DATA INFORMATION AND MANAGEMENT SYSTEM FOR THE DFD MULTI-MISSION EARTH OBSERVATION DATA

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INTRODUCTION

The German Remote Sensing Data Center (DLR/DFD) operates the Data Information and Management System (DIMS) for the production, archiving, ordering and delivery of digital earth observation data products. The development of DIMS is a joint effort of DLR and Werum Software & Systems [1]. Designed for the multi-mission purpose from the very beginning, the modular system today proves stability and performance in the DFD multi-mission facility.

Being deployed at the two sites Oberpfaffenhofen and Neustrelitz, the DFD multi-mission facility serves various earth observation missions of geostationary and polar orbit satellites and airborne sensing campaigns. About 30 processing systems are online to compute the data of optical, atmospheric and radar sensors. In its archives based on robot media libraries for long-term preservation, the DFD hosts about 100 TByte of data ranging from raw data to high level information products. Per month library throughput averages 50.000 products and the online user interface (http://eoweb.dlr.de) serves 3000 user sessions.

The Data Information and Management System supports various tasks of digital product handling in a payload ground segment facility. Heterogeneous sources of digital data can systematically load new products into the system, initiating subsequent data driven processing chains including near-realtime data delivery. Users can subscribe for products matching specific features and get served on product availability event basis. Users can search and order existing products (already processed and archived), producible products (to be processed based on raw data) and future products for which acquisition will be planned based on mission and sensor resources and capabilities. The ordering process includes order validation and quotation, the initiation of processing and online or media delivery controlled by various options specified by the user.

This paper presents an overview on the DIMS family of services and their functions used at the DFD facility. The focus is set to the scenarios for product preservation, processing, ordering, delivery and monitoring/control as they are daily practiced in the operational context.

PAYLOAD GROUND SEGMENT ARCHITECTURE – A SERVICE-ORIENTED VIEW

Earth observation missions classically define a segmented architecture for their operational exploitation. Apart from the space segment (the satellite platform itself), the missions control (telemetry, commanding), the instrument control (calibration and degradation monitoring) and the data reception, the payload ground segment is responsible for all payload data handling. As more and more missions aim to reuse multi-mission facilities to reduce development and operations risks and costs, an abstract definition of payload ground segment functions is required.

Payload data handling is a task that usually outlives an earth observation mission’s duration. Acquired payload data has to be preserved and handled far beyond the initial satellite platform’s lifetime, since its value often increases with its age, for example in the domain of global change monitoring. On the other hand, near-realtime applications arise requiring instantaneous access to value-added data, such as in the domain of hazard situation management.

With regard on these developments, the earth observation mission payload ground segments evolve from proprietary mono-mission systems for data processing, archiving and distribution to generic multi-mission systems with additional functionality such as data ingestion, complex value-adding and cross-mission production workflows, ordering of future acquisitions, data subscription, near-realtime delivery and online user services. In order to be able to easily integrate future missions, multi-mission systems need not only to be scalable in terms of processing and storage capacity. They have to rely on abstract metadata, data and service models that allow identification of required functions, configuration of new workflows and extension of data structures to support specific mission requirements. Endowed with this flexibility, multi-mission systems are optimally suited to provide system and payload data sustainability, and to realise operating cost savings through unified operative processes.

The way of finding abstract services as well as abstract data and metadata representations naturally passes through a deep analysis of past and present mission ground segments. Leaving the system composition aside, we concentrate on common functions, processes and business data such as digital products, user orders and production requests. *Abstraction* and *generalisation* thereby help to hide mission-specific details without loosing the functional context when choosing the right level. *Encapsulation* is often required to allow transportation of mission-specific details in globally generalised interfaces. *Standardisation* is a very strong way of assimilation, imposing common structure and behaviour. It is however required for open interfaces and connectivity with foreign external systems which is another important aspect for system and payload data sustainability.

Figure 1 shows a system definition process which passes through the identification of abstract services. A context analysis collects all external interfaces and the overall functions to be provided. Some basic processes define the main use cases for the system in order to achieve the expected overall functionality. In an iterative process detailed scenarios are defined as a sequence of partial functions provided by a family of abstract services. These abstract services provide a high-level functional decomposition of the system and lead to a system architecture, where concrete collaborating components implement the abstract services.

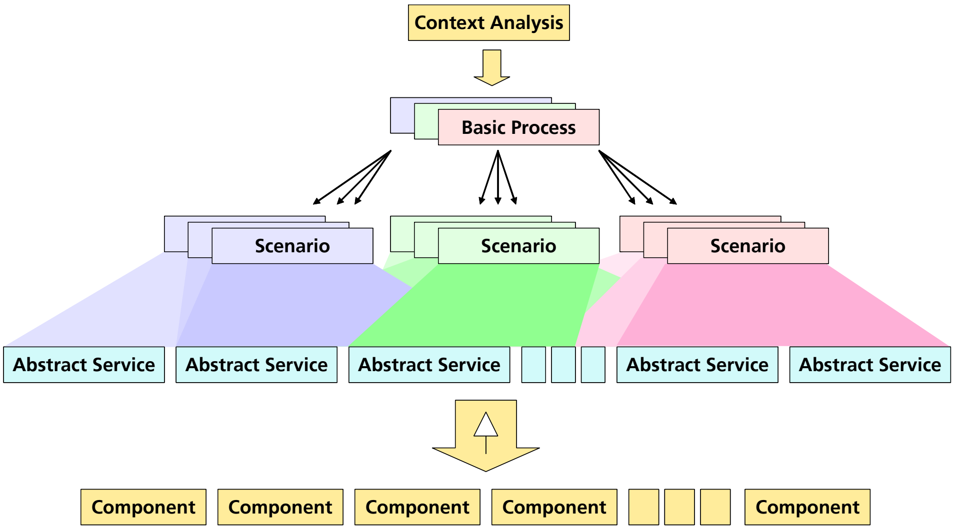

Fig. 1. System definition process through abstract services

The Data Information and Management System is based on an abstract, service-oriented view on ground segment functionality. We identify abstract services in payload ground segments based on the following basic groups of processes:

- systematic, product data driven processes
- event-based, request driven processes
- operations support processes

For each group of processes we describe payload ground segment scenarios that turned out necessary and practicable in the operational facility. These scenarios, the affected service instances, the implementing software components and their interactions are discussed in the following sections.

SYSTEMATIC, PRODUCT DATA DRIVEN PROCESSES

Systematic processes are characterised by a regular and autonomously repeated activity. The external event for this kind of processes is in most cases the availability of new product data at facilities in or external to the payload ground segment, for example a receiving station providing acquired data after demodulation and decryption. These processes are often called product data driven, because the functional chain of ingestion, processing, transformation and distribution is initiated and maintained by the product data itself.

Systematic Data Ingestion

A central task of multi-mission payload ground segments is the long-term preservation and provision of earth observation product data. Not only acquired sensor data is of interest, also auxiliary data required for correct interpretation of the data and its processing to value-added information has to be managed in order to ensure product quality, consistency and traceability. Traceability means the capability to re-generate products in future for example based on enhanced algorithm versions reflecting technical and scientific progress. Examples for auxiliary data are satellite orbit state vector information required for geolocation and global weather model data required for ground albedo computation in atmospheric chemistry products.

The multi-mission and multi-sensor acquisition data and auxiliary data usually become available to the payload ground segments through data files of various formats on pick-up points. The ingestion process receives an external signal or polls the data source in regular time intervals, fetches newly available data files, extracts metadata, possibly transforms the data to standard structures and formats as defined in the ground segment facility, possibly generates new components (e.g. browse images) out of the data and bundles the metadata and files to a new structured product.

The Data Information and Management System (DIMS) implements systematic data ingestion through ingestion service instances, typically one instance per data source. These service instances make use of the software component Processing System Management (PSM) [6]. PSM autonomously controls the ingestion process by creating and scheduling requests based on external events and an internal timer. It manages a disk cache for local data processing and allows easy plug-in of applications for data transformation and conditioning, and takes over the delivery of the new product to the Product Library service. The Product Library (PL) is the service responsible for long-term preservation, consistently managing products as singular units composed of metadata and data files. This service provides efficient and comprehensive query capabilities [2] and a highly scalable and independent archive.

Systematic Data Processing

Starting from systematic data ingestion, subsequent data processing workflows continuously generate higher level information products out of ingested raw and auxiliary data. These workflows may spawn several processing steps and generate products of different processing levels. As long as the resulting products are standard products of common interest for various applications, these products will also be stored for future use. We denote these products as reference products as opposed to delivery products which are individually generated for a specific user and not preserved.

However, systematic processing has its limits in the size and amount of data to be expected throughout a mission. Systematic processing and preservation is always a trade-off between the amount of data to be stored and the time it takes to generate individual products. If processing on demand is rather simple and does not require expensive resources, it may be advantageous not to process data systematically but on user request. This scenario is described later. Systematic data processing is sometimes required by the processing algorithm itself. The processing of consistent interferometric information (phase unwrapping) out of radar sensor data for example requires continuous processing of sequential scenes. Another example is the precision of atmospheric trace gas concentration information generated out of atmospheric spectrometer data that can be increased by reusing a priori information from antecedent products.

Systematic processing is implemented in DIMS through processing service instances using the PSM component, typically one service instance per product type and processing level. As the PSM supports powerful and flexible workflow configurations, one processing may include several processing steps, each using a distinct algorithm. These steps are composed into a workflow which may include sequences, loops, conditions and parallel steps. The PSM takes control of the workflow and coordinating the execution of each of its steps. Source of all input data and target for generated output data is the Product Library (PL). The PSM is in charge of fetching inputs and posting outputs taking into account its local data cache resources. For systematic processing, the PSM subscribes at the PL for a certain type of input products. As soon as matching products become available in the PL, the PL notifies subscribed PSM service instances so that these can start to retrieve and process the inputs. The PSM manages the local cache also for temporary data accumulating during processing.

Via the mechanism of product availability subscription, systematic processing can chain over several processing service instances. The output of the first step can be input of one or more second steps, and the PL notification automatically triggers subsequent processing steps upon availability of new input products. This way also high level information products can be consistently generated for running missions.

Near-realtime Product Delivery

Customers and external systems sometimes depend on products in near-realtime, i.e. directly after acquisition and processing, in order to provide services based on current data such as weather forecasting and air quality and traffic monitoring. These kinds of applications do not use interactive interfaces to access products but require continuous online supply of systematically generated standard products and this in a very reliable manner, since belated delivery is valueless. Near-realtime delivery is usually based on a flat service agreement and not individually accounted.

In order to implement reliable near-realtime delivery, DIMS integrates the delivery step into the ingestion or processing service instances generating the corresponding products. Therefore the PSM provides an online delivery module that can be chained in the processing workflow. All generated products are automatically packed and delivered via SFTP to the configured customer location. The online delivery can be seen as the last step of a systematic processing chain. Nevertheless the resulting products can also be archived, but archiving is not necessary before delivery completion. Even if the archive has a maintenance downtime, the PSM delivers in time while reference products are posted to the PL as soon as the maintenance is over. As for systematic processing, the size of the cache of a processing service instance has to be chosen at least to hold all input, intermediate and output data required during the maximum archive maintenance downtime. In the DFD facility this is about 48 hours in which the robot library and the tape drives are maintained once a year.

Product Subscription and Delivery

If customers and external systems require products not in near-realtime, but nevertheless on a continuous basis, a subscription mechanism allows them to regularly receive products of their interest. As timeliness is not the major issue, processing may include individual tailoring, often denoted as post-processing, and delivery on offline media. The product subscription allows a user to specify in detail products of interest, for example products of a certain type over a certain area and with certain individual characteristics as defined in the product metadata. Product subscription may either be based on a flat service agreement or individually accounted.

As product subscription and delivery in DIMS relies on services used also for normal product ordering and delivery, the implementation of this scenario is described in the next section.

Product Upload and Publishing

Systematically ingested and processed products have to become accessible in online user information services and sometimes to be published to external systems. The task of uploading products to user service and external systems often includes a filtering of products, a selection of relevant product parts and a transformation. Filtering allows restricting upload to products with certain individual characteristics, such as quality controlled products or products over certain areas. Selection allows choosing for example browse components and transformation includes the adaptation of the metadata structure to external needs and typically the generation of a thumbnail image on the fly. Product upload and publishing is again a systematic process that follows the logic of continuous data-driven activity.

Product upload is implemented in DIMS with the pair of services User Service Loader (UL) and User Service Interface (UI). The UL is configured to request upload of products to a certain target system and the UI is then charged to perform the upload. The upload scenario is based on product subscription at the Product Library: UL subscribes for the availability of products of a certain type and with certain properties characterising the products to be loaded. Upon availability, PL notifies the UL which instructs UI to upload the identified product. UI now retrieves the product with the required components from the PL and performs some transformation before passing the product information to the user service or other external system. UI is a framework component that allows plug-in of adaptors to support individual external systems. Therefore a new UI service instance has to be set up for each external system connected.

In order to be able to upload whole collections, UL is not only able to run on a subscription basis, but may use the incremental product query result retrieval mechanism provided by the PL to iterate through huge collections and stepwise load all products returned by any product query. A systematic publishing of new products to information portals is realised in DIMS through a publisher service, using the Processing System Management component. The PSM subscribes at the PL for products to be published; as soon as a product is available, PSM gets notified, retrieves the product and starts a publication process which includes editorial processing and transfer to the portal system.

User Catalogue and Browse Services

Online catalogue and browse services form the end of data-driven activities. Systematically acquired, ingested, processed and published products can be interactively searched and viewed by external users. Via standard access interfaces, product data becomes accessible on a business-to-business basis for value added application services.

The interactive user services are provided by the DIMS component EOWEB, which includes the web gateway (http://eoweb.dlr.de) for catalogue, browse and order services to earth observation products of the DFD multi-mission facility. In its new version to support the German TerraSAR-X mission, EOWEB will support collection-specific, advanced search criteria, visualisation of swath previews served by mission planning, enhanced authorisation for product collections visibility and order options, advanced order options and a persistent customer shopcart to store order item candidates. In its server layer EOWEB supports the standard protocol CEOS-CIP for search and ordering [5].

Figure 2 shows the DIMS service components and interactions involved in the implementation of systematic, data driven processes.

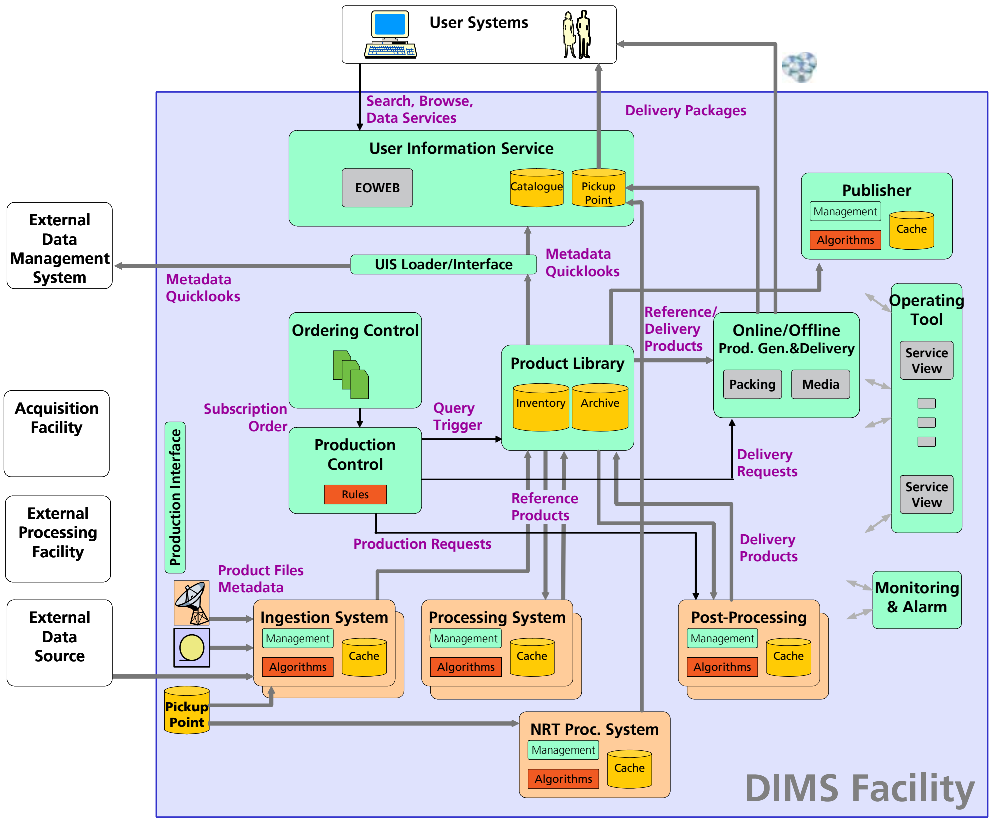

Fig. 2. Systematic, data driven processes

REQUEST DRIVEN PROCESSES

Request driven processes are typically initiated by external users or applications requesting data or services. External requests for data such as user orders are unpredictable, unsystematic events. All activity in the payload ground segment required to satisfy such kind of request is described in this section. In request driven processes the functional chain is initiated and maintained through a request being created, submitted and processed, resulting in the planning, acquisition, processing, tailoring and delivery of corresponding data products.

User Order Services

Based on catalogue and browse services, users can identify products suiting their needs. The catalogue gives access to collection of three principal categories of product availability. Existing products are directly available from the archive. Producible products are based on existing predecessor products of a lower processing level. Future products still have to be acquired and processed, and a catalogue service on such collections serves future acquisition opportunities considering flight, platform and sensor constraints. User order services allow a user to successively add identified products to the shopcart, specify individual order options for acquisition (future products only), processing (future and producible products only), post-processing, formatting and delivery. Ordering services imply user management services where customers can register, specify their coordinates and preferences and monitor their orders.

As already described in the previous section, user order services are implemented in DIMS by the EOWEB User Services component. Once an order has been submitted by the customer or an external application, EOWEB forwards the order to the User Service Interface (UI) instance which passes it to the Ordering Control (OC) service. Other User Service Interface instances are required to receive orders from different external systems and map them to the DIMS order structure. The UI instances also have the task to notify order status modifications so that users can monitor their order in EOWEB or connected external systems.

Order Validation, Processing and Delivery

The order validation has to determine if all options are consistent, all mandatory parameters are specified and if the customer is authorized to order the products. Authorization includes a crisis area check to prevent delivery of products intersecting crisis areas. If the order validation fails, operator intervention is necessary to modify settings and/or to cancel order items or the full order and/or to start order processing. The price is calculated based on standard prices for collections and order options, including reductions and dynamic rates that depend on the product content, such as quality, resolution and data coverage. Orders are confirmed through customer correspondence and delivery papers and invoices are generated. As soon as all order items of one delivery package are available, the delivery package is generated. This means bundling for online delivery via a pickup point, or packing and media generation for surface mail shipment. After shipment is performed, a notification (usually email) is sent to the customer.

The Ordering Control service in DIMS is responsible for the management of user orders. Order management organizes all phases from validation to final shipment and generates the required papers for customer correspondence. The generation and execution of deliveries is delegated to the Offline/Online Product Generation and Delivery (OPG) service. Based on a PSM, this service provides specific functions for selecting, formatting and packing products to be delivered, thereby taking into account the customer's delivery options and media capacities.

The processing of the order itself depends on the availability status of the order items (existing, producible, future). The corresponding order processing scenarios are described in the next subsections.

Ordering of Existing Products

If the ordered products exist, only post-processing may have to be performed, depending on the processing options of the order item. Post-processing is the tailoring of products controlled by order options, such as format conversions and subsetting.

In DIMS any kind of production is handled by the Production Control (PC) service. For post-processing, OC forwards a corresponding production order to PC. This service determines the required post-processing system and forwards a production request to the corresponding PSM instance. This service fetches the product to be tailored from the PL, runs the post-processing algorithm and returns the resulting delivery product back to the PL. The identifier of this product is returned via PC back to OC which uses it to request delivery at OPG as described above.

Ordering of Producible Products

Producible products are reference products that can be processed on demand based on archived predecessor reference products and corresponding processing services. Production ranges from a simple one-to-one relationship between the base product and the producible product to complex dependencies with multiple predecessor products of different types and processing levels, resulting in processing chains to be activated to finally generate the requested data. Production can not only be triggered by a user order, it may also directly requested by the operator. The operator may also request a systematic processing of a whole data set, for example to reprocess all data of a mission/sensor with new processing algorithms. This activity touches the scenario of systematic data processing described in the previous section.

The DIMS Production Control service is responsible to handle production chains over different processing services. It receives a production order from the operator or from OC for the products which do not exist. PC is configured with rules defining the workflows for producible product types. The basic workflow element of PC is the production request issued to a PSM service instance to directly process the requested product or the next intermediate product in a complex production workflow. PC thereby specifies the required input and the expected output product. Upon reception of a production request sent by PC, by batch or directly entered by the operator, the PSM allocates local disk space, gathers the input data from the PL and initiates processing by calling the processors or processing algorithms according to the local processing workflow. Upon completion PSM stores the output products in the PL and returns the product identifiers to the caller. PC may use these identifiers as input to issue new production requests for higher level products or return them to OC which then can proceed with post-processing and delivery as previously described.

Ordering of Future Products, Mission Planning

Future products are based on acquisitions lying in the future. However their principle availability can be predicted with the help of coverage previews presented in user services similar to catalogues of existing products. The search parameters in collections of future products correspond to the inputs of coverage preview services required to restrict the acquisition opportunities, such as orbit direction, sensor modes, the area of interest and an acquisition time window. A user order of future products includes parameters required to plan the acquisition (e.g. the priority) and to control a subsequent processing.

Besides predicted single future products, the customer is also able to order future coverages with order option parameters similar to those for searching future scenes. The coverage defines just one order item and its specification is passed to the mission planning service which will try to plan the acquisitions to cover the requested area as far as possible respecting the given order option constraints.

The processing of user orders on future products is very similar to the workflow of producible products, because the planning, the commanding and the reception of acquisitions can be interpreted on an abstract level as the preceding steps in a production chain, like any other production step. They have to be requested from the corresponding services in the correct sequence and passing corresponding options, and the resulting acquisition data is again the input for subsequent production steps on the way to the ordered product. However, a major difference persists between mission planning and a simple processing step. Data processing is a deterministic action whereas mission planning is a complex task with a considerable amount of uncertainty. Planning acquisitions has to take various aspects into consideration such as satellite platform, sensor and downlink resources, concurrent acquisition requests and their priorities. A final certitude is only given when the acquisition time window elapsed and corresponding data has been ingested. In any case the order status on order item level has to be tracked and made available to the customer. Depending on the mission planning policy, the customer may not be enabled to see the current planning status of the order items as this may change at each planning cycle before acquisition.

Ordering of future products is implemented in DIMS using the same components as for producible products [3]. On the level of Production Control, an acquisition order for a specific mission is passed via a Production Interface (PI) service to the mission planning service. This service is external to the DFD multi-mission facility because it is mission-specific. OC sets the user order on “hold” until the acquisition is performed and optionally processed to a certain level, or the acquisition fails. The acquisition may fail because of platform or communication problems or because the acquisition did not reach the required quality (such as too much cloud coverage). In case of acquisition failure the order is cancelled. If the acquisition is successful, OC continues order processing by controlling production orders sent to PC or directly requesting delivery to OPG as described above. Newly acquired products are ingested into the system through ingestion services using the PSM as described in the systematic data ingestion scenario in the previous section.

Bulk Delivery

For certain applications and customers it is necessary to deliver a huge amount of products at one time. A bulk delivery requested by the operator shall incrementally generate a delivery of for example all products of one collection.

DIMS supports bulk delivery on the level of the Ordering Control service. A bulk delivery order has to be entered by the operator specifying the product type, a query condition to be fulfilled by all products to be delivered and post-processing, formatting and delivery options. OC forwards the order to Production Control. PC queries the PL and for each product to be delivered it submits post-processing requests to the corresponding PSM instances and delivery requests to OPG. The post-processing systems retrieve the input products from the PL, perform the post-processing and store the resulting delivery products in the PL again. OPG retrieves them for direct online delivery or caches them until the data amount for the generation of the next media volume is reached. The next media volume is then produced and can be shipped via surface mail or temporarily stored until the total bulk delivery is completed.

Product Subscription and Delivery

Product subscription and delivery has already been introduced as a systematic process in the previous section. Considering ordering, this scenario gets new facets. For instance a user may be interested in future acquisitions repeated in regular time intervals. Instead of waiting for the availability of corresponding products, these will have to be actively planned. A user may also want regular deliveries, i.e. the delivery has to be scheduled and all products since the last delivery and matching the subscription have to be delivered in one step.

The implementation of product subscription and delivery involves a couple of DIMS components. Subscription orders are entered by the order operator in the Ordering Control (OC) service. This service is responsible for the management of all user orders. A customer is not able to directly place subscription orders as this potentially involves a huge amount of products. Besides the various standard order processing steps (explained in the ordering scenarios above), the Ordering Control service is able to subscribe at the PL for the availability of new input products corresponding to the customers needs. Upon reception of a notification it dispatches a production order to the Production Control (PC) service. For repeated acquisitions, OC places regular acquisition orders for mission planning. Further processing of acquisition and production orders is performed as described in the ordering scenarios above.

Figure 3 shows the DIMS service components and interactions involved in the implementation of request driven processes.

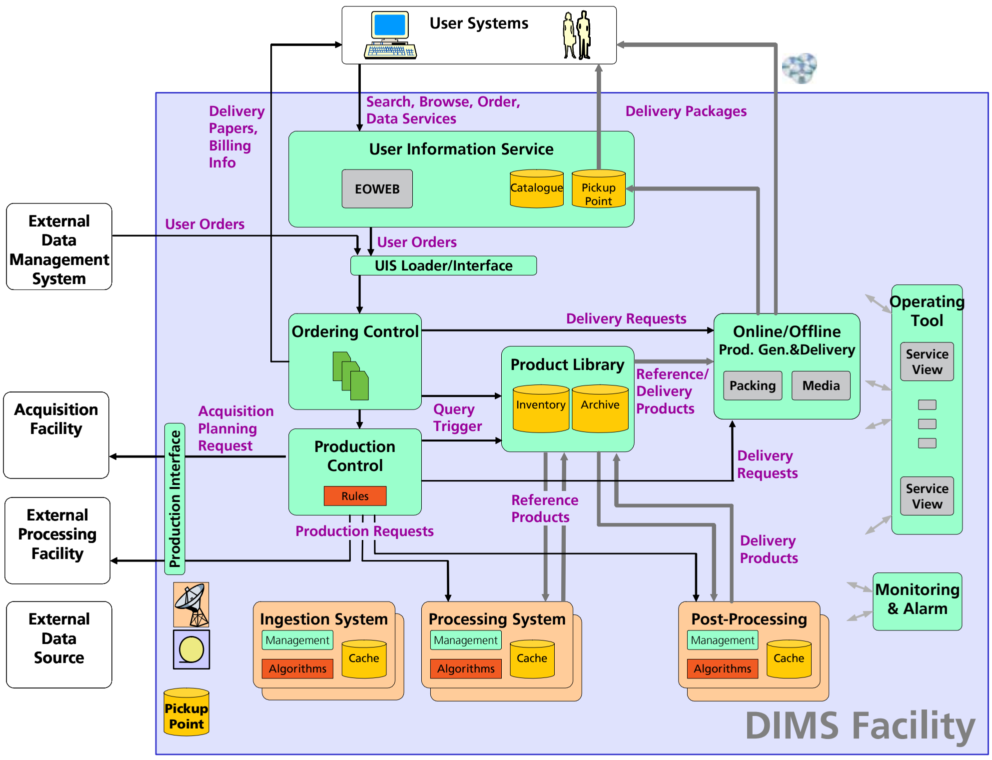

Fig. 3. Request driven processes

MONITORING AND CONTROL PROCESSES

Another important group of payload ground segment processes deal with the monitoring and control of the different services and workflows. Many activities run in an autonomous way and require high reliability. Other activities need operator interaction and control.

Monitoring and Alarm

The systematic data ingestion and processing workflows have to perform in a systematic way, without operator interaction. To ensure high availability, autonomous monitoring and alarm functions continuously monitor different system aspects. Critical states and failure events are propagated to the operator, for example if a single product ingestion or processing fails, if a single product ingestion or processing runs out of time or if the ingestion or processing is inactive due to no new data becoming available in a certain time frame. The same applies to the near-realtime delivery of products which can directly follow a systematic ingestion or processing.

The complete order workflow, from validation to delivery, including acquisition, processing and post-processing has to be supervised by the monitoring and alarm service. Any failures and abnormal delays can provoke an alarm to be sent to the operator. The monitoring and alarm service provides summary and detailed views to monitor the current status and load as well as the history of the distributed components at any time and allows controlled downtimes for maintenance of service components.

DIMS provides monitoring and alarm functionality in every service component. All major resources are continuously monitored and visible online in a central integrated view. Alarms can be sent to the operator on duty via email or SMS.

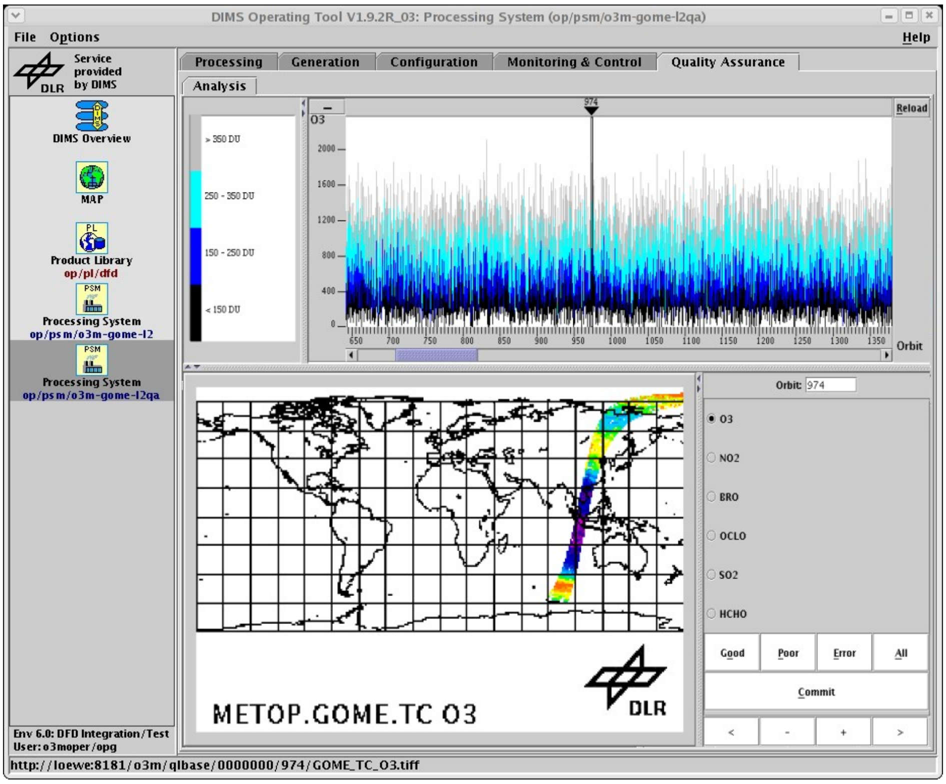

Fig. 4. Product quality assurance for trace gas concentration products with the DIMS Operating Tool

Service Operating

Many product and order management tasks require the ability to directly interact with the corresponding services to place ad hoc queries and perform online analysis. As mentioned in different scenarios in the previous sections, operators have to be able to place orders and production requests and to be part of or intervene in running workflows. In case of failures, the operator has to be able to analyse the situation by viewing workflows, requests and messages, and to perform corrective actions and to resume normal operations.

Figure 4 shows the DIMS Operating Tool (OT) with a specific product quality assurance view, allowing the operator to analyse a timeline histogram of processed atmospheric trace gas concentration products in order to detect runaways and anomalies. This is a typical example for regular operator interaction. The OT is an autonomous client tool that allows the operator to work with all DIMS service components by switching from one service view to the other [4]. Workflows can be traced by navigating through the major business objects such as products, orders and requests. The OT manages different operator roles and the displayed views depend on the operator that logged in.

Reporting

Reporting is the process of condensing and documenting information about the various activities in a multi-mission payload ground segment. From the operations point of view, reporting is important to document the utilization of the facility and the workload of its components. Reporting helps to identify hot spots and bottlenecks in the system and is a basis to decide on further system developments and investments. Regular activity reports are an important information source for general business development and management. Reports may also be used for the accounting of service usage to major entities such as projects and partner organisations.

Typical reports that have to be generated for example on a monthly basis are user service and external data access rates, the number of orders and acquisition/production requests processed, the turnover achieved and the data throughput. Another interesting report is the product population, a computation of the coverage of all products of one collection or mission over time, space or any other metadata parameter.

In DIMS, reporting is supported by some low level tools mainly based on database and log files analysis. An integrated reporting service is under development.

CONCLUSION

Although consciously planned during the design phase, the scenarios to be supported by a multi-mission payload ground segment facility become complete only through the operational experience. Systems need to be based on an abstract service model and to rely on a flexible architecture allowing service enhancements to support new operative tasks. The scenarios of systematic, data driven processes, request driven processes and monitoring and control processes altogether encompass the activity in a payload ground segment and find their implementation in a network of cooperating service instances, as provided by the Data Information and Management System DIMS developed and operated at DLR/DFD.

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