POLAR ORBITING METEOROLOGICAL SMALL SATELLITE

H. Lübberstedt, C. Tobehn, B. Penné
OHB-System AG, Universitätsallee 27-29, D-28359 Bremen, Germany

1. INTRODUCTION

With support of the German Space Agency DLR, OHB-System has developed a concept for a Polar Orbiting Meteorological Satellite for Post-EPS.

The EUMETSAT Polar System EPS [1] is the European contribution, that forms together with the US National Polar Orbiting Environmental Satellite System NPOESS [2] the Joint Polar System of meteorological satellites. The first of a series of three EPS satellites, METOP-A, shall be launched in October 2006 with a Soyuz launcher. Each satellite is planned to be replaced by the next one after 5 years of operations, such that the nominal operational lifetime of the third satellite METOP-C will end in 2020. As the backup for METOP-C is required in 2015 in order to guarantee continuous service, the planning of the successor system Post-EPS has already started.

The METOP satellites carry a variety of instruments as shown in Figure 1 with the following key characteristic:

- Launch Mass 4085 kg
  - Fuel 300 kg
  - Instruments 931 kg
- Power Consumption 1812 W
  - Instruments 885 W

A more detailed introduction to the EPS system, instruments and applications is given in [1].

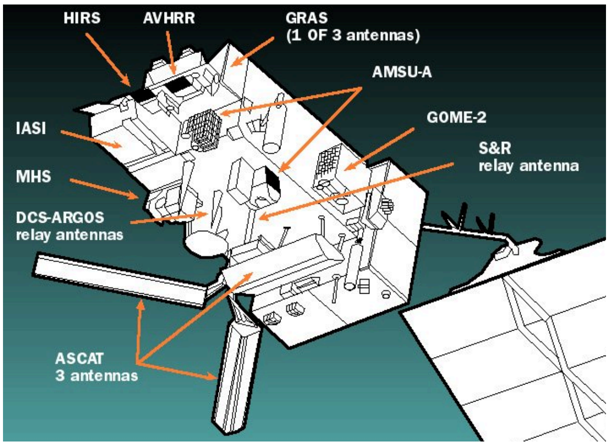

Figure 1: METOP Satellite & Instruments

2. MISSION REQUIREMENTS

The present study is focused on a Low-Cost Satellite to bridge the gap between METOP and the Post-EPS based on a minimum payload complement, which is not covered by the NPOESS satellites i.e.

- The Infrared Atmospheric Sounding Interferometer (IASI) developed for METOP or a follow-on instrument,
- A supporting Imaging Radiometer (IMR) with at least AVHRR (Advanced Very High Resolution Radiometer) performance

Optional a Microwave Sounder (MW) is considered to complement the IASI in cloudy regions as proposed by the user community [3]. This instrument suite can deliver the raw data for data products required by the meteorological users such as temperature and humidity profiles, trace gas column content, air pressure, precipitation, wind velocities, vegetation indices, sea surface temperature, snow cover and fire data. Detailed data product requirements are provided by the World Meteorological Organization WMO.

The Satellite Platform shall provide all necessary means for the payload accommodation, in particular a Payload Data Handling System (P/L DHS) and the following EPS compliant communication links (see Figure 2):

- X-Band Global Data Stream (GDS)
- L-Band High Rate Picture Transmission (HRPT) in real-time.
- Optional Low Rate Picture Transmission (LRPT)
- S-Band Telemetry and Tele-Command (TTC)

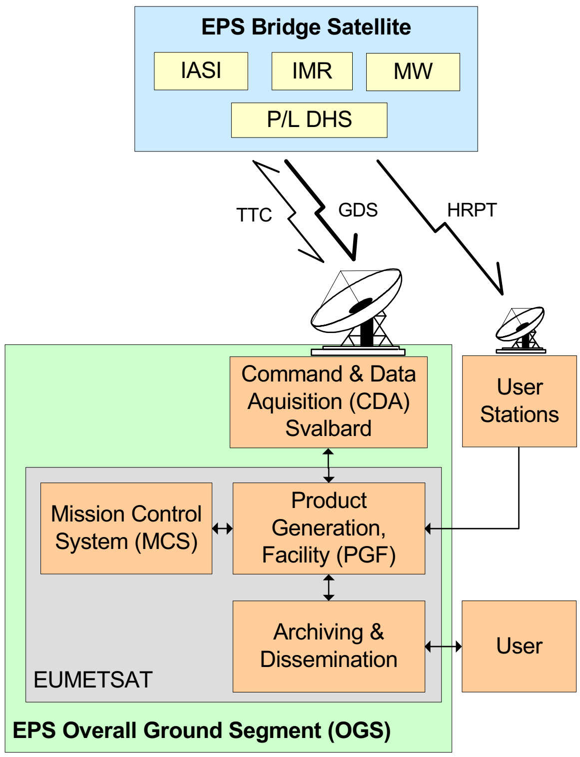

Figure 2: System Overview

The Ground Segment (G/S) shall be based on existing EPS/ METOP infrastructure consisting of

- The Command and Data Aquisition station in Svalbard,
- Global distributed HRPT User Stations,
- The EUMETSAT Core G/S in Darmstadt including Mission Control, Product Generation, Archiving and Dissemination.

Small modifications of the EPS G/S are considered, if motivated by cost-benefit analysis.

The system design lifetime shall be 3 - 5 years. The system shall be readily developed in 2015 as backup for METOP-C followed by up to 5 years storage till a nominal launch late 2019.

2.1. ORBIT & OPERATIONS ANALYSIS

An orbit and operations analysis was performed based on the following assumptions:

- Sun-synchronous orbit with a mean altitude of 825 km compliant to METOP
- One Antenna at Svalbard for the GDS considering a mean antenna elevation of 5°
- Data Aquisition with 100% duty cycle
- Data Delivery (level 1c) in less than 3 h, therefore downlink is required each orbit

From the simulations the following results and conclusions have been derived:

- The minimum access time to Svalbard is 6.6 min. Therefore the maximum possible net data rate is 3.4 Mbit/s (orbit average) based on an X-Band Downlink providing 70 Mbit/ s which is used on METOP.
- An Imager Field of View of ± 55° provides nearly global coverage after 12 h

The Delta V budget including orbit aquisition, orbit maintenance and end-of-life disposal is estimated to ~ 80 m/s including margin.

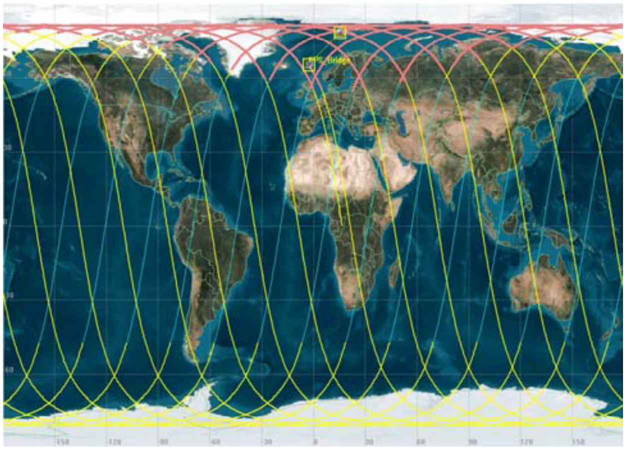

Figure 3: EPS-Bridge Groundtrack after 24 h (yellow = daylight, red = contact to G/S)

3. PAYLOAD

3.1. IASI

The IASI consists of a Fourier transform spectrometer and an imaging system. It is based on a Michelson interferometer and is designed for the measurement of the infrared spectrum emitted by the earth. IASI products are temperature profiles of the troposphere and deeper stratosphere, moisture profiles of the troposphere as well as column content of some chemical components with a strong influence on the green house effect.

The spectrometer has a resolution of 0.5 cm^{-1} in a wave number region between 645 and 2760 cm^{-1}. Data samples are taken at 25 km intervals. The spectrometer is linked with an internal imaging radiometer based on a detector matrix to enable a cloud cover characterisation in the spectrometer FoV. The imager samples the earth with 1 km resolution to enable a co-registration with the AVHRR/3 supporting imager flown on METOP. The main characteristics are summarised in Table 1.

Parameter	Performance
Scan type	Step and dwell
IFOV size at Nadir	12 km
Swath	± 48.3° (±1026 km)
Spectral Range	3 – 16 μm
Lifetime	5 Years
Power	214 W
Dimensions	1.2 x 1.1 x 1.3 m^3
Mass	231 kg
Data rate	1.5 Mbps

Table 1: IASI main features

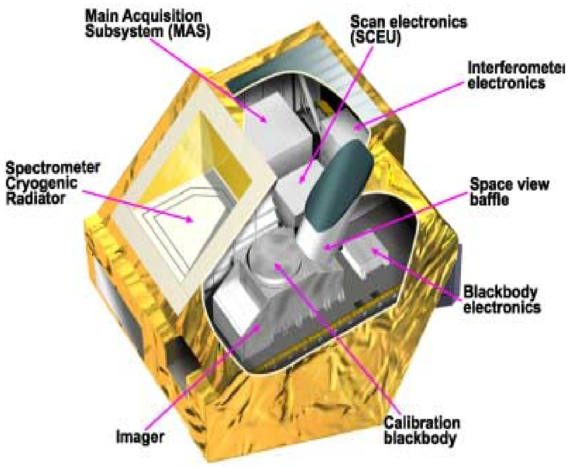

Figure 4: IASI configuration

3.2. Imaging Radiometer (IMR)

As the AVHRR is no longer available, the study was based on the METimage concept developed by JenaOptronik with support of the DLR. METimage is a multi-spectral imaging radiometer with large swath width (2300 km for global coverage) and a GSD < 1 km. It covers all spectral channels from VIS to TIR and with a large flexibility regarding the number of channels and radiometric sensitivity [4].

Taking into account the low-cost approach, 2 IMR options were considered. METimage A and B1 are based on AVHRR respectively VIRI-M requirements. The VIRI-M (Visible & Infra-Red Imager) study have been performed by ESA to define an AVHRR successor. The following Table 2 gives a summary of the most important instrument features of both options. Whereas METimage A meets the AVHRR requirements, METimage B1 even exceeds the VIRI-M requirements for the ground sampling distance (GSD) of the visible channels (VIS).

METimage A	METimage B1
Rotating telescope	Rotating telescope and half angle mirror
Dichroic beam splitter and single detector per channel	Matrix based detector and in-plane spectral separation
Up to 8 channels	11 channels
150 mm entrance pupil	50 mm entrance pupil
Polarisation sens. 5%	Polarisation sens. 5%
Swath >2300 km	Swath >2300 km
GSD 1km	GSD 1km (IR), 500m (VIS)
Volume 74 x 25 x 56 cm^3	Volume 56 x 33 x 28 cm^3
Mass 36 kg	Mass 40 kg
Power 45 W	Power 100 W + 50 W for active cooling

Table 2: IMR options main features

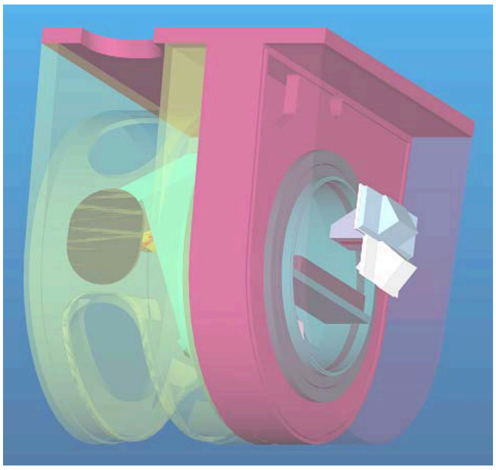

Figure 5: METimage B1 configuration

Both configurations use a rotating reflective confocal telescope. METimage B1 feature a half angle mirror as derotator, a dichroic beam splitter to separate the VIS from the IR spectral channels and 2 detector arrays with in-field spectral separation. A sketch of METimage B1 is shown in Figure 5.

3.3. Microwave Sounder (MW)

As a baseline for the investigations of an optional Microwave Sounder, the ATMS (Advanced Technology Microwave Sounder) was selected. The ATMS will be used together with the Cross-track Infrared Sounder (CrIS) on the NPOESS satellites to provide global temperature and humidity profiles of the atmosphere. NASA/GSFC is responsible for the development, and NPOESS for the future production. Northrop Grumman Electronic Systems (NGES), Azusa, CA, is the prime contractor for ATMS. The first flight is planned for the NPOESS/NASA NPP Mission in 2006 [5].

The ATMS is a successor of the Advanced Microwave Sounding Unit (AMSU) and shall re-place the AMSU-A1/ A2/ B und MHS (Microwave Humidity Sounder) featuring 22 Channels in the range from 63 to 183 Ghz which cover the Oxygen and water vapour spectral lines.

The design was optimized with respect to volume, mass and power consumption leading to the following key characteristic:

- Mass 66 kg
- Volume 40 x 60 x 70 cm3
- Average Power 85 W
- Data rate 50 kbps

The instrument configuration is depicted in the following Figure 6.

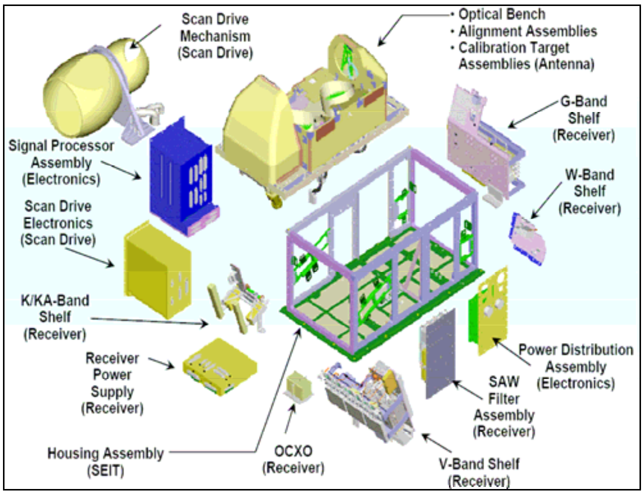

Figure 6: ATMS configuration

4. EPS SATELLITE CONCEPT

The satellite concept is based on the OHB SAR-Sat platform (see Figure 7), which provides very good compliance with the EPS Bridge Low Cost Mission, in particular in terms of reliability and costs.

Figure 7: OHB SAR-Sat Platform (SAR-Lupe mission)

An overview of the EPS-Bridge Satellite Configuration with its subsystems is given in Figure 8. Mission and Payload specific modifications of the SAR-Sat Bus have to be performed for some of the subsystems, in particular the Payload & On-board Data Handling Systems (P/L DHS & OBDH), the Solar Generator and the Structure.

Option	EPS-1	EPS-2	EPS-2 - MW
Instrument Configuration	IASI IMR A	IASI IMR B1	IASI IMR B1 ATMS
P/L mass [kg]	316	321	389
Satellite wet mass [kg]	732	756	865
P/L average power [W]	341	473	562
Satellite average power [W]	527	672	770
Data Volume [Gbit/ orbit]	15.0	19.5	19.8

Table 3: Summary of System Options & Budgets

Based on the different instrument configurations considered, three satellite concept options were developed as summarized in Table 3.

The minimum configuration EPS-1 features the METimage A Imager based on the AVHRR Requirements, whereas the METimage B1 Imager of EPS-2 exceeds the Requirements, which where defined during the ESA VIRI-M study for an AVHRR successor. The maximum Option EPS-2-MW includes in addition the Microwave Sounder ATMS.

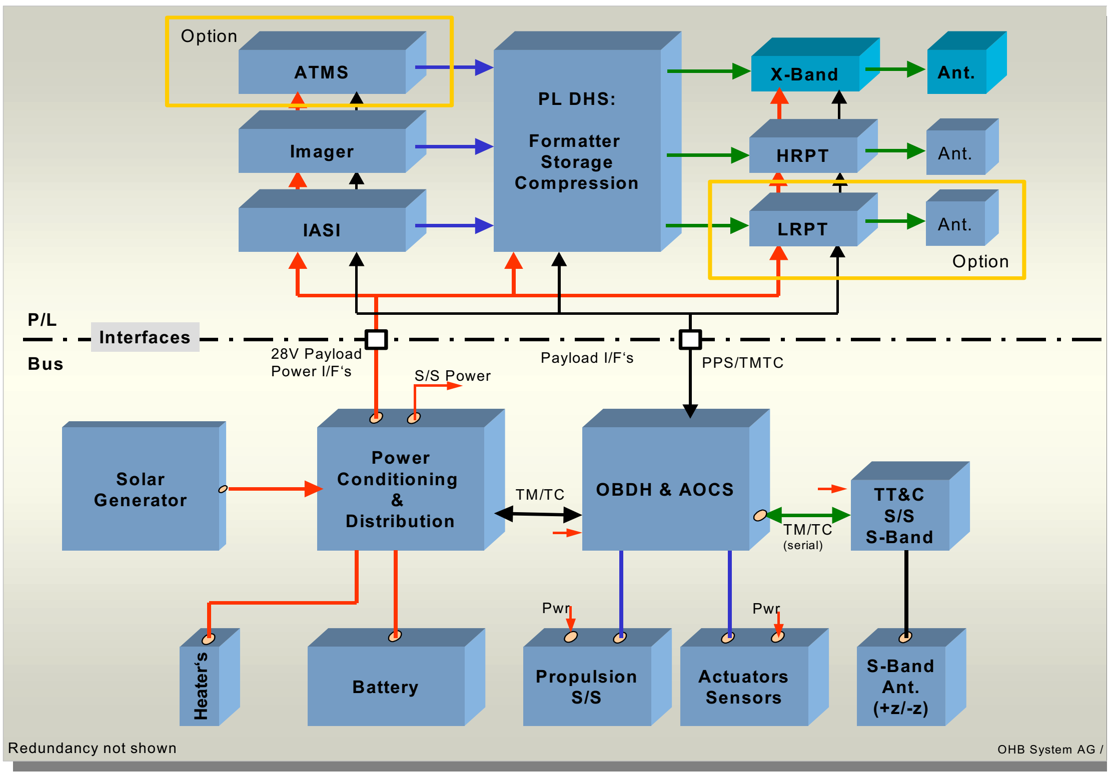

Figure 8: Block diagram of the EPS-Bridge Satellite

The options EPS-1 and –2 are already at the mass limit of the considered small launcher candidates (see Table 4) . For option EPS-2-MW a medium class launcher is required and VEGA is selected as baseline.

Launcher	Payload Mass*	First launch	Status
COSMOS Cosmos International (Europe)	700 kg	1966	740 Launches 97% reliability available on stock
TAURUS XL Orbital (US)	780 kg	1994	7 launches 1 failure
ROCKOT Eurockot (Europe)	900 kg	1990	9 launches 1 failure Availability in 2019 unclear
PSLV Antrix (India)	1200 kg	1993	8 launches 1 failure
VEGA Arianespace (Europe)	1300 kg	2008	Under development

Table 4: Launcher Candidates (*EPS Bridge Orbit)

The satellite configuration is shown in Figure 10 (for option EPS-2-MW) in deployed and in launch configuration. The deployable solar generator can be rotated about the pitch (Y) axis to minimize the required solar array area. For power storage Li-Ion batteries were selected.

For less power demanding options a deployable solar panel without rotation mechanism is considered as shown in Figure 9 (for option EPS-2). This option without microwave sounder allows a more compact satellite structure fitting in terms of volume in all considered launcher candidates.

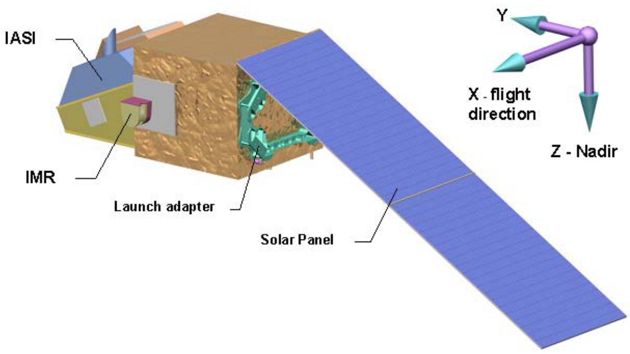

Figure 9: EPS-Bridge Satellite Option EPS-2

The AOCS subsystem is based on Star Trackers and Reaction wheels as main sensors and actuators for attitude control as well as GPS and a Hydrazine propulsion system for orbit control. Its performance is well inside the requirements, which are assumed as follows:

- ±0,17° attitude control in Roll (X) and Pitch (Y) as well as ±0,22° in the Yaw (Z) axis,
- ±0,1° attitude knowledge in Roll and Pitch as well as ±0,15° in the Yaw axis,
- ±50 m position knowledge.

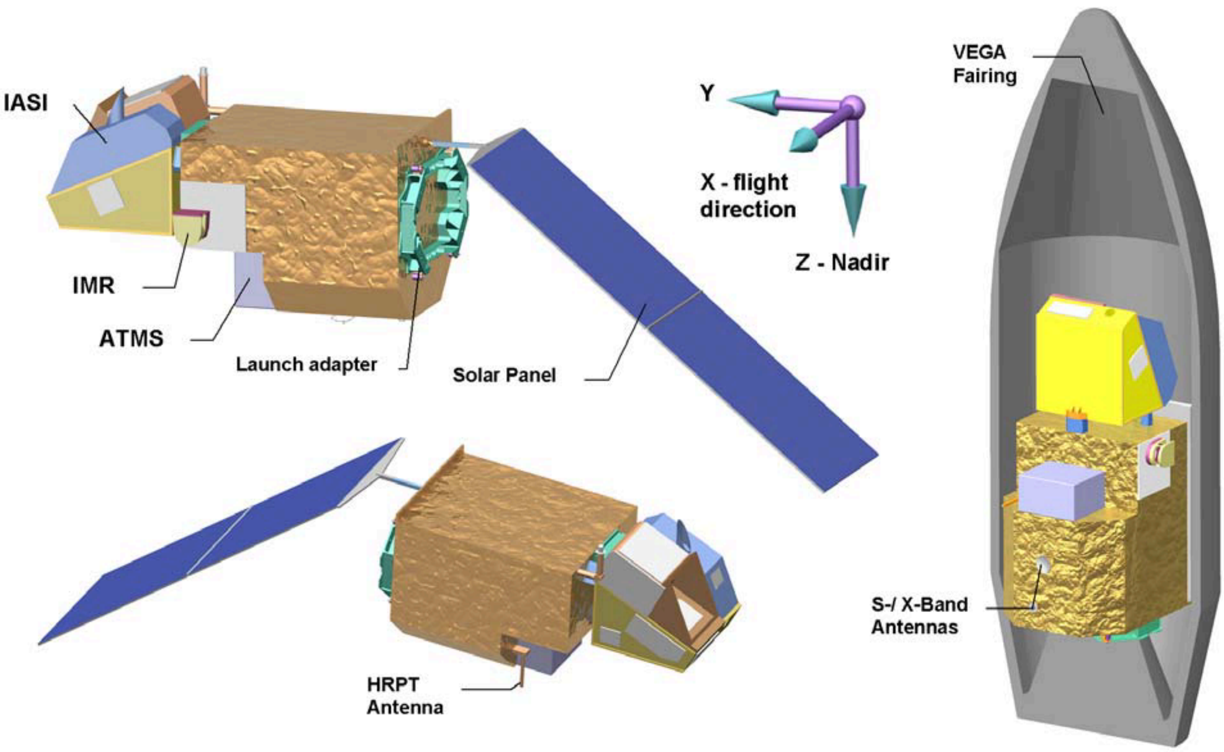

Figure 10: EPS-Bridge Satellite Configuration (Option EPS-2-MW)

5. GROUND SEGMENT COMPATIBILITY

The possibilities for re-use of the current EPS ground segment in the scope of an EPS bridging satellite programme were investigated by VCS AG, Bochum. The study identified potential compatibility issues and commented with respect to their resolution. Here, the study focused on two scenarios:

- GS1: examining the impact of a satellite carrying the IASI and an AVHRR compatible imager only.
- GS2: examining the additional impact when the imager provides enhanced features compared with AVHRR

From a technical point of view it was found that most of the Core Ground Segment CGS subsystems are affected even with option GS1. However, for each of the subsystems the required adaptation work was regarded limited and manageable as long as the space segment design aims at maximum re-use of the ground systems.

For option GS2 it was suggested to split the imager data into an AVHRR compliant part and additional data such that the original processing can be maintained. The additional data would then be used by new processors only.

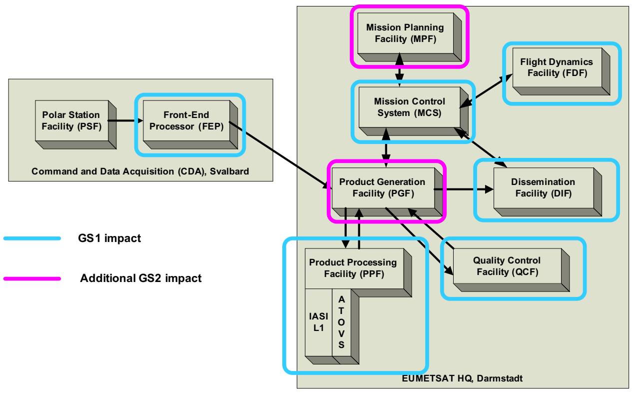

Figure 11: EPS-Bridge Ground Segment Compatibility

6. CONCLUSIONS

In conclusion a small satellite concept for an EPS-Bridge mission based on the existing OHB SAR-Sat platform is assessed as feasible leading to a satellite mass in the 700 – 900 kg range, which allows the use of small to medium launchers in the VEGA class or below. Such a small satellite concept is advantageous in terms of schedule, risks and costs compared to a big programme like METOP.

With respect to the Post-EPS system a constellation of small satellites, each carrying single key instruments with its supporting instrument complements as required promise similar advantages with respect to schedule, risks and costs and allows in addition a more flexible programme in particular regarding the operational implementation of new instruments.

7. REFERENCES

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