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## ***NAOMI instrument: a product line of compact and versatile cameras designed for high resolution missions in Earth observation***

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## NAOMI INSTRUMENT: A PRODUCT LINE OF COMPACT & VERSATILE CAMERAS DESIGNED FOR HIGH RESOLUTION MISSIONS IN EARTH OBSERVATION.

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### ABSTRACT

EADS Astrium is currently developing a new product line of compact and versatile instruments for high resolution missions in Earth Observation.

First version has been developed in the frame of the ALSAT-2 contract awarded by the Algerian Space Agency (ASAL) to EADS Astrium. The Silicon Carbide Korsch-type telescope coupled with a multi-lines detector array offers a 2.5 m GSD in PAN band at Nadir @ 680 km altitude (10 m GSD in the four multispectral bands) with a 17.5 km swath width. This compact camera – 340 (W) x 460 (L) x 510 (H) mm<sup>3</sup>, 13 kg – is embarked on a Myriade-type small platform. The electronics unit accommodates video, house-keeping, and thermal control functions and also a 64 Gbit mass memory. Two satellites are developed; the first one is planned to be launched on mid 2009.

Several other versions of the instrument have already been defined with enhanced resolution or/and larger field of view.

### 1. INTRODUCTION

EADS Astrium is currently developing a new product line of compact and versatile instruments, called NAOMI, for high resolution missions in Earth Observation. This instrument takes benefits of two main strong points: a five CCD lines focal plane and SiC technology. First version of NAOMI has been developed in the frame of the ALSAT-2 contract awarded by the Algerian Space Agency (ASAL) to Astrium in December 2006. An enhanced version is currently developed for the SSOT (“Sistema satelital para Observación de la Tierra”) program awarded by the Chilean authorities to Astrium in July 2008.

### 2. NAOMI FOR ALSAT2 PROGRAM

#### 2.1 Mission and satellite presentation.

Alsat2 is an optical remote Earth observation system composed of a space segment and a ground segment. The space segment is an Astrosat 100 class satellite based on the Myriade platform developed jointly by CNES (French Space Agency) and Astrium for microsatellites missions. The payload is the first application of the NAOMI instrument (*New Astrosat Observation Modular Instrument*) developed for Earth Observation missions.

Image data are acquired with a 2.5m Ground sampling Distance (GSD) in Panchromatic (PAN) at Nadir and with a 10m GSD in four Multispectral bands @ 680 km altitude.

#### 2.2 Instrument overall design

The instrument design is mainly driven by mission parameters and detector characteristics. The Time Delay Integration mode (TDI) in PAN band enables to reduce the pupil size for a given GSD. Pupil diameter is no more sized to comply with SNR requirements which can be achieved by increasing the number of TDI stages and is only driven by MTF requirement. A 200mm pupil diameter has been selected for the camera leading to a very compact instrument. The mass of the instrument is less than 20kg (13kg for the camera and 5.5kg for the Electronics Unit).

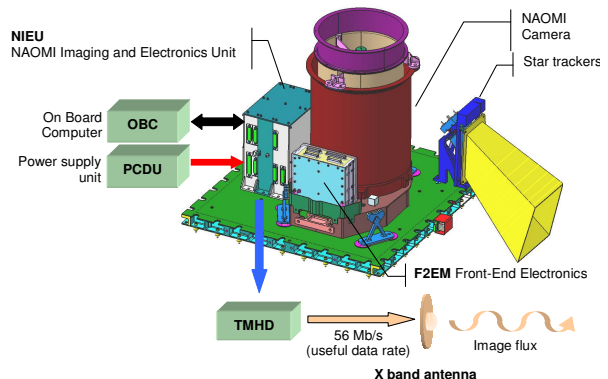


Fig. 1 : NAOMI instrument and interfaces

#### 2.3 Optical design

The optical assembly is based on a Korsch-type telescope including three aspheric mirrors and two folding mirrors.

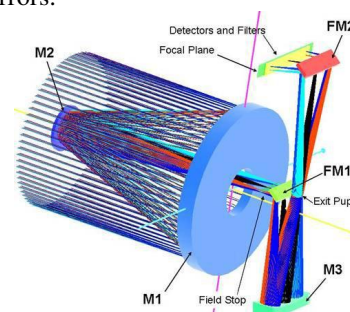


Fig. 2. Telescope optical design

The 200 mm pupil aperture, leading to a F-number of F/16, is located on the primary mirror. The optical filtering is ensured by highly integrated filters, including masks to minimize spectral cross-talk. The filters feature high band transmission, and sharp spectral band edges as illustrated below.

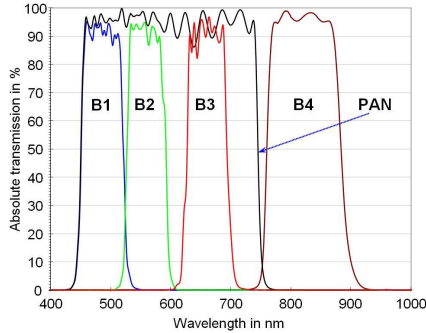


Fig. 3. Spectral response of the optical filters

**2.4 Mechanical and thermal design**

The camera is based on an all Silicon Carbide (SiC) telescope coupled with a compact focal plane unit. The primary structure is composed of three main parts: a baseplate, a cylindrical tube with a spider supporting the secondary mirror, and the focal plane. The baseplate supports the cylindrical tube, the mirrors, the detector and its front-end electronics. It is isostatically mounted onto the platform by means of three Titanium bipods. The secondary mirror is mounted on the spider which is supported by the tube. All these parts are made of SiC. The tube interfaces with the baseplate by means of three bolts. Thanks to high thermal conductivity, low coefficient of expansion and high stiffness of SiC material, this simple and efficient monolithic structure assembly provides excellent thermo-mechanical performances. The structure also supports thermal Multi Layer Insulation (MLI).

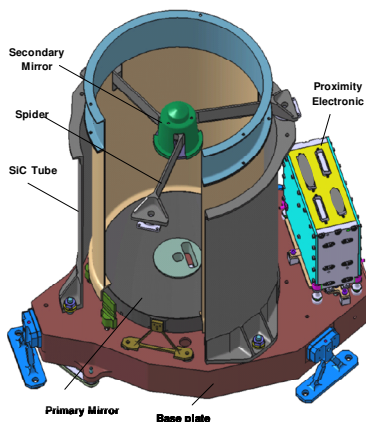


Fig. 4 : Mechanical architecture

The SiC primary mirror is mounted onto the baseplate via three isostatic Invar blades. This fixation device, already successfully used on Astrium optical payloads (Formosat 2), provides good thermal decoupling between the telescope and the primary mirror. An adjustment of the primary mirror thermal control settings allows to control the telescope focus in orbit, if requested.

The secondary, tertiary and folding mirrors are also made of SiC. They have an incorporated isostatic foot (*EADS Astrium mushroom concept*). This type of attachment device, minimising the number of interfaces, ensures a good thermal coupling with the structure, simplifies the integration and improves the overall stability.



Primary mirror



Secondary mirror



Tertiary mirror

Fig. 5 : NAOMI mirrors (at different scale)

The focal plane accommodates detectors, filters and front-end electronics. All the elements are designed in order to cope with a multi-modules implementation capability.

A MLI protection, withstanding high thermal temperature in case of Sun focalisation during non operational modes, is implemented inside the SiC tube. This protection minimizes also the impact of environmental thermal fluctuations and improves the primary mirror stability during operational modes. Additionally, an entrance baffle, thermally coupled to the aluminium tube, aims at protecting the secondary mirror and the spider from direct Sun illumination during operational modes. It is radiatively uncoupled from space by a thermal MLI fixed on the outer surface.

During operational modes, only five lines are necessary for telescope thermal control and the mean power consumption is only 5 Watts.

The thermal lines, located on mirrors, structure and focal plane, are monitored and controlled by PID laws implemented in the Electronics Unit. For non-operational modes, the power supply Unit (PCDU) manages three specific thermal lines which are controlled by thermo switches.

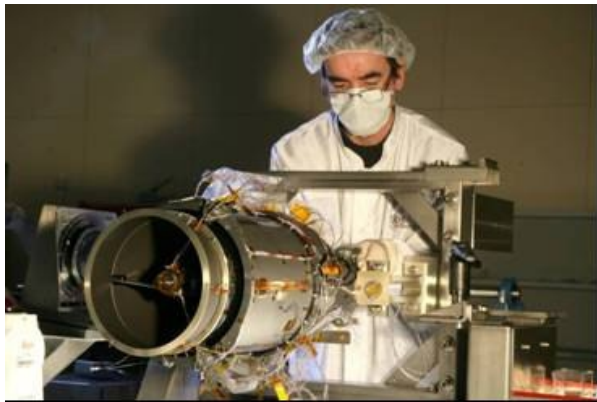


Fig. 6. NAOMI Camera during alignment

### 2.5 Detection chain and electrical architecture

The detection chain is made of three main parts: the detectors, the Front End Electronics Module (F2EM) and the Video Electronics (MEV) which are part of the NAOMI Imaging and Electronics Unit (NIEU).

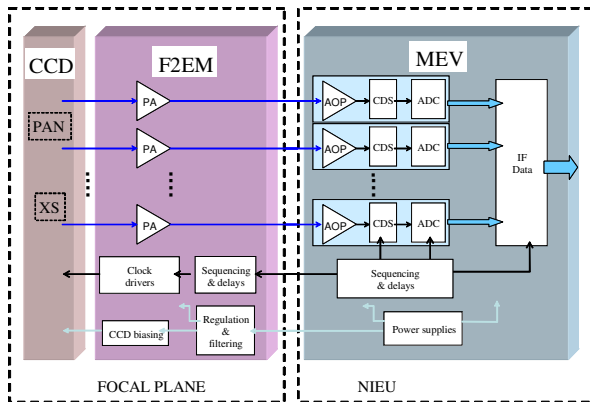


Fig. 7. Overview of NAOMI detection chain

### The PAN + XS focal plane as the heart of the detection chain.

Focal plane is based on customized high performance detector architecture developed by e2v for Astrium with the best of CCD technologies available in their tool box. It takes benefit of all the heritage and skills acquired in CCD architecture definition and in operating with the ultimate conditions of speed and performances. The result of this customization offers an unrivalled level of integration and performances.

All the stringent constraints of dynamic range optimization and power consumption reduction have been mastered with less than 1 watt detector dissipation.

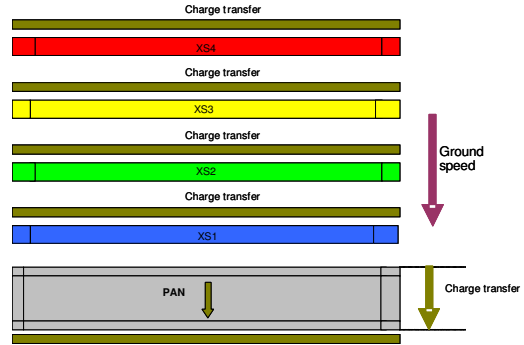


Fig. 8. PAN+XS focal plane Architecture

The space qualified focal plane includes one TDI array of 7000 pixels for the panchromatic channel and four lines of 1750 pixels for the multispectral bands. Antiblooming functions are adjustable via specific commands. The very good detector characteristics (high MTF and high quantum efficiency) significantly contribute to the instrument optical performance.

The Front-End Electronics Module (F2EM) encompasses all the functions to be implemented close to the detectors. Mounted inside the Focal Plane Assembly, it provides the detectors with all the necessary biasing and clocking signals and performs preamplification and transmission of the video signal to the MEV.

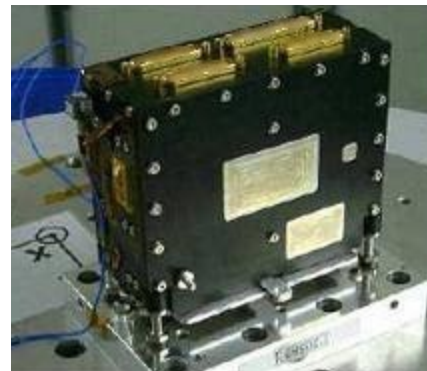


Fig. 9 : The Front End Electronics Module

The 'Module Electronique Video' (MEV) is the back-end part of the NAOMI detection electronics. The MEV provides the F2EM with the primary power supplies and clocks necessary to front-end operation. The video signal from the F2EM is received, adapted and digitally converted to 12 bit in the MEV. The resulting data, rounded down to 10 useful bit, are then transmitted to the digital functions of the NIEU to be real-time processed and stored into the mass memory for further downlink.

**A single electronics unit for the instrument including mass memory function**

The NIEU is the core of the electrical architecture. It is made of two main parts: the MEV is in charge of front-end operation, video processing, A-D conversion and transmission to the ICM via very high-speed digital link; the ICM encompasses the 64 Gbit mass memory and related FPGA based digital electronics and all the NAOMI housekeeping functions.

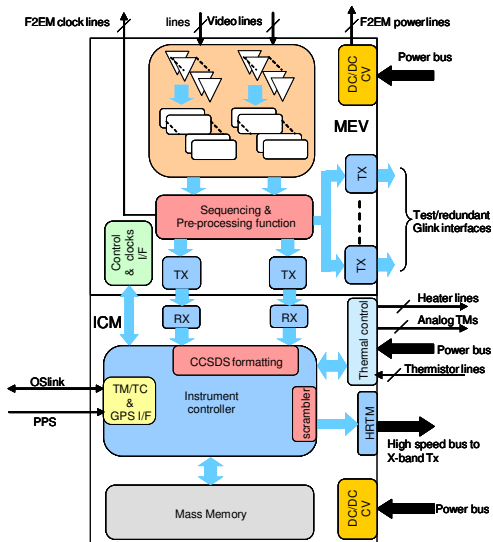


Fig. 10. Functional block diagram of the NIEU

**2.6 Performances and development status.**

The proto-flight camera has already been aligned and tested at instrument level. Performances are fully compliant with the requirements.

	PAN	XS
MTF (static)	> 0.18	> 0.4
L2 radiance W.m <sup>-2</sup> .sr <sup>-1</sup> .µm <sup>-1</sup>	110	[90 – 130]
SNR @ L2 radiance	> 130	> 200
L4 radiance W.m <sup>-2</sup> .sr <sup>-1</sup> .µm <sup>-1</sup>	350	[250 – 390]
Radiometric Range	No saturation up to L4	

Table 1 : Instrument main performances

Mechanical tests and EMC tests have been achieved at satellite level. Thermal and vacuum tests will be performed in early 2009.

**3. NEW APPLICATIONS FOR NAOMI INSTRUMENT.**

The SSOT contract awarded to Astrium by Chilean authorities in July 2008 gives the opportunity to develop a higher resolution version of the NAOMI instrument.

The camera is adapted to feature the mission requirements (1.45 m GSD in PAN band and 5.8 m in MS bands at Nadir @ 620 km altitude).

Thanks to its performances and to its versatility, the instrument architecture allows to accommodate two focal plane modules to increase either the field of view, either the number of spectral bands. Two examples are given to illustrate these boosted versions.

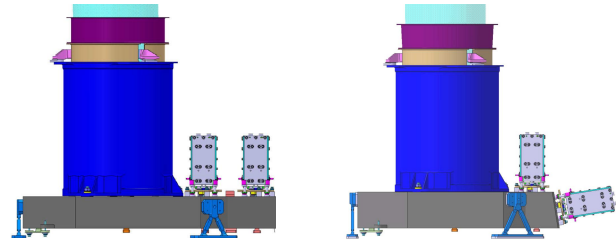


Fig. 11. Camera equipped with 2 focal plane modules.

**4. CONCLUSION**

The challenging development of the NAOMI instruments for ALSAT2 program is on the right track. The first model has already been coupled with the platform and the second model is planned to be delivered beginning of 2009. Performances of PAN and MS channels have been demonstrated.

New versions of the instrument, derived from the first version, and featuring upgraded GSD or larger field of view are currently under development.



Fig. 11 : NAOMI camera before delivery

**ACKNOWLEDGMENT**

EADS Astrium thanks ASAL for having granted its confidence for the development of ALSAT2 program. All the companies involved in the instrument development are gratefully acknowledged.