Data Handling and Preservation for the TanDEM-X Satellite Mission

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ABSTRACT

The main purpose of TanDEM-X – a German SAR (Synthetic Aperture Radar) interferometric satellite mission – is to produce a world-wide consistent and reliable digital elevation model (DEM) with accuracy to the HRTI-3 (High-Resolution Terrain Information) specifications. To reach this goal, the existing TerraSAR-X Mission will be extended by a second radar satellite, which is almost similar to the already flying one. A world-wide network of receiving stations is necessary to downlink the acquired SAR-data with a volume of 350 TB in two and a half year. In addition, also the Payload Ground Segment must be updated to manage the new workflows and the high amount of data up to 2000 TB to produce the global DEM with a volume of approximately 15 TB.

Keywords: TanDEM-X, TerraSAR-X, DIMS, global DEM

INTRODUCTION

This paper describes the necessary supplement of the operational TerraSAR-X mission to the future TanDEM-X (TerraSAR add-on for Digital Elevation Measurements) mission. The main focus is the data handling and preservation.

The German TerraSAR-X mission serves two main objectives, the provision of the scientific community with high-quality, multi-mode X-band SAR data for scientific research and applications and the support for the introduction of a commercial EO-market and development of a sustainable EO-service business[1], based on TerraSAR-X derived information products. The coverage of the complete TerraSAR-X mission can be seen as the whole of individually submitted user orders from science and commercial users.

In contrast, the primary purpose of the TanDEM-X mission – a national SAR interferometric satellite mission - is the production of a global authentic and consistent digital elevation model (DEM) with accuracy at minimum to HRTI-3, partially also in HRTI-4[2]. Therefore, the TerraSAR-X mission will be extended by a second almost similar satellite, whose launch is planned at end of 2009. These two satellites will fly in a close formation for at least two and a half year in operational mode. During this period, every point of the land surface should be acquired two times at minimum. The basis therefore is a systematically generated acquisition plan.

To provide the new requirements, the existing TerraSAR-X Payload Ground Segment (PGS) must be extended by handling the new workflows as well as by managing the high volumes of data. During the

[1] Covered by the Infoterra GmbH, a private partner
[2] HRTI-3 : spatial resolution : 12 m x 12 m; absolute vertical accuracy (90%) : < 10 m; relative vertical accuracy (point-to-point in 1° cell, 90%) : < 2 m
HRTI-4 : spatial resolution : 6 m x 6 m; absolute vertical accuracy (90%) : < 5 m; relative vertical accuracy (point-to-point in 1° cell, 90%) : < 0.8 m

two and a half year minimum operational mission time, up to 2000 TB SAR-data and intermediate products will be generated, but the final global DEM will have just a volume of approximately 15 TB.

OVERVIEW ABOUT THE TERRASAR-X AND TANDEM-X MISSIONS

The TerraSAR-X mission is operational since July 2007 and provides user ordered – commercial and scientific - high-quality, multi-mode X-band SAR data and derived products (for information about the mission, see [1]). The characteristic of this mission is the planning, processing and delivery of the future acquisitions from individual user requests.

In contrast, the TanDEM-X mission will perform the necessary acquisitions by a systematically generated plan (Exception: The reacquisition of data with not satisfactory quality must be done as soon as possible.). This leads to a continuous data stream which must be systematically received, processed and archived by the new, fully data-driven TanDEM-X workflows.

To support the goals of both missions, the TerraSAR-X mission will be extended by a second TerraSAR-X like satellite. These two satellites will be available for both missions. For this reason it was necessary to update the existing TerraSAR-X PGS services and workflows to provide a request and data handling for multiple satellites and to additionally extend the PGS to support the new TanDEM-X mission workflows.

The major tasks of the Payload Ground Segment for the combined missions are:

- Data Reception and Archiving
- Basic Product Generation
- Product Delivery and User Services

The Existing Operational PGS based on DIMS Service

The TerraSAR-X PGS software is based on the Data Information and Management System (DIMS), the multi-mission data handling infrastructure of the German Remote Sensing Data Center (DFD) at the German Aerospace Center (DLR). DIMS is a modular service-oriented multi-mission infrastructure that supports various tasks of digital product handling in a payload ground segment facility [2].

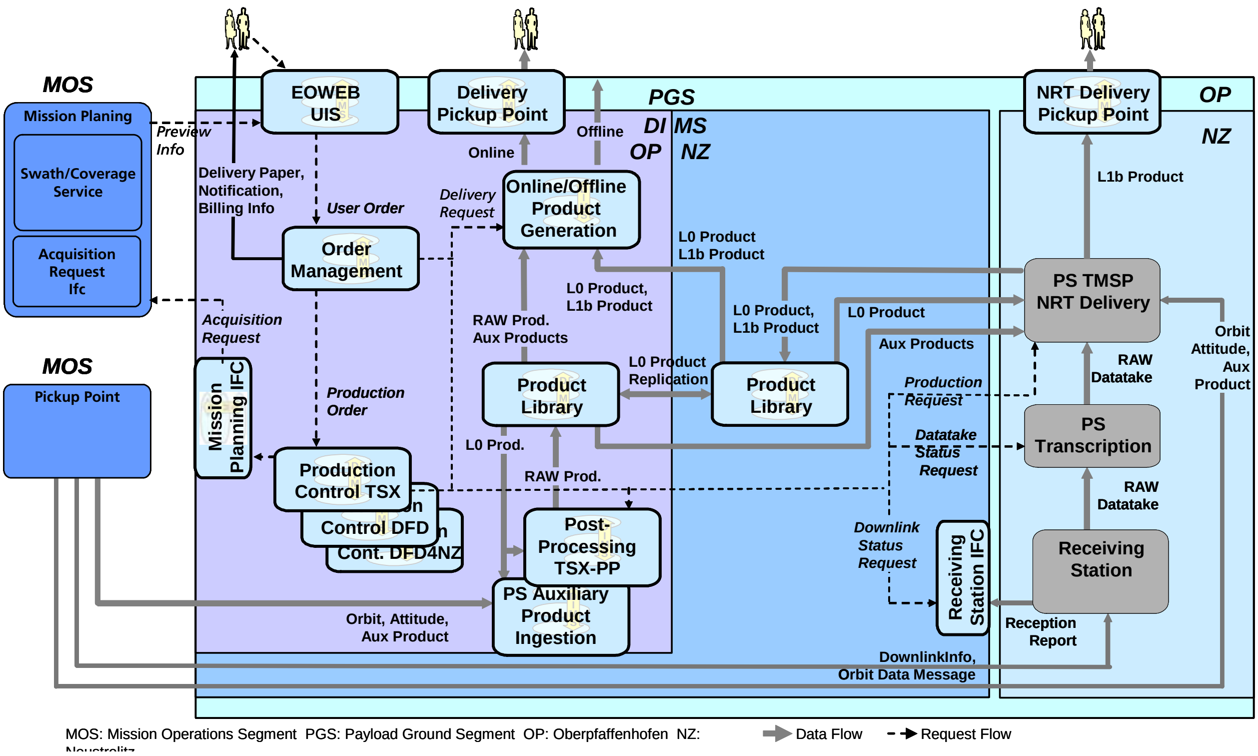

Figure 1: Operational TerraSAR-X PGS

The DIMS services are strictly decoupled according to the main functionalities for user services (e.g. EOWEB), order handling, production control, processing control and product inventory and arching. The services are scalable and can be plugged together within a distributed service network according to the required request and data flows. For TerraSAR-X it supports the PGS scenarios over two sites, Oberpfaffenhofen and Neustrelitz. Receiving, data processing and the short term archiving is done in Neustrelitz, the user services, order handling, production control, product delivery and the long term archive is provided in Oberpfaffenhofen (see Figure 1: Operational TerraSAR-X PGS).

The TerraSAR-X PGS is operational since July 2007 and has already processed about more than 60000 orders resulting in more than 76.500 TerraSAR-X products with a total amount of more than 55 TB[3]

Extension of the TerrSAR-X PGS for the TanDEM-X Satellite and Mission

The already existing PGS for TerraSAR-X was extended to support the challenges of the joined missions TerraSAR-X and TanDEM-X. It supports the request workflow and the SAR data workflow handling of future acquisitions and catalogue orders. Most of the updates for the TerraSAR-X workflows could be handled by simple configuration changes or simple exchanges of service plug-ins 0.

The existing TerraSAR-X user interface service EOWEB is used to provide a catalogue ordering and product distribution service for the resulting TanDEM-X products. The underlying DIMS services provide these features adding TanDEM-X specific configurations.

Due to the fact that the TanDEM-X acquisition request workflows and data processing scenarios are systematically and data driven and therefore quite different to the TerraSAR-X workflows, the TanDEM-X workflows are implemented using the scalability of the DIMS services production control (pc) and processing systems (ps). This approach combines the advantage that the complex TanDEM application logic is decoupled from the TerraSAR-X application logic with the advantage using the general production and processing system features of the DIMS services.

In the context of TanDEM-X, there are three kinds of workflows with different demands on the PGS:

- Acquisition Request Workflow
- SAR-data Workflow
- DEM-Generation

The TanDEM-X PGS is located in Oberpfaffenhofen. Figure 2: shows the involved DIMS services. For an improved survey, the services used only by TerraSAR-X are omitted.

The TanDEM-X Acquisition Request Workflow

The basis for the TanDEM-X mission is a pre-planned acquisition time line. This plan is optimized regarding to satellite resources (e.g. energy, thermal conditions, data cache...), downlink capacity and earth surface.

To reach the mission goal, it is necessary to record the surface at least twice – over difficult terrain more often. The second acquisition should be one year after the first one.
Because of the drift of the two satellites, there exists only one optimum satellite constellation for the recording of the data of a special surface point in every acquisition phase. In case of a bad or failed acquisition, a quick quality feedback allows a reacquisition of the datatakes near the optimum satellite constellation. The information is available as meta data of the rawData – also referred to as L0 products - in the Product Library (PL), from where the responsible service – PC-TDM-ACQ – can enquire it. The feedback mechanism is described in the chapter “Quality Feedback”.

[3] In the Neustrelitz Product Library (L0 products : 42.000; L1b products : 34.500); all values from August 2009

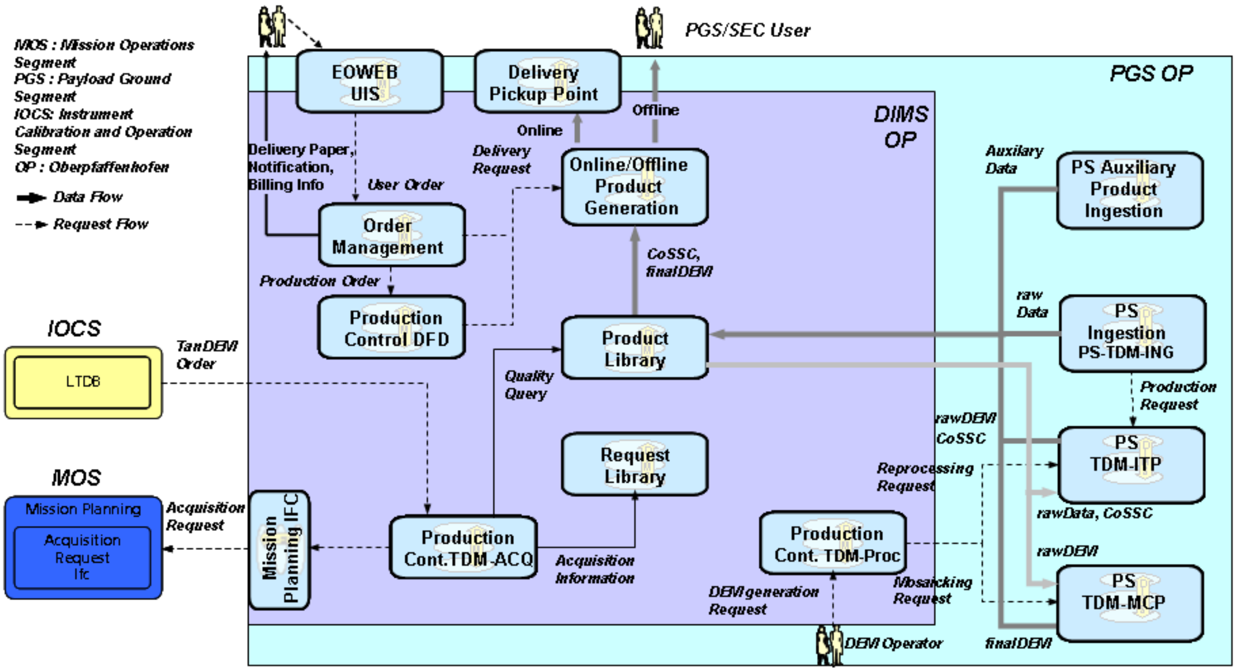

Figure 2: TanDEM-X PGS (without services used only by TerraSAR-X)

SAR-data Workflow

Due to the fact that the satellites will downlink the data at different ground stations – also partial downlinks are possible – and different transfer times to the processing facility in Oberpfaffenhofen, the ingestion system PS-TDM-ING must calculate the completeness of the joint acquisition. The fully data-driven SAR-data processing workflow will not be started till the completeness of the mass data. Also the quality must be sufficient. But the main task of PS-TDM-ING is the ingestion of the L0-data into the DIMS PL – the central archive.

The ingestion system triggers the processing system for the Integrated TanDEM Processor (PS-TDM-ITP). The ITP divides the acquisition items into scenes. For every scene, a CoSSC[4] will be processed using the L0-data and the already existing CoSSCs with the same spatial coverage. The CoSSC and the resulting rawDEM will be stored in the PL. The reason for the storage of these intermediate products – at the expense of high data volumes (for the operational time of two and a half years approximately 1600 TB are expected) – is the time consuming processing.

DEM Generation

In opposition to the acquisition-scene based processing of the intermediate products, the preparation of the final DEM product is a region-based task.

An operator searches for regions which are promising for the processing of DEM-tiles[5] in the required accuracy. To support the operator, reports based on expected acquisitions and existing rawDEMs and their quality will be generated on a daily basis. A production control (PC-TDM-Proc) organizes, if necessary, the reprocessing of rawDEMs by the ITP. Afterwards, the Mosaicking and Calibration Processor (MCP) will be requested with the processing of the DEM tiles of the selected area using the stored rawDEMs. The final products also will be stored in the DIMS PL. Using the existing DIMS services the DEM will be available in the EOWEB catalogue.

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[4] Coregistered Single Look Slant Range Complex

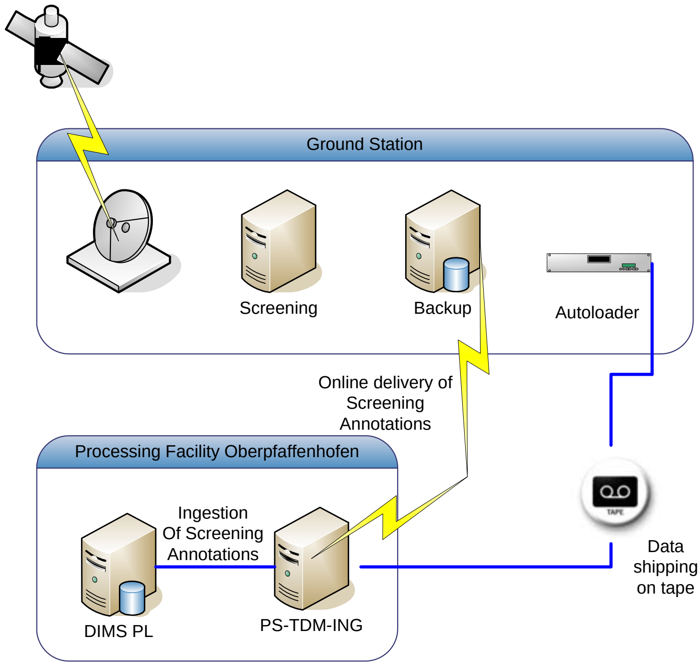
[5] A DEM tile has usually the size of 1°x1° at the equator and 1°x4° at the Polar Regions.

GROUNDSTATION NETWORK

Due to high data rates – 350 TB are expected in two and a half years operational mission – of both satellite radar sensors a highly distributed network of receiving stations is needed. Data takes from different satellites have to be downlinked to different locations around the world. Furthermore a single datatake of one satellite can be downlinked in several fragments for optimal usage of downlink capacity. Every downlinked data fragment is identified by the satellite, which has performed the datatake, the fragment-number within the datatake and a unique identifier for a joint acquisition.

Quality Feedback

Afore mentioned facts and the need of a fast quality feedback to reacquire failed cooperative acquisitions as fast as possible result in the following concept:



Every ground station has to be equipped to act as a small processing facility. On every ground station a quality parameter extraction is performed. The result of this on-site-screening is called “quality annotation”. Every quality annotation is immediately sent online to the main processing facility in Oberpfaffenhofen. Here the data is ingested into DIMS Product Library (PL) by the Processing System for TanDEM-X data ingestion (PS-TDM-ING).

The PL contains a structure for TanDEM-X datatakes. Every unique item corresponds with a single datatake of one single satellite. The Ingestion System adds all the annotations belonging to the datatake as a component to this item and also calculates the completeness status. After two datatakes of a joint acquisition are complete regarding their annotations, PS-TDM-ING triggers an interferrometric quality pre-check (IQPC) which evaluates the common pointing of both satellites, synchronization of sensors etc. If the IQPCs result is negative the joint acquisition has to be repeated.

Raw Data Safety

Raw data received at the ground stations of the ground station network can, due to high data volume, not be transferred online to the TanDEM-X main processing facility. So the data is stored on magnetic tapes and has to be shipped physically to Oberpfaffenhofen. Since the data media have a long way to travel, a backup has to be kept at the ground station until the data has reached the main processing facility safely. Therefore the ground stations are equipped with a small auto loader which can guarantee the safety of downlinks for at least three months.

DATA ARCHIVING AND TRANSFER IN THE PGS

Currently the National Remote Sensing Data Library consists of two media robots, which handle two different media types. SUN Storagetek 9940B and IBM LTO3 with capacities of 200 and 400 Gigabytes are used. The hierarchical storage management software used to handle the current amount of 230 Terabytes of product data is SAM-FS. Less than 3 TB of disk cache is used for 30 projects with each of them resembling one file system in the HSM.

The coming TANDEM-X mission alone will be responsible for more than 2000 TB of new data within three years – including a half year commission phase. To accommodate this, it will be necessary to group the data by its processing level into different file systems. Examples are raw satellite data, intermediate files and finished products ready for delivery. The processing systems are relying on a complete spatial coverage to compute the elevation model for a given region but the satellites can only record relatively short stripes during each orbit. Yet more important is the fact that the receiving stations are spread around the globe too. They rely on an off-line delivery of data tapes via plane or ship for example from Antarctica. Therefore the datatakes for a special region are stored in the archive over a time of several weeks. To speed up the following processing, some of these files have to be kept on-line for several weeks leading to a total cache size required by this mission of 40 TB.

Another challenge is the high data volume with has to be transferred between the archive and the several processing systems. The peak load will be reached during the second acquisition phase with L0 ingestion, CoSSC and rawDEM (re-) processing, DEM generation and product delivery (see Table 1: for detailed information).

Communication between Archive Server and …	Phase 1 (first acquisition)	Phase 2 (additional acquisitions)	Phase 3 (no further acquisition)
PS-TDM-ING	0.32 (1.0)	0.32 (1.0)	--
PS-TDM-ITP	1.68	4.21	1.28
PS-ITM-MCP	2.44	3.46	3.46
Product Delivery	0.5	1.5	1.5
Total	4.94 (5.62)	9.49 (10.17)	6.24

Table 1: Expected Data Transfer Rates between the Archive Server and the Processing Systems/ Product Delivery Service (OPG) in TB/d (Peak Loads in Brackets)

The current network architecture at the DFD is based on 1 GBit Ethernet. Due to its flexibility, widespread utilization and cost-effectiveness, it is ideal for the most common use cases. However, Ethernet has many limitations too. These include unpredictable latency and packet drops when the network traffic increases. Therefore only a part of the actual bandwidth is usable for the data payload which even decreases more as the throughput rises.

For the TanDEM-X mission, exclusive data rates up to 10 TB/d (116 MB/sec) are expected. That's why even 10 Gb/s Ethernet, due to it's unreliability, was not considered an option. The alternatives are Infini-band and IP over Fiber Channel. Both protocols are specialized in transferring huge amounts of data with high data rates of 4 to 40 Gb/s.

Since Infiniband is based on copper wires and the in-house infrastructure is based on fiber optics, only IP over Fiber Channel is suitable to be used to connect the different processing-systems (PS-TDM-ING, PS-TDM-ITP and PS-TDM-MPC) with the archive server. Over this new “private” network, most of the data volume will be transferred without interfere with the ongoing missions. The requests will be sent still over the existing Ethernet. Also the Product Delivery Service remains in the Ethernet network.

CONCLUSION

The TanDEM-X mission has various challenges: a high data volume of raw data and of immediate products, narrow time frame, distributed downlinks of belonging together data and an operational TerraSAR-X mission.

By decoupling the specific TanDEM services from the existing TerraSAR-X PGS, the operational TerraSAR-X mission will not be disturbed. Using a world-wide network of ground stations allows the receiving of the acquired data volumes. Due to the fact of off-line delivery of the received rawData and the necessary of a fast reacquisition in case of failed datatakes, a quality feedback is required.

Fragments of rawData, which are part of the combined datatakes, must be identified from the ingestion system, which triggers in case of completeness the processing of the intermediate products, a scene based task. In contrast, the production of the final DEM bases on regions.

The high data volumes requires an archive organization for the different products, a cache enhancement up to 40 TB and a “private” fiber channel network between the processing systems and the archive server to relieve the existing communication subnet.

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ACKNOWLEDGEMENT

The TanDEM-X project is partly funded by the German Federal Ministry for Economics and Technology (Förderkennzeichen 50 EE 0601).

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Sven graduated from the University of Hamburg, Germany in 2002 with a Diploma in computer science with a major in qualitative spatial knowledge. During his time as research assistant at the University of Konstanz, Germany (2003-2005) he was engaged in knowledge management and collaborative e-learning. Since 2005 Sven works at the German Remote Sensing Data Center, DLR-DFD, department IT.Among the evolution of the DIMS Operating Tool Sven is DIMS system engineer of the TanDEM-X project.

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Max gained his diploma in Computer Science at the “Technische Universität München”in 2006 with a major in Applied Computer Science and a minor in Economy. During the course of his studies he was working for a small IT-company – Jalogo! GmbH – where he was responsible for Key Account Management, Software Engineering and Support. Since 2006 Max is working for the International Ground Segment division of the German Remote Sensing Data Center, DLR-DFD-BI. Here he holds several projects roles in the TanDEM-X project.

Max Wegner

In 2004 Max graduated in Information Technology as B.Sc. at the University of Cooperative Education in Mannheim. He majored in Network and Software Technology. During that time, Max worked for the DLR Institute of Aerodynamics and Flow Technology. In 2005 he changed to the German Remote Sensing Data Center's (DFD) IT department and became a member of the operating team where he's responsible for the central archive. From 2009 on, Max is studying Systems Engineering (MSE) at the University of Applied Sciences in Munich in part-time.

Meinhard Wolfmüller

Meinhard Wolfmüller received the Dipl.Ing. degree in electrical engineering from the University of Applied Sciences in Karlsruhe, Germany, in 1984. For further education, he studies computer science on the University in Hagen, Germany.

From 1984 to 1989, he was development engineer for measurement value logging equipments and engine simulators on MTU, a company for the development of airborne engines and turbines. Since 1989 he is with the German Remote Sensing Data Center (DFD), German Aerospace Center (DLR), From 1989 to 1993 he was development engineer for the development of a Ground Support Program Equipment (GSPE) for Anthrorack used during the German D2 Mission. Since 1996 he developed several components of a data processor for the Global Ozone Monitoring Experiment (GOME) onboard the ERS-2 satellite. From 1996 to 2002 he was jointly responsible for the design, development and integration of a new Data and Information Management System (DIMS) for earth observation products. Since 2002 he is system engineer in charge to extend and integrate the multi-mission Data and Information Management System DIMS for the TerraSAR-X Payload Ground Segment .