Reporting in a Payload Data Ground Segment

Martin Güttler, Vlad Manilici, Katrin Molch, Stephan Kiemle

German Aerospace Center (DLR)

Oberpfaffenhofen, 82234 Wessling, Germany

EMail: {Martin.Guettler, Vlad.Manilici, Katrin.Molch, Stephan.Kiemle}@dlr.de

ABSTRACT

The German Remote Sensing Data Center of the German Aerospace Center (DLR-DFD) operates a payload data ground segment (PDGS) for earth observation satellite missions. The Data and Information Management System (DIMS) has been designed to provide this PDGS functionality. DIMS consists of flexible and generic components for ordering, ingestion, processing, delivery, and long-term preservation of remote sensing data. DIMS supports modeling, execution, and supervision of the involved business processes.

During more than 10 years of operation, demands for processing throughput and storage placed on the PDGS increased nearly exponentially. A large number of complex data processing chains, a wide range of data access patterns for different application domains, a complex network infrastructure of the scalable distributed system, and other aspects of the increased load in the multi-mission environment make it difficult to overlook the overall system activity.

The need for coherent, timely, and accurate reports arose in order to prepare for strategic decisions on long-term preservation as well as PDGS system evolution. Operating the PDGS requires statistical data on the system activity, availability, and performance at different time scales. Planning and scientific work requires knowledge of the contents and usage of long-term Earth Observation data holdings.

This paper describes the concept and implementation of the DIMS Reporting Control (RC) for the multi-mission PDGS environment. The tool compiles reports based on data collected from multiple components. It generates ad-hoc and scheduled reports and employs statistical analyses to depict the current system state or its evolution over time.

This paper introduces DIMS reporting requirements, followed by a discussion on how these drive design decisions. Then involved interfaces and tools are presented. Next the proposed system is compared to existing solutions. The publication concludes with an evaluation of the DIMS Reporting Control implementation from the perspectives of usability and performance.

Keywords: Reporting, DIMS, Product, Ordering and Performance Statistics

INTRODUCTION

The German Remote Sensing Data Center of DLR operates facilities for the continuous reception, processing, archiving and dissemination of earth observation data. To face the challenges of handling large amounts of digital data from multiple missions in a sustainable way, DLR develops and operates the Data and Information Management System (DIMS). DIMS consists of independent software components encapsulating specific functions. These components run as services in the distributed ground segment facility [Kiemle2005].

DIMS supports all the earth observation data management functions required for missions with continuous systematic acquisition as well as missions with individual acquisition schedules.

A ground segment facility operating different DIMS services and configured for multiple specific earth observation missions is able to support scenarios for systematic data acquisition, near real-time processing and dissemination, archiving and publishing, systematic offline and bulk re-processing, user service upload and ordering/delivery of archived products. For missions with individual acquisition schedules the additionally supported scenarios are ordering of future acquisitions (single products and coverages), control of the reception and processing workflow, and archiving/delivery of newly acquired and processed products.

The DIMS system is being continuously extended and updated by DLR and Werum Software & Systems [Werum2011] to support new mission requirements and follow technological developments. For an increasing number of missions timely and accurate reports of system's activity e.g. in terms of number of orders, requests and products handled is needed in order to continuously document the PGS service behavior and performance. To this end, the new DIMS component Reporting Control (RC) presented in this paper is currently being developed.

Reporting in our context is the process of collecting, analyzing, compiling and presenting data from IT systems. Reporting is required for operating DIMS e.g. in order to account for system use or to identify system bottlenecks account for system use. Typical reports describe amounts of product orders and deliveries, system data rates or the composition of the archive. Periodic reports document the system's operational history while ad-hoc reports allow for in-depth investigations of the system behavior. DIMS contains several data sources that can be used to build comprehensive reports. Some of these data sources are structured such as databases for products and orders while others are partially structured such as log files.

Our contributions include:

- integrating a reporting tool in an existing multi-component architecture
- proposing a way of compiling and integrating data from diverse sources with different interfaces and levels of structuring
- extending a centralized interactive control component with reporting functionality
- providing long-term operational history through periodic, scheduled reports
- providing quick insights into the recent system activity through ad-hoc reports

This paper is organized as follows: in the chapter on Related Work we put the term reporting into context and discuss some popular state-of-the-art solutions. The chapter on Requirements and Constraints presents the requirements behind RC and the technological constraints it must account for. We present in the chapter on Realization the architecture of RC, it's functioning and user interface and how it is integrated in the DIMS system landscape. A few typical reports are discussed in detail in Examples. We conclude with a summary of the benefits of RC and a short evaluation of its performance and usability.

RELATED WORK

Decision support systems were introduced in the 1960s [Power2003] for IT systems which compile data in reports to support management decision making. Reports present data in a fixed format. Comparing reports from different points in time allows for an understanding of changes in a system.

In the PDGS context, RC produces reports intended for various user groups such as mission planners, IT managers, software designers, or system operators. It is based on the widely used Eclipse BIRT reporting framework.

Many large players in the business software market offer custom reporting solution. SAP has the Crystal Solutions [CrystalReports2011]. The Microsoft SQL Server comes with an integrated reporting tool [SqlServer2011] while IBM offers the Cognos system [Cognos2011].

Some popular open-source frameworks [Mimouh2005] are Eclipse BIRT [Weathersby2006], JasperReports [Jaspersoft2011] (some of the features commercial) and Pentaho [Pentaho2011]. All of them come with a report designer tool and are able to access different data sources like relational databases (JDBC) or XML files. Report scripting is supported. Significant differences exist in the types of diagrams produced. BIRT excels in allowing multiple data sources (with joins) in a single report and provides more aggregation methods than the other two frameworks.

Another class of software commonly used for data analysis contains statistics packages such as S-Plus [Splus2005] or SPSS [Spss2011]. Statistic software excels in data manipulation, presentation and statistical analysis. The downside is the use of scripting languages and a more difficult integration with a service-oriented architecture and with relational databases.

REQUIREMENTS AND CONSTRAINTS

Needs for Reporting

Reports are needed by different user groups for different purposes. The most important user groups are production operators and system operatiors. Production operators handle the execution of business processes by using the DIMS services. The system operators are responsible for the availability and the consistent operation of DIMS services. The information described next is needed by at least one of system and production operators. They need to know for example, the storage requirements for a month of incoming satellite data, the number of requests to be processed during a month, or how long it takes to process a request. They need the information in order to ensure the swift operation of DIMS. The operations team also needs statistics about user ordering (amount and cost per user) or duration, frequency and type of system failures. This is an important input to account users, distributors and missions, and to declare the fulfillment of a defined service level.

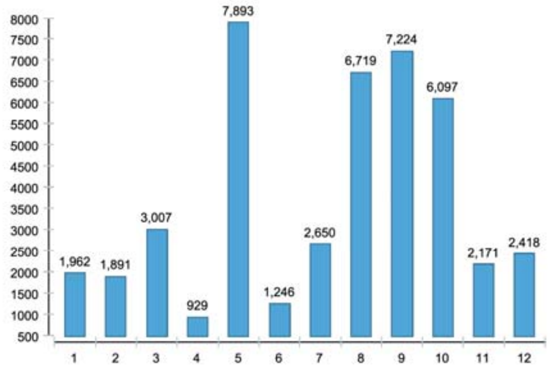
Planning and coordinating a satellite mission is based on specific information about current and past missions such as the amount of data output by a mission, the number of catalogue queries, the number of product accesses, or the product turnover. All missions are also required to submit a proof of service level including reports on system availability, system throughput, and timeliness of the near-real-time service. Important German missions currently supported by DIMS are TerraSAR-X and TanDEM-X and EnMAP (in planning):

- **TerraSAR-X** [Buckreuss2003] is a German X-band radar Earth observation satellite. Launched in June 2007 from Baikonur it has a planned life time of 5 years. TerraSAR-X delivers to users individual SAR acquisitions. Therefore the focus of reporting are any analyses related to orders, products and deliveries. This reporting is relevant in order to get an overview on the order behavior of users and the workload of the satellite. Furthermore, commercial aspects, such as accounting reports, are important.
- **TanDEM-X** [Moreira2004] consists of the previous TerraSAR-X and a similar additional satellite. The two satellites orbit Earth in close formation, allowing for one-pass interferometry. Data rates between the processing and the archiving system are high. 2000 TB of product data are expected in the first two and a half years of operation [Kröger2009]. RC is used to verify that the required processing bandwidth is available and provides information required for continuous optimizing of the system.
- **EnMAP** [Stuffler2007] is a hyperspectral Earth observation mission with a planned start in 2015. Similar to the SAR missions, analyses of orders, products and deliveries are relevant to EnMAP operation. Dedicated reports have additional constraints such as e.g. cloud coverage, processing level, and geo-location.

Finally software developers are interested in performance aspects of DIMS services that are relevant to current changes. They might also look for outliers which could point to potential problems or software errors.

Types of Reports

An important factor in designing RC is to find out which types of reports are required by the users. Once this issue is understood, one may proceed to choose an adequate reporting framework and devise the system architecture. This understanding was gained through interviews with our future users in the process of gathering requirements.



Index	DateFrom	DateTo	Count
1	2010-07-01 00:00:00	2010-08-01 00:00:00	1962
2	2010-08-01 00:00:00	2010-09-01 00:00:00	1891
3	2010-09-01 00:00:00	2010-10-01 00:00:00	3007
4	2010-10-01 00:00:00	2010-11-01 00:00:00	929
5	2010-11-01 00:00:00	2010-12-01 00:00:00	7893
6	2010-12-01 00:00:00	2011-01-01 00:00:00	1246
7	2011-01-01 00:00:00	2011-02-01 00:00:00	2650
8	2011-02-01 00:00:00	2011-03-01 00:00:00	6719
9	2011-03-01 00:00:00	2011-04-01 00:00:00	7224
10	2011-04-01 00:00:00	2011-05-01 00:00:00	6097
11	2011-05-01 00:00:00	2011-06-01 00:00:00	2171
12	2011-06-01 00:00:00	2011-07-01 00:00:00	2418

Figure 1: Report Example: Number of Deliveries per Month (aggregated)

One type of report required by our users is aggregation of key figures. Aggregations are done on criteria such as time intervals, geographic regions, users or order statuses. For each bin a simple item count, a sum of a certain characteristics e.g. the product size or a statistical value such as, the median is computed. Examples of this type of reports are the average duration of product processing or the count of product deliveries per time interval as shown in Figure 1. Twelve months between 2010-07-01 and 2011-07-01 are shown on the X-axis while the numbers of product deliveries per month is shown on the Y-axis. This report reveals that the demand for EO products largely varies from month to month.

Another type of report is a histogram of values such as the processing time of requests of different types. Statistical computations such as minimum, maximum, average, median, variance, standard deviation, or quartiles may also be required for the histogram data. Stacked bar charts are used when the bar diagram requires a third dimension. Bars are segmented proportionally to the values (see Figure 5).

Interfaces

An important prerequisite for the development of the RC is the integration into the DIMS environment. DIMS components use a custom communication protocol. Components register to a centralized name service and send requests and notifications to each other. Communication follows a client-server model with long-lasting sessions. The DIMS service interface allows the client to access persistent business data on the server. Data are organized as ordered lists of objects termed queues. They are searchable by object attributes or method responses. A typical component maintains a request queue while complex components may contain multiple queues of business objects from associated classes.

The RC makes use of the DIMS service interface in order to gather data for reports. It systematically reads information on request objects satisfying specific criteria e.g. if the request was created within a time interval or belongs to a certain mission. Other data sources such as log files or the Incidents Database do not require to be accessed via the DIMS service interface.

A planned dedicated reporting interface allows aggregating the data on the server-side in the DIMS services. This has the advantage that for instance averaging some object attribute will not require transferring all the objects to the RC client. This comes at the price of some processing power on the server-side. Another planned reporting interface allows the access to the standard service logs over the DIMS service interface and the exposition of dedicated log messages for reporting by the service. Currently logs are accessed over some file transfer protocol and processed as text files following the DIMS log format convention.

RC also integrates with the standard DIMS front end, the Operating Tool (OT). OT is described by its author [Reck2002] as *“a flexible application framework with a rich set of features. Common operating tasks as monitoring and control, including startup and shutdown, viewing logs, handling data lists and queues, etc. are accomplished without having to code new programs. New services can be made accessible with few lines in a configuration files“*.

This framework approach allows us to operate RC by presenting OT queues for report templates, scheduled reports and running reports. The user can easily edit a report template and submit it to the running queue. We choose to use the OT interface because it is easy to extend and our users do not require elaborate training for using the added functionality.

Data Sources in DIMS

The data which are stored within the DIMS services embedded databases are being generated while DIMS performs its routine operations. These are e.g. satellite data ingestion and metadata generation via order reception and processing to product generation and delivery.

DIMS consists of several interoperating services, all of them being potential data sources for RC:

- The Processing Management System (PSM) component is used to manage processing workflows for data ingestion, data processing, reprocessing and data publishing. It provides various possibilities to interface data processors and takes over the provision of input data, the transfer of output data and the management of processing and local cache resources. PSM provides information about the processing characteristics like the processing time and duration.
- The Product Library (PL) component provides consistent long-term storage of earth observation products [Kiemle2001]. Products consisting of structured components, data files, and metadata can have their individual object data model, and the PL provides comprehensive product storage, query and retrieval functions. RC taps the PL for product metadata e.g. number of products, types, sizes, geographical locations, acquisition and insertion time.
- The Production Control (PC) component is used to manage production workflows which span different processing systems or which interface the mission planning system and receiving stations.
- The Ordering Control (OC) component processes product orders which may require subsequent acquisition and processing or retrieval and delivery of archived products. It provides information about future and catalogue orders including order and product counts, missions, and processing times.
- Generated products will be delivered by the online/offline Product Generation and Delivery (OPG) component. Information about product deliveries e.g. volume, types, destinations is read by RC from OPG.
- Completed orders are removed from OC and backed up in the Request Library (RL). The same information is read from RL as from OC.
- The EOWEB component provides online user services mainly catalogue and ordering. The User Interface Service (UIF) provides an interface between EOWEB and OC. At the moment this data source is not used.

Further data sources:

- The Incidents Database documents issues resolved by the DIMS operators, including system maintenance and reaction to failures. The data are stored manually. RC uses the information within the database to generate reports about incident frequencies, response times.
- The availability of operational DIMS systems is monitored using the NAGIOS monitoring system [Nagios2011]. NAGIOS collects and stores data about the availability of hosts and DIMS components. RC has access to this information in order to compute system-level availability statistics.
- RC collects information about the progress of order or product processing (status changes) from DIMS log files. These are parsed and the results are persistently stored in an internal data warehouse. The data is then available for RC report generation, providing overview statistics for internal system performance analysis.

A complete view of the order processing (OC and RL) and of the stored products (PL) is thus possible. As a result, RC is able to satisfy our current user requirements from the existing data sources. Additional data sources are possible in the future.

REALIZATION

Architecture

Reporting Control is a DIMS service with a modular architecture depicted in Figure 2. Modules are shown as blocks, and arrows show the main data flow. RC uses custom DIMS frameworks with facilities for persistence, communication, workflow management, logging, and more. The central RC module is the Report Engine based on the Eclipse BIRT report engine. It is responsible for compiling reports which are described by report templates.

RC maintains several persistent databases. One of them is the Template Repository providing report templates which drive the generation of reports. Generated reports are saved in the Report Archive. A Data Warehouse maintains raw data collected e.g. from PL and PSM log files.

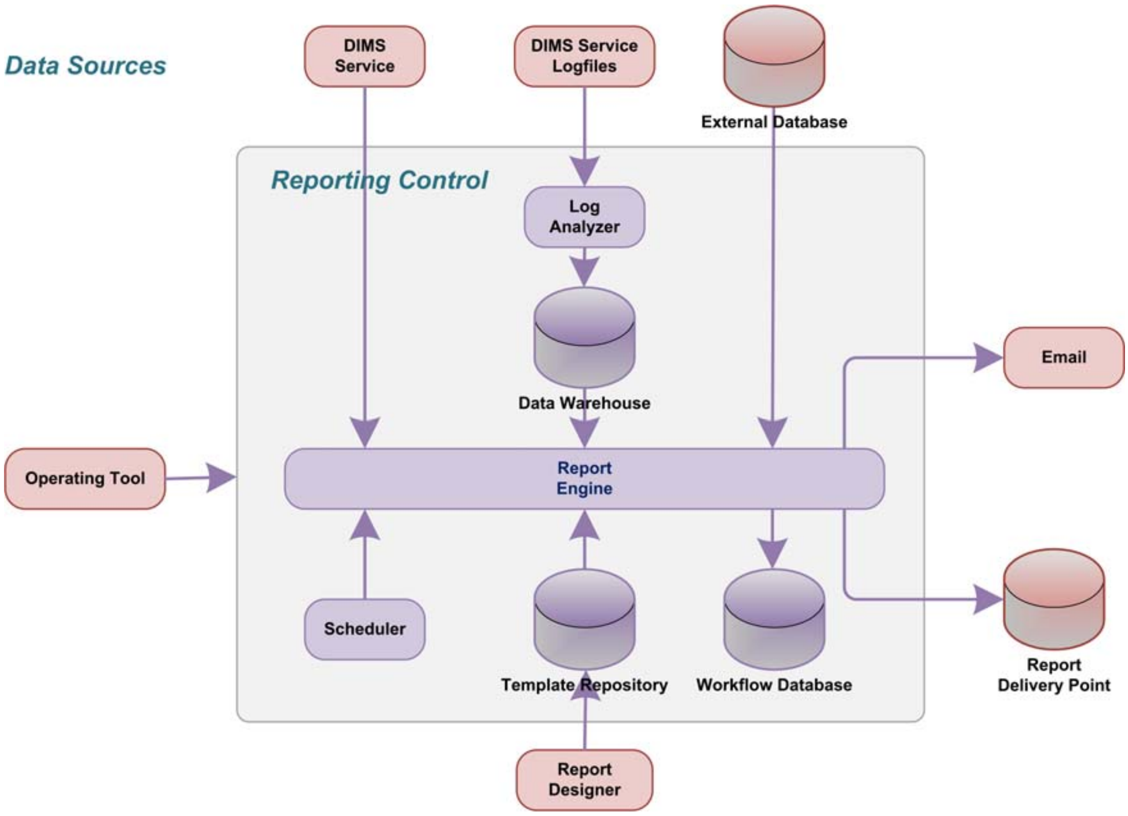


Figure 2: Architecture of Reporting Control

The Report Engine retrieves data either directly from DIMS services over the DIMS service interface e.g. from OC, from the data warehouse or from external databases such as the Incident Database. Reports are delivered both by e-mail and are saved in files at a pickup point. Report generation is triggered automatically by the scheduler or manually by the operator.

The main user interface is provided by the Operating Tool. OT is a DIMS service with the following main functionalities:

- Query the databases (queues) embedded in DIMS services and display the results
- Add (clone), remove and edit items in selected databases
- Send messages to DIMS services, prompting their workflows to initiate certain operations

OT allows the RC user to trigger report generation and provide custom parameters, edit report parameters and manage the workflow. Report templates are generated using the Report Designer and inserted in the Template Repository manually. The scheduler is also configured using the OT.

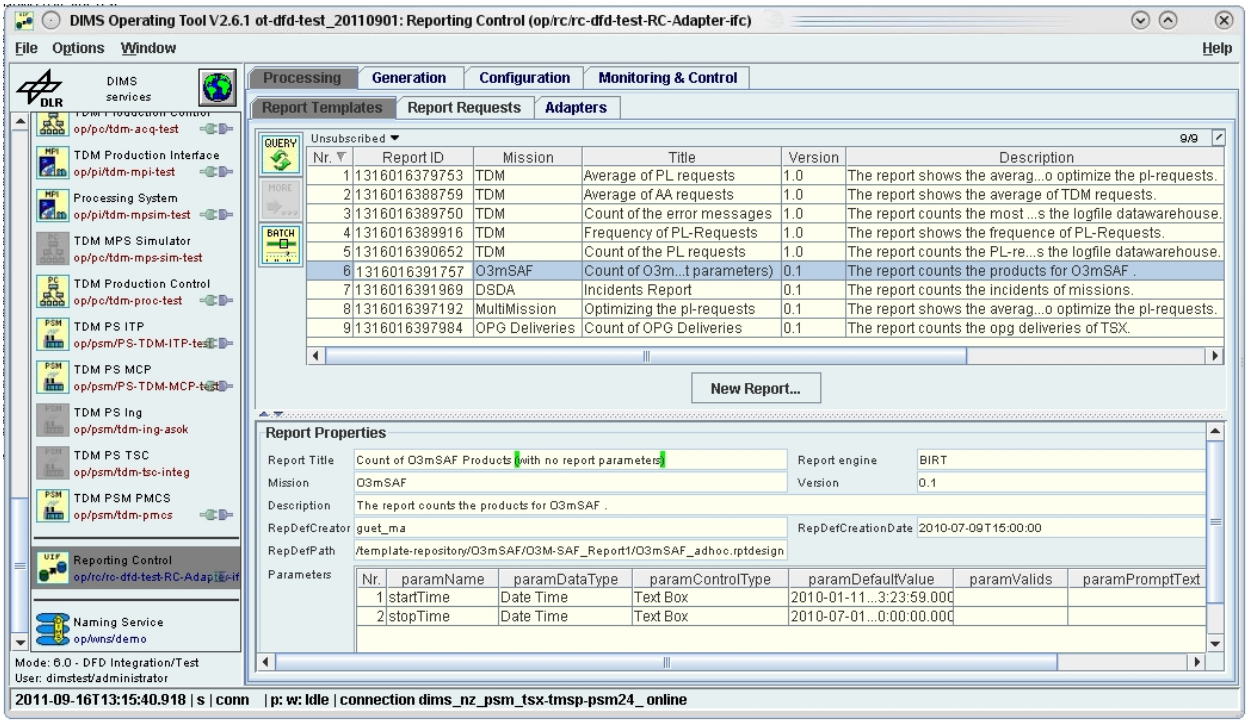


Figure 3: Operating Tool: Reporting Control (RC), Queue of Report Templates

A view of the OT user interface is shown in Figure 3. Available services are listed in the left column. The pane on the right shows a view of the RC service with several report templates.

Report Life Cycle

The life cycle of a report begins with the creation of a report template in the Report Designer. A report template describes the data sources, data selection and processing, report parameters and the format of the final report. The report template is deployed by the operator into the RC service manually.

If required, the report scheduler is configured via OT to trigger the building of a report from that particular template at regular time intervals. As an alternative, a parameterized ad-hoc report can be triggered by the operator via OT. The Report Engine then retrieves data and generates the final report. The report is being disseminated by e-mail, as a file, or both. Files are delivered to the Report Pickup Point.

DIMS Framework

The DIMS software framework offers several facilities, including workflow control, persistence, communication and logging which are all used by RC. It supports multithreaded workflows which manage task initiation and parallel processing of several reports. The workflow status is persisted in the Workflow Database. The RC modules described above run within the DIMS service framework.

The framework provides a workflow facility for request processing. Reports instantiated from templates are themselves controlled by corresponding requests.

A logging module common to all DIMS services allows consistent log creation and format among DIMS services. A log item consists of a timestamp, severity, facility and a free text message.

BIRT Reporting Framework

We chose the Java BIRT reporting framework [Weathersby2006] over other similar projects [Mimouh2005] since it best suited our requirements:

- Flexible access to data sources
- One report can merge data from different data sources (join) directly or using a scripting language
- Parameterization of report generation

BIRT contains the following main components: a Report Designer and a Report Engine. The independent Report Designer is used by RC operators to create report templates. The Report Engine is embedded in the RC application.

EXAMPLES

This chapter presents a number of RC reports considered typical by us and our users. We start with a summary of usage of historical data, continue with an ordering performance report, an incidents report and conclude with a usage report for a specific mission. Out of each report we select one significant diagram. Reports usually include several related statistics on the same data e.g. separately for reading and writing operations or different missions.

One example introduced earlier in this paper is a report of one year of product deliveries, aggregated in months (Figure 1). The data source for this report is the OPG service. The report is generated in 39 seconds.

Utilization Statistics of Historical Data

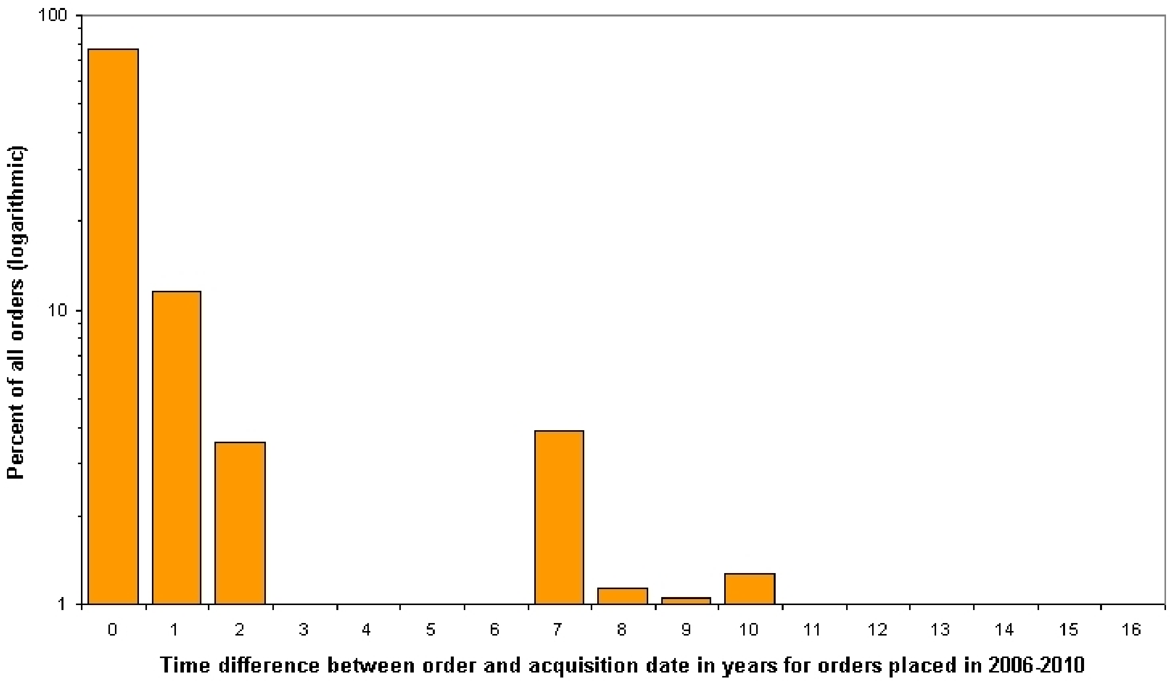


Figure 4: Aggregated graphic representation of time difference between product order and data acquisition

For assessing requirements for long-term data preservation it is of interest to know if users of Earth observation data require recent or older imagery for their work. Thus a report was devised which computes the time difference between the date an individual image order was placed and the date the requested image was acquired. Product ordering and acquisition dates are retrieved from OC and RL in about one hour for all orders placed between 2006 and 2010. Subsequently, this detailed report was aggregated by year and delivered in tabular format. The resulting graphic, in which the results were further aggregated and converted to percentages, is shown in Figure 4 in a logarithmic chart. It can be seen that over 90% of the products ordered from the archive between 2006 and 2010 have been acquired within two years before the order was placed. The users thus clearly prefer recent over older data for their work. However the interest for older products slightly increases again after a couple of years.

Product Archive Retrieval Performance

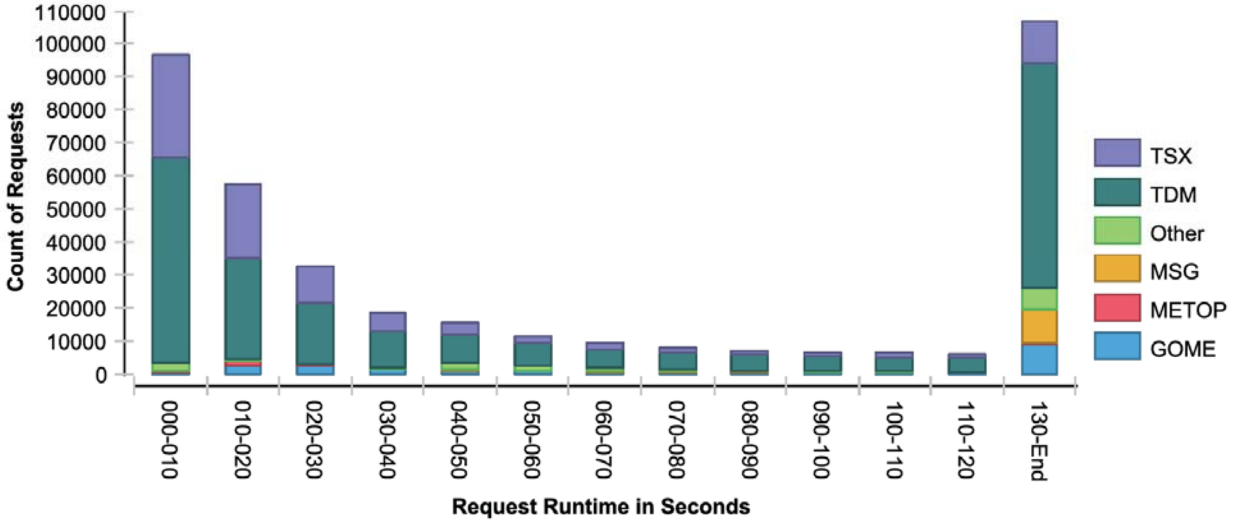


Figure 5: Histogram of product retrieval durations from PL

We analyze the PL performance using a histogram of product retrieval durations between 2010-07-01 and 2011-07-01, displayed in Figure 5. The operation refers to reading a product from the product archive and delivering it to the client program. The information is read from the data warehouse and originates from the PL logs. The interval 0-130 seconds is split in 10-second bins. A final bin contains all runtimes larger than 130 seconds. In this period, 381970 read operations were performed. About a third of them (96766) require less than 10 seconds. However there are a significant number of outliers (106931) with runtimes longer than 130 seconds. The products are classified by mission with TerraSAR-X and TanDEM-X accounting for most of the operations (95634 and respectively 234762).

Incidents Report

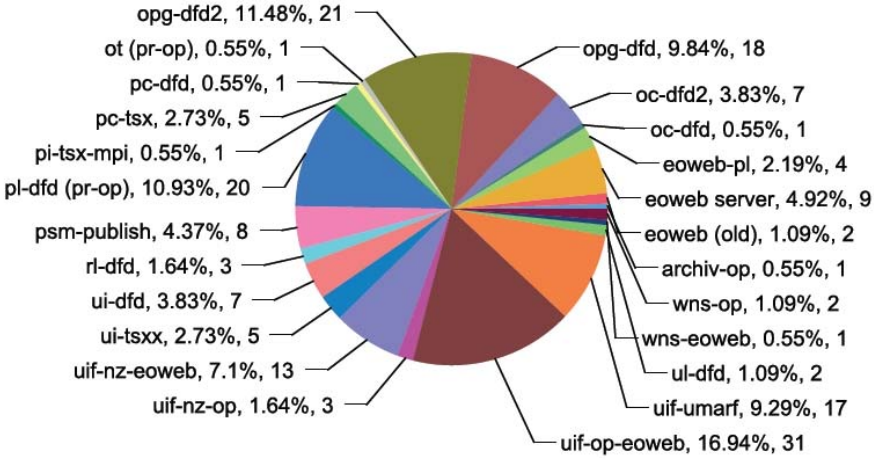


Figure 6: Incidents Report

Incidents, which cause an interruption or reduction of the quality of service [Orand2011] are documented by the DIMS operators in the production environment in a dedicated data base. RC accesses directly the data base and builds this report in only 18 seconds. Figure 6 shows the distribution of incidents per component in the period January-June 2011.

O3M-SAF Ingestion and Order Report

In the context of the EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M-SAF), DLR has to provide an operations report twice per year. This report includes monthly statistics on the amount and quality of archived products and the amount of orders on archived products that have been processed and the amount of data that has been delivered.

Number of archived products (cumulative)	From - To	01/2011 02/2011 19527	02/2011 03/2011 19879	03/2011 04/2011 20352	04/2011 05/2011 20771	05/2011 06/2011 21174	06/2011 07/2011 21636
Number of missing orbit products		0	0	1	1	1	1
Number of archived products with quality parameter	ERROR GOOD POOR	0 491 0	0 352 0	0 471 2	0 418 1	0 403 0	0 462 0
Orders		6	11	12	7	0	1
Orders UMARF		3	9	2	7	0	1

Figure 7: O3M-SAF Report

The data between 2011-01-01 and 2011-07-01 for this report is collected from PL and OC over the DIMS service interface in 13:13 minutes. The reason for the duration is the sequential use of multiple data sources. Data from both sources was merged during the generation of this report.

CONCLUSION

RC is a custom reporting tool designed for the DIMS payload data ground segment. It integrates smoothly in the service-oriented architecture of DIMS while using the standard DIMS interfaces and the standard front-end utility OT. RC provides long-term operational history as shown in the utilization statistics of historical data. It also provides quick insights into the recent system activity as described in the product archive retrieval report or the incidents report.

Our users are satisfied with the RC performance. One important metric is the report generation speed. The reports presented in this paper are generated in between a few seconds and one hour. The actual report compilation only requires a few seconds. Most of the time is used for data acquisition. The performance is highly dependent on the load of the retrieved services, on the number of data sources accessed and on the report complexity. Yet there is some room for improvement. Data collection is a sequential process which could be parallelized. Complex queries like those that place objects in bins would benefit from data base tuning e.g. placing indexes on the right keys.

The report generation and delivery is combined with an intuitive user interface. The GUI is part of the Operating Tool. Users can easily request ad-hoc reports and have them delivered per email, watch the progress of report generation and schedule periodic reports.

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AUTHOR BIOGRAPHIES

Martin Güttler graduated from the University of Applied Sciences Ansbach, Germany in 2009 with a Diploma in Business Information Systems with a major in business applications with SAP. He is currently pursuing a Master's degree in business information systems at the University of Applied Sciences in Deggendorf, Germany in part-time. Since 2009 he is employed at the German Aerospace Center (DLR), German Remote Sensing Data Center. He is responsible for the design, development, and integration of the new DIMS service Reporting Control (RC).

Vlad Manilici holds an engineering diploma in Computer Science (1999) from the Technical University in Cluj, Romania. He was awarded in 2009 a Dr.-Ing. degree from the Technical University in Berlin for research in the area of computer networks. He worked as a software engineer in the fields of Internet security and telecommunications. Vlad joined the German Aerospace Center (DLR) in 2009 where he is responsible for the architecture, design, and implementation of distributed payload data ground segment (PDGS) systems and components.

Katrin Molch holds a Master's degree ('97) in Geosciences acquired in Germany and the U.S.A. For over ten years she has been working as a remote sensing scientist with Canadian and European Earth observation research organizations and in industry. Her scientific focus is on exploiting radar satellite imagery for geological and urban applications. She has developed and given several training courses on satellite image exploitation and radar interferometry to international civilian and military clients. Since 2009 she is the Earth observation data librarian of the German Remote Sensing Data Center (DFD) of DLR. Leading the User Services team, she is working towards improving accessibility to the organization's Earth observation data holdings and increasing their use by a wider customer base.

Stephan Kiemle received the Diploma degree in Computer Science from the Technical University of Munich (TUM), Munich, Germany, in 1995. Since 1995, he has been with the German Remote Sensing Data Center (DFD), German Aerospace Center (DLR), where he started as software developer for the Interactive Satellite Information System ISIS. In 1997, this work merged into the development of DFD's multimission earth observation data system, the Data and Information Management System (DIMS), where he was responsible for the Product Library. Since 2003 he leads the DIMS development team and works as project manager and system engineer for a number of earth observation payload ground segment and infrastructure projects.