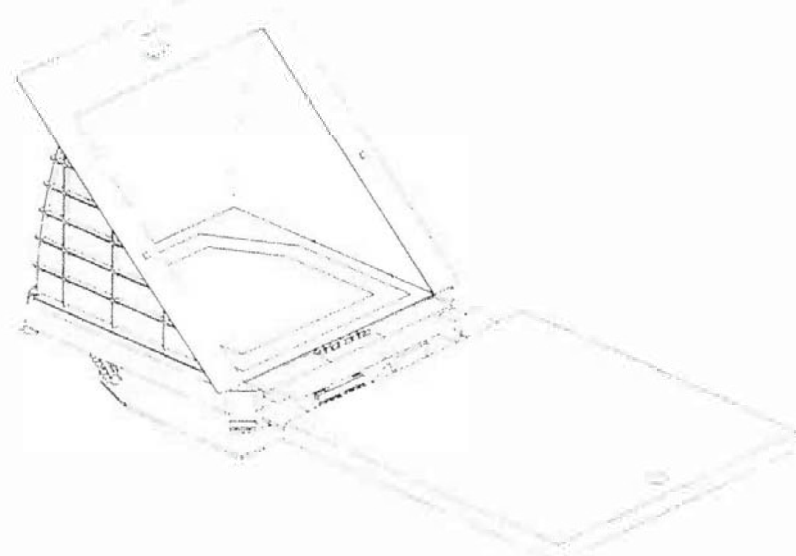

Fig 3 : IASI passive radiator overview

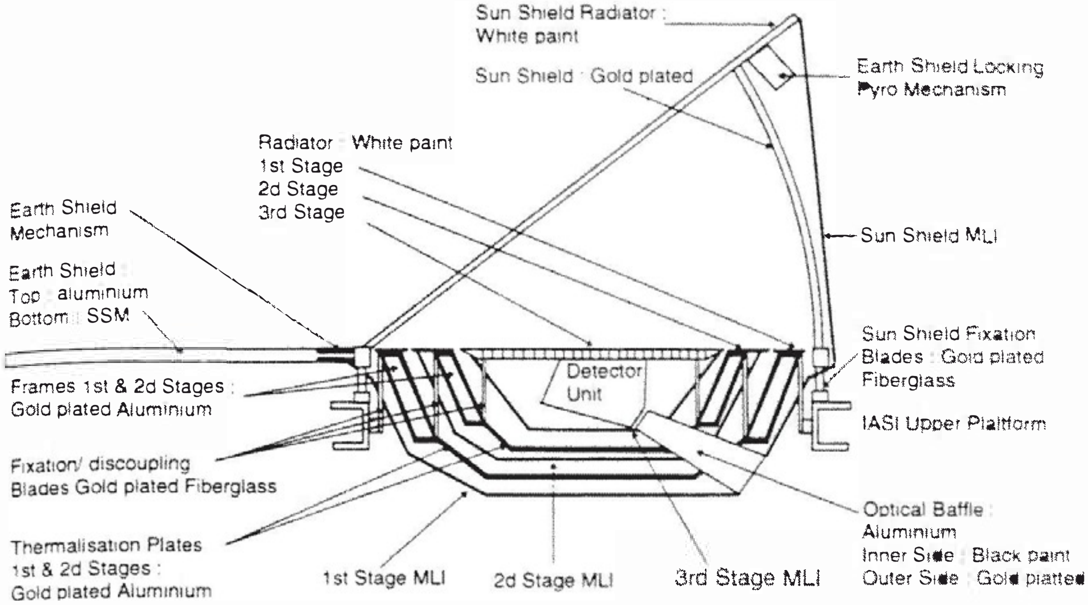


**Fig 4** : IASI passive radiator concept description

In order to avoid all direct fluxes from Earth, the three radiative plates are in the same plane, and in the direction of the Earth limb. They are all coated with a high emittance and low solar absorbtance white conductive paint coating (PCBZ paint). This solution was preferred to an open honeycomb with black paint in order to guarantee a temperature level lower than 333K during safe mode attitude.

Radiative plates are protected from direct solar insulation with a sunshield. This shield is composed of two flats and one cylindrical parts. Main Earth and Albedo fluxes are space rejected by optimisation of sunshield shape, and by using a high specular coating with a diffuse reflectance lower than 1.5%.

In order to minimise direct radiative input from the sunshield on radiative plates, a low emittance gold coating is deposited on the sunshield. This is the same coating developed for ISO spacecraft sunshield. Specific technological tests shall be performed to adapt polishing and deposit procedures to IASI sunshield.

An additional radiator, coated with PCBZ white paint, is located around the sunshield to cool it down.

During ground and launch operations, a cover is used to protect sunshield from molecular and particulate contamination. After launch, the cover will be opened after initial spacecraft outgassing, and used as an earth shield to minimise the Albedo and Earth fluxes on the sunshield. Earth shield is made of a kapton foil on a rigid frame. It is covered with Second Surface Mirror on the Earth looking face, and with Aluminised Kapton on the upper face.

This cover is deployed by a commonly used one shot mechanism (see figure 5). The hinge is realised with two dry-lubrificated ball joints and two torsion springs.

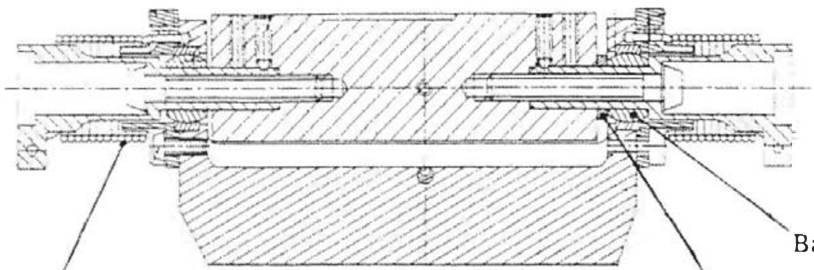


**Fig 5** : Deployment mechanism

Detection unit is directly fastened under the third stage radiative plate to optimise cooling efficiency. First and second stages are made with aluminium alloy frames which are used as radiative surfaces on their upper faces. The third stage is suspended from the second stage, the second stage is suspended from the first stage and the first stage is suspended from the internal instrument with low conductive fiberglass blades to minimise heat conduction. The blades and the frames are coated with gold to minimise radiative effects. Blades were preferred to fiberglass suspensions because it limits the number and the size of singularities in MLI (Multi Layer Insulation), and simplifies integration procedures. Furthermore, fatigue effect is very limited because no pretension is needed. Finally this technology is already used in other project at AEROSPATIALE, which limits development risks.

The characteristics of blades are defined by mechanical analysis to fulfil the following requirements:

- first frequency upper than 110 Hz

- to resist to launch stresses

- to respect alignment stability during operation.

The sunshield is de coupled form the first stage and fixed on the upper panel of IASI instrument by fiberglass blades. This configuration limits the supported weight by the first stage blades, and thus thermal inputs. It also offers the possibility to change sunshield field of view (due to a modification of local hour for instance) with no impact on first, second and third stage blades definition.

First stage and sunshield back face are covered with MLI in order to minimise inputs from the environment. MLI are made of sheets of mylar with clean spacers developed by AEROSPATIALE for cryogenic applications. An optimisation has been made to reduce the number of MLI, and the number and size of singularities. Radiative insulation of second and third stages is obtained either by a MLI. either by a gold coated sheet of kapton.

Two thermalisation plates are located under first and second stage. They are used to drain radiative inputs on their lower part to frames.

The radiator is equipped with different temperature sensors and heaters on each stage and on the sunshield. Cables are carefully thermalised on each stage to reduce thermal inputs.

Outgassing of the radiator can be performed in case of contamination during its operation. This operation is performed by specific heaters which maintain the cooler at 313 K.

The radiator is equipped with a baffle in order to minimise thermal inputs through the hole for the optical beam.

Baffle is made of two parts fastened on first and second stage to minimise emitted energy from baffle to the detection unit. Internal face on the baffle is coated with black paint to reduce reflected energy from the instrument. Ambient and baffle thermal inputs in the detection unit are optimised by the field stop coated with gold around the four holes for optical beam.

## 4. PERFORMANCES

A 130 nodes thermal model of IASI radiator has been made with ESATAN software to predict hot case thermal performances. Radiative couplings and external fluxes are obtained using THERMICA software. The steady state temperatures reached on each stage are the following :

- third stage radiator : 90 K
- second stage radiator : 119 K
- first stage radiator : 183 K
- sunshield radiator : 176 K

Heat loads on each stage and on the sunshield are given in tables 1 to 4 hereafter.

Sensitivity analysis have been made to identify critical parameters in the heat balance of each stage and to define performance margin. This analysis shows that the driving parameters are sunshield gold coating specularity and emittance, fiberglass blades thermal conductivity and MLI (+ 1,7 K for an increase of 100% of MLI efficiency).

The extreme cold stage temperature level in hot operating condition is less than 100 K including total uncertainty margin. The third stage sensitivity at 90K is 12 mW/K.

A detailed structural model of IASI radiator has been made with NASTRAN software. A serie of quasi static and random analysis have been made to perform mechanical dimensioning of structural parts and blades.

First frequency is above 120 Hz, and margins of safety are all above 15%.

| Heat source | Cold stage (mW) |
|---|---|
| Sunshield emission | 72 |
| Detectors | 68 |
| Blades | 37 |
| Earth and albedo | 10 |
| Optical beam + baffle | 10 |
| Third stage MLI | 8 |
| Cables | 5 |
| First stage radiator emission | 4 |
| Second stage rad. emission | 3 |
| Total | 217 mW |

**Table 1** : Third stage heat loads

| Heat source | Second stage (mW) |
|---|---|
| Second stage MLI | 129 |
| Baffle | 123 |
| Blades | 96 |
| Sunshield emission | 40 |
| First stage radiator | 24 |
| Cables | 13 |
| Earth and albedo | 5 |
| Total | 430 mW |

**Table 2** : Second stage heat loads

| Heat source | First stage (mW) |
|---|---|
| First stage MLI | 1224 |
| Baffle | 787 |
| Blades | 716 |
| Cables | 30 |
| Earth + albedo | 5 |
| Sunshield | 4 |
| Total | 2762 mW |

**Table 3** : First stage heat loads

| Heat source | First stage (mW) |
|---|---|
| Ext. fluxes sunshield radiator | 1721 |
| Ext. fluxes internal sunshield | 566 |
| Sunshield MLI | 1582 |
| Blades | 790 |
| Earthshield | 28 |
| Cables | 13 |
| Total | 4700 mW |

**Table 4** : Sunshield heat loads

Total mass of the radiator to 13.5 kg without margin. It is decomposed as followed .

- cold stage (without cryostat) : 0.8 kg
- second stage : 2.8 kg
- first stage : 4.1 kg
- sunshield + earth shield : 5.8 kg

Alignment stability analysis has been performed to identify main budgets. This analysis takes into account all events (integration tolerance, gravitation, thermo-elastic, hygro-elastic, micro-gliding, deformations) which could occur integration, ground tests, launch and in orbital conditions at long and short term. The NASTRAN model has been used for this analysis. It shows that detection unit position knowledge is less than 200 µm and that short term stability over a period of 300 seconds is less than 5 µm.

## 5. TECHNOLOGICAL TESTS

In order to achieve thermal and mechanical performances, some technological tests are necessary to confort modelisation hypothesis, to characterise thermal/mechanical behaviour and performance of materials, and to show the feasibility of chosen solutions.

Those tests concern

- structural holding of NIDA and inserts before and after thermal cycling.

- performance and holding of PCBZ white paint submitted to thermal cycling

- holding of cold stage heaters under thermal cycling

- micro-gliding characterisation of blade interface with frames

- complete qualification of each stage blades

- verification of sunshield gold coating deposit procedures developed for ISO sunshield

All tests have been realised successfully, except the two last ones which are planned during phase C.

Thermal, mechanical, hygro-elastic and thermo-elastic characterisation of fiberglass material used for blades has been performed on an other project.

## 6. CONCLUSION

A three-stage passive radiative cooler has been designed for IASI mission. A passive radiator has a great advantage because it has no moving parts, and has a very limited power consumption.

It takes advantage of the free field of view offered by the heliosynchronous low-earth orbit with a local time at descending node at 10h00. The concept, with the sunshield modularity, makes it applicable for heliosynchronous orbit with a local time at descending node lower than 10h00.

For IASI mission, the refrigeration power on the cold stage is about 83 mW at 90 K (the sum of baffle, cables and detectors heat loads).