Innovative System Concepts for Earth Observation Missions at OHB-System

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Abstract

In order to maintain its leading position in the field of small satellites for high performance Earth observation missions, OHB-System is continuously looking to apply its experience to future Earth Observation missions. In this paper, an overview of new concepts in the area of Earth Observation systems for Germany and Europe will be given, ranging from science and research to operational missions. Both the mission concepts and the key features of the payloads, platforms and overall systems will be presented. A common trait of the variety of missions is the high performance, which can be achieved and leads to a faster development and lower overall cost. Featuring optical, SAR and communication missions, this paper will highlight the following projects:

- **SAR-Lupe –** Capable of generating very high resolution SAR images of <1m for military reconnaissance purposes with fast response time, the SAR-Lupe constellation was recently deployed and has been accepted by the customer. It makes use of intersatellite-links and has a nominal operational lifetime of 10 years.
- **EnMap** – EnMap features innovative hyperspectral sensor systems for detailed and global analysis of eco-system parameters. Its sensor provides data in more than 200 spectral channels from VNIR to SWIR with a spatial resolution of 30m.
- **VHR optical** – Very high resolution missions using an optical payload with <1m resolution are proposed for reconnaissance and dual-use activities of governmental customers. Several next-generation system elements will be presented.
- **HR SAR / optical constellations –** For emergency response services, high-resolution SAR or optical constellations of 1m resolution are currently investigated. For these systems, a short system response-time is the main driver. In combination with existing and planned systems, the proposed constellations will offer unprecedented fast response times.
- **Ocean Colour –** Operating in GEO, Ocean Colour will be a sustainable source for intra-daily data relevant for coastal zone services for environment monitoring, fisheries management and coastal water pollution. The system will provide 14 spectral channels in VNIR with 300m spatial resolution, with which it will act as a complement to the GMES Sentinel-3 mission.
- **Space-based Automatic Identification System (AIS) –** Relating to Earth Observation and navigation, a space-based system of small satellites is designed for receiving AIS data from ships. Although a terrestrial AIS system is already in existence for monitoring coastal areas, the development of a space-based AIS system will enable maritime surveillance on a global scale.
- **Data Relay Satellite** – Critical parameters of a very high resolution system are fast commanding and transmission of large data volumes. In order to realize these parameters, a GEO data relay satellite is 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.

3. Application and Requirements

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).

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) 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.

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 areas and various applications such as:

Civil security and emergency response:

- Maps 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.

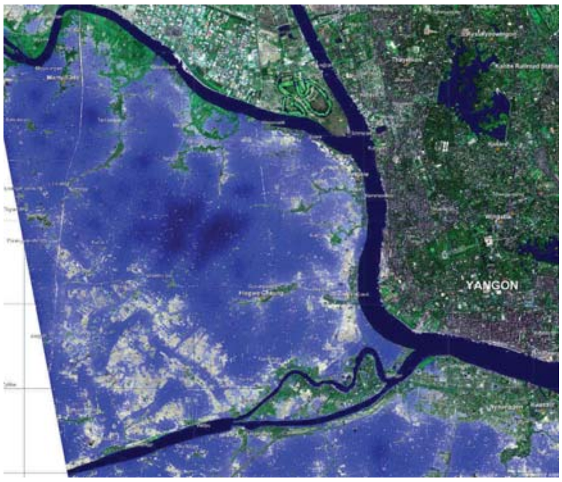

Figure 1: Cyclone in Myanmar, 5/7/2008, water depth estimates, sensor: RADARSAT 2, SAR, ultra fine mode (> 3 m), source: http://unosat.web.cern.ch

Crisis Type	Detailed Level		Overview Level	
	Desired	Max	Desired	Max
Floods	1 m	5 m	3 m	20 m
Landslide	<1 m	5 m	1 m	2,5 m
Hurricanes and Storms	<1 m	5 m	3 m	20 m
Forest Fires	1 m	10 m	5 m	50 m
Earthquakes	<1 m	5 m	-	-
Volcanoes	<1 m	3 m	2 m	1000 m
Tsunamis	<1 m	5 m	3 m	20 m
Oil Spills	1 m	2,5 m	10 m	50 m
Refugee Camp Mapping	1 m	2,5 m	-	-
Population Gatherings	<1 m	1 m	-	-
Population Movements	<1 m	1 m	-	-
Asset damage	<1 m	2,5 m	-	-

Figure 2: Spatial Resolution Requirements for Damage Assessment Maps [from GMES Fast Track – Emergency Response Core Service]

- 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:

- VHR images 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

Security and military:

- object detection, recognition, identification (STANAG 3769, TAB 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

Tab 3: 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 (<< 24 h)
- high geo-localization accuracy (<< 100 m)
- high ground resolution (<< 1 m)
- cost effectiveness
- scalability for satellite constellations
- interoperability for information exchange with partner nations

4. SAR-Lupe

SAR-Lupe (Figure 4) is a German satellite system with the primary objective to generate SAR images with high resolution for military reconnaissance purposes. The five satellites have been launched between December 2006 and July 2008, are operational and have been handed over to the customer.

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 4: SAR-Lupe Satellite

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).

5. 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 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.

The EnMAP satellite (Figure 5) 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.

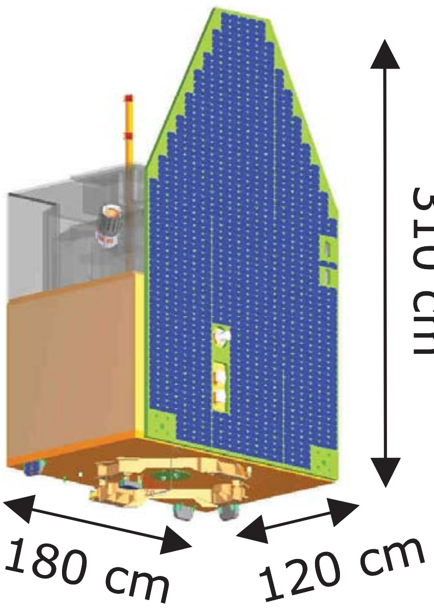

Figure 5: EnMAP Satellite

6. 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.

6.1 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 image characteristics are:

- VHR: GSD 1 m swath 10km
- HR: GSD 2,5 m swath 25km
- WS: GSD 15 m swath 100km
- incidence angles (extended): 20°-55°

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

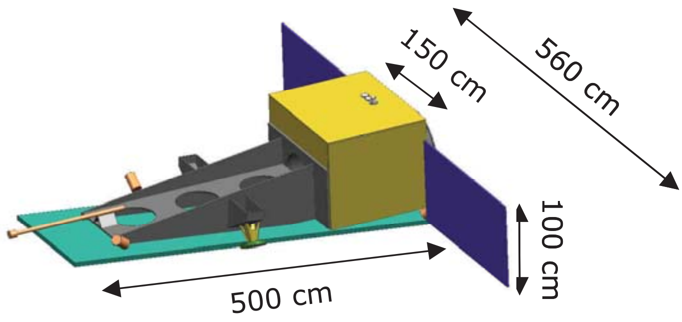

Figure 6: HR-SAR Satellite

6.2 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.

The image characteristics are:

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

Mission characteristics:

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

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.

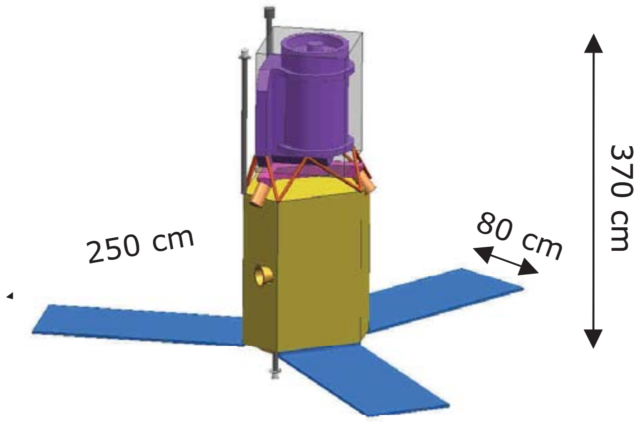

Figure 7: HR Optical Satellite

7. Very High Resolution for Military and Security Applications

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 time frame. 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. The next generation VHR SAR and optical satellites will have a ground solution of less than 1 m.

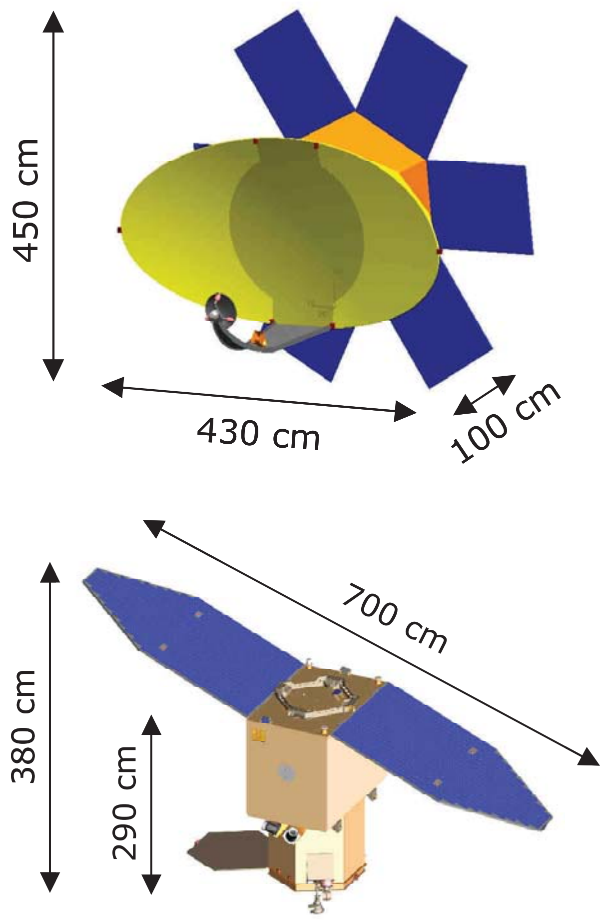

Figure 8: VHR-SAR & Optical Satellite

8. Space-Based Automatic-Identification-System Constellation

An important system in the field of global maritime surveillance is the Automatic Identification System (AIS), which is responsible for transmitting logistical and navigational data of surface vessels. Many entities use land-based AIS for monitoring and guidance of maritime traffic, which requires ships to be equipped with an AIS transmitter that sends logistical and navigational data about this vessel in the VHF frequency range.

In order to be able to perceive the maritime traffic situation beyond the land-based AIS range, introduction of a space-based AIS system is proposed. Performance of a space-based AIS system is measured in terms of probability of detection of a ship's AIS message in case the satellite receives a multitude of AIS messages. As these messages can overlap and interfere with each other, which will not happen at land-based receivers, the challenge is to filter out and decode single AIS messages. Besides these measures taken to manage and mitigate AIS message collisions, other issues have to be addressed during the development of a European space-based AIS system:

- Implementation of an operational and affordable system, consisting of satellite constellation, ground station network, data dissemination and distribution.
- Creation of an operational data policy regulating the responsibility and access to AIS data by users and service providers.

In Europe, several activities have been initiated by ESA and EC to validate AIS receivers, first operational missions and to develop a full European AIS constellation.

OHB-System has developed and operated AIS receivers aboard the two Rubin-7 & -8 missions and is currently performing a System study for the design of an European AIS constellation under ESA contract.

9. Ocean-Colour from GEO

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:

- detection, prediction and monitoring of short and long term biophysical phenomena
- biogeochemical cycle analysis
- 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, with 14 bands in VIS/NIR and a update time of <1 hour for European costal zones. This will provide multiple inter and intra-day observations over Europe of fast evolving biological or dynamical phenomena. The Ocean Colour instrument can easily accommodated on a small GEO platform (Figure 9) together with other Telecom or data relay payloads.

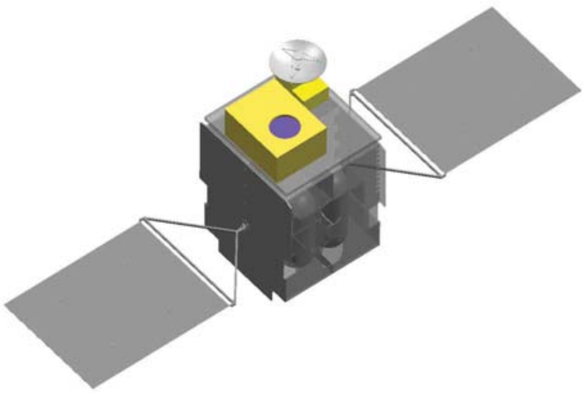

Figure 9: OC Payload auf SGEO Satellite

10. 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 10).

Figure 10: 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 11).

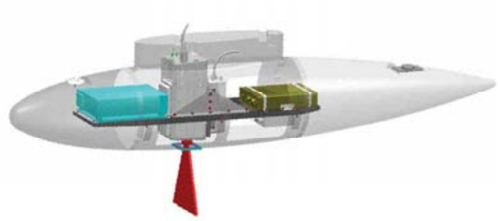

Figure 11: Wing pod with integrated hyperspectral payload

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)

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)

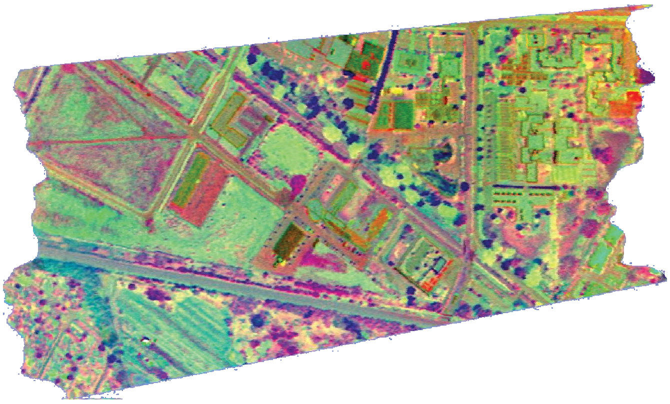

Figure 12: Exemplary image product, derived from hyperspectral information (OHB Headquarters Bremen)

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.

11. Data Relay Satellite

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 GEO-DRS satellite, which weighs 2,5–3,0 tons, 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 10 shows the interaction of the GEO-DRS with other EO system components.

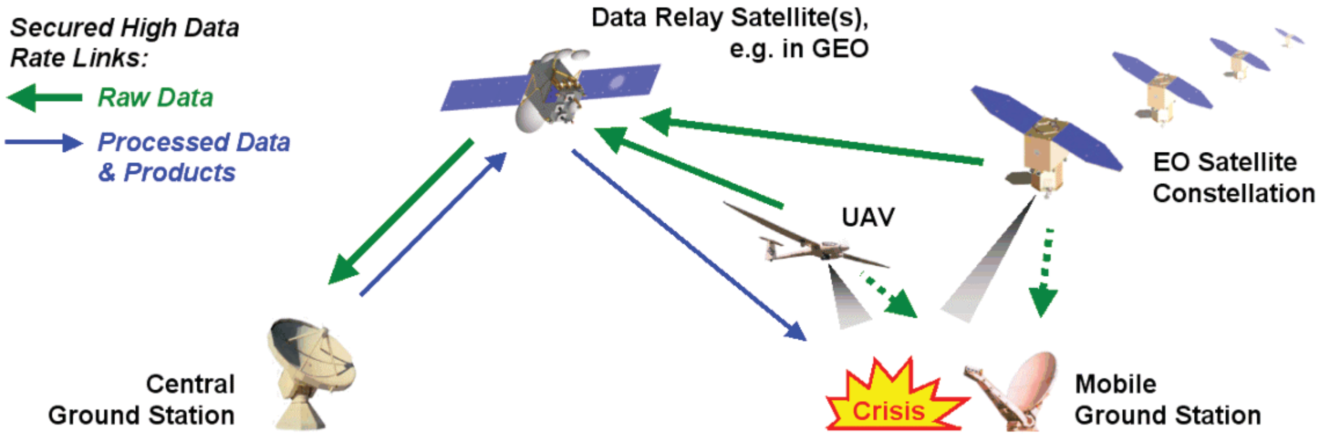

Figure 13: GEO Data Relay System for Emergency Response Service

12. Conclusions

Based on the experience with SAR-Lupe, EnMAP and SGEO 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 1m

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 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.