The Advanced German Hyperspectral Mission EnMAP

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ABSTRACT

For the next generation of optical satellite sensors hyperspectral instruments will play an important role. Extracting the information of over 200 bands in the wavelength range between 420 - 2450 nm, the detected reflection spectra from the earth's surface give scientists and value adders a broad basis for detailed analyses and the generation of data products. Within the programme for the coming German EO satellite mission, our team studies the so called EnMAP (Environmental Monitoring and Analysis Programme) satellites. Basing on hyperspectral payloads, the goals of EnMAP are detailed monitoring, characterization and parameter extraction of rock/soil targets, vegetation, and inland and coastal waters on a global scale.

Supported by the scientific lead of GFZ Potsdam and the industrial prime of Kayser-Threde, DLR has now formed a cooperative mission approach with India leading finally to the definition of a corresponding hyperspectral long-term programme. This plan consists of the launch of two hyperspectral satellites in 2009 and 2012. Beginning from 2006, the handling of hyperspectral data and process analysis procedures is further supported through the operation of an airborne hyperspectral system (ARES) by the research partners DLR and GFZ.

The paper highlights the actual status in the planning phase for the EnMAP satellites and the cooperation with India. Further, a focus will be set on the commercialization of the generated data products.

1. INTRODUCTION

The state of the Earth´s environment and the growing anthropogenic impact that arise from factors such as population increase and climatic change, are the driving factors for EnMAP. The objectives of EnMAP are to derive relevant surface parameters on a global scale - with an accuracy not achievable by currently available spaceborne sensors -, to assimilate those parameters in physically based ecosystem models, and ultimately to provide information products reflecting the status of various terrestrial ecosystems.

An international team of scientific investigators and industry proposes to build, launch and operate within EnMAP state-of-the-art Earth Observation (EO) satellites equipped with spatially high-resolution Hyper-Spectral Imagers (HSI).

Launched in 2009 and 2012, the two five-year hyperspectral missions will focus on issues related to environment, agriculture, land-use, water systems, geology, and related science and applications. EnMAP´s HSIs will be used to identify surface cover types, and provide a quantitative assessment of molecular absorptions that are intrinsic to constituents of vegetation, soils, rocks, and water. In particular, the mission objectives are as follows:

- To provide high-spectral resolution observations of biophysical, biochemical and geochemical variables over the wavelength range from 420 nm to 2450 nm in continuous, 10-40 nm wide bands sampled at 5 to

20 nm intervals. The spatial ground sampling distance (GSD) will be 30 meters.

- To observe and develop a wide range of ecosystem parameters encompassing agriculture, forestry, soil/geological environments, and coastal zones and inland waters.
- To acquire high resolution spatial and spectral data from space that will enable/improve the retrieval of quantitative parameters needed by the users, but which are not provided by multispectral sensors.
- To provide high-quality calibrated data and information products to be used as inputs for improved modelling and understanding of biospheric/geospheric processes. This will further contribute to the assimilation of data/information into such process models.
- To develop and market high-level information products meeting the demands of stakeholders in natural resource management.

To meet these objectives, a close collaboration between scientists, value adding industry, and users will be pursued in all development phases of EnMAP. Additionally, the optimization of hyperspectral and imaging spectrometry technologies and derived products has started using HSI data simulated from state-of-the-art hyperspectral airborne imagers such as HyMAP and ARES.
This will ensure that the retrieved variables and related products from EnMAP HSI observations are of high quality, and that EnMAP will have a significant impact in many environmental disciplines.

2. EnMAP MISSION

2.1 Teaming

The EnMAP team is formed according to the diagram in Figure 1. The teaming structure reflects an optimum concerning the final mission goals including the broad international scientific community, value adders and space industry. As depicted in Figure 1, the missions will be executed within an international cooperation with India.

2.2 Hyperspectral Reflexion Measurements

Figure 2 shows the solar spectrum outside the atmosphere, on sea level and for reasons of comparison, a black body curve with a temperature of 5900 K - the temperature of the sun's surface. The marked area in Figure 2 represents the wavelength range in which the EnMAP instrument is sensitive indicating the hyperspectral capabilities to use the full radiance information in the sunlight.

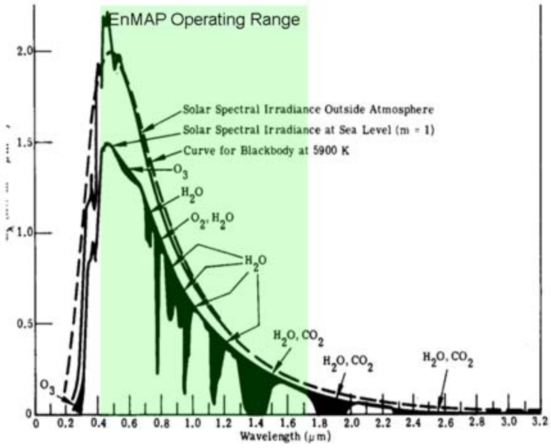

Figure 2 Solar Spectrum (intensity vs. wavelength) and EnMAP operation range.

The hyperspectral satellite detects the scattered sunlight from the earth's surface (compare Figure 3). The identification of the different materials, vegetation, water conditions and snow is done by monitoring the spectral characteristics of the different elements. The advantage of a hyperspectral instrument consists, beside the sensitivity for a large wavelength area, of the ability to detect the spectrum with high resolution (over 200 channels) enabling thus the necessary diversification and identification of different materials. The band selection in the instrument will be done avoiding atmospheric absorption lines. The hyperspectral instrument works in an imaging mode. Thus, the corresponding spectral information is directly correlated to each ground pixel of 30m x 30m.

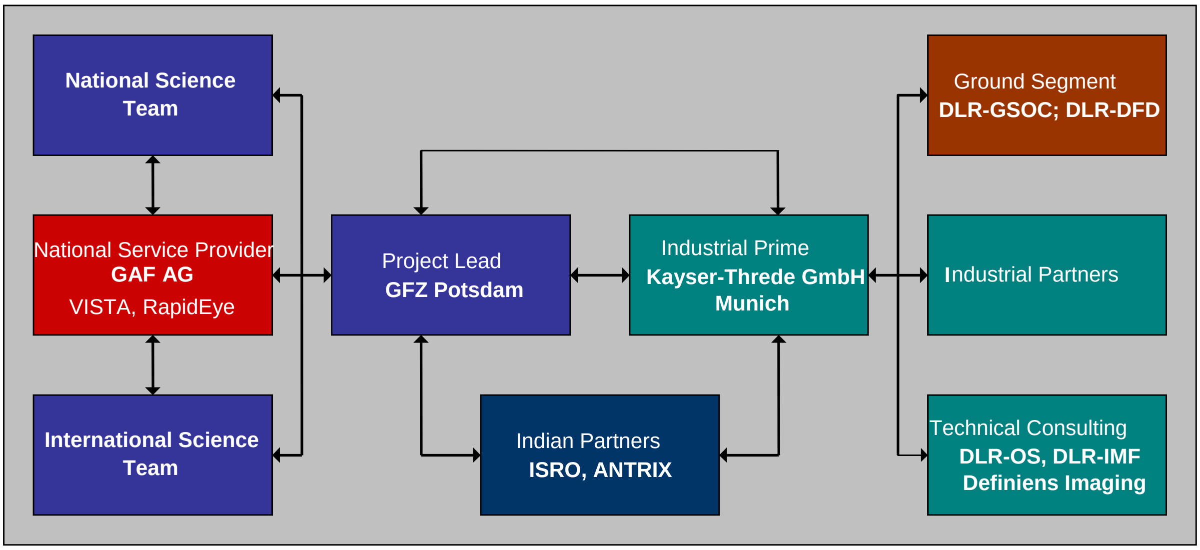

Figure 1 EnMAP Teaming Structure

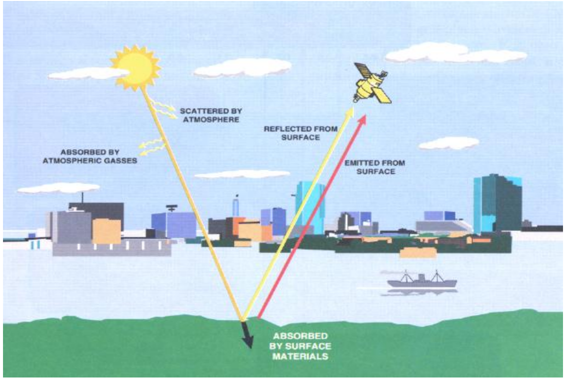

Figure 3 Scheme for the detection of the suns's reflexion spectra from Earth

2.3 The EnMAP system characteristics and mission scenario

EnMAP includes two satellite missions with a hyperspectral instrument each, fulfilling the mentioned objectives. A summary of the instrument characteristics can be derived from Table 1.

To achieve global coverage and constant illumination conditions of the targets, a sun-synchronous orbit has been selected. A local overpass of 11:00 a.m. represents the best compromise between high radiances to achieve the required SNR and to avoid the higher cloud cover after noon. The envisaged orbit heights have been selected with 817 km. With an envisaged mission lifetime of 5 years for each satellite and a launch of the two hyperspectral satellites in 2009 and 2012, there will be an overlap in the satellite operations of at least 2 years.

The satellites work with a nominal swath width of 30 km at nadir and an across track pointing capability of ±30°. Thus, the accessible target range is ± 455 km resulting in a target revisit capability of roughly 3 days. The hyperspectral satellite pointing features are shown in Figure 4.

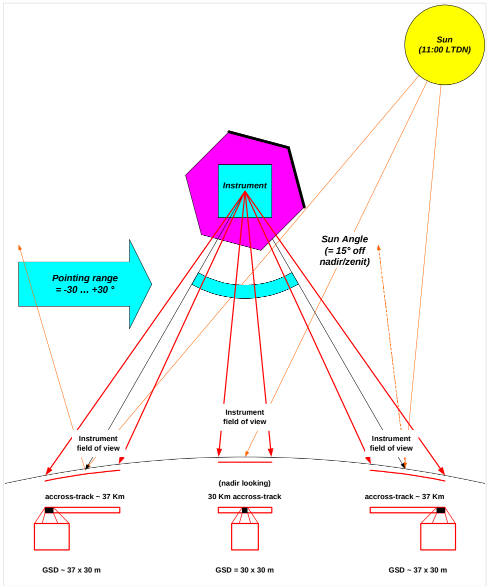

Figure 4 EnMAP satellite pointing features

2.4 The Ground Control and Satellite Operation Concept

The EnMAP space segment relies on common RF equipment (standard S- and X-Band links), and will be completely compliant with the existing ground segment infrastructure at DLR and ISRO. The data are received via the Neustrelitz, other DLR X-Band and different ISRO ground stations.

2.5 Operational Hyperspectral Missions

The EnMAP '09 satellite is conceived as a science and research mission and a pathfinder to evolve towards an operational/commercial service. Thus, in the long-term cooperation programme with India, the '12 hyperspectral satellite targets with the main operations towards the commercial field. The preparative data activities and lessons learned from the operation of the '09 hyperspectral mission will support the commercialization process.

Tab. 1 EnMAP Instruments Characteristics

Optics	Pointing range	+30° from nadir (+455 km)
	Waveband	VNIR: 420 – 1030 nm
		(92 bands)
		SWIR: 950 – 2450 nm
		(108 bands)
		VNIR/SWIR overlap about 3 to 4 bands
	Waveband separation	VNIR/SWIR in-field separation (alternatively dichroic)
	Spectral sampling	VNIR: 5 nm to 10 nm
		SWIR: 10 nm to 20 nm
Focal Planes	VNIR FPA	CCD or CMOS detector with at least 1024 x 256 pixel (EEV or Fillfactory)
	SWIR FPA	HgCdTe hybrid CMOS detector with 1000 x 256 pixel (SOFRADIR/AIM)
Thermal Design	VNIR FPA	Passive cooling
	SWIR FPA	Active cooling
Data Rate and On-Board Storage Capacity	Data Compression	H/W or S/W compression by factor 2.5; loss-less
	Onboard Data Rate	600 Mbps (=> 240 Mbps with factor 2.5 compression)
Power Consumption		< 120 W
Mass		< 150 kg
Envelope		1200 x 700 x 300 mm

The value adding companies in the EnMAP team led by GAF AG shall ensure a smooth transition between the development of science algorithms and the corresponding commercial exploitation. The outline of the perspectives of EnMAP for an operational and commercial service has to consider a number of critical operational factors, such as expected cost/benefit, accuracy, revisit times and operationalization of product processing. EnMAP will thus create revenue streams in.

- Data Sales: Excellent direct opportunities to sell data to an international science community, to value adding industry and to incorporate EnMAP type data and product development for GSE related services leading to a new quality of data. "First to the market" are drivers for the expected demand.
- Sales of Satellite Resources: Is seen as a realistic chance for few countries with a strong mineral sector (e.g. Australia, South Africa and others)
- Value-Adding and Product Generation: Opens up a wide field of services for product and application oriented developments. Development of products possibly including aerial campaigns with an ARES-type hyperspectral airborne system.

Also benefits for the current European "Global Monitoring of Environment and Security" (GMES) programme have been identified and will be further followed-up.

3. CONCLUSION

Under contract of the German Space Agency DLR, GFZ and Kayser-Threde perform a study for the advanced hyperspectral satellite missions EnMAP, scheduled for launch in 2009 and 2012. The realization of the satellites consider a cooperation between the Indian and German Space agencies ISRO and DLR. EnMAP operations will give an outstanding opportunity to the EO science, application and value adding industry to develop ways and products to serve a wide end-user community with a steadily increasing demand in the fields of forestry, disaster management, inland water, coastal zones, soils and land degradation, agriculture and geology.

Planning for EnMAP, Germany consequently follows the way to new future sensors, which are characterised by the broad generation of multiple and enlarged sets of information. EnMAP satellites have the inherent capability to distinguish between the physical and chemical composition of materials.

Also aspects for the commercial use of data are already considered in the definition of the EnMAP instruments. Further information on EnMAP can be retrieved from www.Enmap.de.

4. ACKNOWLEDGMENTS

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