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METimage – PFM Status Report

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METimage – PFM Status Report

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ABSTRACT

METimage is a cross-purpose, medium resolution, multi-spectral optical imaging radiometer for meteorological applications on-board the MetOp-SG satellites.

The fully representative instrument engineering model has been successfully tested and delivered to MetOp-SG. On METimage level this model served for instrument mechanical, thermal and EMC verification, at MetOp-SG level it supports the entire satellite test campaign. The instrument PFM integration is under finalisation by integrating the optical subsystems into the optical head. The preparation of the environmental test campaign and of the calibration and characterization campaign is ongoing.

Keywords: METimage, MetOp-SG, EPS-SG, VII, multi-spectral, radiometer

1. INTRODUCTION

METimage serves the VIS/IR Imaging Mission (VII) of the EUMETSAT Polar System – Second Generation (EPS-SG). The instrument is a passive imaging spectro-radiometer, capable of measuring thermal radiance emitted by the Earth and solar backscattered radiation in 20 spectral bands from 443 to 13.345nm [1]. Continuous scanning orthogonal to the flight direction ensures daily global Earth coverage with an across track swath of ~2670 km, a constant spatial sampling angle across the swath, and a spatial resolution of 500 m at Nadir. The scanning principle also allows for regular views to calibration sources without interruption of the scientific observation and for covering the entire optical and electrical chain. A two-point calibration scheme is implemented with a dark signal level (deep space view) for offset correction and bright sources (solar calibration device and thermal calibration device) for gain calibration. METimage operates on-board the MetOp-SG satellite A in a Sun-synchronous polar orbit with average altitude of 830 km.

The METimage instrument consists of the following main elements on the satellite's Nadir panel:

- The optical head contains the entire optical chain from the entrance aperture up to the detector proximity interface electronics. It is realized by a composite box structure, which carries the radiator assembly, the Nadir baffle, and the optical assemblies (scanner assembly, telescope assembly, de-rotator assembly, cryogenic subsystem) [2]. The optical head also contains the solar calibration device and the thermal calibration device.
- The external electric assembly is realized by a dedicated support structure with radiator and carries the front end proximity electronics and the thermal acquisition electronic unit. It is located just next to the optical head to ensure short paths for the analogue signals.
- The solar calibration device baffle is a mechanical unit providing shielding to avoid direct view to Earth or the satellite.

The METimage central electronics, the cryo-cooler electronics and the cryo-cooler cross-strap box are accommodated inside the payload equipment bay on the satellite's anti-Nadir panel and are connected to the electronic units on the Nadir panel via the external harness. The overall instrument configuration is shown in Figure 1.

For the instrument development a proto-flight approach is applied, supported by development models and breadboards on subsystem and equipment level. In particular an extensive STM program has been performed successfully for the cryogenic subsystem. For support of the MetOp-SG satellite campaigns a functionally representative EFM, a mechanically and thermally representative STM, and a fully representative engineering model (also abbreviated as fE-EM) have been successfully delivered.

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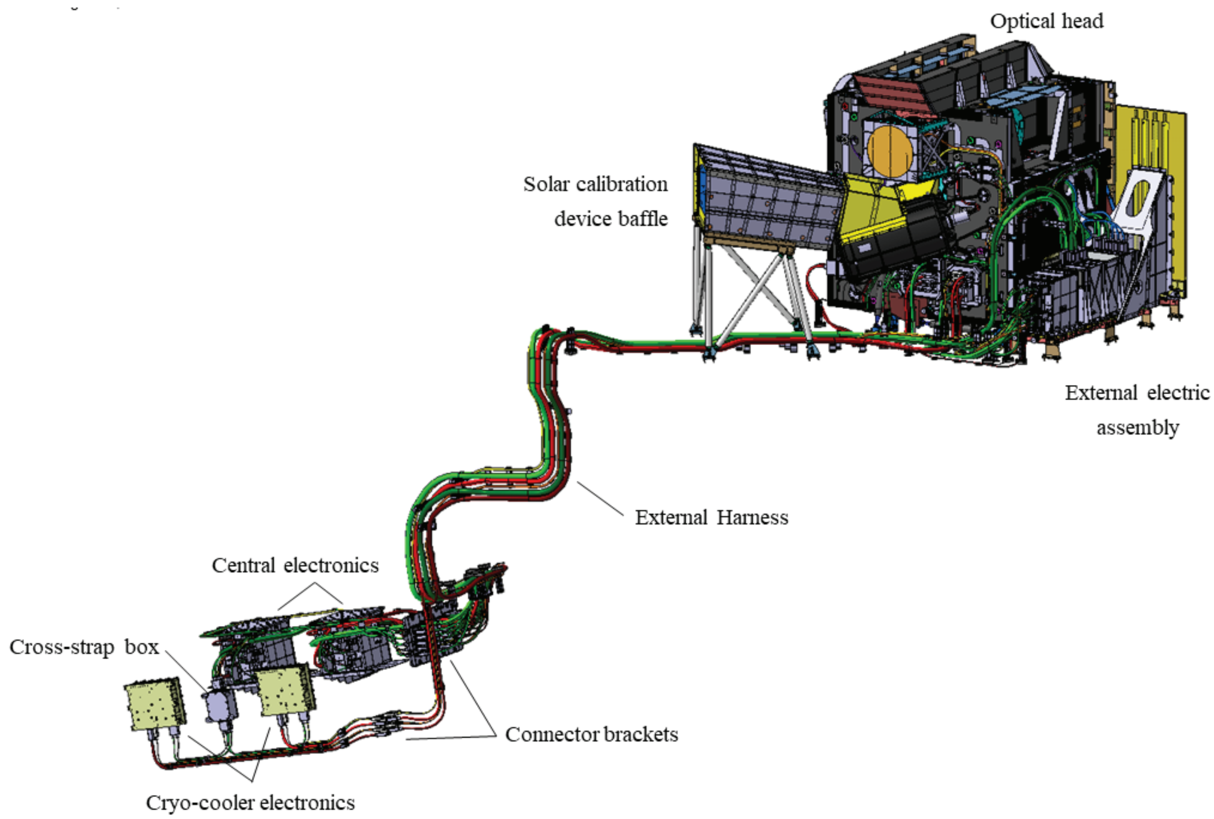

Figure 1. Overall METimage instrument configuration (MLI not shown).

2. INSTRUMENT ENGINEERING MODEL

The main objective of the METimage engineering model is to provide a fully representative instrument model for the satellite PFM campaign in order to decouple the developments and to minimize the schedule interdependencies.

The engineering model is fully representative of the instrument PFM except of the optical elements. The sub-systems of this model are flight-grade (primary and secondary structures, thermal-mechanical hardware, cryo-coolers), qualification models (mechanisms, electronic units, detectors), or structural models (optics). The engineering model therefore is fully representative of the external mechanical, thermal, electrical and functional interfaces to the satellite. Figure 2 shows integration activities on the engineering model and Figure 3 optical head, external electric assembly and solar calibration device baffle in delivery configuration.

With the engineering model an extensive test and verification programme has been performed at instrument level. The EMC test campaign allowed for successful verification of the electromagnetic compatibility within the instrument as well as between instrument and satellite in the presence of self-induced and external electromagnetic environments. Via dedicated integrated subsystem tests the functional test campaign confirmed the functional performance of all electrical subsystems and the interplay between them including application software and FDIR functions and end-to-end TM/TC interfaces. With full functional tests at ambient and in operational conditions the functional integrity of the instrument has been demonstrated in all operational modes and foreseen mode transitions. The mechanical and thermal test campaign allowed for successful verification of the instrument thermal and mechanical architecture and design [3].

Figure 2. METimage engineering model. Integration activities on mechanical structure (left), robot supported integration of cryogenic subsystem STM into optical head (centre), and finalisation of MLI on optical head (right).

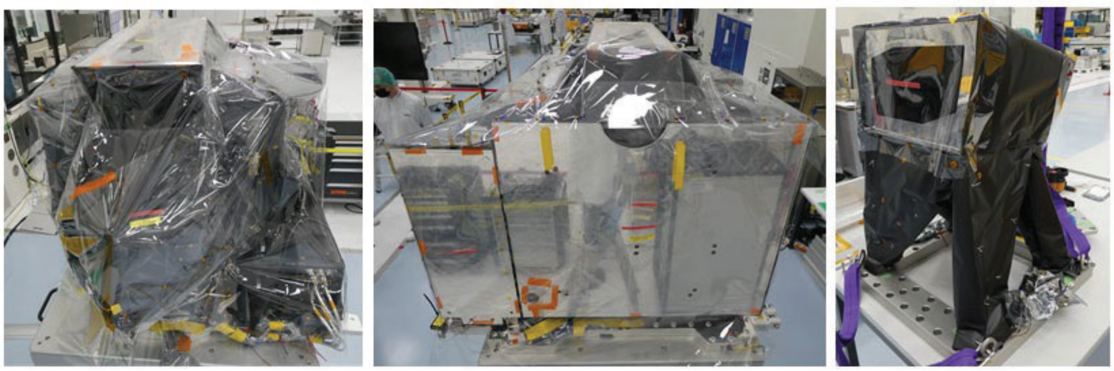

Figure 3. METimage engineering model. Optical head and external electric assembly (left, centre) and solar calibration device baffle (right) with contamination protection covers on the transport adapters.

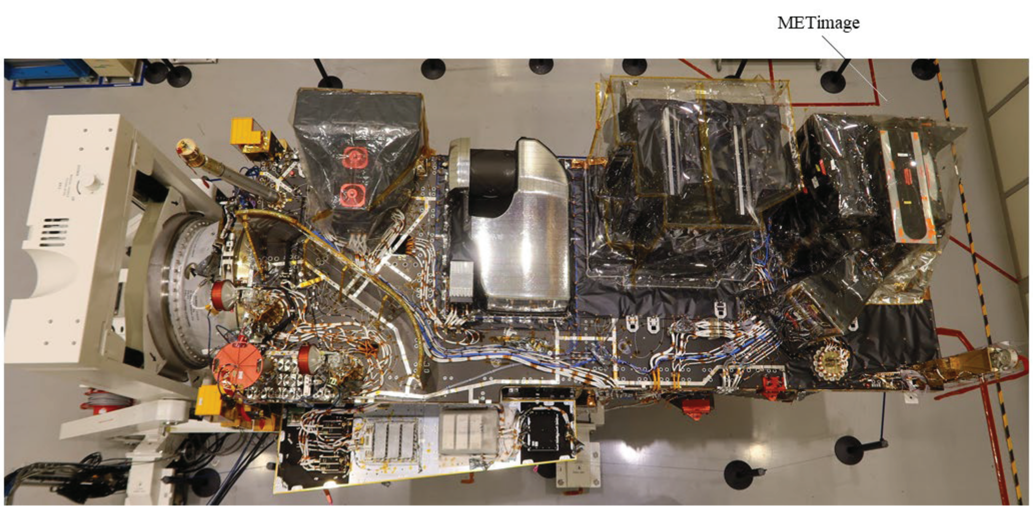

Figure 4. METimage engineering model on-board MetOp-SG satellite A (courtesy Airbus Defence & Space SAS).

The engineering model has been delivered to MetOp-SG in August 2021 and has been integrated onto satellite A, see Figure 4. Electrical integration, instrument full functional tests, and the first Satellite System Validation Test (SSVT-1) including all instruments have been performed successfully. Currently the satellite is prepared for the environmental test campaign. After this campaign the METimage engineering model is replaced by the METimage PFM, except for the external harness which stays in place.

3. INSTRUMENT PFM

The development of the instrument PFM is mainly driven by the availability of flight models of the optical subsystems. The optical head thermo-mechanical assembly (structures, radiators, baffles, instrumentation) is finalized and ready for integration of the optical subsystems, see Figure 5.

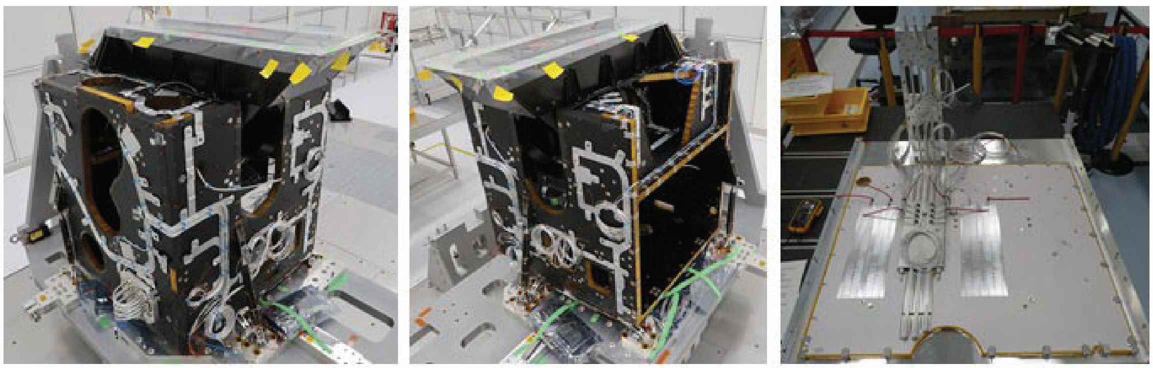

Figure 5. METimage PFM optical head thermo-mechanical assembly ready for integration of the optical subsystems.

The first flight models of the scanner assembly, the telescope assembly and the de-rotator assembly have been fully assembled and successfully tested and are ready for integration into the optical head. Figure 6 shows the scanner assembly flight model with the scan mirror mounted on the drive unit. Figure 7 shows the telescope assembly flight model and the telescope assembly within the optical test setup. The screen in the background shows an image of a target pattern used for distortion measurement. Figure 8 shows the de-rotator assembly flight model with the five-mirror de-rotator optics and the fully integrated assembly. Details about the scanner and de-rotator mechanisms are provided in [4].

The first flight model of the cryogenic subsystem has been fully integrated and the three focal planes have been mutually aligned, see Figure 9. The cryogenic subsystem consists of two optical modules, the warm optical assembly and the cryogenic imaging assembly. The warm optical assembly, operated at ambient temperature, contains the two beam splitters separating the full spectral range for the three detection chains, and the visible detector including the optical bandpass filters for the VNIR channels, see left part of Figure 10. The cryogenic imaging assembly, operated at cryogenic temperatures, contains two sets of bandpass filter, refractive re-imaging optics and infrared detector for both the SMWIR channels and the LVWIR channels, see right part of Figure 10. The cryogenic co-alignment verification test of the first flight model of the cryogenic subsystem is currently ongoing.

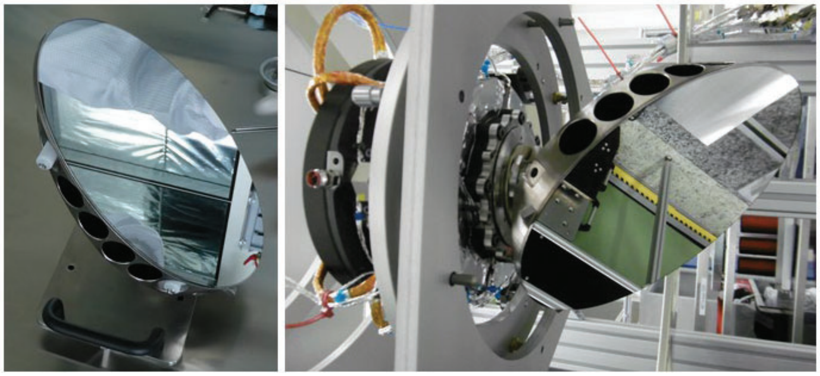

Figure 6. METimage scanner assembly first flight model. Scan mirror (left) and fully integrated scanner assembly (right).

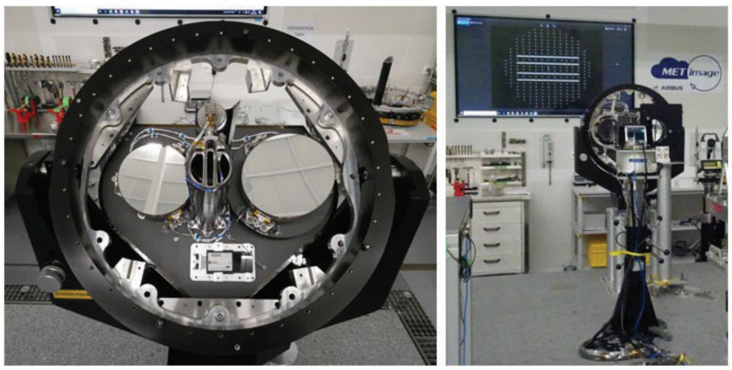

Figure 7. METimage telescope assembly first flight model (left) and telescope assembly in optical test setup (right).

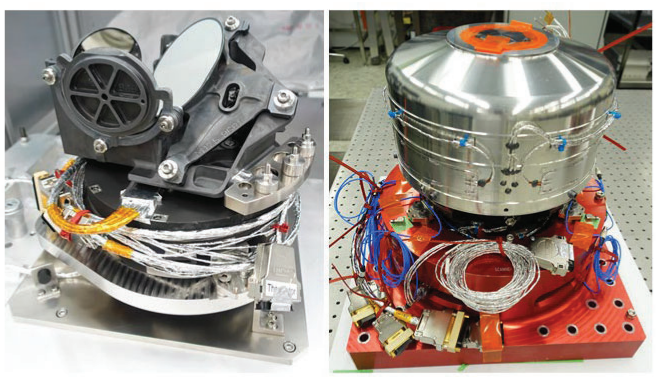

Figure 8. METimage de-rotator assembly first flight model. De-rotator optics (left) and fully integrated de-rotator assembly on vibration test adapter (right).

Figure 11 shows the first flight models of the thermal calibration device and of the solar calibration device, the latter consisting of Sun diffusors mounted on the drive unit. Details about the solar calibration device are given in [5].

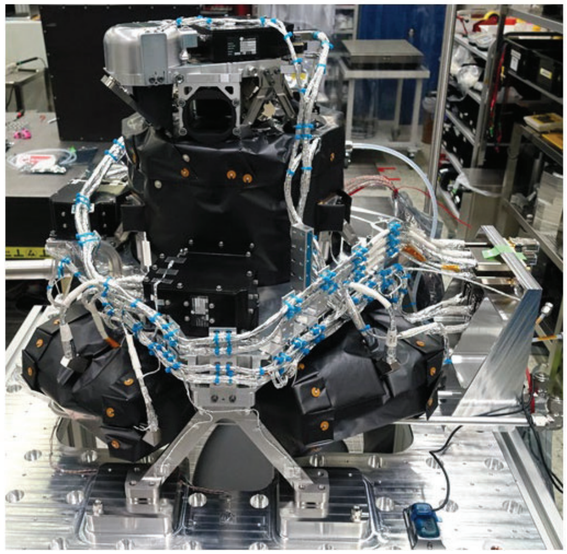

Figure 9. METimage cryogenic subsystem first flight model.

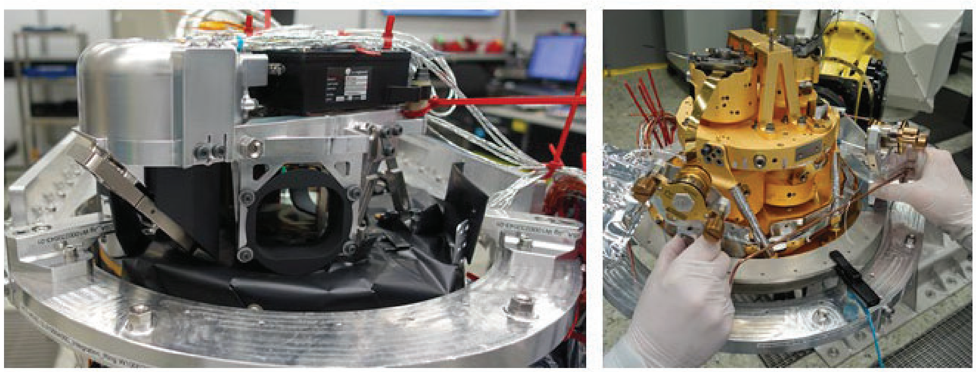

Figure 10. METimage cryogenic subsystem first flight model. Warm optical assembly (left) and cryogenic imaging assembly (right).

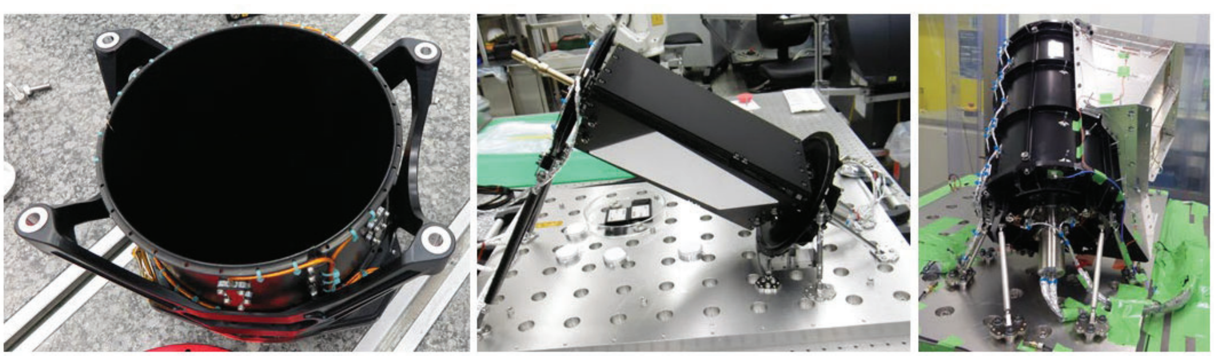

Figure 11. First flight models of the thermal calibration device (left) and of the solar calibration device (right), the latter including the Sun diffusors (centre).

The optical subsystems are integrated according the sequence shown in Figure 12. After the entrance stop assembly is aligned w.r.t. its nominal position in the optical head, the telescope is aligned w.r.t. the entrance stop. Subsequently the de-rotator assembly and the scanner assembly are aligned w.r.t. the telescope and the image plane location is validated by using a dedicated illumination OGSE and an OGSE detector at the location of the cryogenic subsystem. After the cryogenic subsystem is integrated into the optical head and aligned w.r.t. to the front optical elements, the overall optical path is validated using the illumination OGSE and the visible detector of the cryogenic subsystem. The solar and thermal calibration devices are aligned w.r.t. their nominal positions in the optical head.

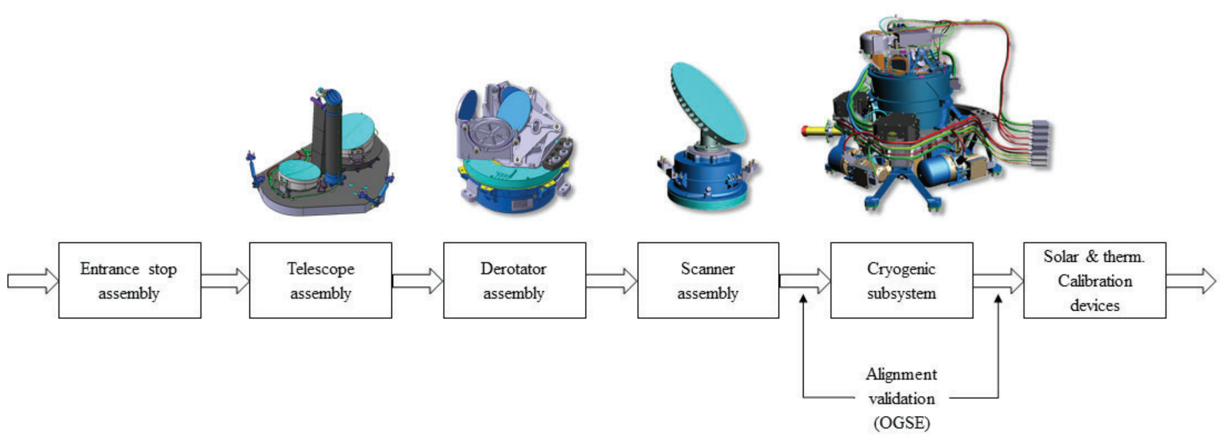

Figure 12. Integration sequence for the optical subsystems.

An electrical-functional test bench is used to support functional testing and electrical integration of the electrical units and to support application software validation prior integration into the METimage PFM instrument, see Figure 13. All flight models of the electronic units are available.

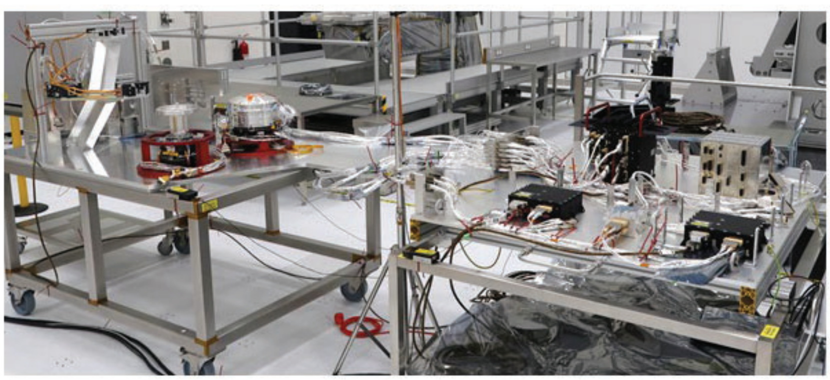

Figure 13. METimage PFM electrical-functional test bench. The electrical units of the payload equipment bay (right) and the electrical units of optical head and external electric assembly (left).

4. OUTLOOK TO CALIBRATION AND CHARACTERIZATION CAMPAIGN

The METimage on-ground calibration, characterization and performance test campaign is realized by an ambient campaign performed by Airbus during instrument AIT (after the alignment verification, see Figure 12) and a thermal-vacuum campaign performed by Airbus at CSL subsequent to the instrument thermal environmental tests.

With the ambient campaign end-to-end tests are performed for the VNIR channels (visible detector). A dedicated OSGE allows for instrument spectral response function and polarisation sensitivity characterization as well as MTF, spatial co-registration and stray light tests.

With the thermal campaign end-to-end tests of the SMWIR and LVWIR channels (infrared detectors) are performed as well as the radiometric calibration of all channels. Similar as for the ambient campaign, a dedicated OSGE allows for instrument spectral response function and polarisation sensitivity characterization as well as MTF and spatial co-registration tests. The radiometric calibration uses for the solar bands a sunbeam simulator OGSE and an OGSE diffusor at the Earth view port for relative calibration between solar calibration device and Earth view and a high-performance blackbody for absolute calibration of the thermal bands.

The development of the OGSEs for the ambient and thermal campaign is ongoing at Airbus, the development of the OGSE for radiometric calibration has been successfully completed at CSL (Sunbeam simulator and OGSE diffusor) and ABB (blackbody).

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