# GMES – DEDICATED SATELLITE CONSTELLATIONS & MISSIONS FOR OPERATIONAL EARTH OBSERVATION

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## 1. ABSTRACT

The objective of the joint EC / ESA initiative for Global Monitoring for Environment and Security (GMES) is to provide high quality environmental information and services on continuous operational basis and also for crisis monitoring. Therefore a GMES space component with observational capabilities based on user requirements has to be implemented in the near future to continue and enhance today's EO missions. These new missions are currently grouped by ESA into the five "Sentinels" for coastal zone & ice monitoring, land & vegetation monitoring, ocean & altimetry monitoring, LEO and GEO atmospheric chemistry monitoring.

Parallel to the current GMES activities so far, a new generation of low cost and fast development small satellite missions are emerging. One representative of these new generation missions is the SAR-Lupe satellite constellation, offering an affordable implementation option for space missions, which request a fast data delivery on a wide area scale. Derived from this experience, OHB-System is currently investigating several alternative and complementary concepts in response of the GMES observation needs, presented in this paper:

- A **SAR constellation** of three satellite to provide 1-2 day coverage above +30°N and below –45°S for coastal zone and ice monitoring. Each satellite in the 1400kg class will be equipped with a C-Band SAR payload.
- For **land & vegetation monitoring** a multispectral high-resolution optical system consisting of a two satellite constellation, in the 500 kg class with 200 km swath VIS to SWIR imager will provide 7 day global coverage. Combining this payload with a wide-swath medium resolution instrument for 3 day global coverage, results in two satellites in the 800 kg class.
- A dedicated **altimetry satellite** in the 500 kg class is proposed, equipped with the radar altimeter, a microwave radiometer for troposphere correction and a precise orbit determination instrument. This satellite will fly in conjunction with a Jason-2 follow-on mission in order to provide a dense enough sample of the full two-dimensional surface.
- For **atmospheric chemistry monitoring** a 1300 kg GeoTROPE satellite is proposed carrying two VIS to IR spectrometers (GeoSCIA and GeoFIS). For LEO observations, a satellite in the 700 kg class is proposed with a Infrared Atmospheric Sounding Interferometer (IASI), a supporting Imaging Radiometer and a Microwave Sounder.

The governmental use of GMES requires a dedicated security concept with access control, data integrity and authentication. Furthermore the dual-use scenario requires data confidentiality. Here OHB-System will contribute with experience in SAR-Lupe and their "Europeanisation", e.g. with the Helios-II system.

## 2. SENTINEL-1 ALTERNATIVE CONCEPT

Sentinel-1 is an imaging radar mission at C-band aimed at providing data to the following services areas:

- Monitoring sea ice zones and the arctic environment
- Surveillance of marine environment (wind speed, oil spill and ship detection)
- Monitoring land surface motion risks
- Mapping of land surfaces: forest (climate change, management, fire), water and soil, agriculture (food security, crop monitoring)
- Mapping in support of humanitarian aid in crisis situations

### 2.1. User Requirements & Options

When analysing the MRD-1 mission requirements one can derive the following three major high-level groups of requirements (see FIG 1):

- Coverage and Timeliness related requirements,
- Payload Performance related requirements, which are especially driven by the requirements to provide a Continuity of the previous ERS, ENVISAT and RA-DARSAT missions, and
- Cost and Risk related requirements.

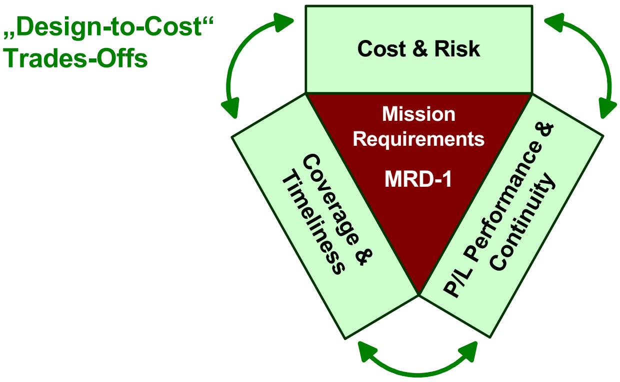


FIG 1. Major Groups of Mission Requirements from MRD-1

Many of the MRD-1 requirements are very demanding. For the adequate SAR mission design, which is able to fulfil these requirements, one will derive to following fundamental statements:

- In order to fulfil the **coverage and timeliness** requirements, a constellation of multiple SAR satellites is mandatory.
  A 24 hours turn-around time for crisis observations understood on a global scale is in the same range as originally stated for SAR-Lupe, that is designed as a five satellite constellation.
- In order to fulfil the **payload performance** and continuity requirements, the adequate SAR payload will feature a high complexity, similar to the SAR payloads on ERS, ENVISAT or RADARSAT.
  This solution is foreseen to lead to a large and complex satellite (above 2000 kg) and therefore at high cost.
- Combining these two findings, one will come to an overall SAR mission solution, which is made of a constellation of multiple ERS-like or RADARSAT-like satellites. This solution would be fully compliant to the mission requirements, but will also be very cost intensive. This solution would follow a design-to-requirements and NOT a design-to-cost strategy.

Out of these statements it becomes obvious, that the mission requirements, as provided in the MRD-1, cannot be fulfilled all at the same time. As already indicated in FIG 1, there has to be a “design-to-cost” trade-off, which will be the issue for the SAR implementation option identification and trade-off.

In order to support the early operational availability of the SAR space segment for GMES, the SAR payload is assumed be based on existing or at least largely investigated payload solutions with the following top-level options:

- High, medium and low performance payload, starting from ERS, ASAR and RADARSAT performance down to payloads only include a minimum resolution wide swath mode for the non-interferometric applications, and provide the minimum polarisation scheme required by these applications.
- Single satellite or constellations, which is necessary to fulfil at least the duration threshold of the coverage requirements of 48 or up to 24 hours.
- Uniform or Non-uniform constellation, consisting of different types of satellites, e.g one dedicated for full performance and some others focused on coverage with lower performance.

## 2.2. Alternative Concept

A trade-off considering performance, reliability, coverage, cost and risk, result in the selection of a medium performance satellite constellation for 48 hour coverage was selected as the baseline system for the SAR mission. The SAR mission design was performed with MDA (Canada), responsible for the SAR payload.

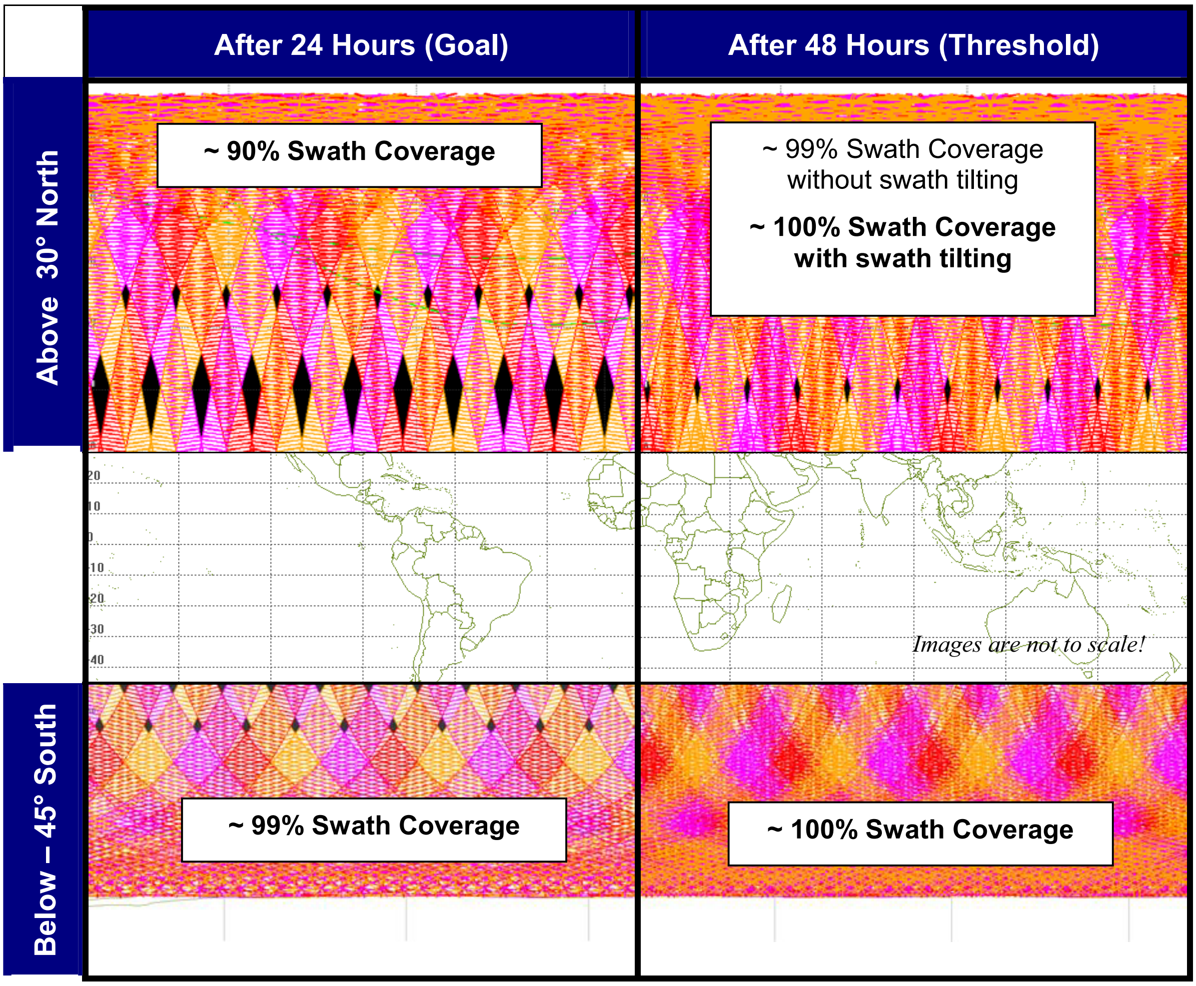


FIG 2. Coverage performance of the three satellite constellation after 24 and 48 hours, taking into account the 400 km medium resolution swath (from baseline orbit; duty cycle not considered)

In the MRD-1 the relevant mission requirements regarding the orbit selection are:

- Bi-weekly exact repeat is required for interferometry, i.e. an orbit repeat cycle of 14 days maximum. This drives the selection of the orbit altitude.
- Polar coverage is required. This drives the selection of the orbit inclination, which has to be near polar.

A further input to the orbit altitude selection is the SAR payload, which on the one hand prefers lower altitudes in order to reduce the power demands. On the other hand the orbit altitude shall not be below ca. 500 km to avoid atomic oxygen problems and to limit the atmospheric drag for orbit stability reasons. Within this orbit altitude range there is only a limited number of orbits, which are feasible to provide exact repeat cycles during the maximum 14 days period. For the first iteration of the SAR mission a reference orbit altitude of 587 km (12 days repeat cycle) is currently selected.

A number of three satellites are necessary as “minimum”, because the complete coverage, which is displayed in FIG 2, will be reduced by the limited duty cycle of each satellite. For a full coverage of the envisaged latitude regions one single satellite requires 55 min of imaging, using both the ascending and the descending branch of the orbit. Such a duty cycle is not feasible. But there is a huge overlap of the image swaths, especially at very high and low latitudes. Here, an adequate observation strategy could be to minimise the “doubling” of image data within one coverage period.

All the analysis results have shown the good coverage performance of the three satellite constellation. This constellation has therefore been chosen as the baseline concept for the space segment of the SAR mission. FIG 3 summarises and shows the major parameters of this SAR satellite constellation.

**Baseline Constellation for the SAR Mission**

**Number of Satellites:** 3, identical
**Mean Orbit Altitude:** ca. 600 km each
**Number of Planes:** 1
**Inclination:** SSO, 97.7°, dusk-dawn orbit
**Local Time:** 18:00 h, ascending node
**Satellite Phasing:** 120° equally spaced

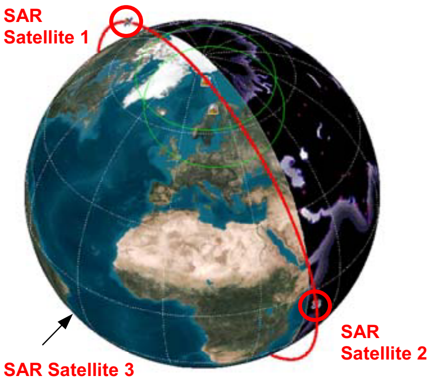
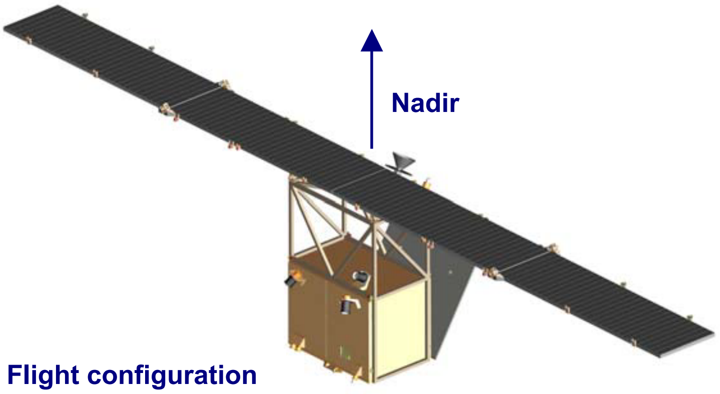


FIG 3. Overview of the three satellite constellation for the SAR mission

The resulting first spacecraft design is shown in FIG 4. The spacecraft is determined by the SAR antenna deployment and accommodation in a small launcher of VEGA class. The SAR satellite features are summarised in the table on the next page.



**SAR Satellite Features**

**Mass:** 1443 kg
**Power:** 294 W (avg)
**Dimensions (stowed):**
2.17 m x 1.26 m x 3.55 m

**Payload**

**Frequency:** C-Band
**Polarisation:** Full quad
**Swath:** 100-400 km
**Resolution:** about20-50m
**NESZ:** Better than -22 dB
**Duty cycle:** 10%-20%

**Platform**

**Features:**

- 3-axis stabilised platform
- Blow-down propulsion system
- Left/Right looking mode
- 7 years of propellant
- 192 Gbit payload data storage

**Mass:** 600 kg
**Power:** about 200 W

FIG 4. Summary of SAR Satellite

Beside the above Sentinel-1 alternative concept, OHB and its partners are also working on complementary concept, that can further extend the performance of a Sentinel-1.

**Small SAR constellation** as high frequent coverage complement to Sentinel-1 satellite. An additional constellation of smaller SAR satellites dedicated to provide high frequent coverage on a cost-effective basis, e.g. with lower resolution, could significant improve the user requirements for 24/48 hours global coverage, e.g. for crisis monitoring.

**Very high resolution data** in the range of 1-5 m is used for assets assessment, urban mapping and risk assessment (see also Risk-EOS – ESA GMES Service Element Project). Here also an additional system can provide this complementary data on regular, reliable, and long-term basis.

# 3. SENTINEL-2 & 3 ALTERNATIVE CONCEPT

Sentinel-2 requirements are based around a diverse and challenging set of land observation applications spanning risk management, land use, forest monitoring, food security, humanitarian aid, and others. Many of these user requirements have evolved from, and in many cases beyond, the existing applications for Landsat, SPOT-5, and similar data.

Sentinel-3 provides the operational ocean observing component of the GMES system and as such it must provide data on coastal and open ocean conditions to users on a routine, robust and reliable basis. Data products provided must be compatible with, and consistent to, the pre-operational services provided from previous missions, including the ERS/Envisat series.

## 3.1. User Requirements & Options

At present, two fundamental types of data products are desired from Sentinel-2:

**Land Mapping:** This requires visible-near infrared (VNIR) and short wave infra-red (SWIR) imagery at moderate resolution (10-30 m GSD), wide image swath (>200 km), with global coverage every 3-7 days. The derived requirements are based largely upon the Landsat and SPOT missions, but include some key advances beyond existing systems, which would enable a great improvement in the number and quality of land observation applications for both global and regional users. Three of these improvements stand out:

A **reduction in repeat coverage cycle time**, from 16 days (Landsat) to 3-7 days, would be an extremely important improvement. This breaks an important threshold in terms of allowing observation of sub-seasonal changes to plant conditions affecting agriculture and forestry. After allowing for typical 50% cloud cover in many parts of the world, Landsat's 16 day repeat coverage cycle often yields only 2 or 3 good images of crops and forests during the growing seasons, which is not sufficient for monitoring the progress of disease and stress conditions. A 3-7 day cycle would permit on the order of 10 good images during the growing season, which allows feedback of imagery to the relevant stake holders in a timely manner.

**Spatial resolution improvement** from 30 m to 10 m would greatly improve the ability to perform mapping, biomass analysis, and monitoring of land usage. Landsat data, at 30 m for example, is not ideal for many urban map-ping/analysis applications, monitoring of water sheds, or detection of illicit crops. Higher resolution opens up a much wider range of applications which users are now ready to employ.

The required **spectral resolution in VNIR/SWIR** depends on the objectives of the mission. As a minimum, the mission must provide most of the Landsat-5 equivalent bands for basic land surface change detection and mapping. This minimal level of data product will soon become obsolete however, as the next generation of Landsat missions will include a high resolution pan band, and additional SWIR bands for correction of cirrus clouds and aerosol in the images. As such, a more "nominal" mission scenario includes collection of data with the equivalent spatial and spectral resolution of the next Landsat mission.
More ambitious imaging goals for Sentinel-2, however, include a much greater number of spectral bands than Landsat or SPOT. These extra bands allow discrimination of key surface features such as absorption of nitrogen, cellulose, and lignin, and also allow better correction of scattering and absorption from atmospheric water vapour (aerosols and cirrus clouds). An additional 4 VNIR and 6 SWIR bands have been identified for this purpose.

**High Temperature Event (HTE) Monitoring**: This requires mid-infrared (MIR) and thermal-infrared (TIR) imagery at low resolution (100-250 m GSD), with very high global revisit time of better than once every 12 hours. This is intended for monitoring of fires, volcanic events, and other large scale HTEs.

The identified optical mission elements to fulfil the optical observation goals are:

- The **HRMS (High Resolution Multi-Spectral system)** is capable to satisfy the primary MRD-2 observations, either the "minimum", the "nominal" or the "optimum". In the case of HRMS the vegetation bands of MRD-3 might already be covered here.
- The **LRMS (Low Resolution Multi-Spectral system)** focuses onto infrared imaging, primarily dealing with the needs of High Temperature Event monitoring from the MRD-2 domain and Sea Surface Temperature measurements (out of MRD-3 applications)..
  The LRMS-plus payload option complements the limited LRMS functionality with the comprehensive VIS/NIR observation capabilities required for Ocean Colour (OC) measurements.
- In addition the "**ESA-HTE**" designated payload element stemming from the FUEGOSAT origins could be combined with certain suitable arrangements of the above items.

## 3.2. Alternative Concept

A trade-off considering performance, reliability, coverage, cost and risk, result in the selection of a combination of LRMS and HRMS instruments in identical configuration on identical satellites, thus allowing a cost effective development approach. The optical mission design was performed with Kayser-Threde (for mission), Jena-Optronik (HRMS) and OIP Sensor Systems (OC/SST/HTE).

The main requirements for this initial orbit analysis were set as follows:

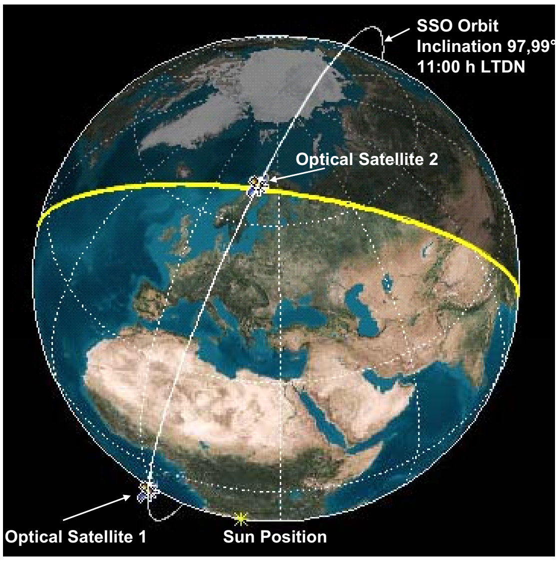
- Sun-synchronous orbit (SSO) with repeating ground tracks,
- Descending node at 11:00 local time,
- Altitude of 651 km orbit was selected to balance orbital drag / delta-v requirements for orbit maintenance and telescope size.
- Global coverage achievable in less than seven days using a 200 km sensor swath (e.g. for HRMS),
- Global coverage achievable in less than three days using a 1,000 km swath (e.g. for LRMS).

For the configuration of identical optical platforms, each one carrying both HRMS and LRMS type instrumentation, a distinct platform constellation approach is selected:

- Only half of the LRMS payload will be flown on one platform forming a swath of 500 km. The other LRMS spectrometer is flown on the second platform, both together complementing to a total swath of 1000 km. A global coverage with LRMS data (2x 500 km swath) is achievable in such a configuration within 3 days.
- In order to reduce sun-glint impacts, the LRMS payloads may be mounted in a suitably across-track tilted orientation , e.g. 150 km on ground towards lower sun elevation.
- For the HRMS payloads (two separated 200 km swath tracks) a global coverage can be achieved within a 7 days period Over such period the inherent “spacing-gaps” between the two satellites are filled by subsequent orbits.

This configuration provides significant advantages with respect to system design aspects in terms of a significant mass, power and data rate saving whereas being able to keep the payload configuration on both platforms absolutely identical.

All the analysis results have shown the good coverage performance of the two satellite constellation. This constellation has therefore been chosen as the baseline concept for the space segment of the optical mission. FIG 5 summarises and shows the major parameters of this optical satellite constellation.



**Baseline Constellation for the Optical Mission**

**Number of Satellites:** 2, in identical configuration

**Reference Orbit Altitude:** 651 km each

**Number of Planes:** 1

**Inclination:** sun-synchronous, 97.99°

**Local Time:** 11:00 h, descending node

**Satellite Phasing:** 65° true anomaly separation

FIG 5. Overview of the two satellite constellation for the optical mission

The spacecraft is based on a standard platform design for the accommodation in a small launcher of VEGA class. It provides a lower compartment containing the platform subsystems and an upper compartment for the payload instruments. Due to the high power demands, a deployable and steerable solar array is used.

The optical satellite features are summarised in FIG 6 and the table beside.

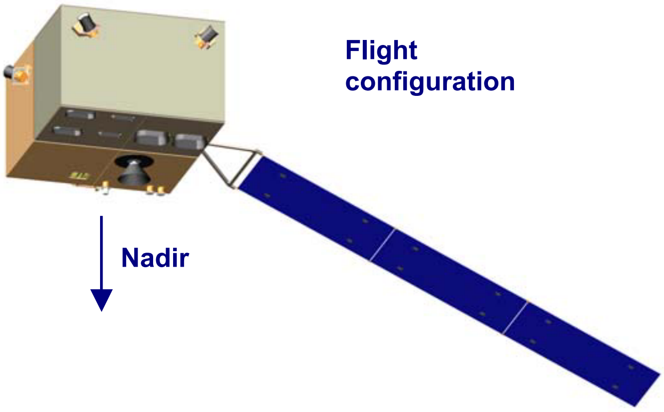


FIG 6. Summary of Optical Satellite

**Optical Satellite Features**

**Mass:** 824 kg

**Power:** 329 W (avg)

**Dimensions (stowed):**

1.90m x 1.27 m x 2.25m

**Payload**

**Instruments:**

**Hi-Res Multispectral (HRMS)**

**High Temperature Event (HTE)**

**Sea-Surface Temperature (SST)**

**Ocean Colour (OC)**

**Swath**:

- HRMS: 156-200 km
- HTE/SST/OC: 4x250 km

**Resolution:**

- HRMS: <30 m
- HTE/SST/OC: 250 m

**Duty cycle:**

- HTE/SST: 100%
- OC: 38%
- HRMS: 24%

**Platform**

**Features:**

- 3-axis stabilised platform
- Blow-down propulsion system
- 7 years of propellant
- 1024 Gbit payload data storage

**Wet mass:** 665 kg

**Power:** 190-400W

Beside the above Sentinel-2 & 3 alternative concept, OHB and its partners are also working on complementary concept, that can further extend the performance of a Sentinel-2.

A **(very) high resolution and agile optical system** with a spatial resolution in the range of 3-10 m with a large accessible area (due to agile spacecraft or instrument pointing) to Sentinel-2 satellite. An smaller optical satellite dedicated to provide fast access time on a cost-effective basis could significant improve the user requirements for access to high resolution data, e.g. for crisis monitoring.

## 4. SENTINEL-3 ALTIMETRY SATELLITE

The topography mission is one element required by MRD-3 [3] for sea surface height and wave height. This results in a group of dedicated instrument classes for topography measurement and corrections. In the following the main requirements on architecture level and the resulting implementation options are described.

The topography architecture element requirements are provided in the MRD-3. When analysing the requirements for topography mission one can divide the provided requirements into three major groups:

- Mission and Coverage related requirements,
- Timeliness related requirements,
- Payload Performance related requirements, which are especially driven by the requirements to provide a Continuity of the previous Envisat/RA-2,

In order to fulfil the measurement / payload performance requirements the following generic sensor suite is necessary:

- Altimeter (ALT),
- Microwave radiometer (MWR) for troposphere correction,
- Precise Orbit Determination (POD) for accuracy level in cm range. For calibration an Laser-retro-reflector could be used optional).

Due to the potential for optimised orbit, coverage and coordination with other required Altimeter missions, the single dedicated satellite option was selected.

The required resources of the GMES Topography Satellite were found to match very well with those provided by the SAR-Lupe platform of OHB. Therefore, the identical structural approach was pursued, i.e. an integration of payload and platform subsystems within a common housing. FIG 7 depict the outside configuration and the subsystem accommodation of the Topography Satellite with SAR-Lupe platform heritage.

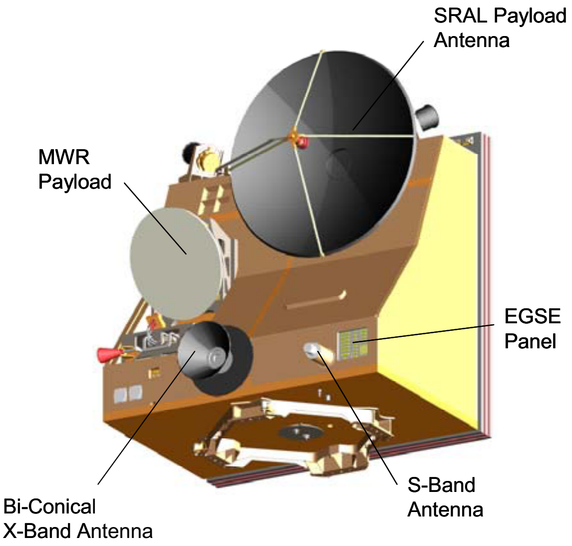


FIG 7. Topography S/C Outside Configuration (view on Earth panel)

FIG 7 shows the in-orbit configuration of the topography satellite. The two auxiliary solar panels are unfolded and canted w.r.t. the NADIR axis with an angle that yields perpendicular sun incidence when the ascending node is passed. In the figures, the narrow upper panel that accommodates the two star trackers points in anti-velocity direction.

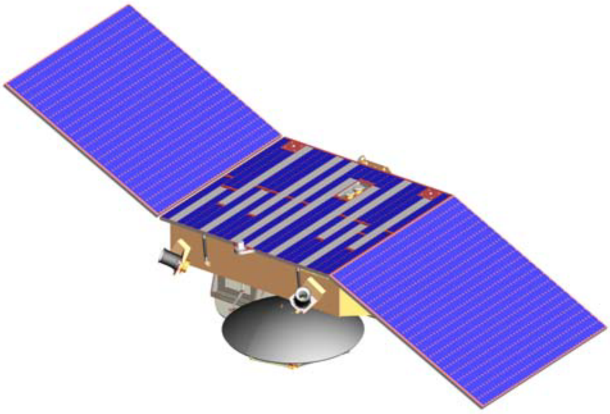


FIG 8. Topography S/C in-orbit configuration (top view)

## 5. SENTINEL-4 & 5 COMPLEMENTARY CONCEPTS

The Sentinel 4 & 5 shall answer the operational needs of the users in the area of atmospheric chemistry, air quality and climate applications. The need for an operational mission to observe the atmosphere, though not for meteorological applications, is driven by the following reasons:

- Atmospheric observations are useful for the monitoring of Global Climate Change (the Kyoto Protocol) and Sustainable Development. These observations provide key information on the monitoring of the climate changes within the Earth system, the knowledge on the state, composition and evolution of the global atmosphere;
- Atmospheric observations provide valuable information for European environmental policies in areas such as the air quality; e.g. for operational applications and services, including forecasts, using near-real time monitoring,
- Atmospheric observations provide useful information for European civil protection in the field of risk management including prevention, monitoring and assessment at European level related to:
  − natural hazards with particular attention to climate related pressures (e.g. drought, extreme weather conditions);
  - hazards with particular attention to risks associated with industrial activities.

The following two concept are investigated, that can complement the Sentinel-4&5 systems:

- The Geostationary TROpospheric Pollution Explorer (GeoTROPE) will improve our understanding, monitoring and forecasting of air quality over Europe through synoptic measurements of changing tropospheric composition, as proposed for Earth Explorer Core Missions Call in 2005 [10].
- EPS Bridging System 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, as described in an other paper [12].

### 5.1. GeoTROPE Concept

The applications and user objectives of GeoTROPE are to enhance:

- Local and regional pollution emission inventories
- Measurements of trans-boundary transport of pollutants
- Quantification of air pollutant fluxes within Europe, imported into and exported from the European area.
- Differentiation between anthropogenic and natural sources of pollutants
- Understanding of chemical transformation in convective systems
- UV radiation monitoring and forecasting

GeoTROPE comprises two nadir-looking instruments, a UV-VIS imaging spectrometer GeoSCIA, and a thermal infrared spectrometer GeoFIS, mounted on a 3-axis stabilised platform located in GEO. This mission focuses on the retrieval of tropospheric composition over Europe and surrounding oceans. The geostationary platform is positioned nominally between 0°E and 10°E longitude. The instrument field of views (FOVs) will cover Europe in E-W direction from about 20°W - 40°E and in N-S direction from about 30°N - 65°N. The GeoTROPE-R instrumentation is designed to measure top of atmosphere radiance (UV-VIS and TIR) over Europe and surrounding oceans at high spatial (2.5 x 5 km2 to 15 x 15 km2 at sub-satellite point) and temporal (60 min) resolution. Options to view Africa or to drift to view a different continent are available.

The GeoTROPE payload consists of the two Instruments GeoSCIA 2005 and GeoFIS mounted on a very stable thermo-mechanical optical bench (OPB) together with the star trackers. This concept promise best stability of the optical axis between the instruments and the attitude pointing reference. This results in a compact payload assembly of about 280 kg an 390 W. Additional a data handling and coding unit (DHCU) and a X-Band downlink transmitter with antenna is required for payload telemetry data handling.

Therefore a small GEO platform in the 1,5 ton class and currently developed OHB LUX systems is compliant with the resources (mass, power, volume) for the overall payload accommodation. The required modifications of such telecom standard platforms are:

- Improved attitude knowledge and pointing stability by factor of 60 (ACS),
- Adapted thermal concept for instrument radiators (e.g. additional baffling)
- Reduced power supply system with half size solar generator and battery

The spacecraft is configured in a similar manner to a standard geostationary telecommunication satellite:

- The GEO platform compartment with all service subsystems and launcher interface (on the rear side)
- The separate payload compartment with the main payload elements in Earth direction:
  - Optical Bench Structure with GeoSCIA and GeoFIS instruments and Star Trackers.
  - Separate electronic boxes for instrument control and data handling
  - Thermal radiators on the north and south panels

This grouped concept provides separate instrument developments and also flexibility in the AIV strategy. The Figure aside shows the GeoTROPE spacecraft based on the LUX small GEO platform, currently in the design phase supported by ESA and DLR. The GeoTROPE mass and power budgets fit well in the performance of a small GEO platform with 1450 kg and 2700 – 4200 W system resources.

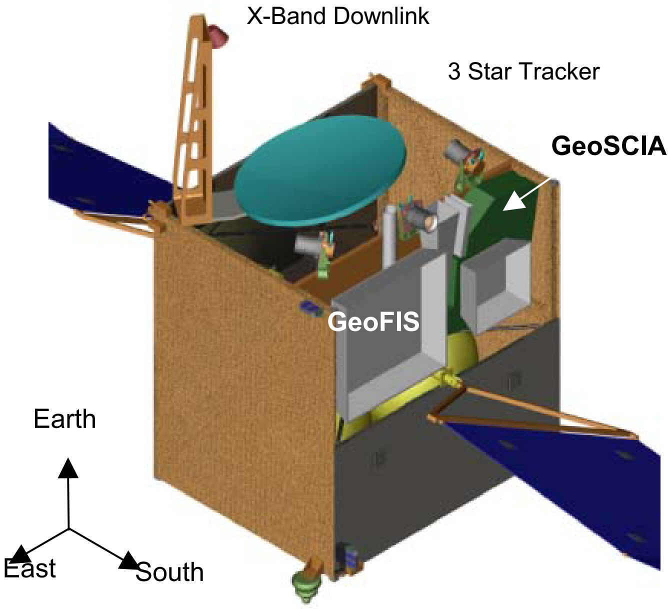


FIG 9. GeoTROPE satellite in-orbit configuration

## 6. GMES SECURITY APPROACHES

Cryptography is an essential element in any communication system that transmits across and open channel. The high costs to develop, launch and maintain a satellite network makes protecting the assets imperative. Advances in technology have reduced the costs of satellite communication devices. This has increased the threat of third parties attacking the system. These attacks may be passive such as eavesdropping on the telemetry (TM) and telecommand data (TC) or it may include an user gaining unauthorized access to the payload data. More serious threat are active attacks that try to gain control of the satellite or the whole satellite network. A successful active attack may find the attacker in control of the satellite, which may lead to the total lost of the satellite asset.

To counter these threats, new satellite systems are designed with cryptographic functions to provide a range of services, including:

- Confidentiality
- Entity and Message Authentication
- Data integrity

Additionally, key management cryptographic services are required to support these services.

The **GMES Sentinel 1** satellite is a relatively autonomous system that requires commanding from the ground station every 96 hours. Due to the high degree of controlling the telecommands have they must be **authenticated and encrypted** to ensure that the satellite receives proper instructions from an authorised operator and that the control data is kept secret. The payload data is **encrypted** to control the access to the raw data. .Users are able to get the verified and calibrated data from the service provider or gateway according to their access level.

The **GMES Sentinel 2, 3, 4 and 5** satellites are relatively autonomous systems that requires very little control from the ground station. Therefore the telecommands that are sent to the satellite are only **authenticated** to ensure that the satellite receives proper instructions from an authorised operator. The payload data is **encrypted** to control the access to the raw data.

The OHB-System crypto concept hardware and software has been fully qualified by the German Department for Security in Information Technology (Bundesamt für Sicherheit in der Informationstechnik, BSI) for space applications with a secrecy level up to SECRET. The cryptographic hardware is designed for the easy exchange of algorithms, thereby providing the option of selecting mission specific algorithms.

For detailed information on the proposed security system and its elements on-board the spacecraft and on ground see [13].

## 7. CONCLUSION

Derived from its SAR-Lupe experience on affordable satellite turn-key systems for Earth Observation with fast data delivery and long-term operations, OHB-System is investigating several alternative and complementary concepts in response of the GMES observation needs.

For Sentinel-1, -2 & -3 alternative concepts of small satellite constellations are proposed that are focused on the demand of fast revisit and data delivery cycles up to 24/48 hours. This will close the main gap in today's Earth observation user demands of fast and reliable data availability , e.g. for crisis monitoring.

Derived from its current development of the small and versatile GEO-platform LUX to offer to the market a turnkey system with low investment risk for the customer and a short development time, OHB propose concepts for smaller geostationary observation systems. One system is the Geostationary TROpospheric Pollution Explorer (GeoTROPE), that will improve our understanding, monitoring and forecasting of air quality.

Also based on the SAR-Lupe experience OHB has a portfolio of security systems and elements for the GMES sentinels required for the authentication and en-/decryption elements on-board and on-ground.

## 8. REFERENCES

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