

# Contributions to Global Monitoring of Environment and Security (GMES) of the German Remote Sensing Data Center

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**Abstract** – GMES, Global Monitoring for Environment and Security, is the second pillar of the European space strategy. Next to the geoinformation services, this operational earth observation program requires a complex and operational earth observation ground segment, integrating the data from the dedicated GMES Sentinel space segment as well as those from national collaborating missions. The German Remote Sensing Data Center (DFD) of DLR already operates payload data ground segments for national missions, ESA and DLR partners. DFD has established global acquisition stations, operates one of Europe’s largest earth observation data centers and supports critical geoinformation services with near real time products. The paper describes how these assets work closely together with applications for the benefit of the GMES program – such as emergency response, air quality and maritime security.

## 1. THE GMES PROGRAMME

The Global Monitoring for Environment and Security (GMES) programme is the second pillar – next to the satellite navigation system Galileo – of the European space strategy. Initiated in 1998 (“Baveno manifesto”), it was officially turned into a European programme in 2001 and subsequently implemented by the European Commission (EC), leading the programme, and the European Space Agency (ESA), accompanied by further European organisations and complemented with European national space and ground assets.

GMES aims to operate a sustainable European earth observation capacity, supporting geoinformation services critical for public and governmental decision making and planning.

The structure of GMES is depicted in Figure 1. The principle space component is created by the Sentinel satellites, managed and operated by ESA. The operational configuration consists of two Sentinels of each series in orbit. Sentinel-1 is a C-Band multimode SAR, continuing the successful ESA ERS and ENVISAT missions (Sentinel-1a launch; end 2012). Sentinel-2 (launch 2013) is a medium resolution multispectral imager, guaranteeing regular European land coverage. Sentinel-3 (launch 2013) carries a set of low resolution sensors able for daily measurements of continental and ocean environmental parameters. Sentinels-4 & 5 will be atmospheric instrument payloads carried on operational geostationary and low-earth-orbit meteorological satellites of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). The series starts with a Sentinel-5 pre-cursor mission (launch 2014); the piggy-pack payloads will fly after 2017.

The data from the Sentinel satellites will be complemented by data from European national contributing missions, delivering higher geometric resolution, further spectral bands and faster access to information. This paper will briefly describe the German space mission contributions to GMES. Further on, the European Environmental Agency (EEA) is in charge to organise the access to data from in-situ observations, aircraft measurements and historical records, as required for the GMES geoinformation services.

The access to the Sentinel satellites, the generation and distribution of data products and the delivery of near-real-time (NRT) services, will be guaranteed thru a ground segment managed by ESA and to a large extend operated by entities in ESA member states, based on existing infrastructure and in synergy with national missions. Sentinel as well as contributing missions data dedicated to GMES services will be available thru a GMES data access system.

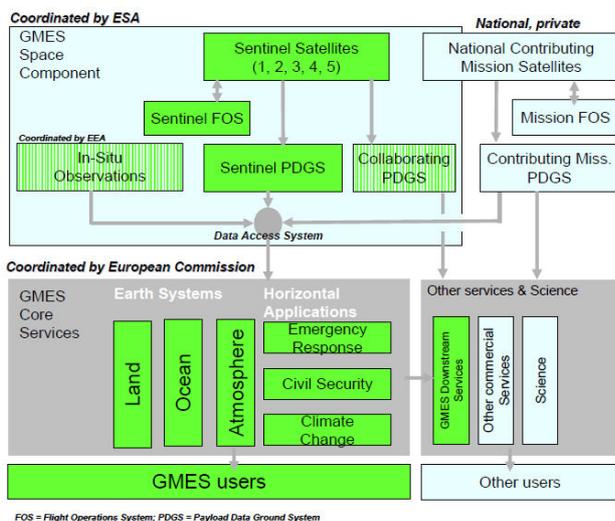
The drivers of GMES are the geoinformation services. By implementation of large-scale precursor projects in the European Framework Research Programs (FP) 6 & 7 and by iterating the requirements of European institutional users, the EC has defined the following core services delivering basic facts and products of the earth systems:

- Land Monitoring
- Ocean Monitoring
- Atmosphere Monitoring

Three horizontal applications take benefit from these basic observations and require further data to deliver services for:

- Emergency Management
- Civil Security Services
- Climate Change Observations

Though focussing on European interests, the services have a global dimension. The products of these core services will be treated as public goods, available without charge.



FOS = Flight Operations System; PDGS = Payload Data Ground System

Figure 1. Overall structure of GMES

Based on these GMES core services, public and private initiatives can create “downstream” services, to meet dedicated requirements for local users and commercial applications. The planned “free & open” data policy of both the Sentinel-data and the core services is meant to stimulate the commercial geoinformation market.

## 2. DLR IN GMES

The German Aerospace Center (DLR) manages the German national contributions to the ESA part of GMES and delivers support for the ministries managing the German contributions to the EC programs. Germany is both the biggest contributor to the ESA earth observation program and the general EC budget.

In its function as the German space agency, DLR ensures the participation of German public and private entities to the GMES program according to their abilities. It strengthens German space industry with their innovative technologies and access to markets, for instance thru national earth observation missions. It ensures involvement of scientists in definition, calibration and innovative applications of GMES sensors and services. Amongst others, this is done thru national GMES application demonstration projects (DeCover, DeMarine, DeSecure).

In addition, DLR performs science, research and operations in earth observations with more than 400 scientists working in various institutes. Development of algorithms and processors to turn earth observation instrument data into products is the task of the Remote Sensing Technology Institute (IMF). Turning these processors into operational services within a ground segment and development of earth observation applications and services is the task of the German Remote Sensing Data Center (DFD) of DLR. In July 2010, the new building for both institutes at DLR in Oberpfaffenhofen (near Munich) was inaugurated and named Earth Observation Center (EOC, Figure 2). Subsequently, also the institute cluster of IMF and DFD was renamed to Earth Observation Center (EOC).



Figure 2. The new Earth Observation Center (EOC) at DLR

Complemented by other institutes at DLR in instrument handling and mission control, DFD operates the Payload Data Ground Segment (PDGS) of national earth observation missions and supports partners in the operations of non-european commercial missions. Namely the PDGS of the public private partnership (PPP) X-Band SAR missions TerraSAR-X and TanDEM-X is based on DFD’s German stations in Neustrelitz, Germany and its international polar data acquisition stations in Antarctica (O’Higgins) and Canada (Inuvik, NWT). The SAR products are subsequently generated, archived and distributed by DFD in Neustrelitz and Oberpfaffenhofen (with commercial distribution carried out by Infoterra GmbH, Germany). Together with the German Space Operations Center (GSOC), performing

the Flight Operations Systems (FOS), the PDGS framework of DFD will be used to manage further national missions such as the continuation of the TerraSAR-X series and the new hyperspectral mission EnMAP. Both mission series are currently defined as national contributing missions to GMES. Pre-operational payloads of national missions, such as the two satellite fire-monitoring constellation (Firebird) complete the series of German earth observation missions planned by DLR.

Further on, missions in partnership with other agencies are managed by DFD. This includes the French-German Methane Remote Sensing Lidar Mission (MERLIN), aimed to measure the global methane concentration. DFD also supports ground segments for commercial earth observation missions. For the German RapidEye constellation, DFD guarantees the data access for science applications. DFD acquires and catalogues all the data for Indian earth observation missions, licensed from India to Euromap GmbH (Neustrelitz). This includes the Resourcesat-series, which is up to date used by GMES pilot services for European land use monitoring, and the stereo-optic Cartosat-Series, used for the generation of precise elevation models. Since 2003, DFD in Oberpfaffenhofen supports European Space Imaging GmbH (EUSI, Munich) in the tasking and data acquisition of IKONOS and subsequently, since 2010, for the WorldView-Series of DigitalGlobe. Figure 3 gives a schematic overview of the above described earth observation missions.

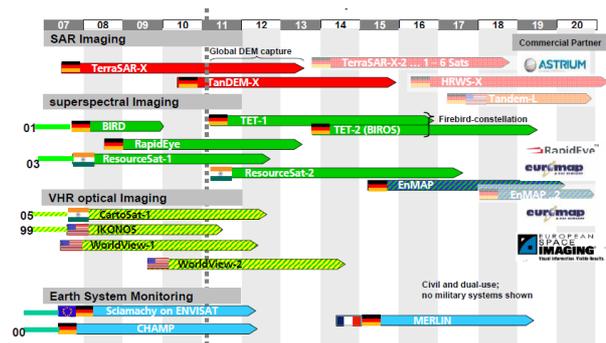


Figure 3. Overview of German EO missions

In supporting these missions, DFD uses the Data and Information Management System (DIMS), developed by DFD and Werum GmbH, as industrial partner. DIMS ensures the end-to-end data and product flow in the PDGS and specifically supports the cataloguing and archiving of data. The latter is done in the national satellite data archive (D-SDA), which is currently upgraded to hold a volume well beyond a few petabyte to accomodate also the TanDEM-X mission data.

Concepts and generic parts of the DIMS design and system have been implemented by ESA and other international ground segments. Since 1991, DFD is part of a network of distributed facilities in Europe, operating the PDGS for the ESA and ESA third party missions. Namely, DFD is the major Processing and Archiving Center (PAC) for the entire atmospheric sensor payload on ERS-2 and ENVISAT. In the recent years, ESA organised the infrastructure and systems of its PDGS in a Multi Mission Facility Infrastructure (MMFI) framework. Besides other facilities in Europe, DFD is acquiring ESA mission data with its stations and is operating ERS- and ENVISAT-processors on behalf of ESA based on MMFI. After ENVISAT, the European atmospheric earth observation payloads will be operated by EUMETSAT, based primarily on its polar orbiting satellites (METOP). In cooperation with other European

partners, DFD is also involved here to operate a „Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring“ (O3M-SAF), processing the GOME-2 data from the METOP satellites.

Beside its active role in the development and operations of earth observation ground segments, DFD is driving the development and demonstration of innovative earth observation applications and the automation of the extraction of geoinformation from earth observation data. Structured in dedicated departments, DFD performs work in earth observation applications concerning land, atmosphere & health & energy and geo-risks & disasters. Within the EOC, IMF complements these works with more instrument related applications of 3-D modelling/photogrammetry, oceanographic applications and atmospheric parameters.

The earth observation applications of DFD generate new information products and geoinformation services, taking benefit of the fast access to the data from the DFD ground segment and using the data management capabilities (DIMS). Therewith, the applications are mostly targeted towards automated information generation and/or time critical applications. Some of these EOC developed applications are offered to partners and users as “geoinformation services”. Time critical geoinformation services are applied not only to European regions for atmospheric parameters or maritime security but also in the framework of international projects such as the German Indonesian Tsunami Early Warning System (GITEWS, Steinmetz 2010, Riedlinger 2009).

### 3. DLR SUPPORTING THE GMES GROUND SEGMENT

As mentioned above, the GMES ground segment will rely to a large extend on existing European capabilities, managed by ESA. Whilst the ESA Space Operations Center (ESOC, Darmstadt, Germany) is planned to be in charge for the flight operations systems (FOS) of the Sentinel 1 & 2 series, the PDGS - acquisition stations, Processing and Archiving Centers - will be operated by selected European national facilities.

The challenge in the downlink of the Sentinel data will be to have sufficient capacity with geographically well positioned stations to acquire the amount of global data. With one operational satellite of the three Sentinel-1/-2/-3 series in orbit, about 164 GB/orbit need to be acquired. Together with the L1 and L2 products generated, this amounts to > 2.7 PB/year. This figure doubles, when two operational Sentinels of a series are in orbit. Challenge in the X-band downlink of this data, are the conflicts between the Sentinel-Series (only one Sentinel-downlink at a station at a time) and the demand for near real time data (in certain areas such as Europe, e.g. for maritime security). While a Sentinel is sending data just acquired to a ground station in line of sight, recorded data from other areas of the globe need to be dumped elsewhere.

The global network of data acquisition stations operated by DFD (Figure 3) will be one offer of DLR to GMES operations. The German national station complex of DFD in Neustrelitz, north of Berlin, is geographically well positioned to cover the larger part of the European land and coastal areas and therewith to acquire data and operate services for time critical near real time (NRT) applications. Such NRT applications are currently demonstrated for maritime security applications in the framework of ESA and EC projects. Space borne SAR data, acquired both from national (TerraSAR-X) and ESA (ERS, ENVISAT) missions are used to automatically detect ships and

their movements and are verified with shore- and space borne AIS (Automated Identification System) data to identify the ships (Brusch, 2010).

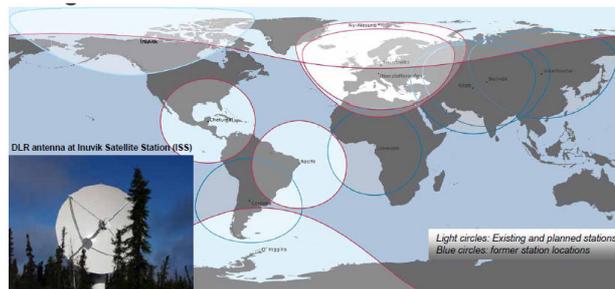


Figure 3. DLR EO data acquisition stations

The demand to dump polar orbiting earth observation satellite data as often as possible was the driver for the establishing of the new DLR station in Inuvik, NWT, Canada. Currently in operations for TanDEM-X, the station is designed and equipped to acquire also other satellites, including the Sentinels. To deal with increased requirements, the partners involved in the development of the Inuvik Satellite Station (ISS), are upgrading the capabilities of the ISS. A second identical 13m antenna has meanwhile been established in Inuvik, mainly serving CNES missions. The existing connectivity from Inuvik to international networks will be increased with fibre connections, based on a regional/national Canadian initiative. ISS will thus increase the capabilities of existing central Canadian stations and is planned to become a major earth observation data hub in the polar region.

The GMES PDGS concept includes also the consideration to use European Data Relay Satellites (EDRS) to dump data via geostationary satellites to ground. To enable this connectivity, Germany contributed a Laser Communication Terminal (LCT) on the Sentinel-1 and -2 satellites. The EDRS satellites will carry a corresponding terminal on board and will send the data via Ka-Band to dedicated stations. Based on national projects, both DFD locations in Oberpfaffenhofen and Neustrelitz will be equipped with Ka-Band antennas, to feed the global data stream directly into the processing chains.

In GMES, these processing chains are represented by “Processing and Archiving Centers” (PAC), turning the Sentinel data into higher level products and delivering these products to the GMES Services and other users. Two PACs per Sentinel series are planned, also to ensure the redundancy of the entire archive of each Sentinel series. Considering the heritage of DFD as ESA PAC for ERS and ENVISAT and based on national earth observation ground segments and existing expertise and infrastructure, DFD is prepared to install and operate the Sentinel PACs in a European network of GMES facilities. Likewise, DFD aims to continue the management of major global atmospheric parameters, generated by the Sentinel-4 & 5 series, in a framework of EUMETSAT SAFs adapted to the needs of GMES.

### 4. DLR SUPPORTING THE GMES SERVICES

One aim of the application development at EOC is to incorporate the capabilities of the PDGS development and operations of the EOC in an “end-to-end” service chain from satellite data reception to geoinformation service delivery. Besides the direct and fast access to the earth observation data, these services use DFD developed information technologies

(e.g. DIMS) to integrate the available domain and application knowledge of the DFD departments. Further on, the services establish a gateway (including personal point-of-contacts) to user communities, which otherwise would have been lost in the variety of earth observation data, technologies and capabilities. To date, the following services have been established at EOC (See Figure 5):

- Center for Satellite Based Crisis Information (ZKI),
- World Data Center on Remote Sensing of the Atmosphere (WDC-RSAT),
- Geovisualisation Center (GeoVis)
- Optical Airborne Remote Sensing and Calibration Facility (OpAiRS),
- Web gateway to the National satellite data archive (EOWEB).

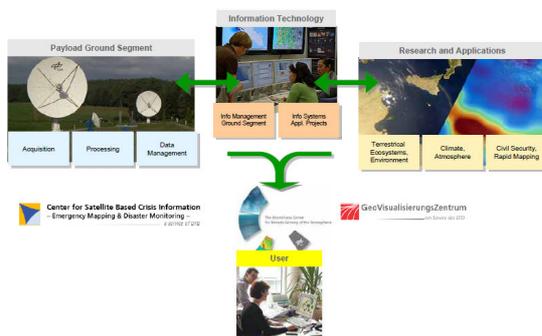


Figure 5. “End-to-end” services offered by EOC

The DLR Center for Satellite Based Crisis Information ([www.zki.dlr.de](http://www.zki.dlr.de)) is taking benefit of the „end-to-end” service capabilities of DFD since 2004, integrating the fast access to satellite data of the national and partner missions. ZKI is a managing member of the European consortium, currently implementing the emergency response as a GMES core service (SAFER, [www.emergencyresponse.eu](http://www.emergencyresponse.eu)) and involved in a variety of other national and international projects to support the natural disasters management cycle with timely earth observation based information products. Since 2010, DLR is also full member of the Charter on Space and Major Disasters, granting access especially to TerraSAR-X and TanDEM-X mission data and supporting charter activations with value added products ([www.disasterscharter.org](http://www.disasterscharter.org)).

The World Data Center on Remote Sensing of the Atmosphere (WDC-RSAT, [wdc.dlr.de](http://wdc.dlr.de)) was established at DFD in 2003 under the auspices of the International Council for Science (ICSU). Meanwhile, it is also a data center for the World Meteorological Organisation (WMO). WDC-RSAT, offers scientists and the general public free access to a continuously growing collection of atmosphere-related satellite-based data sets (ranging from raw to value added data), information products and services. Focus is on atmospheric trace gases, aerosols, dynamics, radiation, and cloud physical parameters. Complementary information and data on surface parameters (e.g. vegetation index, surface temperatures) is also provided. Based on its function as a WDC, DFD is also involved in projects to develop and deliver new services for GMES. As a key member in the European MACC consortium ([www.gmes-atmosphere.eu](http://www.gmes-atmosphere.eu)), DFD focuses on developing GMES services for air quality and health. In this framework, DFD is also priming

the development of an air quality downstream service (Erbertseder, 2010).

Near real time demonstration services to enhance maritime security are operated in various ESA and EC projects from DFD in Neustrelitz. The national and ESA SAR missions acquired there are turned into SAR products and merged with AIS information to monitor ships for the European oceans and east African coastal areas.

These services form the core of the participation of the EOC application departments to the GMES programme. In early 2011, EC plans to continue the outgoing FP7 projects with dedicated projects in the domain for land and emergency response, setting the path for a fully operational service planned from 2014 onwards

## 5. THE WAY FORWARD WITH GMES

GMES has made its way from the early definition in 1998 to a dedicated fleet of satellites and services. Moreover, a framework for coordination has been defined, pooling European resources into one common goal. But GMES has still to face challenges to become fully operational. Besides detailed definition of procedures and responsibilities, a shortfall in the funding for the GMES operations, agreed to be covered by the EC, is a serious threat to keep GMES on the planned timeline. As initiative of the EC, ESA, further organisations and the European member states, GMES need to rely on contributions from all partners. GMES will also contribute to manage environment and security on a regional level. European regional states such as Bavaria (Oberpfaffenhofen) and Mecklenburg-Vorpommern (Neustrelitz) in Germany – teaming with other European regions in the NEREUS network ([www.nereus-regions.eu](http://www.nereus-regions.eu)) – have started initiatives to declare their interest in GMES. Amongst others, the concept of a GMES Center has been developed to act as a core facility within GMES and to support the institutional and commercial contributors and users in GMES in their regions. The applications of GMES, however, are to a large extent of global nature. Satellites, data and services need to be harmonized on a global basis with non-European and global initiatives.

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