TERRASAR ADVANCEMENTS & NEXT GENERATION-MISSION CAPABILITIES SUPPORTING GMES/ COPERNICUS

Katja Bach [(1)], Thomas Schrage [(1)], Jürgen Janoth [(1)], Marek Tinz[(1)], Christian Thiergan[(1)]

[(1)] Astrium Geo-Information Services, 88039 Friedrichshafen, Germany, Email:katja.bach@astrium.eads.net

ABSTRACT

This paper addresses the continuous evolution of the TerraSAR-X Mission in the context of Copernicus, previously known as GMES. From first data contracts starting in 2009, the TerraSAR-X GMES Contributing Mission (TSX-GCM) has become closely integrated with ESA's Coordinated Data Access System (CDS).
TSX-GCM has continuously been working on improving data access for Copernicus users in response to new requirements on timeliness and data products: The TerraSAR ground station network has been upgraded to include Svalbard as a receiving station, and the product portfolio for TerraSAR-X has been enhanced with two new operational imaging modes, a Staring Spotlight and a Wide ScanSAR Mode.
The planned TerraSAR Next Generation (TerraSAR-NG) System guarantees TerraSAR-X data and service continuity and provides advanced very high-resolution products to the user community. A partnership model, "WorldSAR", is envisioned, where partners can participate through co-investment, subscription, and ownership of additional satellites operated in constellation.

1. INTRODUCTION

The TerraSAR-X satellite was launched in 2007 and started its commercial operations early 2008, representing a large step in commercial Earth Observation, as for the first time Very High Resolution X-band data operationally entered the market. Astrium Geo- Information Services (Infoterra GmbH) owns the exclusive commercial exploitation rights for the TerraSAR-X and TanDEM-X data and services. In 2010, TerraSAR-X was joined by its "twin" satellite TanDEM-X. The two satellites have since been flying in a unique satellite formation, at distances of only a few hundred metres apart. The two satellites actually serve two separate missions: For the TerraSAR-X mission, data is acquired by one or the other satellite, depending on orbit position. For the purpose of the TanDEM-X Mission, they work together in bistatic mode to acquire data for a global homogeneous Digital Elevation Model (TanDEM/WorldDEM), which will be available from 2014 onwards.

2. TerraSAR-X AND GMES/Copernicus

Astrium Geo-Information Services and ESA started their commercial relationship with the first data framework contract for GSC-DA already in 2009. During this Phase 1 and subsequently, in Phase 2 (2011), the TerraSAR-X Mission became a GMES Contributing Mission (GCM) and was integrated as one of the first commercial SAR Missions into ESA's Coordinated Data Access System (CDS). From early 2011 on, a 24/7 service was established, addressing the demanding requirements of GMES Emergency Response Services, and an infrastructure maintenance contract was put in place. Also in 2011, the GMES Data Warehouse contract for the period 2011-2014 was established and subsequently amended to include the use of TerraSAR-X as a recovery option for the loss of Envisat. Currently, the GMES Data Warehouse Contracts including 24/7 and Maintenance are being extended until the end of 2014.

2.1. Interfaces

Part of the ESA Contracts for TSX-GCM were infrastructure developments to interface the TSX-GCM with the CDS. Creating these interfaces was done by way of special updates and careful adaptations of ground infrastructure to create an effective environment for GSCDA while continuing to serve the needs of existing commercial customers outside GSCDA. As a result, a common GSCDA interface to ESA with backbones for different functions based on existing commercial service infrastructure of Astrium Geo-Information Services for TerraSAR-X and the Ground Segment of DLR was put into place.
The required adaptations were done in two phases, with Phase 1 adapting the existing operational TSX services to support GSCDA ordering scenarios and operations and start delivering data by use of human operators.
Phase 2 kicked-off in 2011 and was finalized in 2012 with the provision of electronic interfaces for the purpose of archive browsing and the ordering of archived TerraSAR-X scenes, based on the Heterogeneous Mission Access (HMA) Catalogue and Ordering Service Standards, tailored for TSX-GCM. The automated HMA ordering interface is coupled with the CDS emergency satellite tasking tool GEST.
The HMA Interfaces for TSX-GCM are being used by ESA operationally since August 2013. TSX was the first

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GCM to bring its HMA Catalogue and Browsing interfaces into operational use. These interfaces are expected to further increase operational efficiency of GSCDA Operations on both sides, enabling 24/7 rapid response with much reduced need to interact with customer service.
The recently issued Invitation to Tender for 'CDS 3.0' provides an opportunity for further development of HMA Interfaces for TSX-GCM (Sensor Planning Service and Future Ordering).

3. CONTINUOUS IMPROVEMENTS

3.1. Near Real Time Delivery Capabilities

More and more emphasis has recently been placed on the capability to deliver SAR data in a near-real time fashion, especially from the maritime and emergency response user communities. During an ESA GSCDA Operations Workshop in June 2011, a special session was conducted with GCMs to talk about how the response times could be improved for Copernicus users, resulting in a series of recommendations.
TSX-GCM has been working on providing improved data access to Copernicus users. In this context, the TerraSAR-X ground station network has been upgraded in early 2012 to include Svalbard (SGS) as a receiving station. As Svalbard is located much further north (78 degrees latitude) than the default Receiving Station Neustrelitz (NSG) in Northern Germany, it can receive downlinks from satellites in near-polar orbits such as the TerraSAR-X Mission in almost every orbit, rather than twice a day as the Neustrelitz Station. The data is received at SGS and transferred to NSG for processing and subsequent customer delivery. This significantly shortens the time from acquisition to downlink for most acquisitions, thus improving NRT data access for users.

3.2. New additions to the TerraSAR-X product Portfolio for GMES/Copernicus Users

The product portfolio of TerraSAR-X has been enhanced with two new operational modes, a Wide ScanSAR Mode and a Staring Spotlight Mode.

The Wide ScanSAR (WS) mode was introduced to address demands from the maritime community calling for larger footprints than those of existing TerraSAR-X modes, so that there is increased utility of images for maritime surveillance: ship and oil spill detection and monitoring as well as ice classification.
The existing TerraSAR-X ScanSAR mode combines 4 Stripmap beams to achieve a 100 km wide swath. The new Wide ScanSAR has been implemented as a variation of the existing ScanSAR mode with a reduced azimuth resolution, lower range bandwidth and a 200 km wide swath consisting of 6 specific dedicated wide beams [2]. While a standard scene length is 200 km (29 seconds acquisition time), it is possible with this mode to image continuous strips exceeding 1000 km in length. During processing, the strip is cut into standard scene sizes before delivery.
This mode has become operationally available in August 2013, and in conjunction with the improved NRT delivery capability, it is a valuable asset to the maritime community.

Table 1. TerraSAR-X Wide ScanSAR Characteristics

Polarization Modes	HH or VV or HV or VH
Standard Scene Size (Az.)	200 km
Standard Scene Size (Range)	Up to 270 km
Ground Range Resolution	40 m
Azimuth Resolution	40 m
Pixel Spacing	15 m
Geometric Projection	MGD, GEC, EEC
Incidence Angle Range	15.6 to 49 degrees

The new Staring Spotlight Mode (ST) was designed having the highest possible resolution in mind.
The existing TSX Spotlight mode uses phased array beam steering in azimuth direction to increase the illumination time. This results in a higher azimuth resolution at the expense of the scene size in azimuth direction. With the Staring Spotlight mode, the antenna footprint rests on the scene and the scene length corresponds to the length of the antenna footprint [2].

Table 2. TerraSAR-X Staring Spotlight Characteristics [2].

Polarization Modes	HH or VV
Standard Scene Size (Az.)	2.5 to 3.7 km
Standard Scene Size (Range)	4.0 to 7.5 km
Spatial Resolution (Slant Range)	0.6 m x 0.24 m
Spatial Resolution (Ground Range)	0.9 m x 0.45 m
Geometric Projection	MGD, GEC, EEC, SSC
Incidence Angle Range	20 to 45 degrees

Staring Spotlight is currently in the final stages of implementation and testing and will be operationally available in November 2013. The new product will allow recognition and identification of much smaller objects than with the existing Spotlight Mode. Upon its operational release, it will be the mode with the highest resolution available of all existing commercial SAR missions.

4. THE GERMAN SAR ROADMAP

4.1. TSX- PAZ Constellation

The PAZ (Spanish for "peace") satellite will be launched in 2014 into the same orbit as the TerraSAR-X Mission. PAZ is a dual-use mission designed to meet operational requirements, mainly of a defence and security nature but also with high-resolution civil applications.

Astrium GEO-Information Services is now working with Hisdesat, the Spanish operator of the PAZ radar satellite to establish a constellation approach with TerraSAR-X and PAZ. Operating the virtually identical satellites as a constellation will enhance a wide range of time-critical and data-intensive applications through shorter revisit times and increased data acquisition capacities.

With the TSX-PAZ Constellation, independent missions are working together for the benefit of users. The ground segment of each mission is operated independently while the commercial service segments of both missions are interconnected to provide combined product ordering and delivery. Rather than contacting each vendor separately, the customer interfaces with either Astrium Geo or Hisdesat to order data from both missions.

There is a single product portfolio with dedicated 'constellation modes' for both missions, enabling users to seamlessly combine data from both missions, e.g. for the purpose of generating InSAR stacks. During the ordering process, it is transparent to the user which of the missions will acquire the images (either TSX or PAZ).

Delivery of data is performed to the customer using the delivery mechanisms established for the respective mission. A joint pricing strategy will be established, and invoicing for data from both missions is done by the partner that was approached by the user.

By way of this constellation, the time from acquisition to delivery is significantly reduced for time-critical applications requiring rapid tasking, as the tasking is done by the mission that has 'first access' over an area of interest.

The commercial ground segments of both missions will be connected by way of electronic interfaces for data ordering, and the customer service teams of both organizations will cross train each other. For Direct Access Customers (meaning Customers with their own receiving stations) upgrades to their existing stations are available to receive and process data from both missions. This initial constellation will be operational in 2014 and paves the way towards TerraSAR-X Next Generation and ultimately, the WorldSAR Constellation.

4.2. TerraSAR- Next Generation

A second generation X-Band SAR satellite is the next step in the TerraSAR-X roadmap: With this new mission, data continuity is guaranteed through dedicated heritage modes that provide the same performance characteristics as the current TerraSAR-X. In addition, the TerraSAR-NG Mission (TSX-NG) will benefit from an advanced SAR sensor technology allowing a spatial resolution of up to 0.25 meter, and featuring new TOPS (Terrain Observation by Progressive Scan) modes that support large area applications such as vessel detection and oil slick monitoring. It will provide improved overall system responsiveness and service capabilities through the utilization of a network of Direct Access Stations also including near polar Ground Stations for satellite commanding and data reception. The Mission itself and potential extensions will be subject to a partnership model, "WorldSAR", in which partners can participate through co-investment, subscription, and ownership of additional satellites operated in constellation.

4.3. TerraSAR-NG Overview

The Space Segment is initially based on a single spacecraft (TSX-NG) to be launched in a low-Earth orbit while the TerraSAR-X/TanDEM-X satellites and the TSX-PAZ Constellation are still operational, thus providing the opportunity for a constellation with existing as well as new satellites operated by partners in the WorldSAR context. As secondary payload, an AIS receiver will complement the SAR Mission in order to extend ship detection capabilities based on SAR imagery.

The ground segment will consist of a core ground infrastructure and a network of main and external Telemetry, Tracking & Control and reception stations. To improve overall responsiveness, polar stations, reception services provided by Direct Access Partners and a corresponding high bandwidth network are envisaged. In addition, TerraSAR-NG will provide TerraSAR-X heritage products allowing for continuation of existing data stacks and interferometric applications [3].

The TerraSAR-NG commercial Service Segment will provide the information service, ordering and delivery service to the customers. As interoperability with the on-going TerraSAR-X mission is a driving mission requirement, the TerraSAR-X NG mission will provide seamless access to TerraSAR-X, PAZ and TerraSAR-X NG data.

4.4. WorldSAR Constellation

Lessons learned from more than six years of operating space-based commercial Synthetic Aperture Radar (SAR) systems incorporating user and stakeholder feedback have led to the TerraSAR-X NG based constellation concept known as "WorldSAR" [5]. The objective of WorldSAR is to provide Near Real Time (NRT) remote sensing information on a global scale. This will be accomplished through a network of three to five TerraSAR-X NG-type satellites operated by entities in regulated allied partner nations. WorldSAR is a SAR satellite constellation with NRT data access supported by a high-speed workflow/processing capability, providing end-users with high resolution SAR data under a concept of operations that allows for quick mission response and access to all participating satellites of the constellation. In contrast to a

constellation, owned and operated by a single mission operator, who bares all risks, the collaborative approach of a coordinated constellation concept (CCC) entails the sharing of risks and benefits between partners, each of whom owns and operates a part (WorldSAR Component) of the constellation.

5. REFERENCES

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