REVIEW OF ENMAP SCIENTIFIC POTENTIAL AND PREPARATION PHASE

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ABSTRACT:

The Environmental Mapping and Analysis Program (EnMAP) is a German built hyperspectral space sensor scheduled for launch in 2012. EnMAP will measure over the 420-2450 nm spectral range with a spectral sampling between 5 and 10 nm. EnMAP images will cover areas of 30×30 km^2 with a ground sampling distance of 30 m. The primary goal of EnMAP is the exploitation of hyperspectral data for the derivation of high spectral resolution observations of biophysical, biochemical and geochemical variables from a range of surface covers, such as vegetation canopies, rock and soil targets and coastal waters, on a global scale. General descriptions of the EnMAP instrument, the satellite operation concept, the data processing and archiving structures and current project development activities are provided in this paper.

1. INTRODUCTION

Hyperspectral remote sensing, often referred to as imaging spectroscopy, is based on the evaluation of radiance data measured in spectrally contiguous channels. The radiation reflected by the coupled surface-atmosphere system is registered in the visible to near-infrared (VNIR) and short-wave infrared (SWIR) spectral ranges (roughly, 400-1000 nm and 1000-2500 nm, respectively) at typical spectral resolution and sampling of 5 to 15 nm. The detailed spectral characterization of atmospheric and surface absorption features provided by imaging spectrometers enables the use of robust inversion algorithms for the retrieval of geophysical information from the imaged area (Goetz et al., 1985, Schaepman et al., 2006). Moreover, the continuous spectral coverage provided by imaging spectrometers offers the possibility to design multi-purpose Earth observation missions, as the same system can be used for different thematic applications (e.g. agriculture, water or mineral mapping). However, the recognized potential of imaging spectroscopy to provide more and better information about the Earth system than traditional multispectral instruments is currently not counterbalanced by an equivalent availability of hyperspectral satellite data.

The Environmental Mapping and Analysis Program (EnMAP) German hyperspectral mission is intended to cover this gap. EnMAP is a joint response of German Earth Observation (EO) research institutions, value-adding resellers and space industry to the increasing demand on accurate, quantitative information about the evolution of terrestrial ecosystems. EnMAP hyperspectral capabilities will cover the visible, near-infrared and short-wave infrared wavelengths, EnMAP will provide high quality, standardized, and consistent data on a timely and frequent basis. The instrument performance allows for a detailed monitoring, characterization and parameter extraction of vegetation targets, rock and soils, and inland and coastal waters on a global scale.

After a competitive and successfully accomplished phase-A, EnMAP was approved by the German Aerospace Agency (DLR in the German acronym) in the beginning of 2006, and has started the construction phase (phase-C) in November 2009. The EnMAP consortium is formed by the GeoForschungsZentrum Potsdam (GFZ) as scientific leader, the DLR-Oberpfaffenhofen as responsible for the ground segment (GS) implementation and operation, Kayser-Threde GmbH driving the industrial activities, OHB-System AG which provides the bus, and DLR-Agency as the project manager. The EnMAP satellite is currently scheduled for launch in 2012. Its 5-year EO-Mission Program will focus on current issues related to the environment, agriculture, land-use, water systems, geology, and related science and applications. The EnMAP hyperspectral instrument will be used to identify surface cover types and to provide a quantitative assessment of molecular absorptions that are intrinsic to constituents of vegetation, soils, rocks, and water. The overall objectives of the mission are as follows:

- To provide high-spectral resolution observations of biophysical, biochemical and geochemical variables that will enable the improved retrieval of quantitative parameters needed by the users and not provided by operating multispectral sensors.
- To observe and develop a wide range of ecosystem parameters encompassing agriculture, forestry, soil/geological environments, and coastal zones and inland waters.
- To provide high-quality calibrated data and data products to be used as inputs for improved modelling and understanding of biospheric and geospheric processes.

This paper presents a review of the EnMAP mission status and current activities with respect to those already detailed in Kaufmann et al., (2008).

2. OVERVIEW OF THE ENMAP MISSION

2.1 Sensor Description

EnMAP is designed to measure in the 420-2450 range by means of two separate spectrometers covering the VNIR and SWIR spectral regions. It will sample areas of 30x30 km^2 with a ground sampling distance (GSD) of 30 m. The mean spectral sampling distance and resolution is 6.5 nm in the VNIR, and 10 nm in the SWIR. Accurate radiometric and spectral responses are guaranteed by a required signal-to-noise ratio (SNR) about 500:1 in the VNIR and about 150:1 in the SWIR (for a reference radiance level given by 30% surface albedo, 30º sun zenith angle, 0.5 km above sea level and 21 km atmospheric visibility), radiometric calibration accuracy <5% and spectral calibration uncertainty of 0.5 nm in the VNIR and 1 nm in the SWIR. An off-nadir pointing capability of up to 30º enables a revisit time of 4 days. A summary of some mission parameters is displayed in Table 1.

Table 1. Summary of EnMAP sensor and orbit parameters according to the mission requirement document

Imaging principle	Pushbroom-prism
Spectral range	VNIR: 420-1000 nm SWIR: 900-2450 nm
Mean SSI	VNIR: 6.5 nm SWIR: 10 nm
SNR at reference radiance	>500:1@ 495 nm (VNIR) >150:1@2200 nm (SWIR)
Spectral calibration accuracy	VNIR: 0.5 nm SWIR: 1 nm
Spectral stability	0.5 nm
Radiometric calibration accuracy	<5%
Radiometric stability	<2.5%
Radiometric resolution	14 bit
Sensitivity to polarization	<5%
Spectral smile/keystone effect	<20% of detector element
GSD	30 m
Swath width	30 km
Geometric co-registration	0.2×GSD
Swath length (at least)	1000 km/orbit
Coverage	Global in near-nadir mode (VZA≤5°)
Target revisit time	23 days (VZA≤5°) 4 days (VZA≤30°)
Pointing accuracy	100 m at sea level

2.2 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 EO 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. In addition, it is assumed that for the launch and early orbit phase GSOC will cooperate with international S-Band stations operators.

2.3 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 preprocessing of hyperspectral data from airborne sensors. 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. Due to the modular design of DIMS both the automated pre-processing (system correction, radiometric calibration, combined geocoding and 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, signal-to-noise ratio computation for each channel, channel cross correlation analysis, etc.).

2.4 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 to be performed in the future.

3. ENMAP PREPARATORY ACTIVITIES

The main effort during the EnMAP phase-B, ended in March 2008, has been the consolidation of the instrument design and the GS processing chain. A prototype including all the processing modules for the conversion from Level 0+, digital numbers, to geometrically-corrected surface reflectance is already available. The different modules have been designed in parallel with the instrument development so that the processing scheme is consistent with the particular instrument functioning and could compensate for hardware limitations and enhance the data quality by software means.

On the other hand, EnMAP scientific activities have been focused on the support of industrial developments and the consolidation of the mission concept. With this framework, a scene simulator generating EnMAP-like data under realistic conditions has been implemented. It enables the definition of optimal instrument configurations for radiometric, spectral and geometric parameters. The simulator covers the 400-2500 nm spectral region and generates digital number images of 1000x1000 pixels with a GSD of 30 m. e, which simulates spatially coherent and non-coherent noise, drop-outs and calibration coefficients according to the instrument dynamic range.

An example of two EnMAP scenes from the Munich alpine foreland site in southern Germany is displayed in Fig. 1. Data were simulated for two acquisition dates. Simulated cloud patterns were included in one of the dates.

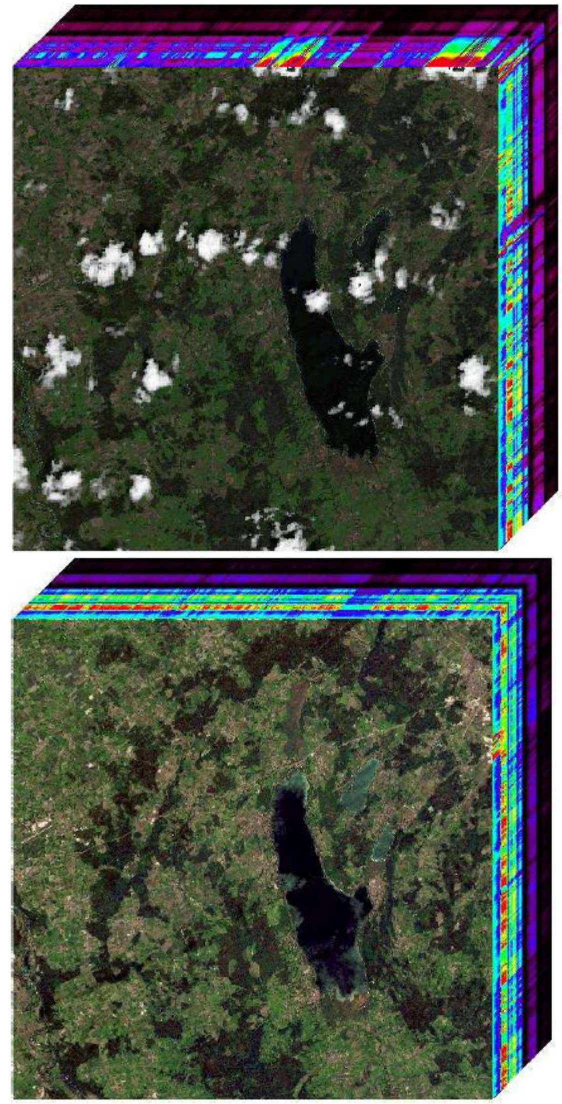

Figure 1. Simulated EnMAP scenes over the Munich alpine foreland in Southern Germany (30.57ºN, 34.83ºE) at two acquisition dates.

In addition to the scene simulator, an EnMAP-specific software environment for the interactive processing of EnMAP data is being designed by the Geomatics lab of the Humboldt University of Berlin and the GFZ. Tools for the pre-processing of EnMAP data and the derivation of higher-level biophysical products are to be included in this software. The main objectives are to facilitate the derivation of higher-level products by consolidated processing algorithms optimized for EnMAP data, and to provide tools for user-driven EnMAP data pre-processing.

Finally, a plan for the EnMAP post-launch calibration and product validation is already under development. The routinary EnMAP calibration strategy based on the monitoring and processing of the on-board measured instrument parameters is being developed at DLR-DFD and DLR-IMF. Complementing this calibration plan, a strategy for the support of in-flight calibration devices with vicarious calibration and validation activities, as well as the interaction between EnMAP and other co-existing EO missions for calibration and scientific purposes is being developed at GFZ. Such a plan is intended to complement the GS measurements with some others which are not considered in the monitoring and calibration plan, as well as to provide backup information on those parameters which are already evaluated by other means. In addition, representative error figures of EnMAP products will be estimated using ground-based measurements. For example, image-based data quality check, spectral calibration analysis, geometric calibration accuracy and ground-based validation activities will be addressed in this strategy.

4. SUMMARY

An overview of the current status of the EnMAP hyperspectral mission has been given in this paper. The EnMAP project is a joint adventure of the GFZ-Potsdam, as scientific leader, DLR-Oberpfaffenhofen as GS responsible, Kayser-Threde GmbH as industrial prime, OHB-System AG as bus provider and DLR-Agency as project manager. EnMAP phase-B finished in March 2008, and the beginning of phase-C, system construction, is expected to be started about September of 2008. EnMAP launch is scheduled for 2012. EnMAP will measure over the 420-2450 nm spectral range at a varying spectral sampling of 5-10 nm. EnMAP images will cover 30×30 km^2 areas at approximate pixel sizes of 30 m. The main objective of EnMAP is the exploitation of hyperspectral data for the derivation of global high-spectral resolution observations of biophysical, biochemical and geochemical variables from a range of surface covers. Main current EnMAP activities are the consolidation of the instrument design and the GS processing chain. An EnMAP scene simulator, a user-friendly software for the exploitation of EnMAP data and the data monitoring, calibration and validation strategy are also under development.

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