ENMAP SATELLITE BUS – A COST EFFECTIVE PLATFORM FOR EARTH OBSERVATION MISSIONS

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Abstract

The Environmental Mapping and Analysis Program (EnMAP) is a joint German initiative under the scientific leadership of the GeoForschungsZentrum (GFZ) Potsdam. The company Kayser-Threde is the industrial prime contractor for the EnMAP space segment, and is responsible for the satellite system and the Hyper Spectral Imaging Payload. The company OHB-System is responsible for the satellite bus. The EnMAP project is carried out under contract to the German Space Agency DLR with funds of the German Federal Ministry of Economic Affairs and Technology under grant No. 50 EP 0801. The EnMAP satellite will be operational in 2013 with a mission duration of 5 years.

With its hyperspectral capabilities covering the visible, near- and short-wave infrared wavelengths, the EnMAP satellite mission will provide high quality Earth observation data on a frequent basis. EnMAP provides information based on 228 spectral bands in the wavelength range from 420 nm to 2450 nm at a ground sampling distance of 30 m x 30 m. The imaging capacity of EnMAP will be at least 5000 km per day. An imaging spectrometer, such as implemented on the EnMAP satellite, can resolve and detect biophysical, biochemical, and geochemical variables in distinct detail.

The EnMAP satellite bus is based on the space proven SAR-Lupe platform of OHB-System. With this platform OHB-System is able to offer a very suitable and cost effective satellite platform for accurate, high resolution Earth observation purposes. The platform provides a scaleable and modular satellite approach, which can form the baseline also for other Earth observation missions in the medium to very high resolution area for optical or microwave applications.

After a successful execution of Phase B the EnMAP project is right now during its realisation in Phase C/D. This paper is going to provide an overview of the project status with a special focus on the EnMAP satellite bus. The paper will highlight the bus core elements and their performances and capacities, which enable the fulfilment of the specific EnMAP mission requirements. An emphasis will be laid upon the modular approach of the satellite bus configuration, as well as on the concepts for accurate and agile spacecraft attitude control and the high rate on-board processing and downlink of the hyperspectral instrument data.

1. ENMAP MISSION OVERVIEW

The Environmental Mapping and Analysis Program (EnMAP) is based on a space borne hyperspectral imaging mission, which is capable of measuring the solar radiance reflected from the Earth’s surface as a continuous spectrum. An imaging spectrometer, such as implemented on the EnMAP satellite, can resolve and detect biophysical, biochemical, and geochemical variables in distinct detail.

With its capabilities covering the visible, near- and short-wave infrared wavelengths, the EnMAP satellite mission will provide high quality Earth observation data on a frequent basis. The data will be applied in soil and land management, water monitoring, diagnostic mapping and analysis (research of raw materials, detection of brownfields) and catastrophe management.

EnMAP is essentially designed as a scientific mission, but the mission data will be used for the preparation of future commercialization and operative services

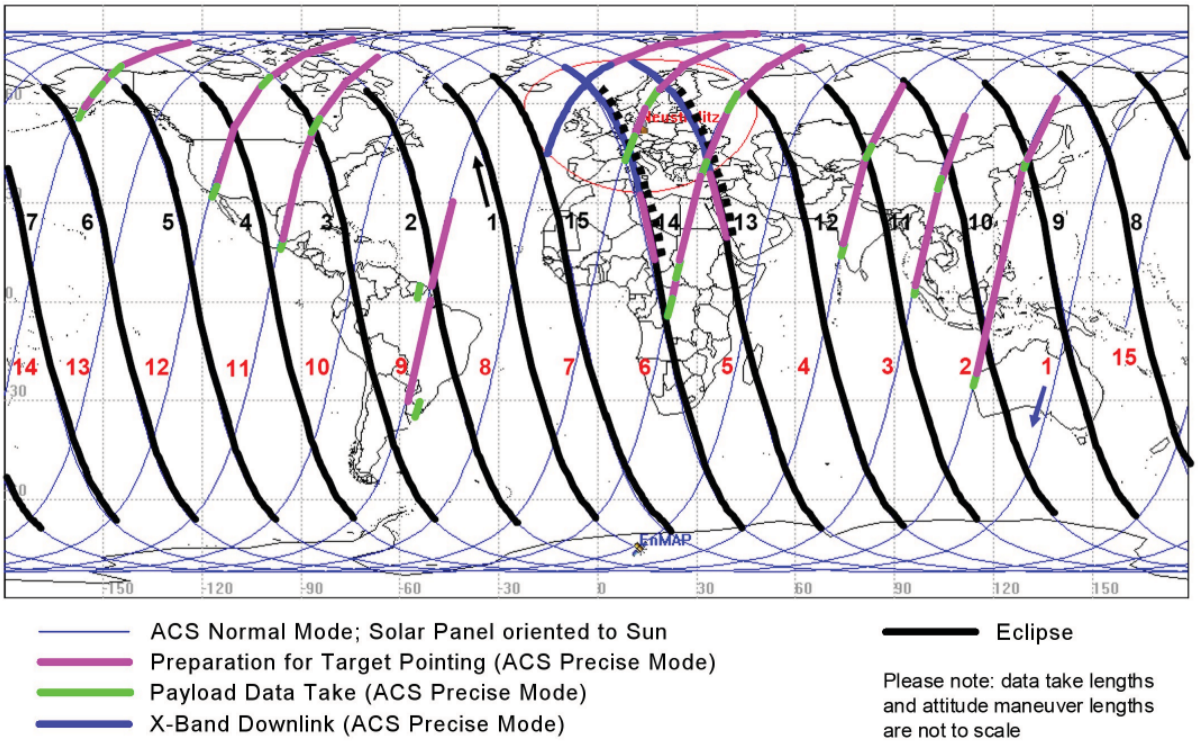

BILD 1. Example Reference Scenario for nominal daily operations of the EnMAP satellite

The EnMAP Hyper Spectral Imager (HSI) payload provides information based on 228 spectral bands in the wavelength range from 420 nm to 2450 nm. It will be operated as push-broom scanner, and covers a swath width of 30 km, with a ground sampling distance of 30 m x 30 m.

The orbit parameters of the EnMAP satellite are mainly the following:

- Altitude: ca. 643 km,
- Inclination: ca. 98°, sunsynchronous,
- Local Solar Time: 11:00 LTDN.

This orbit parameters enable a target revisit capability within 4 days, using the +/- 30° across-track pointing capability of the EnMAP satellite bus.

The imaging performance of the EnMAP satellite is the following:

- Up to 50 images per day,
- Up to 1000 km per orbit; this corresponds to the maximum swath length for one image,
- Total imaging capacity per day of at least 5000 km.

Outgoing from these basic data take performances, a set of daily operational scenarios were established, which include the typical as well as the worst case operational tasks of the EnMAP satellite. These so called reference scenarios were the baseline especially for the design and the performance evaluation of the EnMAP satellite bus. See BILD 1 for one of these EnMAP reference scenarios.

Beside these daily operations, the EnMAP satellite will regularly perform specific calibration manoeuvres, in order to guarantee for the complete mission duration the optimum in-orbit performance of the complete satellite and especially of its hyperspectral payload.

The EnMAP satellite will be operational in 2013 with a mission duration of 5 years.

2. ENMAP SATELLITE BUS

The EnMAP satellite bus is based on the heritage of the successful SAR-Lupe project of OHB-System. The SAR-Lupe satellite system is Germany’s first satellite-based radar reconnaissance system and it consist of five 800kg class satellites on low Earth orbits. The satellites have been placed into orbit between end of 2006 and mid 2008, and all of them are successfully operating since then.

The EnMAP satellite project is the first phase C/D project, which makes use of the proven SAR-Lupe satellite platform for an Earth observation mission, which is quite different regarding the type of payload to be implemented.

Nevertheless, during EnMAP project it has been proven that the satellite platform is very well suited for the specific requirements of the EnMAP mission and its sophisticated hyperspectral imaging payload. This is especially due to its advantages of a very modular and flexible configuration, a highly accurate and agile attitude control concept and a high rate on-board processing and downlink of the payload data.

Because of these features the EnMAP platform provides a very suitable and cost effective solution, which can form the baseline also for other Earth observation missions in the medium to very high resolution area for optical or microwave applications.

The following TAB 1 provides an overview of the highlight features of the EnMAP satellite bus, including the capacity for the operation of the EnMAP payload.

At the time being, the detailed design of the EnMAP spacecraft and its elements and subsystems is taking place, with the Critical Design Review (CDR) of the platform to be held at the end of 2009. In the following the current design status of the EnMAP platform and its subsystems is presented.

EnMAP Satellite Bus Highlights	
Bus Dry Mass Payload Mass Propellant Mass	484 kg (w/o margin) 280 kg (w/o margin) 50 kg
Bus Compartment Payload Compartment	1.8 x 1.2 x 1.1 m³ (w/o solar panel and appendages) 1.8 x 1.2 x 0.7 m³
Lifetime	5 years nominal
Bus Reliability	>86 % after 5 years operation, redundant design
Bus Power Payload Power Solar Panel Capacity	320 W peak / 238 W stand-by primary power 26 - 33.6 V (nominal 31 V) 280 W peak / 189 W stand-by, 910 W EOL (sun pointing)
Attitude Control	High accurate, 3-axis-stabilised
Orbit Control	Hydrazine blow-down system, up to 70 l fuel capacity
P/L Data Storage Data Processing Rate	512 Gbit (EOL) 1.3 Gbit/s, incl. off-line lossless CCSDS data compression
P/L Data Downlink Data Rate	X-Band, 320Mbit/s
TM/TC Data Rate	S-Band, full duplex, up to 4/64 kbit/s (up/down)
Launcher Compatibility	Baseline Launcher PSLV Basic compatibility to most common launchers

TAB 1. Main Features of the EnMAP Satellite Bus

2.1. Spacecraft Configuration

The current configuration of the complete EnMAP spacecraft is shown in BILD 2 below.

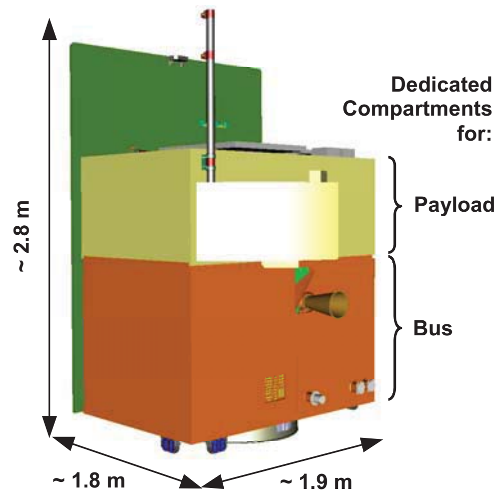

BILD 2. EnMAP Spacecraft Configuration

The EnMAP payload, the Hyper Spectral Imager (HSI), is accommodated separately at the upper part of the spacecraft to account for the demanding stability and thermal requirements of the optical system. Further this accommodation provides maximum independency and most easy assembly of both the payload and the bus subsystems. To minimize heat fluxes the payload is thermally decoupled from other subsystems to the maximum intent.

The overall dimensions of the EnMAP satellite are (WxDxH) 1.9 x 1.8 x 2.8 m³, from which an envelope of approx. 1.5 m³ is provided for the payload (excluding possible appendages, such as baffles, etc.).

The lower part of the spacecraft is the satellite bus compartment, which houses all the subsystems of the satellite bus. The following figures show the accommodation of the bus subsystems within the bus compartment.

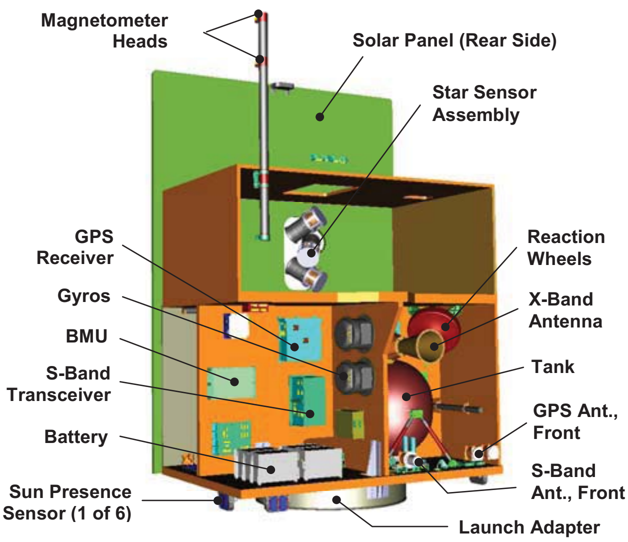

BILD 3. Bus Subsystem Accommodation – Front Side (HSI payload not shown)

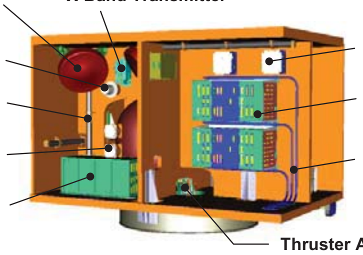

BILD 4. Bus Subsystem Accommodation – Back Side (Bus Compartment shown only)

The HSI payload is not depicted in the above figures. But, one can see in BILD 3 the assembly of the star sensors, which are accommodated directly on the payload optical bench in such way, that thermal and mechanical distortions, which contribute to the pointing error budget, are minimised. With this star sensor orientation and accommodation, as shown in the figure, the optimum pointing performance on satellite level is achieved.

The bus structure itself is a combination of sandwich panels and integral design components. Design materials are aluminium and carbon fibre reinforced plastics.

2.2. Spacecraft Budgets

2.2.1. Mass Budget

The current mass budget of the EnMAP spacecraft is depicted in TAB 2.

EnMAP Mass Budget	
Bus Mass	484 kg
Payload	280 kg
S/C Dry Mass	**764 kg**
Propellant Mass	50 kg
S/C Launch Mass	**814 kg**

TAB 2. EnMAP Mass Budget (without Margin)

Including ca. 50 kg of propellant the overall spacecraft launch mass sums up to 814 kg, without margin.

2.2.2. Power Budget

The power consumption of the EnMAP satellite bus, as well as of the payload, in the corresponding operational modes is summarized in TAB 3.

Together with the established EnMAP reference scenarios these figures are the main drivers for the design of the solar generator and battery performances, which characteristics are presented in section 3.1 below.

EnMAP Power Budget						
	EnMAP Power Modes					
All Values in Watts	Stand-By	Transition	X-band Downlink	Calibration	Data Take	Orbit Control
Satellite Bus	238	271	300	261	262	320
Payload	189	189	189	280	255	189
Subtotal Power	**426**	**459**	**489**	**540**	**517**	**508**
Losses	13	14	15	16	16	15
Total Power	**439**	**473**	**504**	**557**	**532**	**523**

TAB 3. EnMAP Power Budget

2.2.3. Pointing Budget

The EnMAP pointing performance on overall spacecraft level is the following:

- Pointing Knowledge: better than 100 m on ground,
- Pointing Accuracy: better than 500 m on ground,
- Pointing Stability: better than 1.5 m on ground within 4.4 msec,
- Pointing Agility: +/- 30 deg across-track pointing in less than 5 minutes.

2.3. Launcher Compatibility

The design of the EnMAP satellite bus so far has ensured a compatibility to a wide range of small satellite launchers, which are namely:

- PSLV
- DNEPR
- ROCKOT
- VEGA
- SOYUZ-FREGAT
- COSMOS 3M

The on-going detailed design is now focussing on the baseline launcher, which is the Indian PSLV launcher. This focus is especially with respect to the detailed design of the launch adapter. Nevertheless, the EnMAP bus remains basically compliant with the other launchers, as well.

3. BUS SUBSYSTEMS

The following BILD 5 provides the electrical block diagram of the satellite bus, including all subsystems and their interfaces, including also the interfaces to the HSI payload.

The block diagram also depicts the redundancy concept within the satellite bus. All applicable subsystems and components are redundant or feature an internal redundancy (such as especially the solar generator and the battery).

This design concept, which is furthermore based on the utilisation of space proven and reliable components, enables a reliability for the satellite bus of better than 86% after 5 years operation.

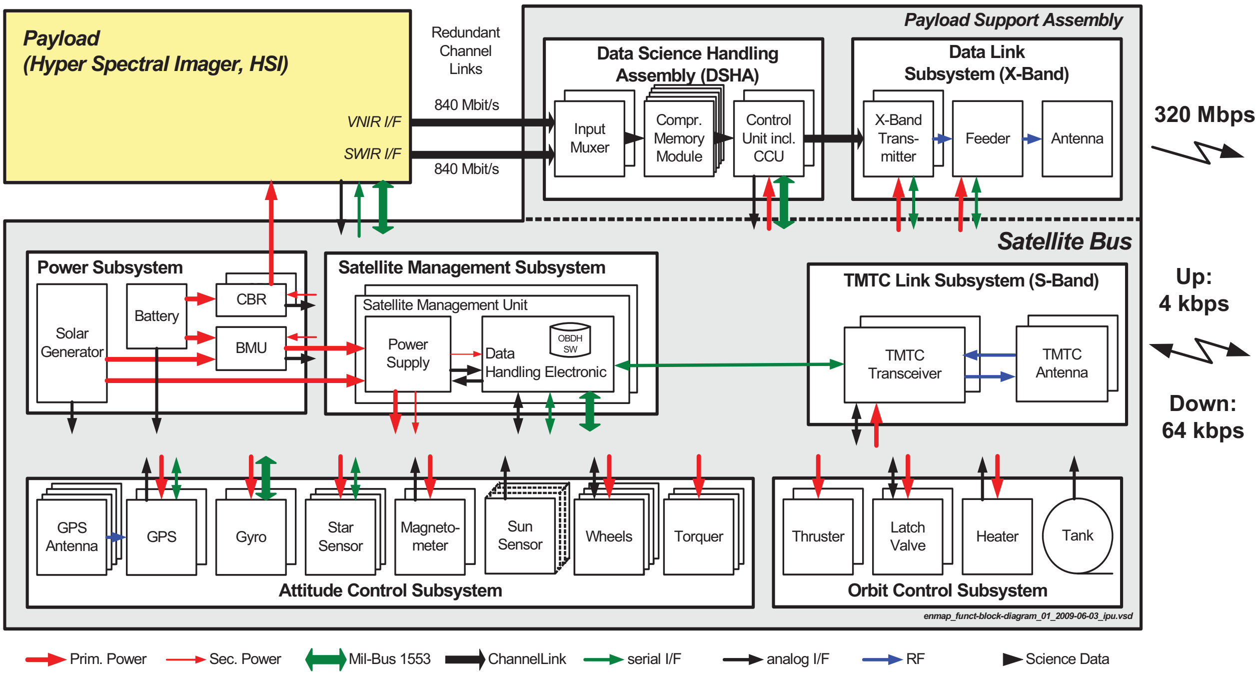

BILD 5. Electrical Block Diagram of the EnMAP Satellite Bus including Bus Subsystems

3.1. Power Subsystem

The power subsystem constitutes of following functional components:

- Solar Generator,
- Battery,
- Battery Management Unit (BMU),
- Circuit Breaker for the provision of primary power to the payload, which includes its own power distribution.

3.1.1. Solar Generator

The panel of the body-mounted solar generator (SG) is made of lightweight aluminium honeycomb structures selectively supported by dedicated CFRP elements. In this configuration the panel provides an area of approx. 5.1 m² that is available for solar cell assemblies.

To satisfy typical high power demands of Earth observation payloads the SG is equipped with state-of-the-art GaAs triple junction solar cells providing an efficiency of approx. 28% @ begin-of-life (BOL). The relatively low degradation of these types of cells enables the SG to provide sufficient end-of-life (EOL) power to the complete spacecraft. For shadow protection each solar cell is equipped with an individual integrated bypass diode.

The electrical layout of the SG comprises 58 single strings with 20 cells in series, providing the necessary EOL performance of approx. 910 W @ 115°C cell temperature and under consideration of two string failures at EOL. Each string is equipped with one blocking diode.

Beside thermal impacts on the solar cells, this power prediction is further considering loss factors on solar cell level, which are derived from statistical assumptions and supported by strong space heritage to determine damages caused e.g. by micrometeorites and cover glass losses during the EnMAP lifetime.

In addition to the solar cells, the SG accommodates dedicated sun presence sensors, the GPS and S-band antennas, and it also includes the cut-out for the star sensor field of views, as depicted in the previous accommodation figures.

On the rear side the solar panel is covered by MLI to reduce thermal impacts to the satellite bus and the P/L compartment.

3.1.2. Battery

The EnMAP battery delivers the energy for the satellite in the eclipse as well as in sun phases where the power consumption exceeds the available SG power.

It consist of Li-Ion cells that provide an energy density of 113 Wh/kg, where voltage ranges from 22 to 33.6 volts can be achieved. The overall battery consists of two identical modules, where each module comprises 44 parallel cell strings of 8 cells in series each, totalling to 704 cells for the complete battery. This sums up to a capacity of the EnMAP battery of 132 Ah @ BOL.

BILD 6 below depicts the battery, which is foreseen for the EnMAP satellite bus.

The complete power subsystem is designed to fulfil the required operational scenarios of the EnMAP mission, which are especially defined in the set of EnMAP reference scenarios (see section 1). The battery is designed to fulfil 40,000 charge/discharge cycles (8,000 per year) during the nominal lifetime of five years in orbit.

As indicated already, beside standard charge phases during sunlight and discharge phases during eclipse (approx. 27400 cycles during nominal lifetime), also potential peak power buffering for sporadic P/L operation purposes or attitude manoeuvres with insufficient sun incidence have been considered.

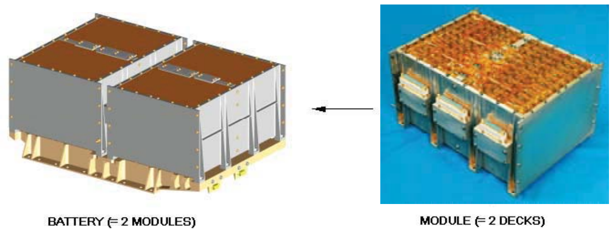

BILD 6. EnMAP Battery Layout

The end-of-charge-voltage of the battery will be optimized in that way that the capacity fade during lifetime can be kept to a minimum, providing the best possible battery performance. By this an EOL capacity of at least 70 Ah can be achieved, which guarantees the fulfilment of the EnMAP reference scenarios with sufficient margin. Also battery cell failures and thermal impacts are taken into account in the performed power simulations.

The following BILD 7 provides an example result from the EnMAP power simulations, which take into account the satellite power consumptions per mode (as in TAB 3) and the EoL performances of both the solar generator and the battery. The two graphs indicate the progression of the battery state-of-charge (SoC) during a specific EnMAP reference scenario, which is especially power demanding. The simulations reveal, that for initial an SOC of better than ca. 40% also this demanding reference scenario can be fulfilled.

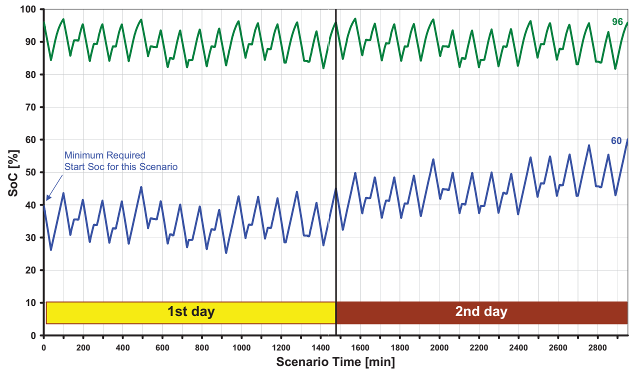

BILD 7. Progression of the Battery SoC during a demanding EnMAP Reference Scenario

3.1.3. Battery Management Unit

The BMU supervises all battery relevant parameters and autonomously protects the battery in case of fatal software malfunction. The unit acquires the housekeeping data necessary for the S/W in order to manage the satellite energy sources. In addition, the BMU will switch-on the satellite after separation from the launcher.

The BMU implements the following functions:

- Under-Voltage Protection,
- Over-Voltage Protection,
- Battery Current Monitor,
- Battery Voltage Monitor.

Charge management and power distribution functions are implemented on the corresponding SMU boards.

3.2. Satellite Management Subsystem

The Satellite Management Subsystem of the EnMAP bus consists of two identical Satellite Management Units (SMU) and the On-board Data Handling Software (OBDH S/W). A single SMU includes the data handling electronics boards and the power supply electronic boards. These PCBs are integrated in one electronic box with one common backplane (see BILD 8).

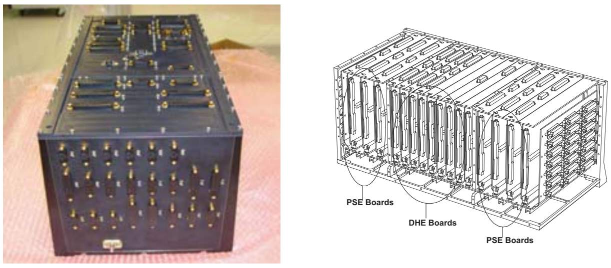

BILD 8. Layout of the EnMAP Satellite Management Unit

The SMU is able to interface and control all electronic subsystems of the satellite by onboard autonomy. The power supply electronics supplies the data handling electronics and provides power distribution to the subsystems. The data handling electronics controls the power electronics and acquires the housekeeping data.

The redundancy is realized by the use of two Satellite Management Units as part of the SMS. In nominal operations, one SMU is operated and the other is in stand-by mode. The telecommand decoder of both SMUs are always switched on.

The SMU provides one (redundant) MIL-1553B bus. This interface is used for command and telemetry transfers between the SMU and especially the payload and payload data handling subsystems.

The SMU hosts the OBDH S/W, which is running on a single radiation hard digital signal processor (DSP). The EnMAP OBDH S/W is able to perform all required tasks to control and monitor the complete EnMAP satellite. The overall architecture of the EnMAP OBDH software including the attached hardware subsystems is shown in BILD 9.

On bus level the following modes are implemented:

- Normal Mode,
- Safety Mode, including autonomous FDIR functions.

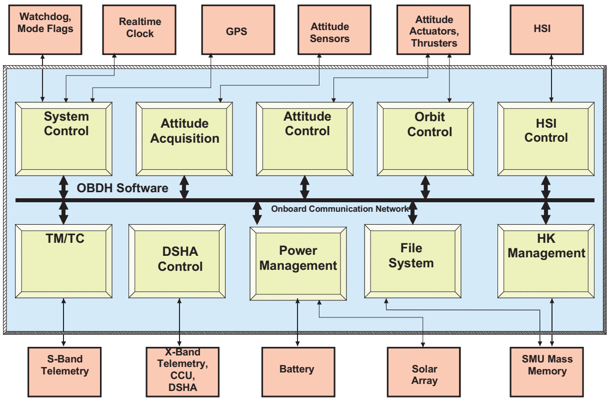

BILD 9. Overview EnMAP OBDH software overall architecture

The OBDH of EnMAP is designed as such, that the satellite can nominally be operated from ground with minimum operational effort. Specific tasks such as data takes are commanded by Time-tagged Telecommands, which contain all information to execute the addressed task autonomously.

State-of-the-art authentication methods are implemented for satellite commanding and control.

3.3. Attitude Control Subsystem (ACS)

The EnMAP bus provides high accurate and reliable attitude control capabilities as required for optical and microwave instruments performing Earth observing applications. To fulfil the requirements for various operational tasks, different ACS modes are implemented, which are in detail:

- INIT MODE: Check out of basic functionality of the ACS elements according to a defined sequence of activities.
- NORMAL MODE: 3-axis autonomous attitude control with the solar generator pointing to the sun; ACS standard operational mode.
- PRECISE MODE: Most accurate attitude performance is provided; in this mode the attitude of the satellite is manoeuvred according to dedicated attitude profiles in order to carry out specific tasks.
- EMERGENCY MODE: Spin-stabilised coarse sun pointing in case of critical anomalies.

The specific tasks of the spacecraft and especially of the payload are commanded by means of time-tagged telecommands (TTTC). If a specific ACS pointing is required, the TTTC always includes a so-called ACS guidance list, which represents the required ACS pointing profile in form of attitude quaternions. The ACS on-board software will process the information contained in the uploaded list and will reconstruct (by means of interpolation) the complete guidance profile originally computed on ground. An example of a simplified guidance profile is depicted in BILD 10, showing a fictive sequence of different ACS precise modes to perform a number of subsequent image acquisitions at different pointing angles.

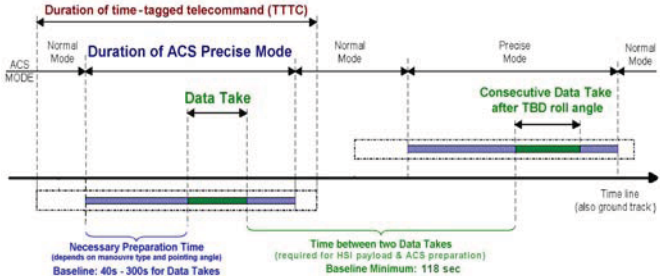

BILD 10. Simplified Satellite Guidance Profile

By this guidance concept the satellite bus is able to perform different precise pointing attitudes and profiles, such as the following, which are required during the EnMAP mission:

- Standard ground observation: Push broom attitude profile with up to +/- 30° across-track pointing.
- Payload calibration manoeuvres: Deep space pointing or direct sun pointing (of the HSI sun calibration port).
- X-Band downlink: Ground station pointing (of the high gain antenna).
- OCS Manoeuvre: Attitude or inclination control manoeuvres for accurate orbit acquisition and maintenance.

More complex pointing profiles, such as for mosaicing, are not required for EnMAP, but could also be performed with this attitude guidance concept.

In general, the hardware elements of the EnMAP ACS comprise sensors, controllers and actuators (see also previous block diagram in BILD 5), where the main functional components are explained in more detail in the following TAB 4.

Component	Description
Star Sensors	Three identical star sensors (STS) are implemented to provide autonomously accurate 3-axis information. Accommodation directly on Payload optical bench. Only one STS information is sufficient for accurate pointing performance. This accounts for the redundancy case and in case that one STS is blinded during any potential complex attitude profile.
Gyro Unit	The gyro unit comprises a redundant set 3-axis attitude sensors. Supply of a very direct, accurate and smooth angular velocity signal.
Reaction Wheels	The reaction wheels are used as main actuators for the attitude control system. Four wheels are arranged in a tetraedric configuration for internal redundancy.
Magneto-meters	A redundant set of magnetometers is used, which provide reliable 3-axis measurement of the Earth magnetic field for coarse attitude information and for the selective operation of the magnet torquers.

Component	Description
Magnet Torquers	Three redundant magnet torquers are used as actuators for safe and robust attitude control and for momentum management. Momentum management is autonomously performed during ACS Normal Mode.
Sun Presence Sensors	A redundant set of sun presence sensors is used for an omni directional, rough assessment of the sun direction.
GPS	A redundant GPS unit is implemented to provides accurate position and timing information.

TAB 4. EnMAP ACS Components

The optimized arrangement, together with the optimized control of above described components allows to realize the required pointing performance during image acquisition as reported in section 2.2.3.

In order to support the post-processing of the payload data on ground, auxiliary information from the ACS sensors (STS and GPS) is permanently sampled and stored on-board, and is downlinked to ground via the X-band link.

3.4. Orbit Control Subsystem

The EnMAP bus is equipped with an Orbit Control Subsystem (OCS), which comprises the following main functional components:

- Hydrazine blow-down system,
- Propellant tank with up to 70 litres capacity,
- 2 thrusters with 1 N each ,
- Pressure and electrical components (such as valves, filters, transducers, etc.).

A block diagram of the EnMAP OCS is depicted in BILD 11 beside.

The OCS is required for the satellite commissioning and first acquisition of the nominal orbit after separation from the launcher, as well as to provide controlled thrust and thrust momentum for maintaining the nominal orbit during the operational lifetime. Also the execution of EOL de-orbiting manoeuvres require the OCS, in order to fully comply with the corresponding code of conduct for space debris mitigation.

To realize the maximum possible reliability of this subsystem, the OCS for the EnMAP bus is designed to the criteria of minimum complexity.

3.5. High Rate On-board Data Handling

The EnMAP payload data handling comprises highly-efficient and reliable components that are capable to process optical Earth observation payload data with its typical high rates and volumes requiring minimum resources.

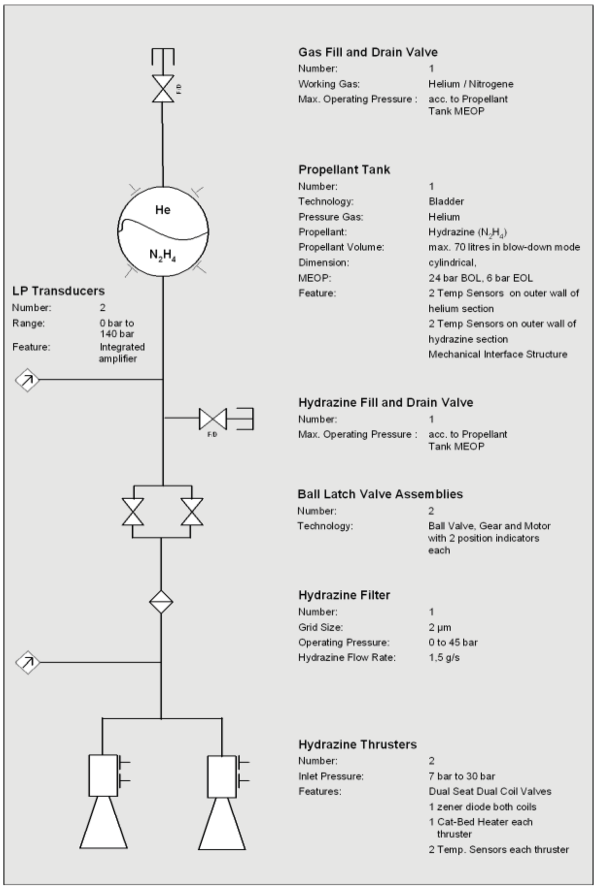

BILD 11. EnMAP OCS Block Diagram

The following subsystems are part of the EnMAP payload data handling:

- Data Science Handling Assembly (DSHA), which includes high rate input multiplexer, mass memory and channel coding unit, conforming with CCSDS,
- X-band transmitter, performing data modulation and providing the RF signal,
- high gain antenna.

The DSHA interfaces to the HSI payload via two redundant channel links, each of which is operating at 840 Mbit/s data rate, i.e. the complete input data rate of the DSHA is 1680 Mbit/s. One highlight feature of the EnMAP DSHA is the thematically sorting of the hyperspectral data into files, where one file includes the data of one channel per image only. This unique file handling concept significantly eases the downlink and the further processing of the payload data on ground. The channel files are stored within the mass memory of the DSHA, which has the EoL capacity of 512 Gbit.

The X-band transmitter provides to the antenna the RF signal at around 8200 MHz that allows the downlink of payload data with a data rate of 320 Mbit/s.

For data transmission a high gain antenna is used, which ensures the high transmission rate with sufficient link margin. This concept has the drawback, that the downlink requires a dedicated ACS pointing manoeuvre, during which no imaging can be performed. To overcome this drawback a lossless data compression is implemented within the DSHA, which enables a compression ratio for the EnMAP hyperspectral data of at least 1.6. Due to this, only the night time contacts with the X-Band ground station in Neustrelitz are sufficient to dump the complete EnMAP payload data, which is sampled during one day (ca. 600 Gbit).

For the EnMAP mission no payload data encryption is implemented, but this functionality can be included for other Earth observation missions, as well.

The modular approach of the payload data handling subsystems enables the realization of highly-flexible mission operations, and enables the S/C to comply with the requirements of various ground segments.

3.6. TM/TC Link Subsystem

The Telemetry and Telecommand (TM/TC) subsystem is in charge of the communication between the satellite and the operational ground station. Therefore it provides both

- a command function according Packet Command Standard, in charge of reception and demodulation of telecommands sent from the ground, as well as
- a telemetry function according Packet Telemetry and Telemetry Channel Coding Standard, in charge of modulation and transmission to the ground of housekeeping data.

The TM/TC subsystem works in S-band and can be operated in full duplex mode. Hence, it is possible to transmit data with up to 64 kbit/s and receive telecommands from ground at the same time with a data rate of 4 kbit/s.

The simplified hardware concept is illustrated in BILD 12 and comprises following elements:

- Single TM/TC unit comprising two S-Band transmitters and two receivers, operated in hot redundancy,
- Two Antennas (+/- X direction) to guarantee TM/TC link in any case,
- Splitter, diplexer and harness.

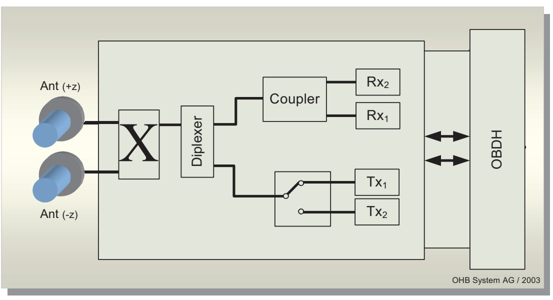

BILD 12. TM/TC Subsystem Block Diagram

The purpose of the S-band TM/TC antenna system is to provide a nearly omni directional antenna pattern in order to ensure the availability of the telemetry and telecommand link to the satellite independent from the actual attitude of the satellite.

This nearly omni directional pattern is achieved by the parallel operation of two identical, hemispherical S-band antennas, which are mounted on opposite sides of the satellite. The boresight of the antennas are aligned in +X and –X direction respectively.

3.7. Thermal Control Subsystem

The Thermal Control Subsystem (TCS) is responsible for the regulation of the thermal environment within the satellite bus. This is primarily achieved by means of passive thermal control measures, such as multi-layer insulation (MLI) and heat pipe assemblies.

To minimize complexity and costs dedicated structural panels not covered with MLI serve as thermal radiators for waste heat removal from the bus subsystems themselves. As the payload compartment is thermally decoupled from the platform, the payload includes its own thermal control elements, according to the relevant payload requirements, without any functional dependence from the bus subsystems.

Active thermal control of the satellite bus is only required for OCS components. Therefore the propellant tank, valves and filters are equipped with heating foils in order to avoid propellant freezing in orbit during critical mission phases.

4. CONCLUSION

Based on the SAR-Lupe heritage OHB-System offers with the EnMAP satellite bus a highly reliable and flexible satellite platform, which allows the customer to realize Earth observation missions in a cost-efficient manner. Further, its modular configuration supports the accommodation of optical as well as microwave payloads, which enables the platform to comply with various mission objectives.

The specific highlights of the EnMAP project are in summary:

- This platform was selected from the customer DLR to realize the next German Earth Observation mission EnMAP according its challenging technical requirements and within its tight programmatic framework.
- The EnMAP project is currently in Phase C/D, with the critical design review for the platform to be held at the end of 2009.
- The ENMAP satellite will be operational in orbit in 2013.
- The EnMAP project has proven the successful adaptation of the basic platform design concept to the demanding requirements of a specific Earth observation mission.

In parallel to the EnMAP project, various studies and early projects are currently being performed at OHB-System, where the use of the EnMAP satellite bus for other missions is investigated in detail. This again includes the implementation of various types of Earth observation payloads, such as radar and different optical instruments.