THE TANDEM-X MISSION - TOWARDS A GLOBAL DIGITAL ELEVATION MODEL FOUR YEARS OF EXPERIENCE IN LARGE VOLUME DATA MANAGEMENT

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ABSTRACT

This article provides a short overview about the TanDEM-X mission, its objectives and the payload ground segment (PGS) based on data management, processing systems and long term archive. Due to the large data volume of the acquired and processed products a main challenge in the operation of the PGS is to handle the required data throughput, which is a new dimension for the DLR PGS. To achieve this requirement, several solutions were developed and coordinated. Some of them were more technical nature whereas others optimized the workflows.

Index Terms— data management, Earth observation, TanDEM-X, payload ground segment

1. THE TANDEM-X MISSION

The main objective of the German spaceborne radar mission TanDEM-X (TerraSAR-X-Add-on for Digital Elevation Measurements) is to generate a consistent, global, high resolution digital elevation model (DEM) of the world's land mass. Flown in close formation, two X-band synthetic aperture radar sensors will provide the input data for generating the DEM by means of radar interferometry. The TanDEM-X configuration consists of the TerraSAR-X satellite, launched in 2007 and its twin brother launched in 2010. Data acquisition for the global DEM started in December 2010 and was largely concluded by August 2014. Depending on land cover and topographic conditions two to four (sometimes even more) local coverages were required to match HRTI-3 specification[1].

As of July 2014, 374 terabytes (TB) of acquired L0 data have been processed to 2200 TB of intermediate products for the final production of the global DEM. 95% of the global DEM coverage should be available by the end of 2015.

[1] HRTI-3: relative vertical accuracy 2 m (90% linear point-to-point error), absolute vertical accuracy 10 m (90% linear error), absolute horizontal accuracy 10 m (90% circular error), post spacing 12 m x 12 m

2. THE TANDEM-X PAYLOAD GROUND SEGMENT

Similar to the TerraSAR-X mission, the TanDEM-X payload ground segment (PGS) was developed and is being operated by the German Remote Sensing Data Center of the German Aerospace Center (DLR), using parts of the multi-mission PGS infrastructure available within the German Satellite Data Archive (D-SDA).

The basic architecture consists of the following components:

- data management
- processing systems
- long term archive

Data management is based on the Data and Information Management System (DIMS), a modular multi-mission software suite, developed in-house in collaboration with an industrial partner [1]. A central part of DIMS is the Product Library (PL) which is responsible for the cataloguing, archiving and long term preservation of all TanDEM-X data products.

The processing is performed by two different processors – the Integrated TanDEM-X Processor (ITP) and the Mosaicking and Calibration Processor (MCP). The ITP combines bistatic SAR processing, interferometric processing, and the generation of (intermediate) digital elevation models from the differential phase information [2]. The MCP calibrates the intermediate elevation products produced by the ITP. The calibrated products will be merged in a further processing task to generate the mosaicked final DEM [3].

The design of the PGS based on the requirements of the TanDEM-X mission and past experience. The high throughput requirements (up to 5,3 TB/d from the archive to the processing systems and 1,4 TB/d in reverse direction) of the systematic interferometric radar processing chains added a new dimension to the DLR PGS infrastructure, calling for adequate solutions, in particular for data archiving, access and transfer.

For example, it was necessary to enhance the multi-mission infrastructure by a separated network which connects the processing systems and the archive including the storage cache separately.

Because of the scientific character of the mission and the operational experience the PGS scenarios changed during the operational phase. So, it was also necessary to optimize procedures and performance during the operational phase.

Also a monitoring was established to detect problems in the PGS and to evaluate the results of taken actions.

3. CHALLENGES AND SOLUTIONS

A characteristic of the TanDEM-X mission is that there are different processing phases. The processing of the acquired L0 data (first coverage) to intermediate products was the performed in the first phase. During the second phase, further acquired L0 data become processed using the intermediate products of the previous runs. Also, the production of final products was started. Thus, the second phase is the most demanding one. In the third phase no more L0 data will be acquired.

The following sections describe some challenges and their solutions in the TanDEM-X PGS.

3.1. Reducing the Time to Provide requested Products

One big challenge in the processing chain of the TANDEM-X mission consisted in the retrieval of products from the long term data archive. While the ingestion of newly processed products into the archive was fast enough, the other way was lagging far behind**.** The Product Library (PL) of the German Satellite Data Archive consists of a metadata catalog and a Hierarchical Storage Management System (HSM). Due to the huge amount of data produced during the mission lifetime, the 75 terabyte of archive storage were maxed out in a matter of days. In the background, the HSM writes two additional copies of the data to magnetic tape and afterwards frees the archive cache again. At first, the HSM system worked fully transparent: requests to retrieve files from the archive were firstly processed by the PL which in turn initiated the file transfer via FTP. Unfortunately, the files were no longer on hard disks any longer and the HSM had to read back the files from the tapes (staging) with the help of tape drives and robotic libraries. File after file, without any optimizations.

The solution was to introduce a better way of data handling by means of a pre-staging for some selected workflows. Several hours before any product retrieval request was triggered, the processing systems summarized their upcoming workload and sent the information to the archive. These systems in turn prepared for the upcoming data retrieval by already staging the needed files from tape to disk in advance. When the processing system actually activated the product retrieval procedure later, the files could directly be transferred by eliminating the substantial amount of tape handling needed otherwise. This procedure proved to be highly affective and unsophisticated enough to be introduced into the official DIMS software later.

3.2. Improving Storage Cache Throughput

In the second phase it became evident that the storage comprising the cache file systems for the used HSM file could, in its preconfigured state, not deliver the required data throughput. In its current state, the storage was able to deliver a peak throughput of 450 MB/s, but only under optimal conditions, which were never met during phases of high activity. Since funding was an issue and the data sheets of the storage promised higher throughput, as could be gained with the current configuration, some researching became necessary. Therefore, the file systems were moved to a spare part of the storage, which made them even slower, but provided the freed capacity for the necessary tests to acquire a faster configuration.In this process it became obvious, that the storage has limitations concerning single raid sets. So e.g. bigger raid sets, although having more rotating hard disks, will not exceed a certain throughput limit and especially will not gain more IOPS (input/output operations per second) from more hard disks. The throughput limit is reached with even a low number of hard disks and will decline with higher raid levels.

The newly developed configuration is - after some more file system moving - able to deliver a maximum of 1.6 GB/s with the same storage. It is comprised of many very small raid sets which are striped together via the HSM file system in the archive server.

3.3. Optimizing Processing System Management

The ITP processing system management handles the provision of input data, resource allocation and communication with the other components of the PGS. During operations of this system several changes were implemented, to improve the overall system performance.

A first analysis of the resource requirements for preparation of processing (this includes retrieval of input data from the long term data archive as well as decompression) and processing the input/output requirements of these two task indicated a high concurrency situation if handled in parallel. Monitoring of resource allocation during operations revealed a significant lower concurrence than expected. This deviation to the expected behavior has especially for tasks with a large amount of input data positive effects. In these cases data preparation represents a significant amount of the combined time.

During the mission several different processing scenarios have to be employed. From the data management view they differ mainly w.r.t. required input data. During operations a reduction of the required input data was indicated on a scientific level. The implementation of an improved input data selection scheme reduced the data required for a processing run considerably.

3.4. Product Library Load Balancing

With this mission, the Product Library is exposed to exceptional data traffic due to the fact that a co-registration of L0 data scenes needs to be completed on large coherent geographic areas before being able to start the generation of the digital elevation model. As described before, these co-registered intermediate products are even larger than the raw data, so they cannot be kept online in the processing cache but have to be archived and retrieved later. This extreme input/output load is even more challenging due to the fact that the Product Library is embedded in the multi-mission PGS environment and needs to equitably serve multiple other processing systems, product uploads to user service/data access systems and deliveries of ordered products to users.

The Product Library handles product transfers through requests e.g. for insertion, retrieval and deletion. Requests are executed in concurrent workflow steps of different types, e.g. the cataloguing of a metadata record or the archiving of all files of one product component. The Product Library resources are limited mainly by the number of concurrent transactions, the archive cache size for different product types (amount of data being staged from tapes) and the number concurrent file transfers within the local network. Maximizing the throughput is not a matter of raising all limits because these have interdependencies.

In order to determine a good configuration for the different concurrency settings, an in depth analysis of the Product Library request and step durations has been performed based on statistics on more than one month of multi-mission operations. This revealed that most time is spent with file transfers, including the staging of data from tapes into the archive cache filesystem. In consequence, the limits for all other concurrent steps have been reduced in favor of the number of concurrent staging steps which have been significantly raised compared to the number of concurrent transfers into the local network. Finally, the Product Library uses priorities for different sessions (e.g. different processing systems both multi-mission and TanDEM-X specific), allowing more concurrent active requests but preventing starvation of low-priority sessions. This is realized through the dynamic computation of limits based on the total concurrency limit and the actual number of active sessions.

In order to react on a changing input/output behavior during different TanDEM-X mission phases, the Product Library request runtime statistic has been repeated several times, leading to new concurrency settings for step types, product types and session priorities.

4. SUMMARY AND CONCLUSIONS

The main lessons learnt from developing and operating the TanDEM-X mission PGS are:

- the subsystems must be balanced as a collective and not only the direct interacting partners
- in addition to the application software also the configuration of used hardware must be optimized (e.g. the used storage)
- the subsystems and there components must be flexible to serve various scenarios and to react to unexpected situations
- system monitoring is necessary to detect dysfunctions in time and to evaluate system changes
- the transfer of products from the long term archive to the processing systems and back is very time consuming. In future, other technics have to be developed.

In conclusion, the TanDEM-X mission set a new standard for systematic, large volume Earth observation data processing. Future missions, such as the Copernicus Sentinel missions, will require even larger amounts of data to be handled – and more flexibility in data access.

5. REFERENCES

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