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THE HYPERSPECTRAL INSTRUMENT ONBOARD ENMAP, OVERVIEW AND CURRENT STATUS

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I. INTRODUCTION

The Environmental Mapping and Analysis Program (EnMAP) is a German space borne science mission that aims at characterizing the Earth's environment on a global scale. The single payload of the satellite is the hyperspectral imager (HSI). It is capable of measuring the solar radiance reflected from the Earth's surface as a continuous spectrum in the spectral range of 420nm to 2450nm, with a spectral sampling of 6.5nm (VNIR) and 10nm (SWIR). The EnMAP swath of 30km is sampled in spatial direction with 30m.

In this proceeding, we give an overview on the design of the instrument and the current status of the integration: Key design drivers of the instrument are optical throughput and image distortion. The instrument features a TMA with a 20cm aperture. A double-slit splits the field of view into the two separate fields for VNIR and SWIR. The two spectrometers disperse the light using large, curved prisms and collect the light in a modified Offner configuration onto the VNIR and the cooled SWIR detector. In addition, the instrument features calibration capabilities using a deployable, full aperture solar diffuser in front of the telescope and on-board calibration sources that can be fed into the spectrometers. Demanding requirements on thermal stability of the instrument are covered by an active thermal control of the whole instrument using loop-heat pipes.

The mission is currently in the middle of Phase D. Qualification on component level has been successfully performed for most of the components. All optical sub-assemblies have been finished and the instrument is being integrated. At the moment of writing, the telescope alignment is completed and the final characterization is ongoing. The VNIR spectrometer will start its integration this summer, followed closely by the SWIR spectrometer. Remaining flight hardware is close to delivery. In parallel to the integration of the instrument, the platform is also in the middle of its assembly process, readying the mission for a launch in 2019.

II. THE EnMAP MISSION

The EnMAP mission is a German satellite mission. The scientific topics addressed by EnMAP cover a broad application range, from climate change impacts, land cover changes, biodiversity processes, and natural ressources, to geohazard and risk assessments [1]. With a substantial improvement in terms of signal-to-noise over hyperspectral missions such as Hyperion, it fills an important gap to allow measurements and quantification of key science parameters of the earth only possible with EnMAP. In addition, it will complement multispectral missions such as Sentinel 2 (see Fig. 1).

DLR space agency has contracted OHB Oberpfaffenhofen as prime for the space segment (see Fig. 2). While the spacecraft bus is assembled at OHB Bremen, the instrument constructed in responsibility of OHB Oberpfaffenhofen.

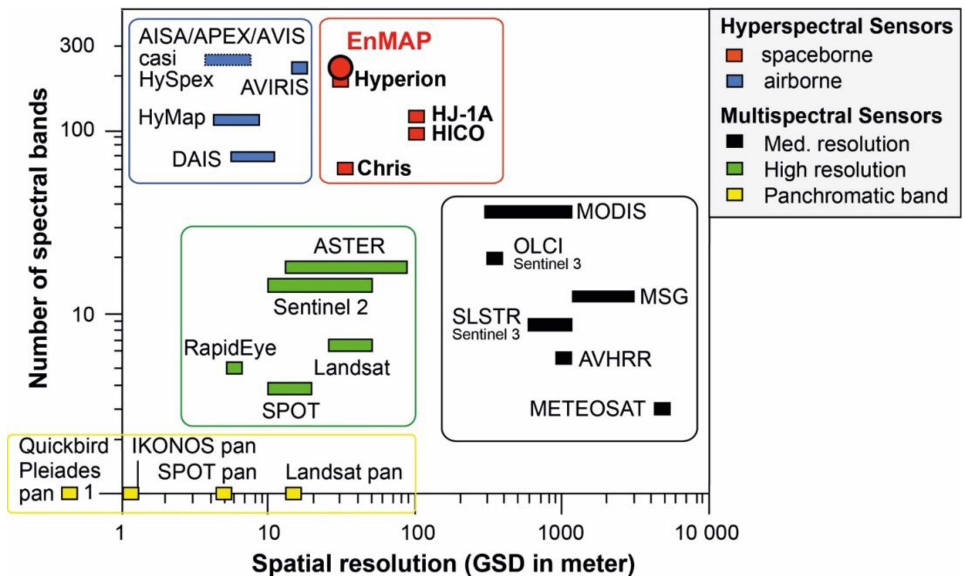

Fig. 1. Overview of the spectral and spatial resolution of selected airborne and spaceborne hyperspectral and multispectral sensors [1].

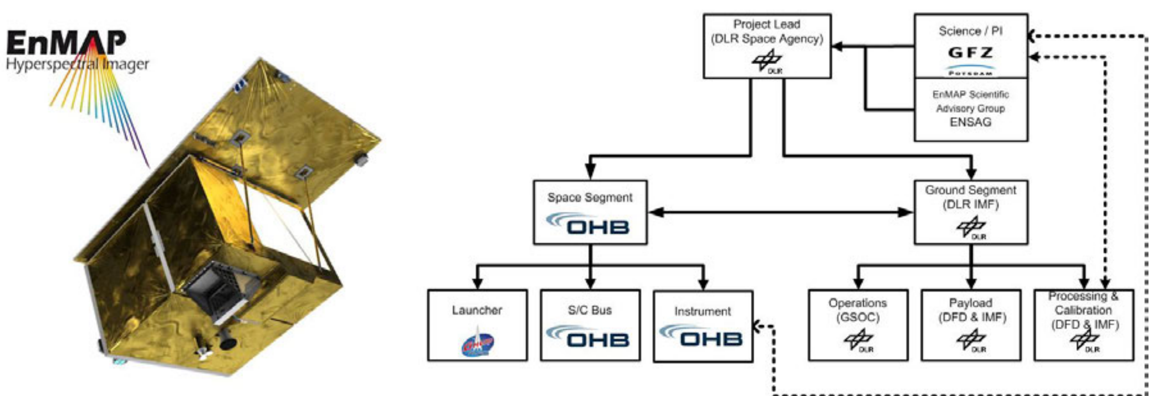

Fig. 2. : Left: The EnMAP Satellite. Right: Overview on the project structure.

The satellite is a push-broom earth observation satellite. With dimensions of roughly 3 x 2 x 1m³ and a mass of one tonne, it will orbit earth in a sun-synchronous, low earth orbit of 650km. Crucial for the scientific aims of EnMAP are the target revisit times of 27 days (VZA <5°) / 4 days (VZA <30°). The launch of the satellite is slated for 2019, with a design mission lifetime of 5 years.

The single payload of the satellite is the hyperspectral imager (HSI). It is capable of measuring the solar radiance reflected from the Earth's surface as a continuous spectrum in the spectral range of 420nm to 2450nm, with a spectral sampling of 6.5nm (VNIR) and 10nm (SWIR). The HSI is described in more detail in the following sections.

III. THE INSTRUMENT DESIGN AND CURRENT STATUS

The HSI main performance characteristics are summarized in Table 1.

Table 1. HSI main performance characteristics.

	VNIR	SWIR
Spectral range	420 – 1000 nm	900 -2450 nm
Number of spectral channels	89	155
Spectral sampling interval	6.5 nm	10 nm
Spectral bandwith (FWHM)	8.1 1.0 nm	12.5 1.5 nm
Signal to Noise ratio (SNR)	> 400	> 150
Spectral calibration accuracy	0.5 nm	1 nm
Ground sampling distance	30 m (at nadir; sea level)	
Swath width	30 km (field-of-view” 2.63° across track)	
Swath length	1000 km / orbit; 5000 km / day	

The HSI consists of 4 main optical units: The telescope, the VNIR spectrometer, the SWIR spectrometer and the calibration equipment. Both spectrometers as well as most of the calibration optics (with the exception of the solar diffusor) are integrated on a common 3D-optical bench, i.e. the instrument optics unit (IOU, see Fig. 5, left). The standalone telescope is connected to the IOU via isostatic mounts.

The two spectrometers have separate on-ground FOVs, with the VNIR spectrometer FOV following the SWIR spectrometer FOV by about 600 m (on ground). In order to compensate the thermal external environment which is changing over the orbit, active mini-loop-heat pipes are thermally stabilizing the two spectrometer line-of – sights to each other. In addition, the platform’s star trackers are directly connected to the IOU in order to optimize the stability of the pointing knowledge.

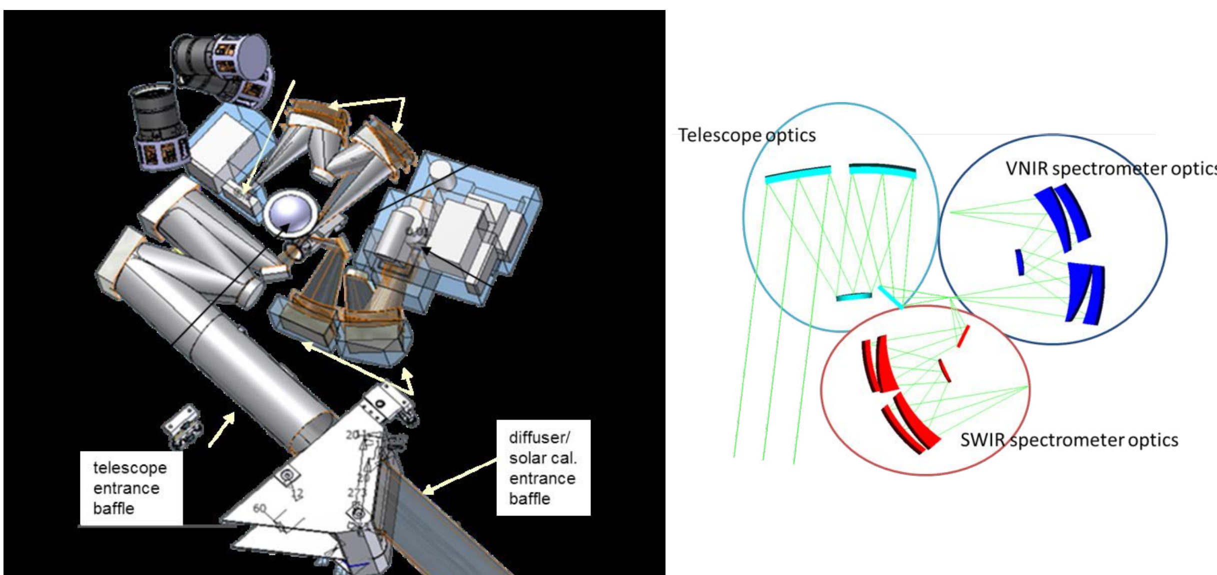

Fig. 3. Left: Basic concept of the instrument optics. Right: optical layout of telescope and spectrometers (not showing calibration).

A. The telescope

The EnMAP telescope images a 2.63° field of view (across track) onto two 24 µm x 24 mm slits. The telescope design is a TMA with a 20 cm entrance aperture and includes one additional fold mirror, see Fig. 3.

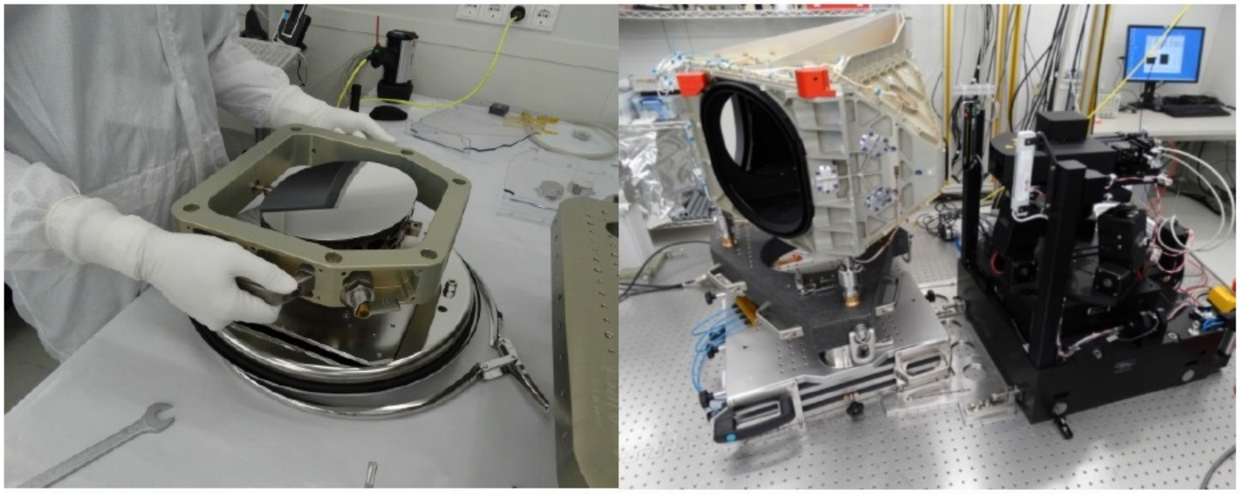

Fig. 4. Optical flight components of the telescope. Left: An individual mirror of the TMA. Right: The telescope during its alignment (together with its dedicated optical ground support equipment).

The telescope's alignment process is based strongly on the precise knowledge of the characteristics of all as-built optical components and is described in detail in [2]. The two-staged alignment process consists of a precise mechanical placement with an accuracy better than 50 µm / 80 arcsec. In the second step, the WFE optical quality of the system is analysed and a compensation adjustment using two of the telescope's mirrors is derived and applied. At the moment of writing, the flight telescope assembly has been successfully aligned, with the telescope exceeding its performance requirements. The final characterization measurements are ongoing.

B. The spectrometers

The entrance image of the two spectrometers is provided by the field splitter slit assembly (FSSA), a silicon-based double slit optimized for image quality, structural and thermal stability. For the SWIR spectrometer, the FSSA also includes a pick-up/fold micro-mirror.

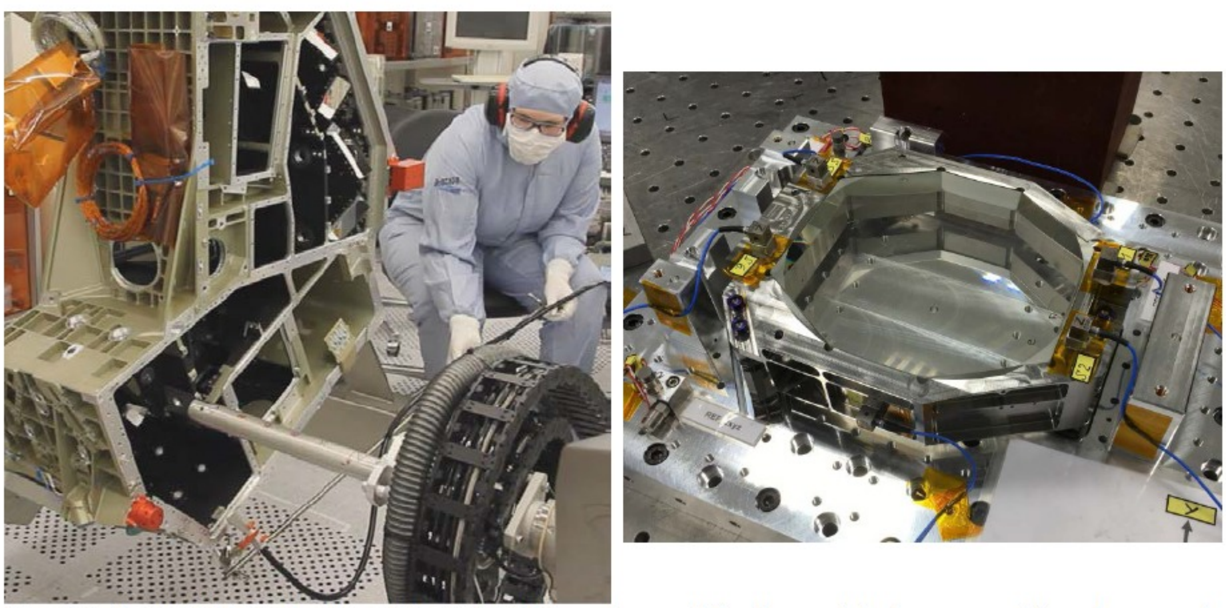

Fig. 5. Left: Final ISO5 cleaning of the IOU. Right: prism qualification model after successful environmental qualification at IABG.

The optical dispersion is provided using large prisms. In order to realize an as compact as possible design, dispersion and focussing the beam onto the detectors is merged into a common, complex optical system using curved prisms in a modified Offner configuration, see Fig. 3. The alignment of the spectrometers is based on the same process that was used for the telescope. At the moment of writing, all optical subassemblies are finished [3] and the mechanical placement of the optical units into the IOU is in preparation.

The EnMAP mission requirements transfer to demanding requirements on the two EnMAP detectors. The VNIR-CAM is a high-speed CMOS 1024x108 pixel image sensor featuring on-chip correlated double sampling to provide low noise in snapshot mode including stare-and-scan capabilities. It is optimized for a large full well capacity, high quantum efficiency, high resolution, high speed operation, low power consumption and low noise. The dual column amplifiers divide the detector into two areas (bottom, top) with dual low and high gain. A 10W thermos electro cooler (Peltier element) provides thermal stabilization during operation to a base temperature of 21°+/-0.05°C. The SWIR-CAM is a mercury-cadmium-telluride (MCT) based sensor providing images via a 1024x256 pixel photovoltaic array (PV array). With indium bumps the PV array is attached to the silicon read-out-integrated-circuit (ROIC) chip forming the so called IR-hybrid. The amplification provides two integration capacitors, which can be selected line by line individually for gain adjustment. The hybrid is optimized with respect to quantum efficiency and sensitivity operating at a nominal temperature of 150K. The operating temperature is supplied by a split stirling cooler with a pulse tube coldfinger and the cooler electronic. Both cameras have seen extensive testing and evaluation on EMs. The flight models are now in the manufacturing and assembly stage, with a delivery for HSI integration planned for early next year.

C. Calibration units

The EnMAP instrument foresees several different calibration methods relying on internal calibration sources as well as the sun.

In front of the telescope, a deployable full-aperture solar diffusor (FAD) made of Spectralon® allows a monitoring of the instrument response non-uniformity (RNU) over the mission lifetime using the sun as absolute radiometric standard. Such measurements are performed on a monthly basis. A possible diffusor aging will be tracked using vicarious calibration.

On a weekly basis, the spectral response function is monitored using EnMAP internal sources of the on-board calibration assembly (OBCA). RNU is assessed using a broad band Spectralon® integrating sphere. A second sphere made of doped Spectralon® MS provides a spectrally structured light source and is used for monitoring spectral performance of the spectrometers. A detailed description of the OBCA is given in [4]. A mirror wheel (the shutter calibration mechanism, SCM) in front of the spectrometers' slit can either inject the light of the calibration source or the earth-view. A third, closed position of the wheel is used to obtain dark measurements preceding and following each data take.

LEDs directly in front of the cameras are used to characterize and monitor the detector linearity.

At the moment of writing, the flight mirror wheel mechanism is undergoing its acceptance environmental testing campaign. The OBCA and FAD both are assembled and in preparation to their qualification campaigns, see Fig. 6.

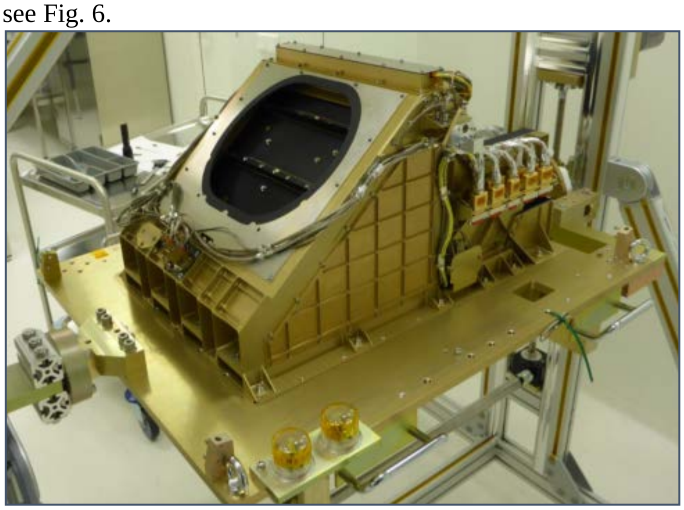
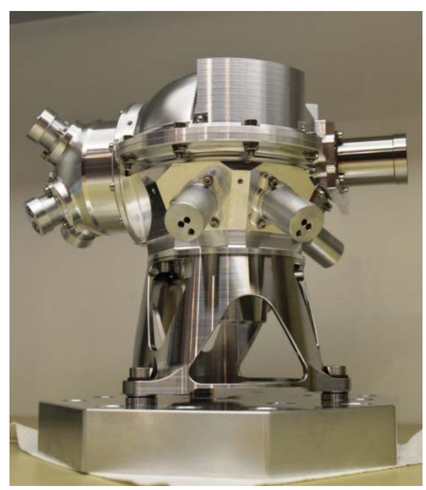

Fig. 6. QM calibration units. Left: Full aperture solar diffusor hatch. Right: The on-board calibration assembly including the two calibration spheres.

IV. CONCLUSION AND OUTLOOK

The EnMAP instrument is in the middle of phase D. Critical components have already undergone their successful qualification campaigns. The assembly of the flight hardware is ongoing, with the telescope being the first integrated system. The spectrometer assembly will start this fall, finishing with the installation of the flight cameras in 2017. In a next step, the telescope will be installed on the IOU, readying the instrument for its environmental test campaign and extensive on-ground calibration. Following the installation of the instrument on the platform and the satellite level environmental test campaign, the launch of the satellite is currently planned for 2019.

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