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A modular satellite platform for Earth Observation mission in the low Earth orbit

Stephan Strauß, Amin Shahsavar, Frank te Hennepe

OHB-System AG, Universitätsallee 27-29, D-28359 Bremen, Germany
Phone: +49 421 2020 8, Fax: +49 421 2020 700, www.ohb-system.de
(Phone St.Strauß: +49-421-2020-9775; e-mail: stephan.strauss@ohb-system.de)

ABSTRACT

The LEOBUS-1000 is a generic satellite platform developed by OHB-System for low Earth orbit missions using small launchers. It is a development based upon the company's heritage from SAR-Lupe and Galileo. The LEOBUS-1000 platform has accumulated over 17 years of in-orbit heritage through the five successful SAR-Lupe satellites.

One of the main objectives of LEOBUS-1000 is to realise a modular and flexible platform designed for various Earth observation missions. In order to achieve this goal, the platform has been designed with separated payload and platform modules in order to increase the flexibility of the platform. This reduces the cost due to partial Assembly, Integration and Test (AIT) process parallelization.

The modular design makes the platform a perfect solution for a wide range of Earth observation missions. The total spacecraft mass for satellites using the LEOBUS-1000 is in the range of 600 to 1300 kg, including up to 450 kg of payload. The platform supports payloads with an average power demand of up to 1.5 kW but offers as well flexible and cost effective options for less power demanding payloads. The design lifetime of the platform is 5 or 7 years and it provides agility and high precision pointing capabilities for high performance Earth observation payloads. This, combined with the platforms high rate payload data on-board processing and downlink system (up to 640 Mbit/s X-band downlink and 2 Tb payload mass memory), provides a good foundation for all kinds of earth observation payloads

The LEOBUS-1000 platform is compatible with most small sized launchers including VEGA, PSLV and ROCKOT. Due to its ability to accommodate various payloads and the platforms heritage, it has been used for several ESA satellites studies like the ESA Earth Explorer 7 candidate missions, GMES Sentinel-5 Precursor and a radar altimetry satellite constellation.

1. INTRODUCTION

The LEOBUS-1000 is OHB System's generic satellite platform for low Earth orbit missions using small launchers. It incorporates a design that combines subsystems from two of OHB-Systems flagship platforms: the SAR-Lupe and Galileo platforms. The reliability and proven flight operation is provided by the SAR-Lupe heritage, while the modernity and capability for future services is provided by the Galileo heritage. The platform design heritage is depicted in Figure 1.

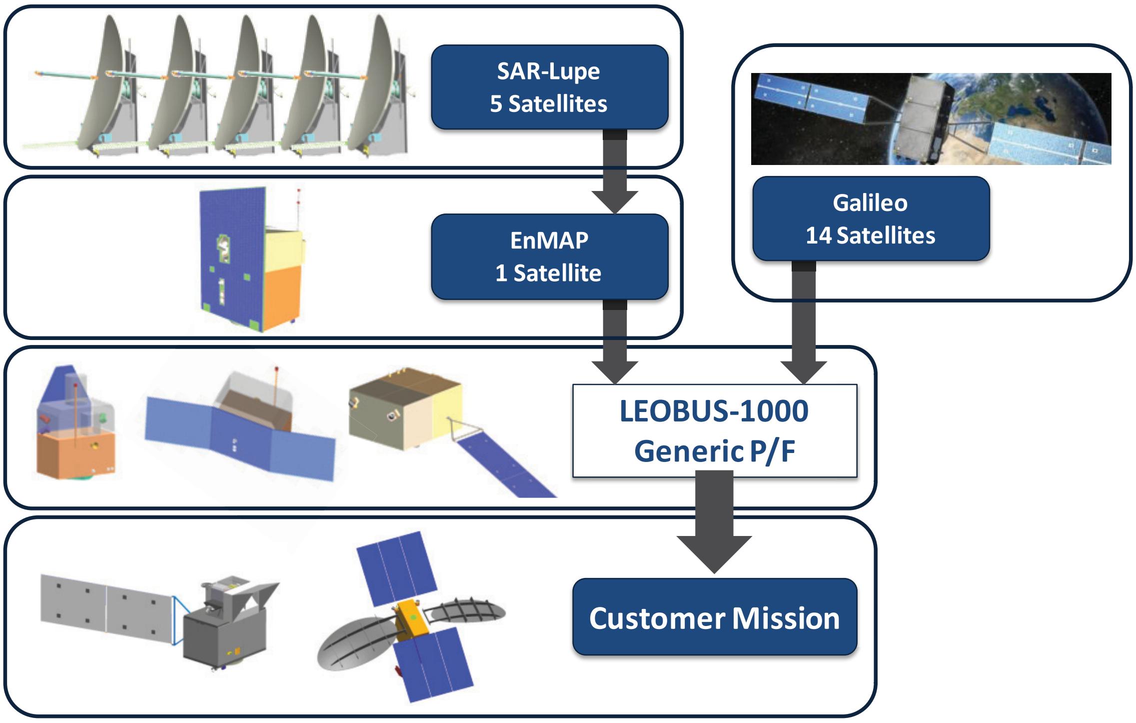


Figure 1: LEOBUS-1000 heritage cycle

LEOBUS-1000 is a derivative of the EnMAP[1] platform, which is a successor to SAR-Lupe. Consequently, LEOBUS-1000 has an accumulated in-orbit heritage of >17 years from the 5 SAR-Lupe satellites.
The Galileo heritage comes from the on board computer and power conditioning of the 14 Galileo satellites - a contract awarded to OHB-System in 2010. The project is currently in Phase C and is scheduled to fly its first satellite at the end of 2012.

2. GENERAL DESCRIPTION

The LEOBUS-1000 platform is designed for Earth observation missions with a mass in the 600 to 1300 kg range that can be launched with small launch vehicles like VEGA, PSLV or ROCKOT. Among its main features are:

- reliability greater than 90% after 5 years,
- high agility,
- very precise attitude control performance,
- high rate payload data processing chain including broad storage and downlink capacity,
- cost efficiency by modular configuration.

1. EnMAP is a national project under the German DLR Earth Exploration program and is the first phase C/D project which makes use of the proven SAR-Lupe satellite platform for an Earth Exploration mission

As a generic platform, different bus standard compartments as well as a structure design to mission needs are available. The P/L compartment is typically separated from the bus compartment to achieve:

- a maximum interface independency (thermal, structural),
- easy assembly, integration and test (AIT)
- widely recurring bus compartment design

Figure 2 shows an example configuration of the LEOBUS-1000 with all baseline subsystem components.

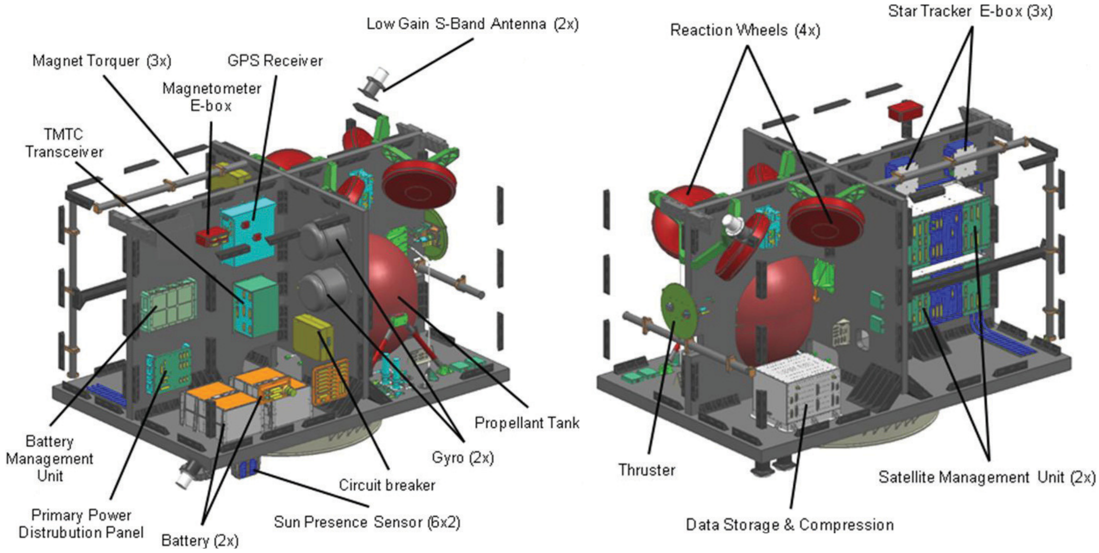


Figure 2: LEOBUS-1000 Subsystems

The functional Architecture of the LEOBUS-1000 platform is depicted below in Figure 3, which includes all subsystems, their interfaces and the interfaces to the 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). Components varying by configuration are marked blue.

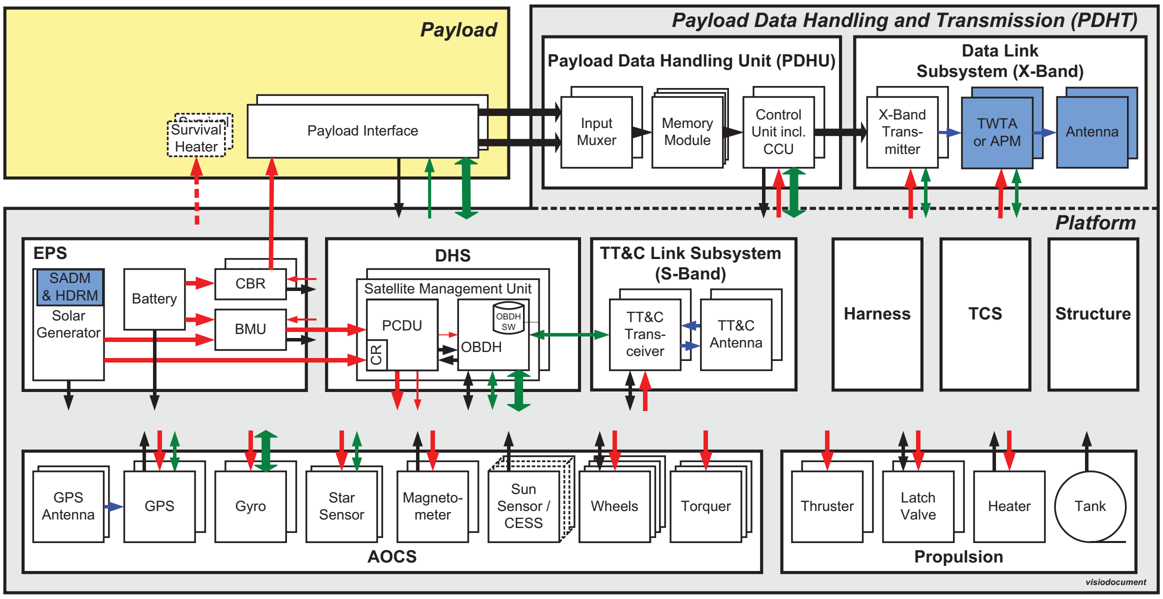


Figure 3: LEOBUS-1000 Functional Architecture

The following descriptions on the generic LEOBUS-1000 platform present the unmodified heritage design:

For the design lifetime of 5 years the platform has a reliability of more than 90% in all configurations. After an extended design lifetime of 7 years the reliability remains greater than 80% with consumables left for an extension of operation in most cases.

The standard design schedule lasts less than 48 months from Phase B Kick-off till System Flight Readiness Review.

The platform can mount payloads with a total mass of up to 450 kg. The maximum average available power for the payload that the platform can provide at end of life is 1.5 kW (for ideal illumination conditions on an eclipse free dusk-dawn SSO).

A high performance ADCS gives the platform a pointing accuracy of <<100 arcsec and a slewing capacity to change from any orientation to any other orientation within 4 minutes including the stabilization time for highest pointing accuracy.

The propulsion system is designed to provide a Δv of up to 250 m/s depending on the total satellite mass.

The PDHT design follows a scalable approach offering a downlink data rate of up to 640 Mbit/s, a mass data storage capacity of up to 2 Tbit and options for lossless real-time compression and encryption.

The omni directional coverage of the S-Band TMTC ensures contact to the ground station.

3. LEOBUS-1000 CONFIGURATIONS

There exists mainly three LEOBUS-1000 design configurations. Each of these configurations offers a high performance - yet cost effective - solution for the suitable payload category.

The payload category is determined by the following payload parameters:

- Duty cycle
- Pointing constraints
- Power Demand
- Mission Orbit Parameters

The configurations cover the resulting changes from power demand to the payload data downlink concept. There are three solar generator options as well as three downlink concept options. The three main design configurations combining the three power and three data transmission concepts are presented. These combinations show typical solutions for typical payloads and orbits. The platform is not limited to these configurations; any other combinations of the power generation concepts and payload data transmission concepts are available.

3.1. Configuration 1

This configuration is optimised for missions with a low payload duty cycle and low to medium power requirements but a high agility, precision and stability demand. Equipped with a large body mounted solar array the default attitude for this concept is Sun pointing. A large battery allows flexible payload operations outside the sun/charging phase. After the payload peak operation period the following phase is used for recharging the battery. The agility of the platform is as well used for a very reliable and cost and power effective payload data downlink concept. The spacecraft tracks the ground station while transmitting the payload data and allows thereby the use of a fixed high gain horn antenna without an additional antenna pointing mechanism. This configuration is used by EnMAP.

Key facts:

- Low duty cycle, typically $\leq 10\%$
- Default sun pointing
- Low to medium power demand
- Single fixed body mounted solar generator
- Single fixed high gain antenna

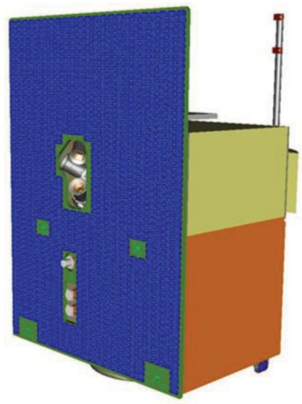


Figure 3-1 Example of Configuration 1

3.2. Configuration 2

Configuration 2 adds deployable but fixed solar array wings to the body mounted solar array as used for configuration 1. This offers more power for the payload and allows a higher payload duty cycle. Depending on the payload pointing restrictions and duty cycle this configuration can perform mainly/partly Sun pointing or permanent Nadir pointing. The payload data downlink concepts uses X-band high gain antennas with APMs because of their low power demand and the degrees of freedom they offer for platform pointing during downlink. This configuration type is well suited for sun synchronous dawn-dusk orbits. Suitable missions for this configuration are for example planned small and medium size GMES Sentinel and ESA Earth Explorer missions.

Key facts:

- For high duty cycle with medium P/L power consumption or low duty cycle with high power consumption
- Simple deployable solar generator
- Two antenna pointing mechanisms with high gain horn antennas
- Usually best choice for dusk-dawn EO SSO missions

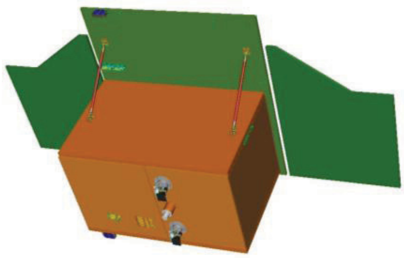


Figure 3-2 Example of Configuration 2

3.3. Configuration 3

Configuration 3 is the solution for high power and permanent (>90%) operating payloads. It uses a SADM to improve the power generation capabilities of the platform. The downlink concept baseline for this configuration is an isoflux antenna as many very high duty cycle missions require more or less permanent Nadir pointing. For high agility missions with a parallel measurement and downlink requirement the use of APMs would be baseline. This configuration can additionally offer more flexibility for payload accommodation and is suitable for e.g. medium and larger GMES Sentinel and Earth Explorer Missions.

Key facts:

- For high duty cycle, or high power P/L requiring virtually permanent observations (>90%)
- Constant and full Sun illumination on S/A's – even when along track pointing
- More complex system with a SADM
- Often Nadir or fixed pointing
- X-Band isoflux antenna with TWTAs

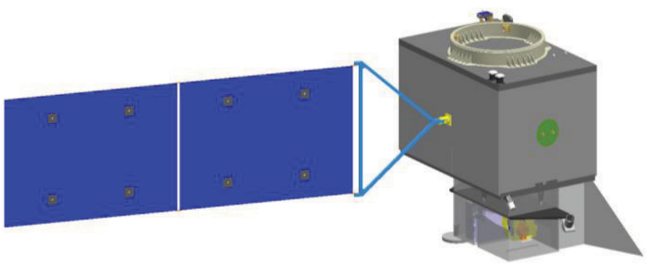


Figure 3-3 Example of configuration 3

4. CURRENT STUDY DESIGN EXAMPLES

In this chapter, current studies using the LEOBUS-1000 are presented in the Table below.

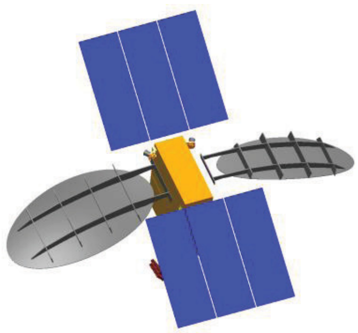
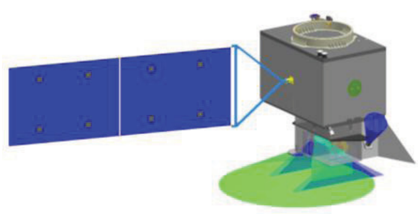
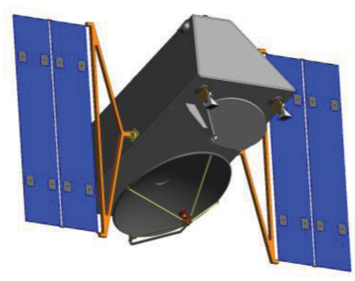
Earth Explorer 7 Candidate: e.g. CoReH2O	**GMES Sentinel-5 Precursor**	**Radar Altimetry Constellation**
The CoReH2O mission is one of three remaining candidates for ESA's Earth Explorer 7 mission. CoReH2O would measure the snow and ice mainly at high latitudes with its twin frequency synthetic aperture radars (9.6 and 17.2 GHz). The information could be used e.g. for climate change monitoring in cold regions.	Sentinel-5 Precursor shall bridge the gap between Envisat's retirement and Sentinel-5. Its payload will be two spectrometers covering UV-Vis-NIR-SWIR frequencies. The mission objective of S5p is to provide high temporal and spatial resolution measurements of elements relevant to atmospheric chemistry, like ozone, BrO, NO2, SO2 and formaldehyde .	A Radar Altimetry satellite constellation as follow-on for Sentinel-3 satellite. The mission's objective is to continue and improve sea surface height observations for oceanography.
		
S/C Mass: ~ 1200 kg S/C Power: ~ 2400 W Payload: ▪ X-Band SAR ▪ Ka-Band SAR Altitude: ~ 660 km Inclination: SSO, dusk-dawn Expected launch date: 2018 Design features: ▪ Modified PCDU because of vast payload power demand ▪ Very compact design ▪ Improved ACS	S/C Mass: ~ 850 kg S/C Power: ~ 1300 W Payload: ▪ UVN ▪ SWIR Altitude: ~ 825 km Inclination: SSO Expected launch date: end 2014 Design features: ▪ Short schedule, recurring ▪ Payload accommodation: complex fields of view in all 3 axis (e.g. two instrument)	S/C Mass: ~ 550 kg S/C Power: ~ 900 W Payload: ▪ Altimeter ▪ MWR ▪ GNSS Receiver ▪ LRR Expected launch date: 2020+ Number of Satellites: 12+ Design features: ▪ Multi launch concept ▪ Very precise orbit determination

Table 4-1 Current studies using the LEOBUS-1000

5. CONCLUSION

The LEOBUS-1000 based on the heritage of SAR-Lupe with more than 17 years of cumulated in-orbit experience and is upgraded by the heritage from Galileo. It is designed for typical Earth observation missions in the 600 to 1300 kg class. With its different configurations and its modular design approach the platform offers solutions for a diverse range of payloads. Additionally it offers great flexibility and reliability having a design lifetime of 7 years.

This platform is currently proposed or under study for several missions such as ESA's Earth explorer missions and next generation GMES missions like Sentinel-5 Precursor. A further application of this platform is currently studied with a multiple satellite climate monitoring constellation.

The LEOBUS-1000 meets the requirements for future GMES-Security and very high resolution commercial systems very well, since:

- It provides a very agile platform with very high pointing accuracy and pointing knowledge that are required by very high resolution Earth observation payloads
- It offers a high capacity payload data rate handling and transmission subsystem
- The propulsion subsystem provides not only orbit maintenance capabilities but enables constellation and formation flying as well.