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ENMAP – AN ADVANCED HYPERSPECTRAL MISSION

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ABSTRACT

In the upcoming generation of satellite sensors, hyperspectral instruments will play a significant role, being considered world-wide within different future planning. In this context our team is proposing the advanced hyperspectral sensor EnMAP (Environmental Monitoring and Analysis Program) as the next German satellite mission, scheduled for launch in 2009. The instrument performance allows for a detailed monitoring, characterisation and parameter extraction of rock/soil targets, vegetation, and inland and coastal waters on a global scale. By the scientific lead of GFZ Potsdam and the industrial prime ship of Kayser-Threde, the ongoing planning aims towards an internationalisation of the mission approach.

The EnMAP instrument provides information based on 218 contiguous spectral bands in the wavelength range from 420 nm to 2450 nm. It is characterized by a SNR of > 500:1 in the VNIR and >150:1 in the SWIR range at a ground resolution of 30 m x 30 m. A national and international broad science and application community can draw from an extensive and highly resolved pool of information, supporting the modelling and optimization process on their results. Operation of an airborne system (ARES – a joint venture of GFZ and DLR), starting in 2006, and the evolution of data handling and extraction procedures will further support this process.

The presented paper describes the instrument and mission, as well as science and application scenarios, highlighting the international embedding, and the actual status in the presently conducted EnMAP phase A study.

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 core of the justification for the Environmental Mapping and Analysis Program (EnMAP). EnMAP is directly relevant to natural and anthropogenic issues that are of immediate concern to all people. The objectives of EnMAP are to derive relevant surface parameters 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 partners propose to build, launch and subsequently operate a state-of-the-art Earth Observation (EO) satellite equipped with a spatially high-resolution targeted Hyper-Spectral Imager (HSI).

The EnMAP satellite will be launched in 2009, and its five-year EO-Mission Program will focus on current issues related to the environment, agriculture, land-use, water systems, geology, and related science and applications. EnMAP´s HSI 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 scientific 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 contiguous, 5-10 nm wide bands sampled at 10 nm intervals. The spatial resolution is 30 m x 30 m.
- 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 that are not provided by multispectral sensors.
- To provide high-quality calibrated data and data 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 is pursued in all development phases of EnMAP.

EnMAP and TanDEM-X (TerraSAR Add-on for Digital Elevation Measurements) have been selected as candidates for a future German space mission following the TerraSAR-X mission currently under development. Both missions have been evaluated in separate phase A studies until fall 2005. A financial frame of 60 MEURO is envisaged for the mission including instrument, satellite and launch. We have finished phase A end of this year (2005) and are presently waiting for a decision of DLR-Headquarters and BMBF to proceed into phases B,C,D.

ENMAP MISSION

The mission is executed within a national context, with a international scientific focus but a strong commercial component aiming at the support of GMES related services. This is reflected in the mission team that is composed from a German and international science team as well as a commercially oriented value-adding team led by GAF. Kayser-Threde is the instrument prime and OHB-systems will provide the bus. An EnMAP Science Advisory Group is established to ensure the scientific quality of the mission proposal.

EnMAP represents a satellite mission with a hyperspectral instrument fulfilling the requirements listed in Table 1. To achieve global coverage and constant illumination conditions of the targets, a sun-synchronous orbit has been selected. A local equator crossing time of 11:00 represents the best compromise between high radiances to achieve the required SNR and the increasing cloud coverage. A trade-off has been performed considering the orbit height, the resulting decay rate, the swath width, and the revisit frequency to achieve the best compromise in terms of technical realisation effort and achievable data quality. This has resulted in an orbit height of about 675 km. This already takes into account, that with a mission life time of five years and a launch in 2009, the satellite will fly towards the solar maximum. Thus, it is necessary to reduce as far as possible the impact of atmospheric drag, in order to keep the fuel required for orbit maintenance within an acceptable range.

Table 1: Geometric and radiometric outline of the instrument

Parameter	**Requirement**
Spectral Coverage	420 nm - 2450 nm
Noise equivalent delta radiance	VNIR: (420-1030 nm): 0.005
[mW/cm^2 sr µm]	SWIR I (950-1390 nm): 0.003
	SWIR II (1480- 1760 nm): 0.003
	SWIR III (1950-2450 nm): 0.001
Spectral sampling	VNIR: 5/10 nm
	SWIR: 10 nm
Spectral stability (VIS-NIR-SWIR)	0.2 nm
Radiometric stability	≤ 2.5 %
Ground sampling distance (GSD)	30 m x 30 m nadir at sea level
Swath width	30 km
Smile and smile effects	≤ 0.2 pixel
Band-to-band registration (VNIR -SWIR detectors)	≤ 0.2 pixel
Local equator crossing time	11:00 hrs

With a nominal swath width of 30 km at nadir and an across track pointing capability of ± 30 º, the accessible target range is ± 390 km. This results in a target revisit frequency of roughly 3 days. The target sizes correspond to an imaging period of 3 minutes or a strip length of about 1000 km/orbit (5000 km/day). From the operations point of view, data can be collected per day, resulting in a data volume of about 360 Gbit. With four contacts per day to the Neustrelitz and e.g. Prince Albert ground station, each with a contact duration of 7 minutes, all spectral bands can be downlinked (datarate: 100 Mbps). The optional use of a 300 Mbps downlink data rate allows the acquisition on a global basis of up to 16 strips, i.e. an area of approximately 0,5x10^6 km².

The Ground Control and Satellite Operation Concept

The EnMAP space segment will rely on common RF equipment (standard S- and X-Band links), and will be completely compliant with the existing ground segment infrastructure. Mission control will be located at DLR GSOC (German Space Observation Center) Oberpfaffenhofen with satellite commanding via Weilheim. Operational data reception facilities for small satellite missions dedicated to Earth observation exist at the Neustrelitz X-Band ground station. Other international stations have already expressed their interest to receive EnMAP data and offer downlink capability, what would increase the throughput of data and attract additional user communities.

The EnMAP operations procedures can mostly be taken from previously flown German missions such as e.g. CHAMP. In addition, it is assumed that for the launch and early orbit phase GSOC will cooperate with international S-Band stations operators.

Data processing and archiving structure

The processing and archiving of the received EnMAP data will be under the responsibility of DLR-DFD (German Remote Sensing Data Center) in Oberpfaffenhofen. The processing chain comprises the conversion of the raw data to Level 0+ and Level 1. Level 1 and/or Level 2a/b data will be made available to participating scientists and value-adding companies via a mission dedicated user access portal. In order to reduce the amount of the data, only the Level 0+ data will be archived at DFD.

At DLR-DFD software packages already exist, that fulfil the requirements of an operational and semi-automatic pre-processing of hyperspectral data from airborne sensors such as HyMap, DAIS 7915 and ROSIS. These software tools are adapted to the needs of EnMAP and integrated in DLR's Data Information and Management System (DIMS), an automated processing environment with robot archive interface as established for the handling of satellite data.

Besides the handling of automated data pre-processing and archiving, DIMS provides user information services such as on-line and off-line delivery, post-processing, a product library, ordering control and production control.

Key features offered by DIMS are:

- Multi-mission facility, supporting products from many sensors/satellites/missions in parallel
- User information services including guide, directory, inventory, browse and ordering
- Product library, including automatic robot archive and inventory with optimized spatial access methods
- Robot archive, with an extendable capacity of 300Tbyte
- Interfacing of local and remote processors
- Product delivery on media or via Internet
- Unified operating using Java/WWW-technology
- Support of distributed sites based on interoperability with CORBA

Due to the modular design of DIMS both the automated pre-processing (system correction, radiometric calibration, combined geocoding / atmospheric correction) and the integration of newly developed information products during the operation period of EnMAP can be assured. Quality checks will be carried out in every step of the processing chain (e.g. histograms of bands, SNR computation for each channel, channel cross correlation analysis, etc.).

Launch Vehicle

A number of launchers, such as Eurockot, DNEPR, KOSMOS and PSLV are basically compatible with the EnMAP requirements and characteristics. For all launchers, the necessary I/Fs with the DLR-GSOC are already established. A detailed trade-off for the optimum launcher is performed in the future.

CONCLUSION

GFZ and DLR together with Kayser-Threde and other industrial and commercial partners are studying technical possibilities for the high performance hyperspectral mission EnMAP. Scheduled for launch in 2009, the satellite is meant as a roadmap for optical future hyperspectral satellites with scientific and strong operational character. EnMAP thus, represents the consequent next step for Germany following the trend towards advanced future systems. Those systems are characterised delivering multi-disciplinary information to give value adding companies and EO product generators an optimised basis for their activities. Finally, the integration of EnMAP and its data into the cascade of future optical super- and hyperspectral missions raise the system’s value by far.