Replication of Archive Data:
Experiences with the TerraSAR-X Mission

Stephan Kiemle [(1)], Anne-Katrin Schroeder-Lanz [(1)], Marcus Wilkniss [(2)]

[(1)] *German Aerospace Center (DLR)*
German Remote Sensing Data Center (DFD)
Oberpfaffenhofen, D-82234 Weßling, Germany
EMail:Anne-Katrin.Schroeder-Lanz@dlr.de, Stephan.Kiemle@dlr.de

[(2)] *Werum Software & Systems AG*
Wulf-Werum-Strasse 3, D- 21337 Lüneburg, Germany
EMail: Marcus.Wilkniss@werum.de

ABSTRACT

The German Remote Sensing Data Center (DFD) has developed a digital library for the long-term management of earth observation data products. This Product Library is a central part of DFD's multi-mission ground segment Data Information and Management System (DIMS) and has been successfully in operation since 2000 at the DFD sites in Oberpfaffenhofen (near Munich) and Neustrelitz (north of Berlin). Since the launch of the new German earth observation satellite mission TerraSAR-X, the Product Library is responsible for the storage of all mission data at both sites, Neustrelitz being the main receiving and processing facility, and Oberpfaffenhofen being the complete mission long-term archiving site providing the user services. According to mission-specific policies, TerraSAR-X products are automatically replicated from one archiving site to the other. This paper presents the purpose and requirements for distributed archiving sites, the distributed archive functions provided by the DIMS Product Library and the experiences made for implementing and operating data replication for the TerraSAR-X mission.

Keywords: digital library, distributed system, long-term archiving, data replication

INTRODUCTION

As a central component of the Data Information and Management System DIMS, the German Remote Sensing Data Center (DFD) has developed the Product Library for the long-term management of earth observation data products [1]. Within DFD's multi-mission ground segment [2] the Product Library stores acquired raw data that is input for processing chains. It also stores the value added data that is output of processing. This data is uploaded to the online user service system EOWEB[®] [3]. The Product Library's feature set is regularly extended to support requirements of upcoming earth observation missions.

One major extension required by the new TerraSAR-X mission [4] is support for replication of data products. The DFD multi-mission ground segment is distributed over two sites in Germany, Neustrelitz and Oberpfaffenhofen. Both sites operate a distinct Product Library instance. Data reception, initial pre-processing and preliminary storage are handled at the Neustrelitz site. After successful quality assurance products are replicated to the archive in Oberpfaffenhofen for long-term storage. Subsequently product information is propagated to the user interface EOWEB[®] and customer-specific databases to ensure public availability.

In this paper we discuss the purpose of distributed archiving sites for TerraSAR-X, we describe the architectural and design principles of the adopted distribution and replication solution and outline technical challenges during deployment. The paper concludes with an evaluation discussing benefits and operational experiences gathered during the TerraSAR-X commissioning phase.

PURPOSE OF DISTRIBUTED ARCHIVING

Before starting with technical details of distributed archiving, we should explain our decision to realize a complex solution based on systematic data replication. There are other, simpler ways to replicate data between different sites, such as offline replication by exchanging data on medium like DVD and tapes, or database replication. However, these replication methods do not take into account properties of data management in large scale digital libraries, in our case storing hundreds of Terabytes of earth observation data products. The key issue is the consistent handling of product metadata and data with fully automatic data ingestion, replication and access functions.

Before the TerraSAR-X mission, the two DLR archiving centers for earth observation data independently handled data of different missions, mainly because the data were received locally at the two sites. For TerraSAR-X it has been decided to initially store received and processed data in the Neustrelitz archive, running the so called "data driven workflow" which includes the steps reception, transcription, processing and archiving of TerraSAR-X products. This site also ingests all mission data coming from remote Direct Access Stations. But the processed L0/L1b products are only temporarily stored in the local Product Library in Neustrelitz. The products are systematically replicated to the Product Library in Oberpfaffenhofen, this site being the high capacity long-term archiving center. After a certain time period (several months) the products are automatically removed from the Neustrelitz archive, but they remain locally visible and accessible through the Product Library.

Thus, the purpose of distributed archiving can be summarized by the following objectives:
- Local Independence – Locally received or processed data can be stored directly, independently from other archiving sites.
- High Availability and Performance – Local archives always have better availability and performance for data storage and retrieval.
- Data Security and Load Balancing – Distributed archiving sites reduce the risk of total data loss and allow the distribution of data storage and data access requests.
- Separation of Concerns – Different archiving sites typically have different roles, e.g. due to local reception and ingestion facilities or due to physical storage capacity.

The archive usage scenarios of the TerraSAR-X mission are complex. The following section details the requirements for distributed archiving, data replication and transparent data access.

REQUIREMENTS AND SCENARIOS

Distributed Archiving Requirements

The Product Library must fulfill the following main requirements for distributed archiving:
- The local Product Library shall store locally received, ingested and processed data.
- Data products shall be consistently and automatically replicated from one Product Library to another, controlled by a configurable policy.
- The Product Library shall use the shortest way to deliver replicated products, preferring the archiving site which is local to the user/client.
- Replicated data products and temporary products shall be able to expire and be automatically removed, controlled by a configurable policy.

Data replication is a central part of the distributed archiving concept. The specific requirements for data replication are:
- The replication shall start automatically as soon as new products are available.
- The replication shall be configurable in terms of product types, preferred replication times, priorities and targets.
- The replication shall be manually suspendable and resumable.

- It shall be possible to replicate different product components in separate steps, e.g. only metadata and browse with high priority in a first step and primary data in a second step.
- Near real-time replication – The replication of certain product components shall be started as soon as possible to be available for user information systems like EOWEB.
- The replication shall be possible in each direction.
- The replication shall include a consistency verification of the replication status.
- A replication policy configurable per product type shall define if products of the source Product Library should not be deletable until the replication is completed.
- The products shall be visible in the source Product Library, even though replication has already taken place and respective components have been deleted locally.

TerraSAR-X Replication Scenario

The basic replication scenario starts with the insertion of new TerraSAR-X products in the Product Library in Neustrelitz. A product consists of metadata as well as several components like raw data, several browse images, processing logs etc. These products have to be replicated to the Product Library in Oberpfaffenhofen in two steps. In the first step, the metadata and browse images should be replicated as soon as possible to become available for user information systems like EOWEB, allowing external users to search for current products and order derivates.

In the second step, the other components like raw data etc. have to be replicated. The main reason of this step-wise partial replication is the size of the components. The metadata and browse images are small and can be transferred very fast. The big data components will be transferred later.

As soon as products are fully replicated, both Product Libraries are able to deliver the products to subsequent processing systems or to external users. The concept for data access also foresees that before delivery the Product Libraries analyze the location of the client requesting for data and ensure that data is not unnecessarily transferred from one site to the other. This optimization is not yet implemented.

After a certain period of time individually defined for each product, the Product Library in Neustrelitz expires replicated products, removing the product files from the local archive but preserving the metadata. Therefore expired products are still searchable and can be retrieved through the remote archive. Non-replicated products are preserved.

DISTRIBUTED PRODUCT LIBRARY ARCHITECTURE

In view of these required features, the tasks were separated into two core aspects. The first aspect is the management aspect which controls the replication workflow. The management defines what and when should be replicated. This function is handled by a Replication Manager. The second aspect is the underlying data replication which is handled by the Product Libraries themselves.
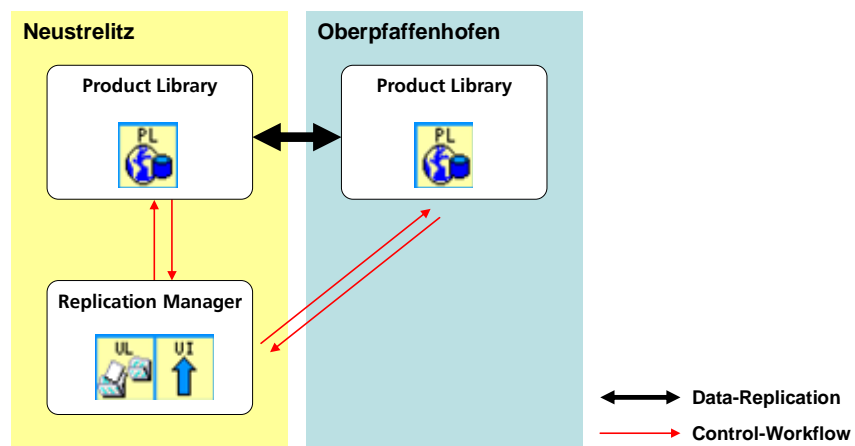

Figure 1: Replication Sites and Components

Replication Manager

The Replication Manager is realized using a component of the Data Information and Management System DIMS called User Information Services Interface UIS. It is an event driven component which uses the subscription mechanism of the Product Library to be informed about new available TerraSAR-X products. If a new product is available, the UIS creates a so called upload request which represents the replication progress. The replication is automatically started, no operator interaction is required. The replication itself is configurable for each product type. The configuration contains several aspects like priorities, partial data replication, preferred replication times and replication targets. Next to these features the UIS additionally supports persistent storage, handling of downtimes and bulk replication of historical data.

The replication workflow comprises several steps. The next figure is a sequence diagram showing the detailed interaction of the Replication Manager with the Product Libraries to replicate a product.
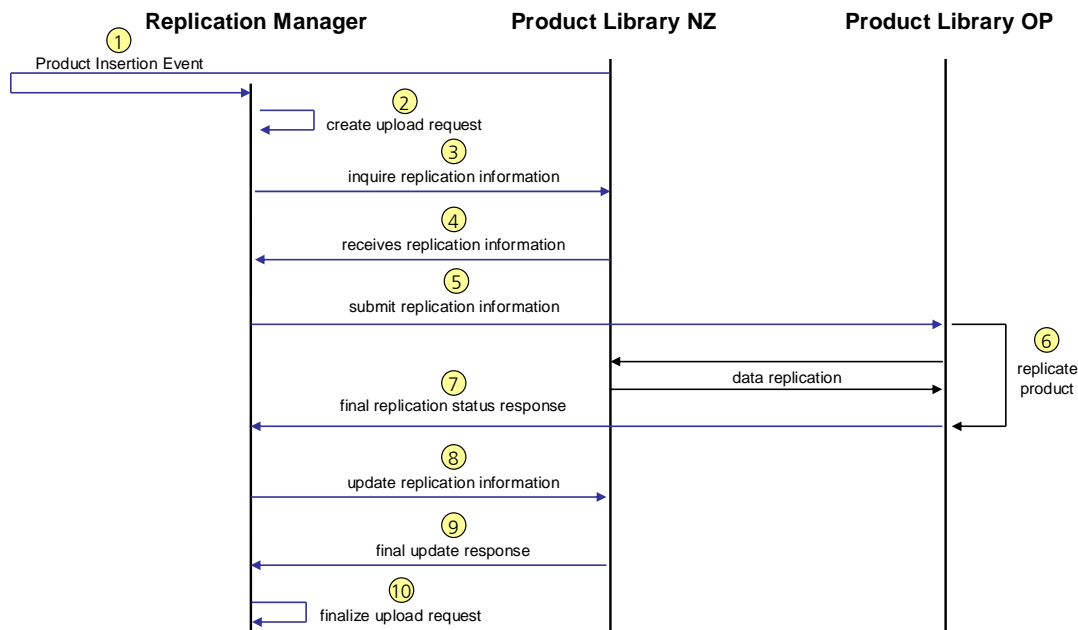

Figure 2 : Replication Calling Sequence

1. The Replication Manager receives an event that a new product is available.

2. It creates an internal upload request which visualizes the replication progress.

3. It inquires the replication information from the source Product Library.

4. The Replication Manager receives an asynchronous response which contains the replication information. This information consists of an item information file (IIF) in XML format, describing the complete product metadata and product structure. This is almost the same structure as used for products which are inserted into or retrieved from the Product Library. The only difference is that in this case the IIF contains the information about the product file locations within the archive of the source Product Library.

5. The Replication Manager submits the replication information to the target Product Library.

6. The Product Libraries starts the data replication of the product, i.e. they ingest the product metadata from the IIF and transfer the product files directly from the source archive into the target archive.

7. The Replication Manager receives an asynchronous response which contains the final replication status.

8. The Replication Manager updates the replication information in the source Product Library to include the second site archiving the same product.

4

9. The Replication Manager receives a final synchronous response which contains the update status.

10. The Replication Manager finalizes the upload request.

Collaborative Product Library Components

Within the Product Library, the management of metadata and product data files is handled in different subcomponents. The Product Library components themselves provide all product management functions and ensure the overall consistency of products by managing transactions spanning all activities of the subcomponents. The Inventory Control component stores product metadata and management information such as replication and expiration status and policies. The Archiving Control components manage the files of product components by applying path rules, storing the internal file locations and delegating file transfer activities to Archive Area components.

When accessing distributed data products, the Product Library has to find the best way to deliver data in order to reduce as far as possible unnecessary network traffic. The following figure shows the concept for transparent access to replicated product data. A client located in Oberpfaffenhofen (e.g. the DIMS component for Product Generation and Delivery) wants to retrieve a product originally archived in Neustrelitz. The client does not require any knowledge about the replication status, though does not know, if the product is already replicated and available in the local Oberpfaffenhofen archive.
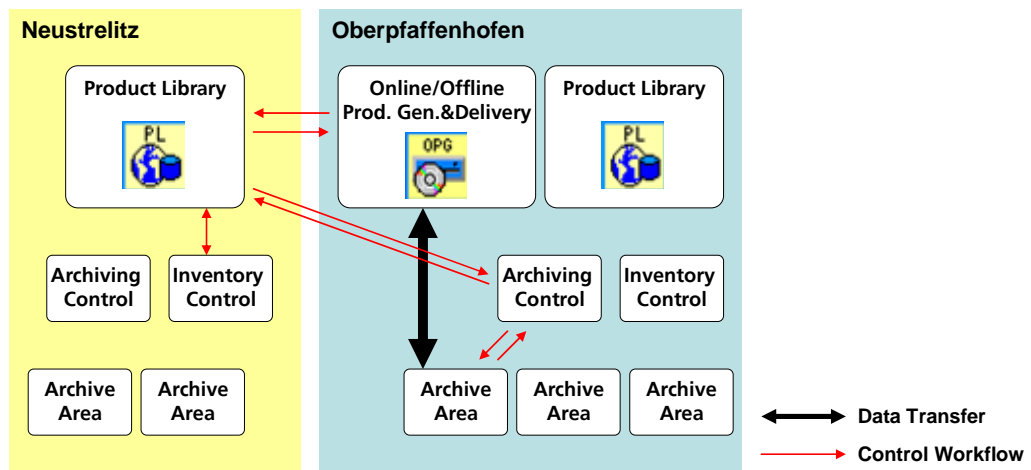

Figure 3: Distributed Product Access

The product retrieval workflow consists of the following sequence:

1. The client sends the getProduct request to the Product Library in Neustrelitz.

2. The Product Library looks up the replication information, evaluates the different archiving sites for this product and determines the site nearest to the client, Oberpfaffenhofen in this case.

3. The Product Library connects the remote Archiving Control service, requesting to deliver the product components.

4. The Archiving Control chooses the responsible Archive Area and requests the transfer of the product files to the client location.

5. Upon successful transfer, the services send notifications back to the requesting service, finally the Product Library in Neustrelitz signals the client that the product has been delivered.

While the optimization of the choice of the nearest archive is not yet implemented the transparent data access through any of the Product Libraries by clients as the most important feature is. The two workflows described above illustrate the distributed architecture of the Product Library and how the requirements for replication and transparent data access are met.

EVALUATION

The presented architecture has been developed as part the DIMS extensions for the TerraSAR-X payload ground segment. During ground segment integration, the replication scenario was already operated on the two sites, helping to evaluate and configure the required network link between the sites.

The following figure shows the DIMS Operating Tool, viewing the replication manager with a list of replication requests. The requests are created by event notifications received from the Product Library. The selected request represents the typical replication of a TerraSAR-X product. The query field shows the condition which must be fulfilled in order to replicate products.
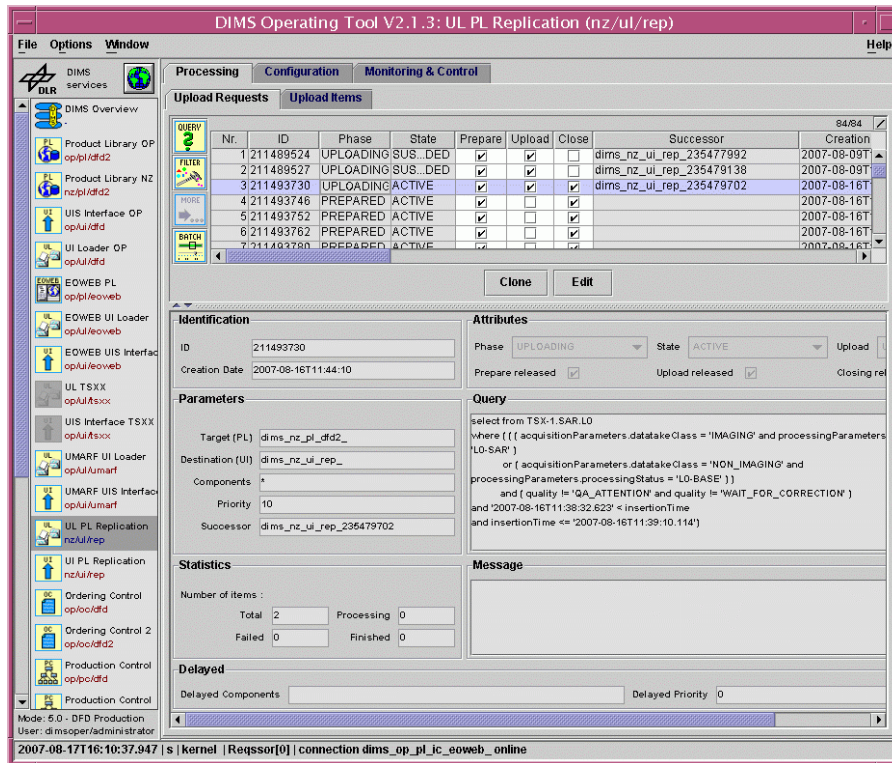

Figure 4: DIMS Operating Tool: TerraSAR-X Product Replication

Nowadays TerraSAR-X is in the commissioning phase and hundred Gigabytes (average) are archived and replicated per day. The following figure shows the Runtime Plotter of the Product Library which visualizes the product traffic at the Product Library in Oberpfaffenhofen on a normal day. The GUI is separated into two panels, a control panel on the right and a runtime display on the left side.

The runtime display has two axes, the time on the x-axis and the grouped client sessions on the y-axis. The visible sessions are only a selected subset of the concurrently running sessions of the Product Library. Each of the small horizontal bars represent the duration of one interaction with the Product Library like insertion, replication or retrieval of a product. The bars show different product types in different colors.

The top session represents the load caused by the replication of TerraSAR-X products. It shows that the requests are added in small chunks. Requests are subsequently processed and finished. Between the chunks some spare time is left until the next chunk is started. This means that there currently is no overload and replication is working regularly.

There are concurrent activities in a multi-mission environment. As an example the last session represents the load caused by the upload of products to EOWEB. These upload requests are short running requests because only meta data und quicklooks are uploaded. For TerraSAR-X only quality approved imaging products are uploaded to EOWEB. Thus, there is not yet the same upload traffic during the commissioning phase as it can be expected for TerraSAR-X later.
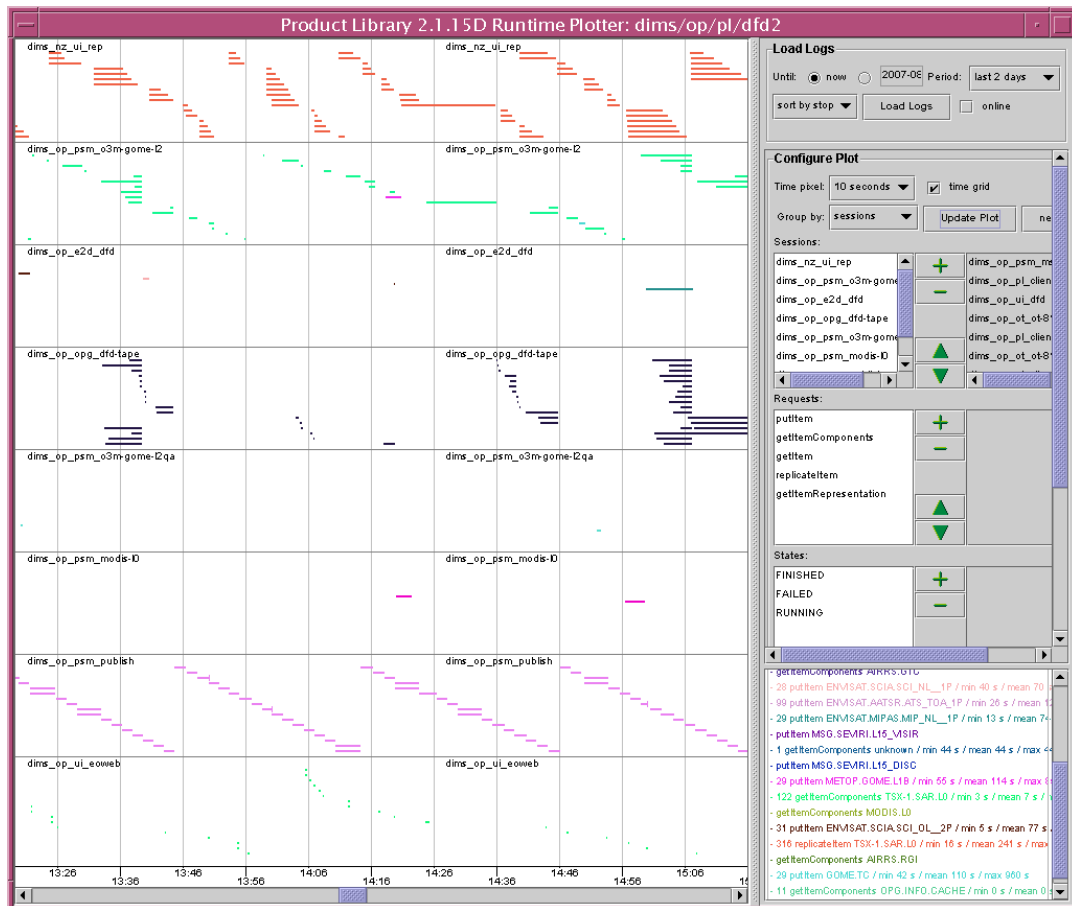
Figure 5: DIMS Product Library: Typical Product Ingestion and Retrieval Traffic

CONCLUSION

The concept for distributed archives presented in this paper is based on distributed autonomous functional components. The Product Libraries ensure consistency of their local data. A Replication Manager controls replication with the granularity of collections of earth observation products and their components, optionally with constraints on their metadata.

The solution is applicable for archives with online connection while it obeys constraints of limited bandwidth. It optimizes data transfer by direct replication of primary data between archives with a single copy. And it optimizes data access by selecting a local Product Library for the clients if possible.

The solution is implemented and used as part of a multi-mission system at DLR. The ongoing commissioning phase of TerraSAR-X shows its operational performance.

REFERENCES

[1] – S. Kiemle: From Digital Archive to Digital Library – a Middleware for Earth-Observation Data Management. In: Agosti, M., Thanos, C. (eds.) ECDL 2002. LNCS, vol. 2458, Springer, Heidelberg (2002)

[2] - S. Kiemle, E. Mikusch, C. Bilinski, B. Buckl, D. Dietrich, S. Kröger, C. Reck, A.-K. Schroeder-Lanz, M. Wolfmüller, Data Information and Management System for the DFD Multi-Mission Earth Observation Data. Ensuring Long-term Preservation and Adding Value to Scientific and Technical Data, PV 2005, Edinburgh UK, 21.-23.11.2005, Digital Curation Center Conference Proceedings, The Royal Society Edinburgh, (2005)

[3] - DFD's online user services EOWEB. Available in the WWW at http://eoweb.dlr.de

[4] - German TerraSAR-X Radar Satellite Mission homepage at the German Aerospace Center. Available in the WWW at http://www.dlr.de/tsx/start_en.htm