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INNOVATIVE MISSION CONCEPTS FOR EARTH OBSERVATION APPLICATIONS

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Abstract

In the field of Earth Observation (EO), present day users and stakeholders impose stringent demands on spaceborne imaging systems. At a high pace, very high resolution multispectral imaging, very high resolution SAR imaging and very short system response times are becoming main stream objectives.

In this paper, new concepts are presented for addressing German and European EO user needs, ranging from scientific and research objectives to operational demands. In addition to very high resolution multi-spectral and SAR missions, high resolution (optical and SAR) and hyperspectral mission concepts are illustrated. These concepts include the following projects:

- **Very High Resolution SAR and Optical** M**issions** – Offering optical images with a spatial resolution below 1 m, very high resolution optical missions are proposed for reconnaissance and dual-use applications of governmental customer and for emergency response.
- **High Resolution SAR and Optical Constellations** – 1 m resolution constellations are currently being investigated for emergency response and disaster management services (e.g. GMES). The main user requirement for these applications is a short system response time. By combining these new constellations with existing systems, overall performance will be significantly improved.
- **EnMAP** – Featuring innovative hyperspectral sensor systems, EnMAP will be used for detailed and global analysis of ecosystem parameters. Offering more than 200 spectral channels from VNIR to SWIR, the sensor array provides images with a spatial resolution of 30 m.
- **Ocean Colour** – Ocean Colour is a GEO platform, which shall be used as a sustainable source for intra-daily data for coastal zone services, such as environment monitoring, fisheries management and coastal water pollution.
- **Ground Segment** – The Ground Segment contains all necessary functions to monitor and control the satellite, to plan and execute image orders, to receive the optical data and to generate the image products.
- **Data Relay** – Fast delivery of large data volumes is of importance for very high resolution systems. For this matter, GEO data relay satellites are currently investigated as a possible solution for the growing demand of data traffic from EO satellites to ground stations.
- **Airborne Earth Observation** – OHB is developing an operational service for airborne hyperspectral imaging, including mission planning, data acquisition, data processing and value adding and data provision. The aircraft platform of OHB-System is called CONDOR.

This paper gives a review over these projects and describes their main features.

1 INTRODUCTION

Earth Observation (EO) has become indispensable for monitoring of geo-physical processes, resources, environment and security applications. To fulfil dedicated user needs in the future, sustainable services will require more and more high-quality geo-information data at improved spectral resolutions (multispectral or hyperspectral) and/or spatial resolutions down to less than 1 m. Beside military reconnaissance, typical civil applications and users of this kind of very high resolution (VHR) data are for instance urban mapping and emergency response (natural disasters monitoring & humanitarian aid).

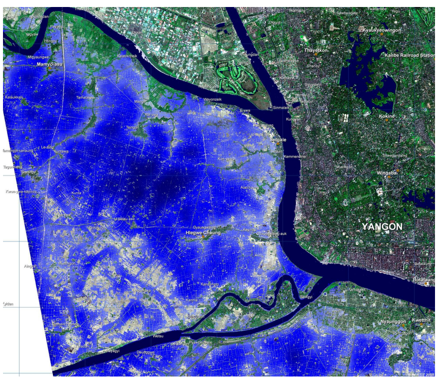

Figure 1: cyclone in Myanmar, 5/7/2008, water depth estimates, RADARSAT 2, SAR, ultra fine mode (> 3 m), [1]

Efficient environmental monitoring from space is therefore a fundamental necessity to provide reliable services on a global scale. Also the European initiative on Global Monitoring for Environment and Security (GMES) [2] requires long-term contributions from independent co-operating missions providing frequent multispectral and VHR data.

The main bottle-neck for fast delivery of data and increased data volumes is the downlink from sensor data down to the ground station. Here existing technologies can be used for smart data relay system in geostationary orbit (GEO). The GEO provides also the best location for high frequent or intra daily observations of environmental changes, like chlorophyll, plankton, algal blooms and sediments in coastal zones.

2 OHB-SYSTEM HERITAGE

OHB-System and its partners have successfully developed and launched the SAR-Lupe satellite constellation. Another source of experience is the Small GEO satellite project and the operational airborne EO platform CONDOR. Derived from this heritage OHB-System develops the future EO missions described in this paper. The following section presents the heritage.

2.1 SAR-Lupe

SAR-Lupe (Figure 2) is a German satellite system with the primary objective to generate SAR images with high resolution for military reconnaissance purposes.

The first of the five satellites has been orbiting the earth since December 2006 and three further followed. All four satellites have already repeatedly proven their full functionality. One remaining launch is scheduled for July 2008 in order to complete the satellite constellation.

SAR-Lupe satellites are in the 800 kg class and provide an integrated BUS / SAR system with a highly innovative SAR-sensor concept. The ground resolution is less than 1 m with a swath width of 5,5 - 8 km.

The SAR-Lupe satellite concept is characterised by the following features:

- Large conventional parabolic SAR antenna, which is rigidly mounted to the satellite structure to achieve a simple mechanical design.
- SAR antenna dual used for imaging and data transmission
- Attitude Control System, which performs high accuracy pointing manoeuvres of the entire satellite during image acquisition and P/L data downlink.
- integrated and modular design for satellite bus and SAR payload sensor
- few and simple mechanisms yield reliability and cost efficiency
- command data relaying through Inter-Satellite Link yields reduced system response time

Figure 2: SAR-Lupe

Based on this heritage the next generation platform for VHR and HR civil applications will be able to accommodate high performance EO payloads of both categories, optical as well as microwave (synthetic aperture radar - SAR). Furthermore the ground segment was derived from this project.

2.2 SGEO

The goal of the Small Geostationary Satellite initiative (SGEO) [3] is the establishment of a general purpose, small geostationary satellite product, which will be competitive in the commercial telecom market for small platforms and which may also be used for institutional applications. In spite of the trend towards larger satellites, the market niche of small GEO satellites is expected to increase.

The ESA ARTES-11 programme SGEO is composed of two subelements: first the development and manufacturing of the generic platform and second the development, manufacturing and launch of the leadoff satellite mission. Phase B of the platform development was kicked off in 2007. The first in-flight demonstration mission and payload is currently being selected planning for a launch end 2011.

OHB-System AG, together with its partners developed the present platform concept and the SGEO satellite product. The baseline offers a small satellite platform for a 300 kg and 3 kW payload to be launched into geostationary orbit.

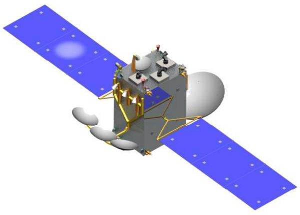

Figure 3: SGEO satellite

Derivates from the SGEO project are the Data Relay satellite and the GEO Ocean Colour satellite.

2.3 CONDOR

The operational airborne EO system CONDOR consists of the aircraft (Figure 4) and mobile base stations, that allow a flexible mission or campaign setup including the possibility for near real time data transmission and exploitation. The in-situ and airborne EO is a complement to the spaceborn EO systems.

Figure 4: CONDOR aircraft

3 APPLICATIONS AND REQUIREMENTS

Earth Observation are of interest for operational services like GMES (Global Monitoring for Environment and Security), military and commercial services. More and more countries are entering the field of earth observation, so in near future 22 countries will have their own sensors in space. Already 10 of them are involved in VHR earth observation.

Earth Observation has uses in a number of different areas and various applications such as:

Civil security and emergency response:

- natural disasters monitoring: Constellation's observation capabilities in the optical and radar bands, combined with the short revisiting intervals will pay an important part for disaster monitoring and damage assessment such as earthquakes, floods and fires as well as man-caused disasters.
- security like humanitarian aid (estimate intact routes, coordinate humanitarian aid measures)
- traffic monitoring and identification: For safe shipping or the implementation of rules and regulations for environmentally friendly maritime transport a reliable monitoring, which can be achieved by satellite based systems, is necessary.

Environmental monitoring:

- environmental monitoring: Images took by VHR systems will contribute to the determination of polluter. Environment health status and changes due to climate change and/or human interactions
- mapping: mapping of urban areas for monitoring the evolution of cities and for urban planning, making new maps and updating older ones
- global information systems (e.g. GEOSS)
- hyperspectral: precise discrimination of different types of soils, vegetation, water

Military:

- object detection, recognition, identification (STANAG 3769, Table 1)
- theatre overview and
- instructions on targets

Object	Detection	Recognition	Identification	Technical Analysis
Terrain Features	800 m	90 m	3 m	0.75 m
Urban Areas	60 m	15 m	3 m	0.75 m
Roads	6 m	4.5 m	1.5 m	0.38 m
Railroad	15 m	4.5 m	1.5 m	0.38 m
Bridges	6 m	4.5 m	1.5 m	0.3 m
Airfield Facilities	6 m	4.5 m	3 m	0.15 m

Table 1: Examples of the STANAG 3769 target types

Derived from the requirements for the different applications, three types of systems for EO can be distinguished:

- very high resolution (<< 1 m) for military applications and emergency response
- high resolution (1 m) for civil security and emergency response
- hyperspectral and fast response for environmental monitoring

The main reason for the higher geometrical resolution is based on military requirements, but it is also useful for civilian application. A VHR system should fulfil the following requirements:

- large instrument Field of View (FoV)
- very short system response times on a global scale (<< 24 h)
- high geo-localization accuracy (<< 100 m)
- high ground resolution (<< 1 m)
- cost effectiveness
- scalability on system level (satellite constellations)
- interoperability for information exchange for partner nations

4 EARTH OBSERVATION MISSION CONCEPTS

For this three fields of earth observation applications OHB-System AG has developed different system concepts, which are depicted in Figure 5. SAR and optical satellites are developed for both, high and very high resolution applications. For environmental monitoring the EnMAP satellite and the GEO Ocean Colour project are most suitable. Furthermore the proposal of EO applications is completed by additional system components like a ground segment, a data relay satellite and a platform for airborne EO.

The four domains of this system concepts, showed in Figure 5 can interact to create a complete EO system with the following components:

- EO instrument: satellite constellation and/or UAV (VHR, HR or hyperspectral)
- data relay satellites
- ground station: fixed and/or mobile

In the following the OHB mission concepts are presented.

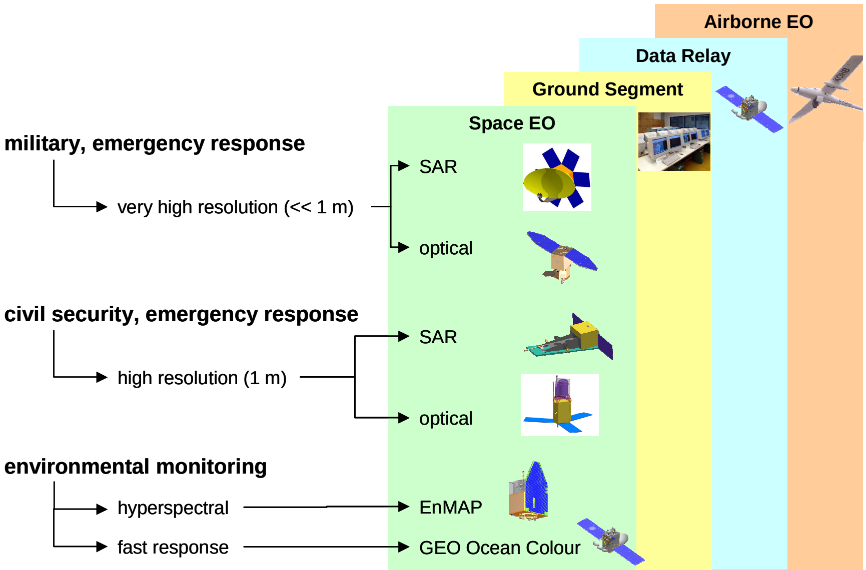

Figure 5: Earth Observation – OHB System Concepts

4.1 Very High Resolution for Military Applications and Emergency Response

Timely availability of VHR imagery of ≤ 1 m is a fundamental driver for risk management applications like a crisis or a natural catastrophe. Satellite missions are excellent means for providing such imagery due to their capability of providing access to any point on the Earth in a short timeframe.

An industrial consortium under the leadership of OHB-System AG is investigating the possibilities for dedicated VHR satellite missions for risk management under contract of ESA.

Two mission concepts are being developed: A SAR mission as a reliable source for weather-independent day and night observations, and an optical mission providing panchromatic and spectral information in easy-interpretable images.

4.1.1 VHR-SAR

The SAR satellite will have a ground solution of less than 1 m and weigh 1200 kg. The OHB-System satellite solution for a future SAR mission is shown in Figure 6.

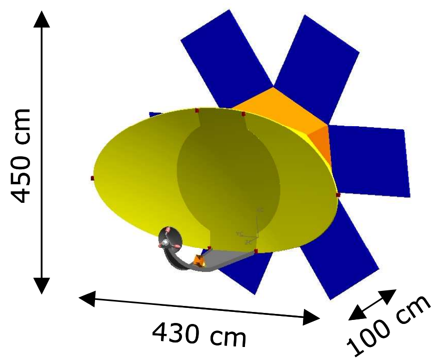

Figure 6: VHR-SAR satellite

4.1.2 VHR-Optical

The next generation VHR-optical satellite will have the following features:

- mass: 770 kg
- ground resolution: << 1 m

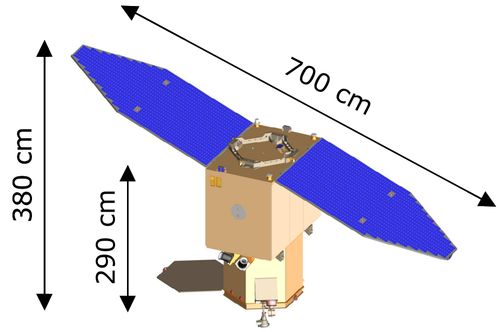

Figure 7: VHR-optical satellite

Both Satellite concepts are prepared for multi-user capability and for transportable remote ground station.

4.1.3 VHR System

As a prospect a potential VHR system could consist of following elements:

- ground segment (for mission control, image reception and image exploitation), consisting of
  - one fixed ground station and
  - one transportable remote ground station,
  - space segment, consisting of two satellites.

It could have the following features:

VHR next generation system	
system capacity	90 spot images/day (1 shift, 40% clouds)
survivability	resident against space environment, secured against hijacking, and electromagnetic counter measures (ECM)
security	secured and encrypted data links: satellite / ground; ground / ground

Table 2: VHR system features

This mission concept is a national design study and for allied nations, too. There exist CD proposals.

4.2 High Resolution for Civil Security and Emergency Response

A SAR and an optical satellite are developed for high resolution (about 1 m) missions. The missions are defined taking into account the performance of existing and planned missions with related objectives e.g. Cosmo-Skymed and Pleiades. To benefit from synergetic effects both concepts should be complement to these missions.

4.2.1 HR-SAR

The SAR mission is designed to provide a fast response VHR imaging capability with a performance allowing object detection and rough land cover classification. The mass of the satellite will be 1000 kg.

The system offers the following main features to provide a fast and flexible observation capability:

- left and right looking payload
- wide incidence angle interval
- electronic beam steering
- ground station contact in every orbit
- orbit design to complement other SAR missions

The image characteristics are:

- VHR: GSD 1 m swath 10 km
- HR: GSD 2,5 m swath 25 km
- WS: GSD 15 m swath 100 km
- incidence angles (extended): 20° - 60°

Mission characteristics:

- 3 satellite constellation
- LTAN 00:00 a.m.
- altitude 659 km, SSO
- image duty cycle >3% (HR and WS mode)

timeliness:

- global revisit (stand-alone) < 14.2 h
- global revisit (with Cosmo-Skymed) < 7.5 h
- image ageing to level 1b product < 3 h
- system response time (stand-alone) < 20 h

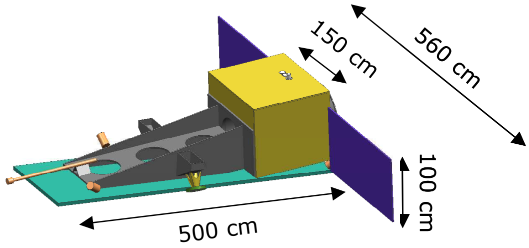

Figure 8: HR-SAR satellite

4.2.2 HR-optical

The HR optical mission is focused on improving fast system response time as a dedicated mission or in combination with the Pleiades mission. This mission is understood as add-on to basic Sentinel-2 scenarios. The satellite is in the 700 kg class.

His image characteristics are:

- GSD 1 m PAN, 500 - 680 nm
  4 m MS, 450 - 900 nm
- swath width 12 km

Mission characteristics:

- 2 satellite constellation, phasing 180°
- LTDN 10:30 a.m.
- altitude 614 km, SSO
- off-nadir pointing: ±30 (goal ±45 deg)
- image mosaics: 3 x 12 km swath (goal 4 x 50 km)

The two HR missions for civil security and emergency response are in their definition phase and aim at implementation in 2012 - 2013 with an overall lifetime of 15 years.

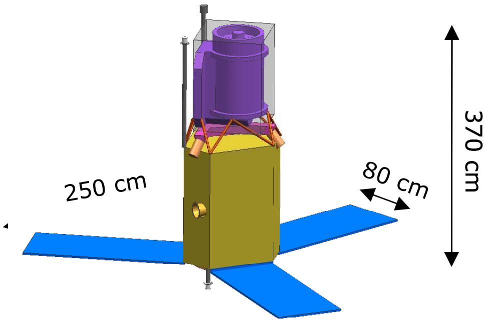

Figure 9: HR-optical satellite

4.3 Hyperspectral and Fast Response for Environmental Monitoring

For environmental monitoring a very high ground resolution isn't necessary. Advantageous is a high number of spectral bands and a short response time to assure timeliness. The OHB mission concept EnMAP, which is characterized first in the following, provides more than 200 spectral bands. Afterwards the GEO Ocean Colour satellite and its features are described.

4.3.1 EnMAP

The Environmental Mapping and Analysis Program (EnMAP) is a joint German initiative founded by the DLR and lead by the GeoForschungsZentrum Potsdam, under the industrial prime ship of Kayser-Threde. The EnMAP satellite platform is derived from the heritage of

the SAR-Lupe mission and therefore under OHB-System responsibility. Its main application is the analysis of the evolution of terrestrial ecosystems.

With its payload, the Hyper Spectral Imager (HSI), covering the visible, near- and short-wave infrared wavelengths, EnMAP will provide high quality Earth observation data on a contemporary and frequent basis. EnMAP gains information based on about 250 spectral bands in the wavelength range from 420 nm to 2450 nm and with a spectral resolution of 5 - 10 nm. The ground sampling distance is 30 m x 30 m with a swath width of 30 km. The imaging capacity of EnMAP will be at least 5000 km per day.

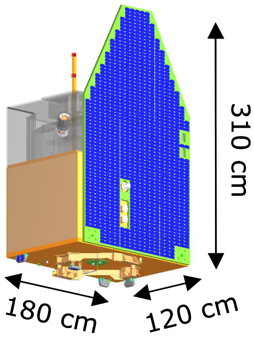

Figure 10: EnMAP satellite

The EnMAP satellite (Figure 10) weighs 840 kg (inclusive 46 kg propellant) and is compliant to all standard LEO launchers.

The project is now in phase C/D. Its launch is planned for 2011 comprising a mission duration of at least 5 years. The EnMAP satellite will be operated by the German Space Operations Centre (GSOC) with secured TM/TC via S-Band.

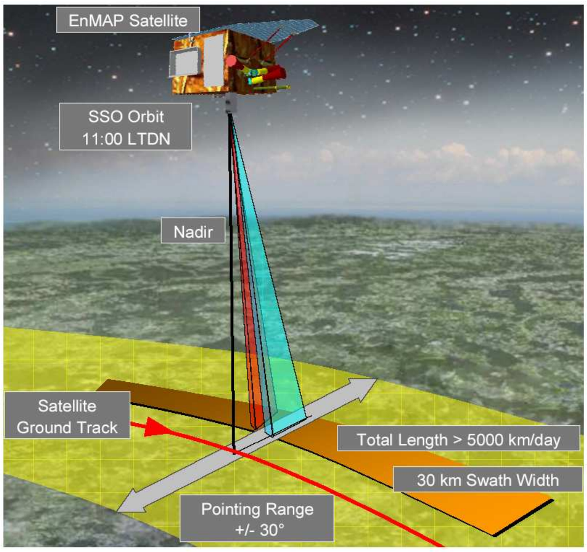

Figure 11: EnMAP satellite mission

4.3.2 Ocean Colour

The objective of this mission is to provide a sustainable source of ocean colour images in coastal and in-land waters for (but not limited to) GMES marine and coastal environmental services and applications. Based on the user needs the main applications include (Figure 12):

- detection, prediction and monitoring of long term but especially short term biophysical phenomena
- biogeochemical cycle analysis and associated parameters
- detection, prediction and monitoring of noxious or toxic algal blooms
- marine ecosystem health monitoring
- geological and biological response to identified physical dynamics
- coastal zone and resource management
- enhanced marine fisheries data

Designed as a complement and extension to the Sentinel 3 mission this mission aims at a resolution of better than 300 m and a frame time of ~1 hour. This will provide multiple inter and intra-day observations over Europe of fast evolving biological or dynamical phenomena such as phytoplankton blooms (particularly the coastal toxic blooms known as “red tides”), the biological response to atmospheric events (wind forcing, storms, episodic dust events etc.), the response of coastal ecosystems to short-term effects (e.g. tidal currents), sediment transport in coastal turbid areas as well as the diurnal cycles of other biological phenomena.

The Ocean Colour satellite, which weighs 1800 kg, has the following image characteristics:

- GSD 300 m
- bands 14 (413-900 nm)
- spectral resolution 20 nm
- swath width : 600 km x 600 km
- scan width: 3700 km x 2900 km
- SNR 1000 as a goal
- digitisation 12 bit

The payload is well suited for the Small GEO/Luxor platform. The mission characteristics are:

- 1 GEO 7°East
- Revisit 60 min. (30 min goal)
- Launch date 2012 planned
- Life Time 10 years design
- Mass 1918 kg
- Power 1 kW
- Downlink 50 Mbit/s Ka-Band

The project Ocean Colour from GEO is a design study.

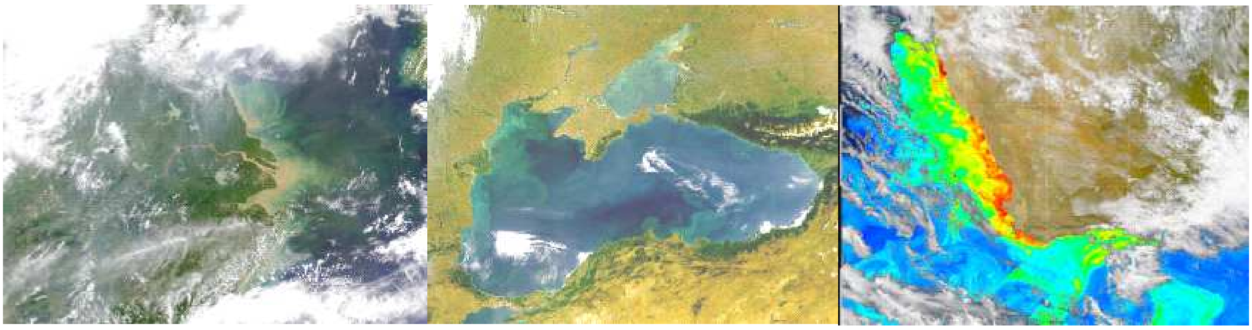

Figure 12: Yangtze river flood, Black Sea, and South-African coast chlorophyll (images provided by the SeaWiFS project, NASA/GSFC and ORBIMAGE)

4.4 Ground Segment

The ground segment contains all necessary functions to monitor and control the satellite, to plan and execute image orders, to receive the optical and SAR data and to generate the image products.

Most processes are executed automatically by the ground segment using high performance computers. It can be monitored and controlled by the ground operations team with adequate user interfaces. This supports a reliable and convenient satellite control and image generation, and additionally ensures the economical operation of the satellite system with a small team.

The ground segment is organized in a modular way providing an optimized "cost to benefit relation" and clear options for customization and upgrades.

The ground segment comprises two elements. Optionally a transportable remote ground segment, which is a reduced subset of the main ground segment, having the same functionalities at reduced capacity can be offered. The ground segment elements are organized in two main parts:

- satellite control: This is the core of the ground segment. It combines all necessary subsystems to monitor, control, and command the satellite. It provides all subsystems for automatic mission management, data reception and level 3 image product generation.
- information management: It contains the order management subsystem with the functions customer interface, image order creation, management and status monitoring and interfaces to the automatic mission planning processes running in the satellite control. In addition, it contains the customizable functions comprising the image exploitation and archiving.

The ground segment hardware and software is based on the proven experience of the SAR-Lupe ground segment and the further OHB developments for E-SGA (Europeanization of the SAR-Lupe system) which deals with optical image data in exchange to SAR data, the corresponding image data processing and the bi-directional image order management.

Further features of the ground segment are listed in Table 3. The development of the ground segment is in phase C/D at the moment. There is a high allied nations interest.

ground segment	
processing time	< 2 h from level 0 to level 3 for one spot image
archive size	700 TBytes for 65.000 spot images for 7 years operation
interoperability	prepared for multi-user capability and for transportable remote ground station
scalability	scalability of the archive: up to 1300 TBytes

Table 3: ground segment features

Figure 13: SAR-Lupe ground station

4.5 Data Relay from GEO (GEO-DRS)

The primary objective of the mission is to enable an increase of LEO observation time and reduce image ageing of LEO Earth observation data. A secondary objective is seen in the decrease of the system response time. As emergency response is one of the applications for the Sentinel missions a quick commanding capability of these spacecrafts enabled via the GEO-DRS could be beneficial in the future. ESA has high interest at this design study.

A single GEO-DRS satellite, which weighs 2500 –3000 kg, will be able to provide the service over half the globe with a focus on Europe and Africa. The GEO-DRS satellite will comprise a bent-pipe payload with laser inter-satellite-links for data upload from LEO satellites to GEO-DRS and standard Ka/Ku-band downlinks from GEO-DRS to the ground station(s). The total data rate required for the next generation of GMES Sentinels is about 1 Gbps with peaks up to 1.4 Gbps. Figure 14 shows the interaction of the GEO-DRS with other EO system components.

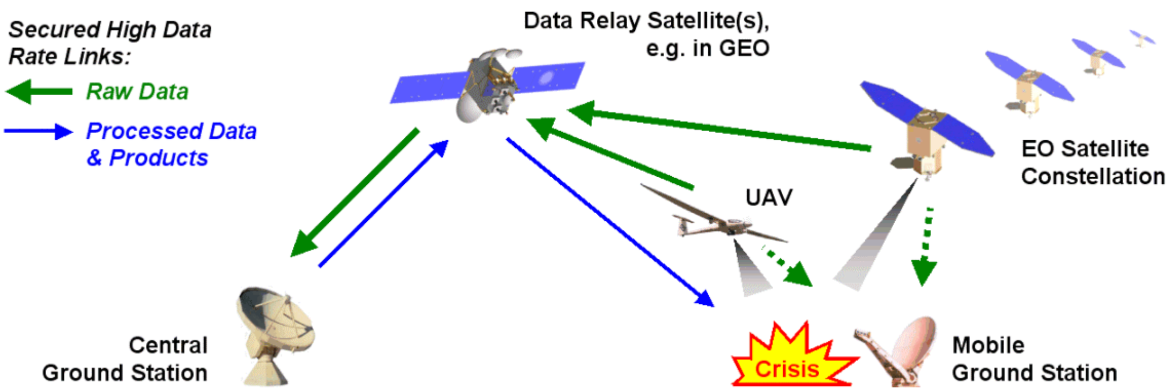

Figure 14: GEO Data Relay System for Emergency Response Services

4.6 Airbone Earth Observation

OHB will develop an operational service for airborne hyperspectral imaging, including mission planning, data acquisition, data processing and value adding and data provision. The aircraft platform of OHB-System is called CONDOR (Figure 15).

Figure 15: CONDOR aircraft with attached wing pod

CONDOR can be used with different sensor types. An Example for an application of CONDOR is the project CoastEye. In the attached wing pod of the aircraft is an hyperspectral payload integrated (Figure 16).

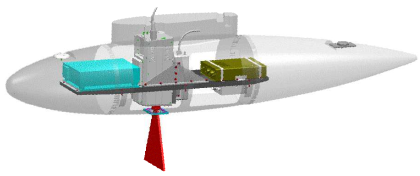

Figure 16: Wing pod with integrated hyperspectral payload

The image characteristics are:

- VHR: flight altitude 600 m, GSD 0,4 m, swath 300 m
- HR: flight altitude 1600 m, GSD 1,0 m, swath 1000 m
- WS : flight altitude 3000 m, GSD 2,0 m, swath 2000 km
- radiometric resolution 14 Bit
- spectral resolution 2,4 nm
- different standard product levels and value added information available

mission characteristics:

- VHR: ~100 km² per day possible
- Highly flexible mission planning (changeable during flight)

Figure 17: three band (visual rgb) composite of image data, radiometrically and geometrically corrected (location Bremerhaven, October 2007)

The very high spatial and spectral information characteristics result in the need for specialised processing techniques. These are set up by state-of-the-art methods, that can be customized for various use scenarios:

- coastal ecozones (highly sensitive areas at the German coast like saltmarshes, tidal flats or dunes. compensatory measurements for at-shore construction activities)
- ports (monitoring of sedimentation processes in port basins)
- urban environments (Bremen and Bremerhaven used as urban demonstration sites with very high spatial and spectral detail)
- rivers / estuaries
- monitoring of shoreline and salt-, brack- and freshwater
- reconnaissance and surveillance (including emergency response)

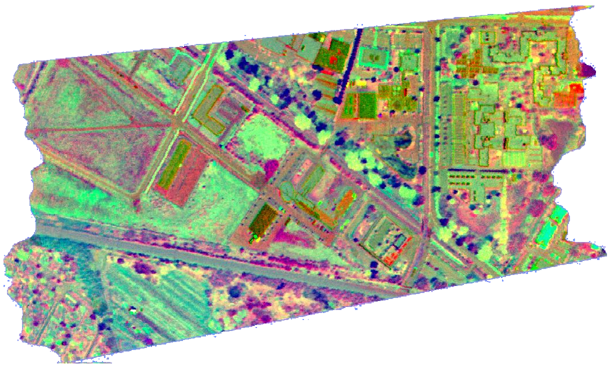

Figure 18: exemplary image product, derived from hyperspectral information (OHB Headquarters Bremen)

The results of the CoastEye activities are planned to be transferred to satellite based hyperspectral imagery when EnMAP is available. The project CONDOR is now in phase C/D.

5 CONCLUSIONS

Based on the experience with SAR-Lupe, SGEO and CONDOR OHB-System is working on the design of near future Earth observation systems. Derived from the user demands the number of EO applications can be distinguished in three areas:

- civil security and emergency response, which require high resolution imagery (about 1 m)
- environmental monitoring, which needs fast response and hyperspectral imaging
- military and emergency response, which require very high resolution imagery under 1 m

For all three fields of Earth observation applications OHB-System provides very cost effective solutions. With its current development of the very high and high resolution satellites with SAR or optical payload, OHB fits the requirements of the military and civil user groups. The derivates from the Small GEO platform, the data relay satellite and the Ocean Colour satellite, solve the bottle-neck of high EO data volumes and faster system response time for EO satellites. The mission concept of the EnMAP satellite, which provides 250 spectral bands for hyperspectral measurement, is a further highlight in the product portfolio. The offer is completed by a ground system and the airborne EO platform CONDOR.

Due to security aspects, the very high ground resolution together with a fast system response time will play a dominant role in the near future. Such systems can be implemented on national level but also a co-use with the Global Monitoring for Environment and Security (GMES) initiative could be an approach for the benefit of Europe.

6 REFERENCES

[1] http://unosat.web.cern.ch
[2] GMES Office Bremen Brochure: Global Monitoring for Environment and Security Solutions “Made in Bremen”
[3] Website of ESA Telecommunications, Small GEO programme: http://telecom.esa.int
[4] website of the OHB-System AG Germany: www.ohb-system.de