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METimage Instrument Development Status

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ABSTRACT

METimage is a cross-purpose, medium resolution, multi-spectral optical imaging radiometer for meteorological applications onboard the MetOp-SG satellites. It is capable of measuring thermal radiance emitted by the Earth and solar backscattered radiation in 20 spectral bands from 443 to 13.345 nm.

We provide an overview over the instrument design and present the instrument development status.

Keywords: METimage, MetOp-SG, EPS-SG, VII

1. INTRODUCTION

METimage is implemented as a passive imaging spectro-radiometer [1]. Daily global coverage is achieved by continuous scanning orthogonal to the flight direction. The instrument covers a large across track swath of ∼2670km (±53 deg scan angle) with a constant spatial sampling angle across the swath and a spatial resolution of 500 m at Nadir. It operates in a Sun-synchronous orbit with average altitude of 830 km.

The instrument is developed under DLR contract and will be provided as a customer furnished item to the Eumetsat MetOp-SG program.

An artistic view of the instrument is given in Figure 1, the key parameters are summarized in Table 1.

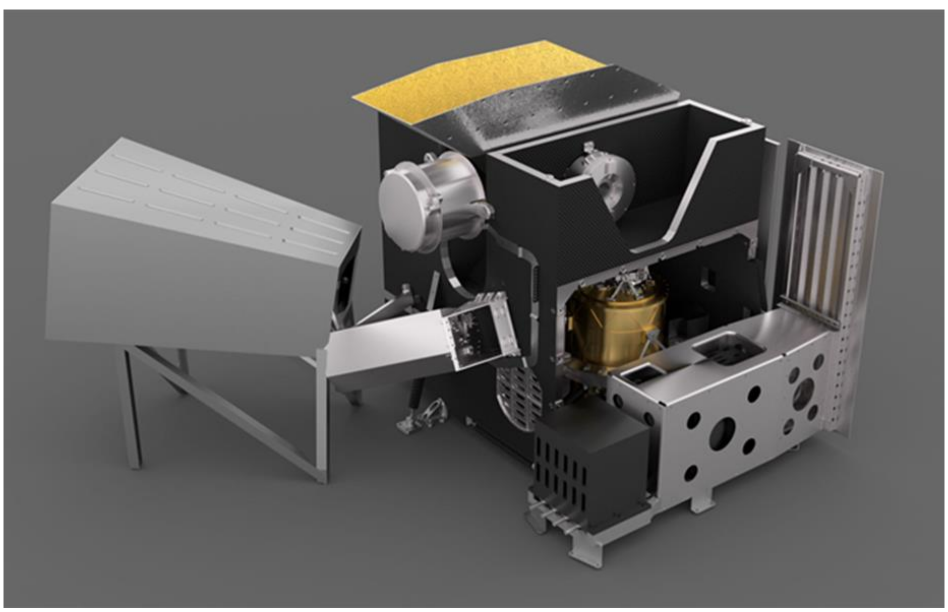

Figure 1. The METimage instrument (MLI and some structural parts removed).

Table 1. METimage key parameters

Customer	DLR (German Aerospace Center) for EUMETSAT
Mission Objectives	Continuous multi-spectral optical imaging for operational meteorology, clouds, aerosols, oceanography and climate applications
Mission Orbit	MetOp-SG, sun-synchronous polar orbit, 830 km average altitude
Instrument type	Passive imaging spectro-radiometer • in-beam scanner, 1.729 s scan period • synchronous field de-rotation
Spectral range	443 nm to 13.3 µm • 3 focal planes (VNIR, SMWIR, LVWIR) • 20 spectral channels
Swath	• 12 km along-track defined by detector size • 2670 km across-track defined by ±53 deg scan range
Spatial resolution	500 m x 500 m at Nadir
Calibration	2 point calibration scheme • offset correction (deep space view) • gain calibration (solar and thermal calibration devices)
Service life	>7 years
External interfaces	• Mass: 315 kg • Power: 465 W nominal operations 287 W survival & LEOP • Data rate: 18 Mbps dayside 9 Mbps nightside • Data volume: 82 GBit over 1 orbit

2. INSTRUMENT KEY FEATURES

The METimage instrument is designed for a broad spectral range providing full daily coverage of the complete Earth, based on following main features:

- In-beam scanner with static telescope and synchronous beam de-rotation ensures a regular imaging geometry over the full scan range. The synchronization between scanner and derotator is realized by a dedicated rotation control module of the METimage central electronics.
- Telescope with an instantaneous field of view of 1.6 deg, supporting 24 ground pixels of 500 m resolution in flight direction and 10 slots for spectral channels or TDI stages for each focal plane.
- The full spectral range is covered by 3 focal planes, a CMOS array for the VNIR channels (443–914 nm) and 2 MCT arrays for the SMWIR channels (1240–5040 nm) and the LVWIR channels (6725–13345 nm).
- The spectral bands for the 3 focal planes are realized by beam splitters (spectral separation), the spectral channels for each focal plane are realized by filter stripes (spatial separation).
- To ensure optimum spatial co-registration, all detectors are implemented in the cryogenic subsystem. The ambient temperature part includes the beam splitters and the VNIR detector with the VNIR filters, the cryogenic temperature part includes the 2 infrared detectors and, for each of the detectors, a refractive relay optics with the IR filters and field mask at its entrance. An artistic view is given in Figure 2.
- The required operational temperature of <60 K for the infrared detectors is obtained by a cryostat and active cooling with a pulse tube cooler.
- Continuous scanning (full rotation of 360 deg) allows for regular views to dedicated calibration sources without interrupting the scientific observation. The two point calibration scheme uses a dark signal level (deep space view) for offset correction and bright sources (solar calibration device, thermal calibration device) for gain calibration. During each scan the full thermal-optical and electrical chain is calibrated.

- Compact CFRP composite structure supporting all optical and calibration elements.
- Instrument control electronics including data formatting and mechanisms synchronization.

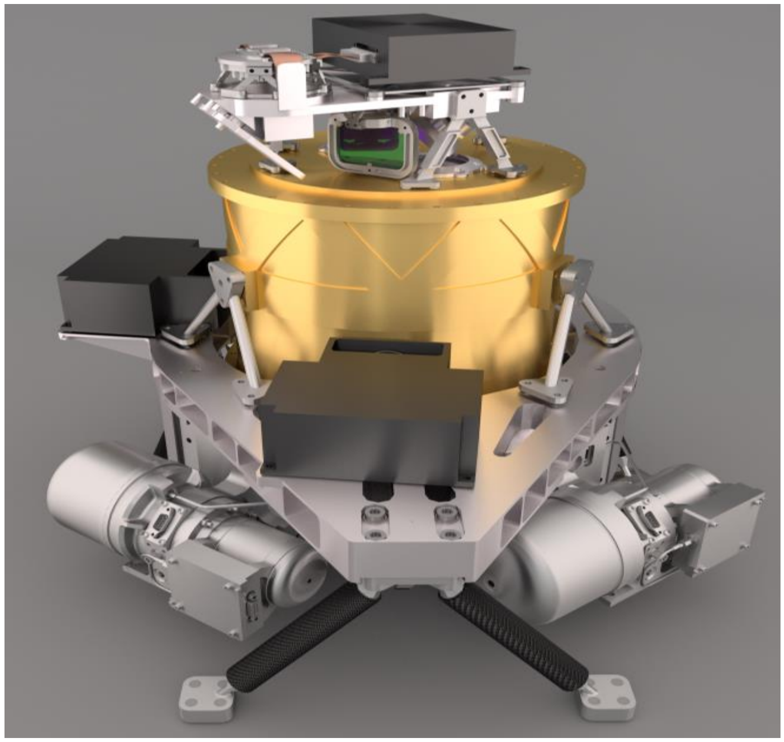

Figure 2. The METimage cryogenic subsystem (MLI removed).

3. DEVELOPMENT STATUS

Scanner Assembly

The scanner assembly is built up of the scan mechanism and the scan mirror. The scan mechanism consists of a brushless DC motor, high precision bearings to minimize wobbling and a 21 bit absolute optical encoder. It is driven by the rotation control module (RCM) which also realizes the synchronization with the derotator mechanism. For the scan mechanism several development and life test models have been built. Combined functional tests will be performed for early performance validation, the life tests have been started. The scan mirror is oval and has a cylindrical shape (~760 m radius) to improve the MTF in along-track direction. It is made of Beryllium with NiP layers for high-performance polishing and is coated with protected silver optimized for the full spectral range. The manufacturing of the Beryllium substrate is in progress.

Derotator Assembly

The derotator assembly consists of the derotator mechanism and the derotator optics. The derotator mechanism is similar to the scan mechanism but uses a single duplex bearing. For the derotator mechanism dedicated life tests are foreseen. The interface between mechanism and optics is realized by an Invar ring for CTE matching. The derotator optics is realized by of a system of 5 planar mirrors to minimize the polarization impact [2]. The mirrors as well as the baseplate are realized in SiC technology to secure the demanding stability requirements. The optical mirror surfaces are treated with CVD cladding to allow for high performance polishing and are coated with protected Silver optimized for the full spectral range as the scanner mirror. The manufacturing of the SiC parts is in progress.

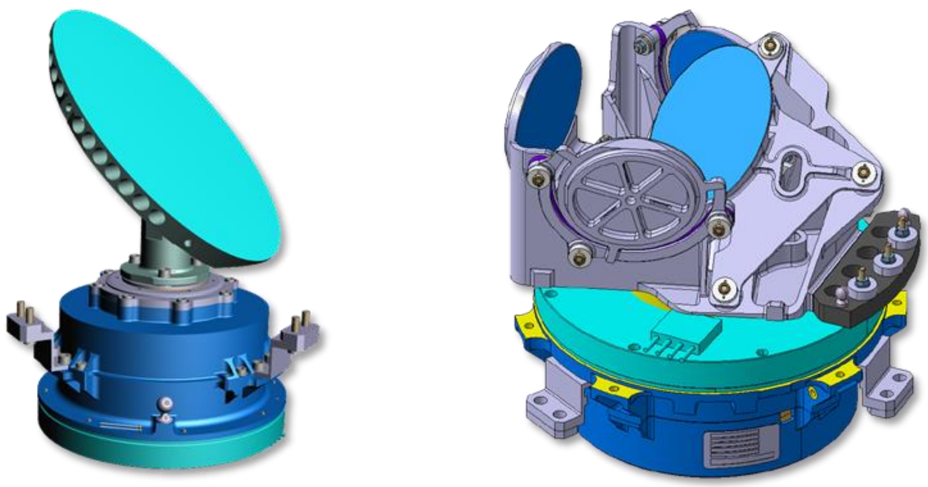

Figure 3. Scanner assembly (left) and Derotator assembly (right, courtesy of AMOS s.a [2]).

Telescope Assembly

The telescope assembly is defined by a TMA optical design optimized wrt image distortion and implemented by Zerodur mirrors on a highly stable CFRP composite structure. The mirrors are light-weighted and designed for low deformation of the optical surfaces due to influences like gravity, temperature variation and mechanical stress originating from the mirror mounts. The mirrors are coated with enhanced protected silver as the scanner and derotator optics. The mounts of M1 and M3 are realized by Invar spring blades, M2 has an Invar mount connected to the mirror back side. Mirror blank and mounts manufacturing is in progress. The telescope baseplate is a rigid sandwich panel with low moisture strains and very low thermal distortion. The M2 support structure is made of a CFRP tube with Titanium end fittings. It is designed for a very high stability with near zero moisture strain and by the combination of CFRP and Titanium with zero thermal distortion.

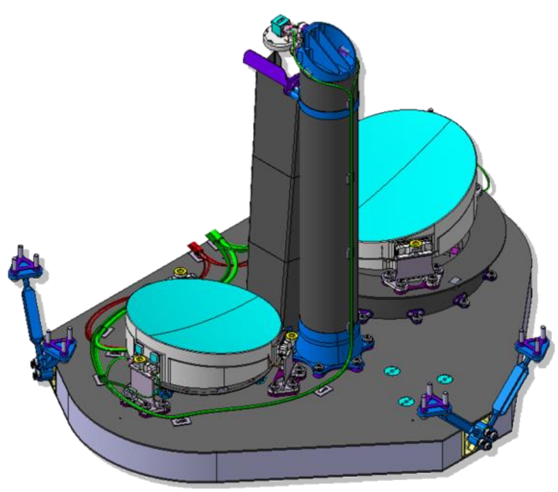

Figure 4. Telescope assembly.

Cryogenic Subsystem

Most challenging for the cryogenic subsystem is providing the cryogenic temperatures to the infrared detectors. To achieve this and to minimize any parasitic heat load to the cryo-cooler a series of thermal shields of low emissivity is implemented which minimize the radiative flux from the cryostat housing. Gold coated Aluminum enclosures are supported by CFRP blades and carry additional insulation layers made of VDA/Mylar/VDA SLI. The cryostat housing is made of Aluminum with a low emissivity inner gold coating and an outer surface covered by MLI to thermally decouple the cryostat from its environment. For cleanliness reasons it is tight and designed to allow for overpressure as well as for continuous purging. The mechanical feasibility of the shielding concept has been demonstrated by a dedicated vibration test. For the overall cryogenic subsystem an STM program is running with the main objective to demonstrate the required thermal performance for operation of the IR detectors. Most hardware components have been manufactured, the coating processes and the assembly are ongoing. The test results are expected early next year.

The relay optics maps the intermediate image of the telescope onto the detectors and scales it by a factor of 0,135. The SMWIR relay optics consists of ZnSe and Si lenses, the LVWIR relay optics is made of Germanium optics. To compensate the CTE mismatch, the Titanium lens mounts include suitable solid body joints. The relay optics tubes and the structure are also made of Titanium. The latter interface the cryostat housing via GFRP bipods to minimize temperature gradients and thermo-elastic deformations. The relay optics supports the infrared filters and field masks at its entrance and the infrared detectors at its image plane. The lens mounting concept has been demonstrated by a breadboard. For the GFRP bipods a qualification program has been completed successfully. As input for the cryogenic subsystem STM program, a relay optics STM has been developed.

The infrared detectors are directly linked to the cryo-cooler cold tip via the thermal link assembly. This assembly realizes the thermal link between the two IR focal planes and the nominal and redundant cryo-cooler. It is made of high performance Aluminum foils and EB-welded end-fittings with optimum thermal conductance. The cryo-cooler FM and the thermal link assembly QM and FMs have been delivered.

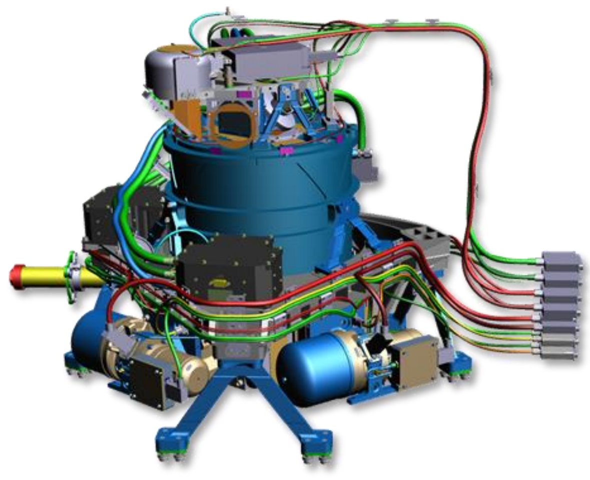

Figure 5. Cryogenic subsystem.

Detectors

The VNIR detector, covering 7 spectral channels in the wavelength range from 443 to 914 nm, is a frontside illuminated monolithic CMOS detector with AR coating. The detector package consists of the CMOS sensor glued onto an Invar base which provides the mechanical and thermal interface. The electrical connection is provided by a flex-PCB. The photosensitive area consists of 10 spectral channels (including TDI channels) with 98 x 4 readout pixels per channel and a readout pixels size of 250 x 250 µm. One ground pixel corresponds to 4 x 4 detector pixels. The VNIR detector is operated at ambient temperature. EM detectors have been delivered and tested in-house.

The SMWIR detector covers 7 channels in the wavelength range from 1.240 to 5.040 nm, the LVWIR detector covers 6 channels in the wavelength range from 6.725 to 13.345 nm. Both detectors are hybridized MCT-ROIC IR detectors with AR coating. The detector package consists of the hybridized sensor glued onto a Molybdenium base which provides the mechanical and thermal interface. The electrical connection is provided by a semi-rigid PCB detector cold wire. The SMWIR consists of 60 x 39 readout pixels. The LVWIR detectors consists of 2 MCT chips on a single ROIC, the LWIR with 36 x 39 readout pixels and the VLWIR with 12 x 39 readout pixels, for each range MCT with an appropriate design cut-off wavelength has been produced. One ground pixel corresponds to 3 x 3 pixels of 90 x 90 µm size, which in turn consist of 3 x 3 sub-pixels of 30 x 30 µm size. The latter can be enabled and disabled separately, to allow for de-selection of defective and of not illuminated pixels. The IR detectors are operated at cryogenic temperatures <60 K. EM detectors have been delivered and will be tested in a dedicated in-house facility (Figure 6).

The Front End Electronics supplies the detectors with all their biases and clocks, as well as reading out the video signals in a separate video-chain, with 2 channels being read out sequentially through each video chain. For the detection chain validation facility a dedicated Front End Laboratory Electronics has been developed and is being used for the in-house testing.

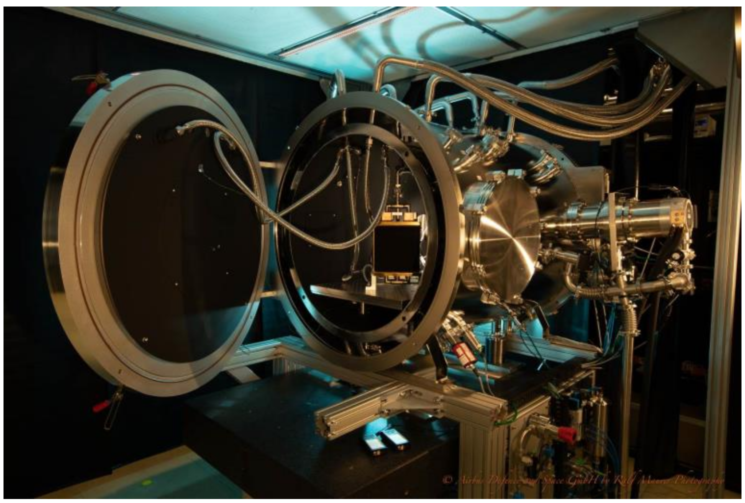

Figure 6. Detection chain validation facility.

Instrument Support Structure

The instrument structural concept is based on a closed box of a composite structure which provides high torsional stiffness and good dimensional stability under thermal loads as well as high design flexibility. The panels of Aluminum honeycomb and CFRP facesheets are connected via CFRP bonding angles, with one panel being removable to provide access during integration. The isostatic platform interfaces are realized by CFRP tubes with end fittings and interface brackets made of Titanium. The feasibility of the inserts has been demonstrated by a breadboard program, the platform interface struts have been qualified.

ACKNOWLEDGEMENTS

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REFERENCES

[1] O. Wallner, T. Reinert, C. Straif, "METimage – A Spectro-Radiometer for the VII Mission onboard MetOp-SG", Proc. SPIE 10562 (2016)

[2] E. Renotte, et.al., "Full-SiC Derotator Optics for METimage: Preliminary Design and Verification Approach", these Proceedings