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COPERNICUS COLLABORATIVE GROUND SEGMENT TO SUPPORT MARITIME SITUATIONAL AWARENESS

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Abstract

Copernicus (former GMES, Global Monitoring of Environment and Security) is the European Earth Observation Program, conducted jointly by the European Commission, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the member states.
In the context of the Copernicus Collaborative Ground Segment initiative, DLR‘s German Remote Sensing Data Center (DFD) currently extends the ground station Neustrelitz to support the Sentinel-1 mission as external Local Ground Station (LGS) in addition to the Core Payload Data Ground Segment. This article describes the DLR LGS to be developed and operated and gives an overview of the collaborative ground segment services to be established by DLR's Maritime Safety and Security Lab in Neustrelitz. The activity aims to the fulfilment of all mission requirements, primarily to support the need for near real time performance up to 10 minutes, as those in maritime situational awareness. The development and implementation cover the task of Level 0 processing, based on DLR’s Front End Processor (FEP), the implementation of the framework for real time processing up to level 2 (value adding), as well as the development of a hardware-independent virtual processing platform (VM-Ware).

1. BACKGROUND

The department National Ground Segment of DFD, situated in Neustrelitz, in the federal state of Mecklenburg - Western Pomerania, handles the reception, processing, distribution and long term archiving of payload data for a multitude of satellite missions. The work is carried out as part of the German space program or on behalf of private industry, and in cooperation with international space agencies. The range of activities were continuously expanded and further developed over more than 45 years of ground station operations. The relevant experience covers all parts of the service cycle from interface definition and implementation, to near real time data reception and operational near real time processing, product generation and dissemination.

2. COPERNICUS MISSION SENTINEL-1

Sentinel-1A launched at 3rd April 2014 is one of the two European Copernicus satellites armed with a C-band Synthetic Aperture Radar (SAR). It follows the missions ERS 1, ERS 2 and later ENVISAT ASAR and acquires comparable radar images. Sentinel-1B will be launched in early 2016. All Sentinel-1 products are available free of charge for commercial and scientific use.

The Sentinel-1 SAR instrument payload provides four acquisition modes enabling global imaging for a wide range of applications. Following resolutions and swath widths, as shown in Figure 1, are possible [2]:

- Strip Map Mode: 80 km swath width, 5 x 5 m spatial resolution
- Interferometric Wide Swath: 250 km swath width, 5 x 20 m spatial resolution
- Extra-Wide Swath Mode: 400 km swath width, 25 x 100 m spatial resolution
- Wave-Mode: 20 km x 20 km, 5 x 20 m spatial resolution

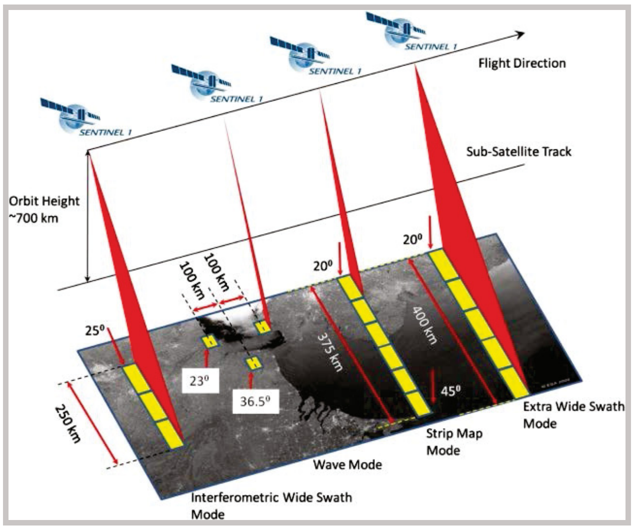

FIGURE 1. Sentinel-1 imaging modes [2]

The polarization depends on the mode and the task of image acqusition. Single and dual pole polarization products will be available according to the mission acquisition plan considering the users needs. For example, dual polarization is useful for sea-ice classification.

The mission acquisition plan is in principle static for a certain period. The instrument operation mode is planned for specific regions in advance and ends up in an observation plan which can change from cycle to cycle. Over Europe in general the Interferometric Wide Swath (IW) mode with dual polarization VV-VH is active. For now the repeat cycle is 12 days, and will be reduced to 6 days later on when the constellation of both satellites Sentinel-1A and 1B becomes operational.

All payload data are downlinked to one of the three core ground stations (CGS) Svalbard, Maspalomas, and Matera, which are part of the Sentinel Core Ground Segment. Additional to the CGSs, the reception of data can be done by so called local ground stations (LGS). They can operate in listening mode, receiving all downlinks of the CGSs, and will be able to receive image data acquired over Europe and transmitted in direct downlink mode for near real time (NRT) processing.

In the Payload Data Ground Segment (PDGS) of Sentinel-1, all products are systematically processed to level 1 (L1) and published on the data hub operated by ESA. The products are available at the data hub as level 0 (L0) and also as L1 in two quality levels: Single Look Complex (SLC) and Ground Range Detected (GRD).

3. COPERNICUS LOCAL GROUND STATION NEUSTRELITZ

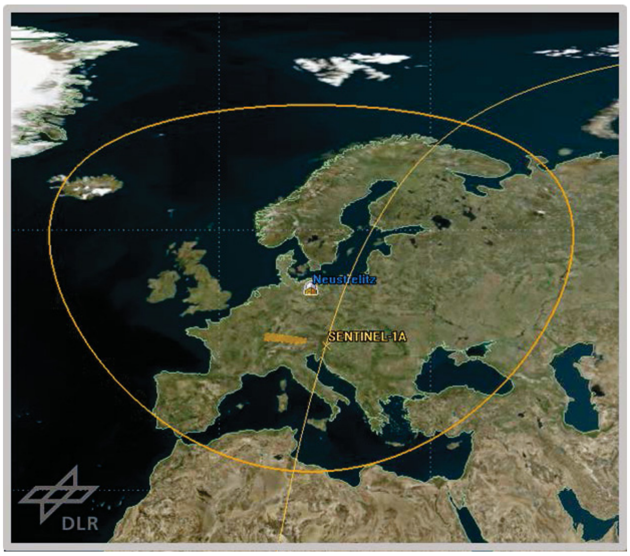

FIGURE 2. Ground Station Neustrelitz, elevation mask for Sentinel-1, 5 degree elevation.

Already in 2013, as an answer to the ESA activity "Collaborative Ground Segment", DFD decided to upgrade the Neustrelitz ground station to a Local Ground Station (LGS) as part of the DLR Copernicus Collaborative Ground Segment. Located in the middle of Europe and also in the reception area of the Sentinel-1 core ground stations, Neustrelitz is very suitable for receiving Sentinel-1 data in direct downlink mode. Figure 2 shows the 5 degree elevation mask of Neustrelitz.

In the Framework of national maritime safety and security projects EMS and EMSec, the preconditions for Sentinel-1 reception, processing, and dissemination are established. A new 11.5 meter antenna system and the processing environment, a VM Ware cluster solution, are purchased. While the processing cluster is already online, the antenna system is under construction and will become operational in spring 2016. The development work is being co-financed by the Federal Ministry of Economic Affairs and Energy and the State of Mecklenburg-Western Pomerania.

In May 2015 the first Sentinel-1A IW dataset was successfully received by one of the antenna systems already in place, processed to level 0 SAFE format and afterwards to a Ground Range Detected (GRD) level 1 product. Figure 3 shows the image slice (218 km x 250 km) acquired by Sentinel-1A at the north-east coast of South Africa at 7th of May 2015 16:29 UTC and received 23 minutes later (16:52 UTC) at the Neustrelitz local ground station.

Figure 1. Sentinel-1 image received and processed at the local ground station Neustrelitz, 7th of May 2015.

The direct downlink mode is not activated on Sentinel-1A yet. Therefore a systematic near real time processing of images acquired over Europe is not possible currently.

3.1. Data Reception

The data reception is realized in general by the Neustrelitz Ground Station Multi-Mission Reception System, which currently consists of three 7.3 meter antenna systems, redundant CORTEX HDR receivers, and Front End Processor (FEP) [1] systems.

The FEP's have been developed at DFD and realizes a number of important functions of the near real-time reception chain e.g. payload data storage, processing of Channel Access Data Units (CADUs), and product generation according to the specific mission requirements.

The system is composed of the Ingestion Unit, to support data ingestion and storage, the Telemetry Processing Unit which supports a wide range of CCSDS standards and is used for the reconstruction of Instrument Source Packets (ISPs) and L0 processing, and the Product Distribution Unit, undertaking the product delivery.

To support the Sentinel-1 mission, the FEP software has been extended by specific mission dependent functions like ISP stream segmentation according the data take borders, data take slicing, and the level 0 (L0), in Standard Archive Format for Europe (SAFE) product generation function. This includes as well the data take assembly for data take constituents, which have been sent over two simultaneous downlink channels. So it was an important achievement to have a sliced and assembled SAFE product ready for distribution and further processing just a few seconds after completion of a data take downlink.

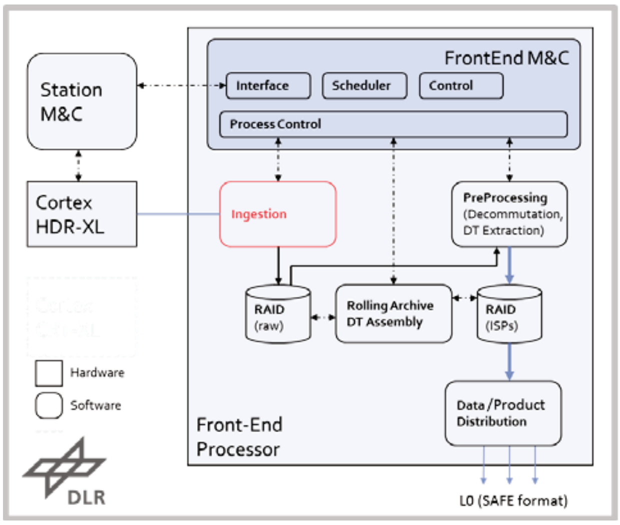

FIGURE 4. Overview Sentinel-1 Front End Processor for L0 generation.

Figure 4 shows the principle FEP layout of hardware and software elements. The Front-End Monitoring & Control module is responsible for the internal control flow between all modules within the FEP as well as the activity control and communication with the Station Monitoring & Control unit, part of the Station Control System at the ground station.

Following the multi-mission operation approach it was more or less easily possible to reuse ground station system components, which are already in place. Once completemented with the new antenna system the LGS Neustrelitz will fulfil all Sentinel ground segment specifications. The already existing X-band antenna systems can be used for data reception at a higher elevation.

3.2. Processing, Archiving and Dissemination

The processing system is implemented based on the DLR/ Werum framework Processing System Management (PSM) which allows a systematic parallel processing and management of earth observation products. The PSM is monitored and controlled with the Operating Tool (OT), part of the Data Information Management (DIMS), which provides a set of views and allows operator interactions. Figure 5 shows the design of the PSM instance.

For the higher level processing a data driven approach is implemented. The processing starts automatically as soon as the L0 product becomes available at the system pickup point, which is part of a Storage Area Network (SAN). The L0 to L1 generation is driven by the original ESA PDGS Instrument Processing Facility (IPF). This processor is developed, licensed and supported directly by MacDonald, Dettwiler and Associates Ltd. (MDA), Canada on behalf of ESA.

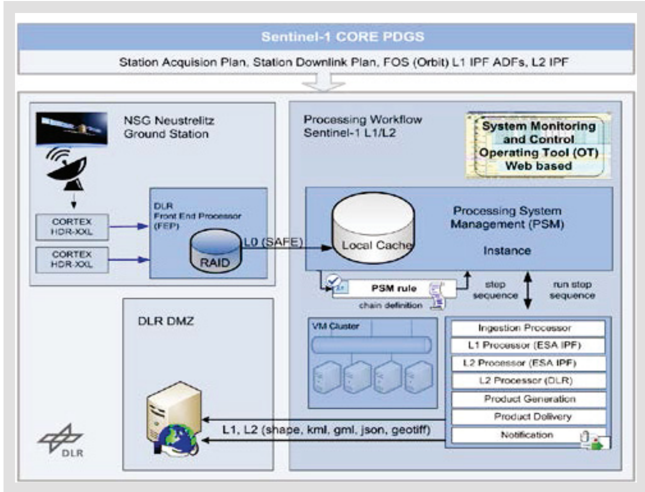

FIGURE 5. Overview Sentinel-1 processing system developed by DLR.

Adding a subscription service to the processing system which allows selecting the processing level (GRD/SLC), the system enables flexibility of processing and dissemination, e.g. additional value adding like ship detection processing or different delivery options. While for the flood mapping application L1 SLC products are required, for the maritime application products in GRD format will be processed, serving as the input for level 2 processing. The implemented solution supports processing of several products in parallel. Further rules are applied to prevent processing the same products twice.

For the maritime domain level 2 (L2) products can be generated by implementing the L2 tasks, licensed by MDA as well. In addition the adaption of DLR value adding processors, developed for the TerraSAR-X PDGS is planned. The core processors provided by the Maritime Safety and Security Lab in Bremen facilitate value adding in terms of ship- and iceberg detection and the generation of wind and wave products enabling the support of services for maritime situational awareness.

Additionally to these value adding chain it is possible to append a hole frame work to the workflow by delivering the subscription outputs directly to a third party processing system pickup point. For near real time applications this in general assumes a processing system located physically in Neustrelitz to reduce latency by the network. As one of the first DLR facilities the Center for Satellite Based Crisis Information (ZKI) installed their flood processing application to generate flood map products for observation of European rivers.

3.3. Hardware Environment

At Neustrelitz an experimental environment of hard- and software components was developed and implemented to check out which constellation fits for near real time processing of Sentinel-1 L1 products. Aim of the ongoing research and development will be to set up a hardware and software concept which will facilitate to deliver L1 products as well as the value added L2 information products within the near real time requirement of 10 minutes.

To run the Sentinel-1 IPF the following hardware is required in minimum:
- Intel Xeon 5680, 3.33 GHz or better, with 2 sockets and 6 cores per socket
- 48 GB of RAM

source : S1-MA-MDA-53-7596 1/0 2015-02-06 [3]

First test on comparable hardware showed a limitation of parallel CPU usage. Running two MDA IPFs processes at the same time on the same machine reduces the number of cores used by each process by the half. For this reason a number of parallel installed virtual machines (VM) which always handles only one IPF task seems to be the best solution. First tests with real physical against virtual machines running in a VMware VSphere solution showed a minimal overhead and only a minimal processing time reduction for the real machines. Another outcome of performance measurements was that the processor frequency is more important for increasing the performance than the number of parallel cores.

For the processing cache solution two shared file system solutions are tested. First GFS 2, as a solution for sharing a lune on a data store, connected via fibre channel to the processing nodes. At the second a CEPH solution sharing local SSDs over all processing nodes. The environmental tests for both solutions are currently not finished therefore the results will be published at a later state of the EMSec project.

4. APPLICATION FOR MARITIME SITUATIONAL AWARENESS

National public authorities and European organizations like the European Maritime Agency (EMSA) are working on solutions to improve the maritime situational awareness in terms of safety and security to protect people, maritime constructions and the environment against catastrophes, e.g. pollution, accidents, illegal activities and so on. Science projects demonstrated already the usability of SAR imagery for these tasks.

As one answer to this requirement, already during the design ESA set high value on the usability of Sentinel-1 products for maritime applications. The availability of the constellation of two satellites (Sentinel-1A and later 1B) will help to support enhanced revisit frequency, coverage, timeliness and reliability for operational services. By using Radarsat-2 and TerraSAR-X/TanDEM-X additional to Sentinel-1 the repeat cycle for a certain ROI will be reduced again.

The adaptation and validation of algorithms, developed for ERS and Envisat ASAR (both C-band SAR) and TerraSAR-X/TanDEM-X (X-band SAR) is currently part of the research at DLR's Maritime Safety and Security Lab in Bremen. The research aims to the operational availability of maritime L2 value adding products.

4.1. Ship Detection

One of the first results of software revision is the ship detection product shown in Figure 7. Figure 6 gives an idea of the coverage of an IW slice taken at 9th of August 2015 17:08 UTC from Sentinel-1A over the German Bight and German/Danish Baltic Sea. Because of the unavailability of direct downlink mode of Sentinel-1A at that time the SAR L1 input data product was downloaded from the ESA data hub [5].

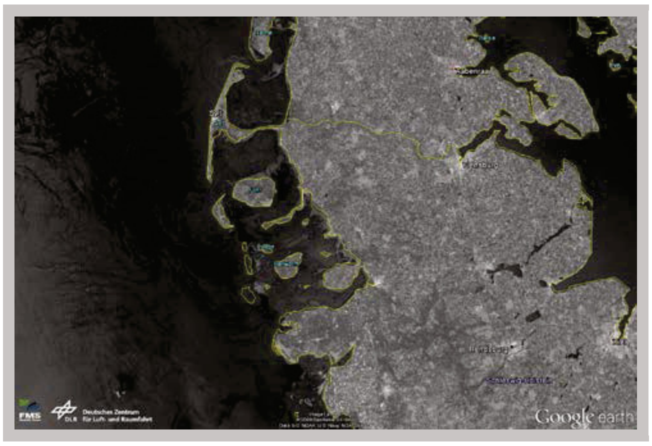

FIGURE 6. German Bight and German/Danish Baltic Sea at 9 th of August 2015 17:08 UTC as seen by Sentinel-1A.

Appling the ship detection value adding chain, composed of the SAR ship detection processor, developed at the Maritime Safety and Security Lab in Bremen [4] and the AIS data fusion processor developed in Neustrelitz, a first satisfactory result becomes available. An open issue concerning the SAR detection algorithm development is e.g. the ambiguity detection. Furthermore the IW tops mode a current research topic, including also the length and width calculation of detected ships.

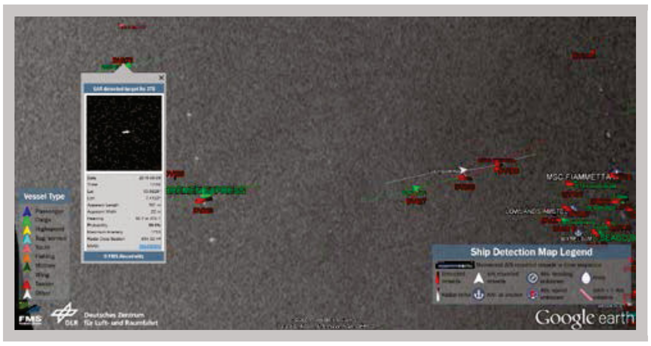

FIGURE 7. Sentinel-1 Ship detection product example (kmz file, and SAR image section, visualized in Google Earth).

5. CONCLUSION AND OUTLOOK

With activation of the Sentinel-1A direct downlink mode over Europe, Neustrelitz LGS will be ready to support near real time L1 processing enabling the integration and operationalization of L2 value adding processing to support maritime situational awareness. The research on the best hardware/software solution is still in progress, algorithm adaptation and validation projects are ongoing.

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