IT-Based Quality Management of Earth-Observation Operations at ESRIN

W. Lengert
Earth Observation Applications Department, ESA Directorate of Application Programmes, ESRIN, Frascati, Italy

U. Gebelein & G. Lavaux
Serco SpA, Frascati, Italy

The functions and services provided within the Earth-observation operational environment at ESRIN have grown rapidly in recent years. This has resulted in the need for a rationalised approach providing transparency, optimum use of human and facility resources, and structured reporting as a basis for sound decision making, planning and resource allocation. Methodologies have been developed to improve both the quality and efficiency of the Earth-observation operations, with an intranet-based framework to support quality management.

Introduction

The ESRIN Earth Observation (EO) operational environment consists of a network of remote facilities (acquisition stations and processing and archiving facilities) scattered throughout Europe and Canada, supporting the payload data-handling operations for the Earth-observation satellites operated by ESA. The network is managed by ESRIN in Frascati, Italy, where a centralised facility supports the operational activities.

The facility was created within the Earthnet Programme in the late 1970s to ensure the minimum capability needed for solving problems encountered at the remote sites and for supporting the remote operations. Since then, the ESRIN facility has been growing steadily in terms of the number of missions handled and adapting to the changes in technology and the constantly increasing user requirements. With the Agency's ERS missions, the ESRIN facility became the 'Central Processing Reference Facility' (CPRF), including the functions of ERS operational mission planning, ERS sensor monitoring and control, and product generation and distribution, mainly related to data received from remote international ground stations.

The rapid growth in the functionality and the services required resulted in an increasing number of on-site contractors from several different companies, quickly transforming the Centre into a complex operational environment. This in turn has called for constant organisational adjustments and has demanded a very rational approach to the management of the access to and control of the computing infrastructure and the related human resources.

This complex task of rationalisation has been completed by applying an Information


Figure 1a. The main computer room in 1980's


Figure 1b. The main computer room at present

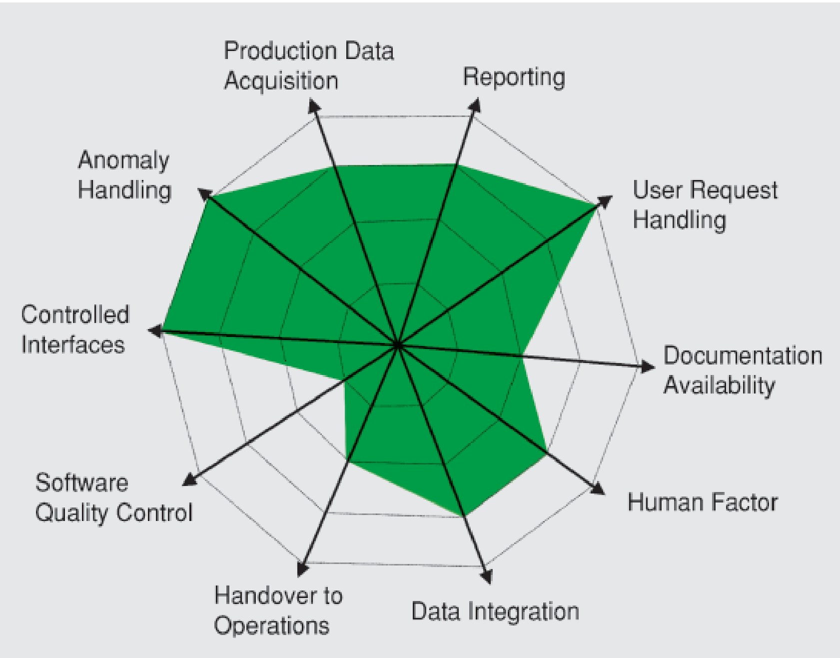
Technology (IT) based framework, into which identified key functions have been integrated and are monitored to provide reliable quality management. This solution allows the standardisation of procedures for handling service requests, service provision, conflicts of requirements monitoring, resource allocation and control, and generally improves visibility for the user and the management. This article describes the methodology adopted, the off-the-shelf tools used, and the many benefits that have been obtained on a comparatively short time scale.

The complexity of the environment

The operational computing environment consists of a non-homogeneous mix of computer equipment in the computer room and various offices running operational and scientific applications, including applications under operational qualification on both old and new technology equipment. The infrastructure is based on about 100 platforms from the most popular vendors, and several hundred peripherals of various types (magnetic/optical), plus quite a number of very specific pieces of equipment and laboratory-type units. Most hardware items are running very specialised applications, which requires specific configurations.

Operations also require an adequate logistics set up including hot spare parts, shipment of products, consumables procurement and storage, tracing of hardware and software configuration changes, tracking of data and hardware (down to board level) in transit to and from the remote facilities (stations, Processing and Archiving Facilities) and hardware undergoing repair or on loan.

Figure 2. Kiviat graph of identified QM functional



The EO operations consist of some predictable routine work, activities initiated by random user requests and special tasks, requiring continuous adaptation of the infrastructure as well as ad-hoc solutions:
- day-to-day operations
- data-transfer monitoring
- product generation and distribution
- reference system operations
- acceptance of new operational chains
- installation of EO applications and system integration
- application/system troubleshooting
- product and system operational qualification
- product and software quality control.

The major tasks can be grouped into seven broadly defined 'key classes':
- Computer Operations (including support to specialised services)
- System Administration
- Historical Data Archiving
- System/Application Library
- Logistics
- Shipment
- Hardware/Software Inventory.

Quality-management objectives in operations

Commitments to be fulfilled at all times as part of the routine service to external users by the operational facility can be summarised as:
- Guaranteed availability and reliability of the resources.
- Satisfaction of customer/user needs.
- Defined and committed product quality.

The problem was how to fulfil such commitments despite the complexity of the service requirements highlighted above, and the constant evolution in the environment being managed. The solution was to adopt a proper integrated management system allowing those responsible to work in a fully synchronised fashion, with everyone aware, at any given time, of the system requirements, the expected workload, the availability of resources, and the expected output. Full system visibility has thereby been extended to all people involved in the operational process, including the service requesters.

The main objectives set for quality management were:
- ensuring transparency in the EO operations-provided services towards ESA management and within the industrial contract providing the operational services to ESA
- ensuring continuous control over best usage of the human and facility resources, for increased system efficiency and monitoring

Services	Computer Operations	System Administration	Historical Data Archive	System/Application Library Logistics		Hardware/Software Inventory Shipment	
Controlled Interfaces	M	M	M	M	M	M	M
User Request Handling	M	M	R	M	N	N	M
Anomaly Handling	M	R	O	O	O	O	O
Reporting	M	M	M	M	M	M	M
Handover to Operations	R	R	O	O	N	O	O
Production Data Acquisition	R	R	M	O	O	O	O
Documentation Availability	R	R	O	M	O	O	O
Software Quality Control	R	O	N	N	N	N	N
Human Factor	M	M	M	M	M	M	M
Data Integration	R	R	O	O	O	M	O

Legend

M (Mandatory)	absolutely necessary
R (Recommended)	helps in the day-to-day work, but depends on the service requestor
O (Optional)	value-added service, case-dependent
N (Not Applicable)	functional activity not part of service

– providing for structured reporting and decision mechanisms for the timely identification of any necessary corrective actions to the core services
– allowing proper planning for resource allocation, taking technological evolution and evolving user requirements into account.

The QM methodology adopted

An analysis of the work processes and flow identified ten major functional activities as being of highest priority and therefore candidates for constant monitoring and improvement to ensure the continued availability of high-level EO services and products.

The methodology adopted was based as a first step on an evaluation of the relationship between the functional activities and the services to be provided. The accompanying matrix (above) serves as an example of the identified links and assigned weights, depending of the value of the operational process. The idea was to build up an adaptive system to allow flexibility and incremental implementation.

The Kiviat graph in Figure 2 depicts each function along an axis and shows a qualitative measure of its importance for improving the performance of EO operations.

To implement the chosen methodology, an Intranet-based framework called the Common Support System, or CSS, was built up. Reflecting the structure of the rationalised organisation, it links the chosen support tools to an integrated information system and is thus a logical model of the operational support structure. The entry page is shown in Figure 3.

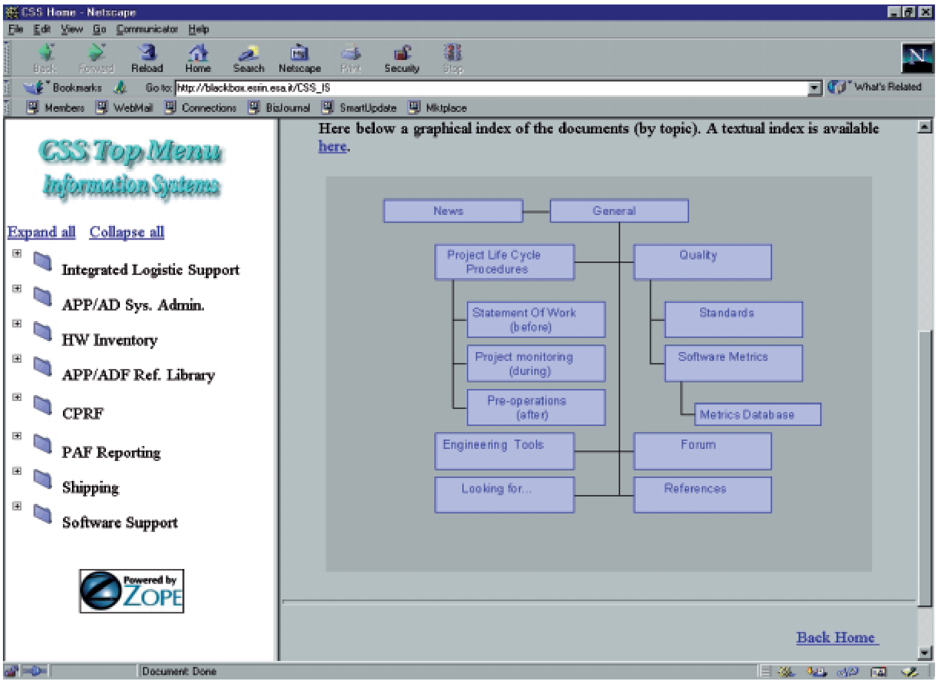


Figure 3. Top level of the CSS framework

Controlled Interfaces
The complexity of the system to be managed demanded that careful attention be paid to interface identification and control. The methods employed had to be flexible and adaptable to the different levels of communication required. The information necessary to support operation and monitoring must be systematically organised and kept in such a way that it can be easily retrieved and analysed.

Formalisation of the interactions between service units was therefore considered a key issue in improving quality management. Means had to be found to:
– collect data and maintain the historical data records

– structure and attribute the data
– foster the adherence to predefined sequences
– allow monitoring of interactions and control of deadlines
– allow basic reporting with the provision of more flexible reporting
– become an integral part of the work processes without disturbing them
– make previously 'personalised' information easily available to staff and management.

Within the CSS framework, such interactions were therefore modelled and formalised via Web data-entry pages. Work-flow management was implemented where task execution needed to be synchronised.

User Request Handling

Adequate methods needed to be identified and implemented to:

– register user requests
– log the current status of activities
– keep track of activities performed
– control deadlines
– keep any information related to requested tasks
– allocate resources and assign priorities.

Within the CSS, requests can be structured hierarchically both in terms of time scale (subdivided into reporting periods) and request type. Additional information can be attached to all hierarchical levels.

Reporting

Proper structured reporting is required for monitoring purposes, but also to measure the performance of the service and thereby support decision-making. The presentation of the information needs to be standardised, with a distinction between two types of report: those to management presenting trends, systematic problems, and the scope of the work performed, and detailed reports allowing the technical officer to closely follow the services being provided.

Operational production data are, by their nature, inconsistent, incomplete and, in isolation from their context, not very meaningful. Processing anomalies have to be handled properly by data collection tools, which ensure data consistency and integrity.

Reporting is updated on a weekly basis mainly with data extracted from application log files (processing, distribution). The reports themselves are kept in a database that can be queried to answer operational questions concerning performances, bottlenecks and critical dependencies. Figure 4 is an example of a typical report used today within the CSS framework. The work packages are linked to applications, to staff and to the computer systems utilised. The throughput of critical systems for each work step is displayed and is checked for consistency with the overall system performances, thereby ensuring the reliability of the information in the report.

Anomaly Handling

Existing knowhow was used to control anomaly handling, leading to the implementation of a distributed Change Request Management System (CRMS). This COTs package was considered not only easy to use, but also the leading defect tracking system, linkable to a configuration-control tool, and therefore best suited to manage information throughout the software life cycle. The CRMS is fully configurable, and change requests can be easily submitted and queried via a Web interface.

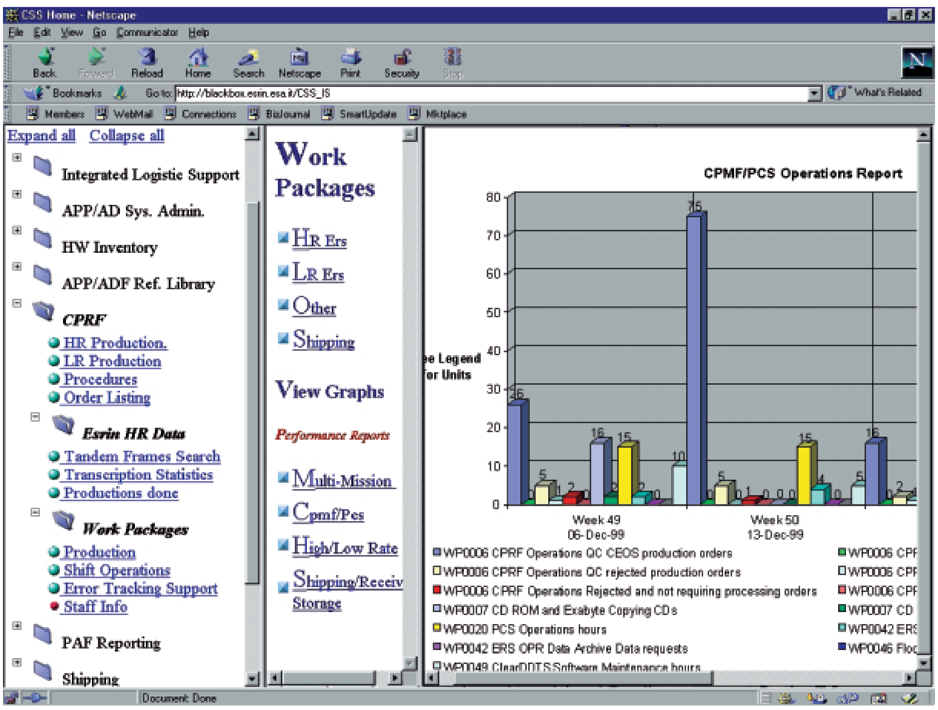
Production Data Acquisition

EO applications generally produce extensive logs, which are checked both manually and automatically. They are collected and displayed on the Information System Intranet page.

The integrated system makes best use of available production data by providing two levels of product-generation status visibility:

– Monitoring: for example, the state of currently ongoing productions is visualised and critical production status is flagged

Figure 4. Structured reporting



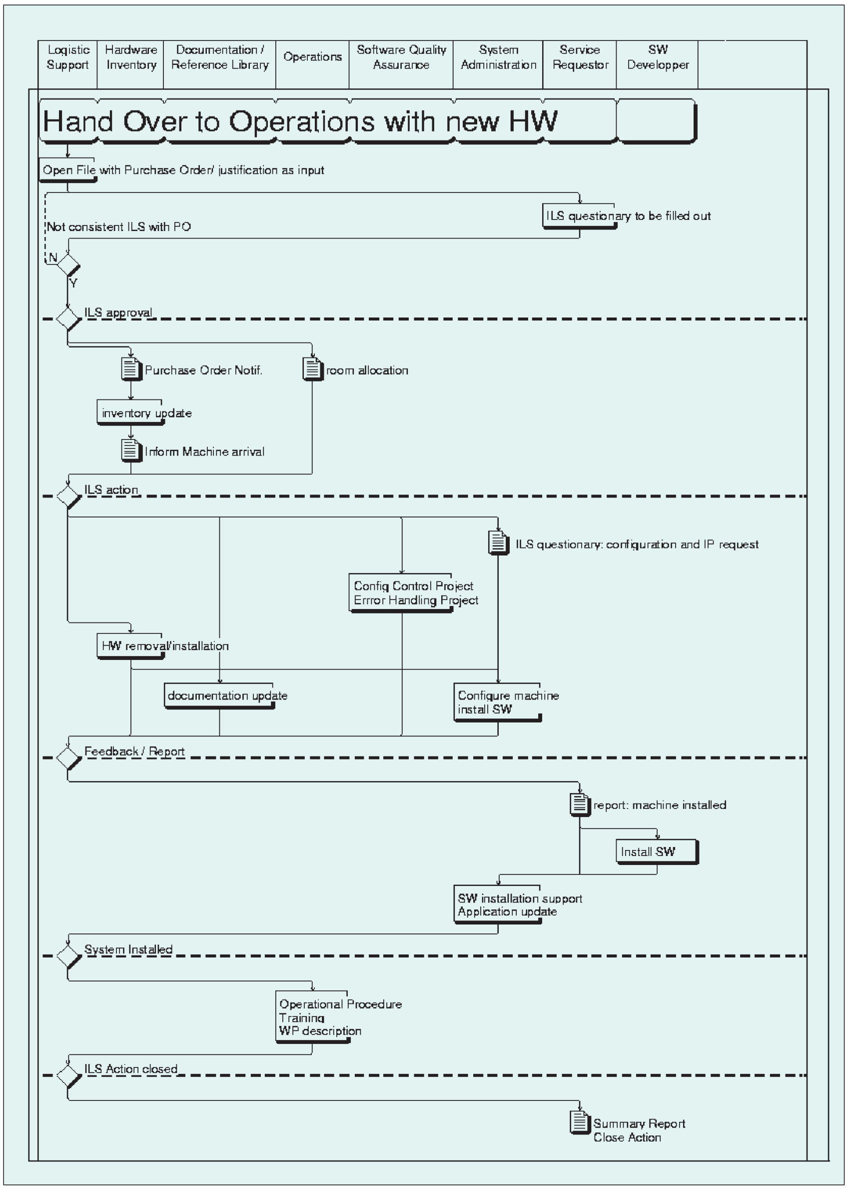


Figure 5. Example Handover workflow

– Reporting: production data is systematically collected and stored in a database, allowing flexible retrieval and easy evaluation of both the data and performance parameters.

Software Quality Control

Software quality is essential for ensuring smooth and continuous operation. However, noisy telemetry or corrupted or wrongly treated media must also be handled in operations, including data outside specifications. In order to ensure reparability, adaptability, expandability and robustness of the operational systems, it was agreed to ensure stricter application of recognised software-engineering standards and guidelines. Software metrics have been applied following the idea of Tom De Marco that "you cannot control what you cannot measure".

A suite of appropriate engineering tools was established and made available to foster standardised working practices during the several project/life cycle phases (anomaly handling, configuration control, test execution, source code analysis, quality guidelines) and thus create comparable historical records (Fig. 3).

Handover to Operations

To satisfy the objectives listed above, the system handed over to operations first needs to be qualified. This requires knowledge of the application, the system configuration, special requirements for integration in the operational environment, project history, test configurations, etc.

Since qualification is not always applicable, the Hand-Over-to-Operation for Quality Management is classified in the following two categories:

– With operational qualification; the operation team operates the system and takes commitments for associated products and services;
– Without operational qualification; the operation team operates the system on a best-effort basis for associated products and services.

In Figure 5, it can be seen that the handover process involved up to 7 service/user groups, and hence a considerable co-ordination effort. The methodology implemented assists the planning and co-ordination activities and allows monitoring and deadline control for the ongoing activities. Threshold exceeds are automatically communicated by the reporting system via e-mail and must then be justified. To help decide on the best corrective action, the test information, acceptance test documentation, configuration items, hardware/software inventory, reference data, etc. needs to be readily accessible. An additional approach channelling the information to the operations team was used, compacting these data by Intranet questionnaires. Accessing these data is easy because it is the retrieval of structured information, while searching for specific information of systems/application in documents might be tedious and sometimes unsuccessful.

Data Integration

The utilisation of data as ‘information’ must be approached very carefully, since operational data can be:

– incomplete, due to operational disturbances or certain data not being identified when requirements were defined
– inconsistent, due to changes in application programs, formats or work processes, and therefore no longer comparable
– incorrect, due to operational disturbances or being an uncontrolled copy of duplicated data
– inaccessible, by being difficult to access or retrieve from where it is stored, or the system does not efficiently support crucial queries.

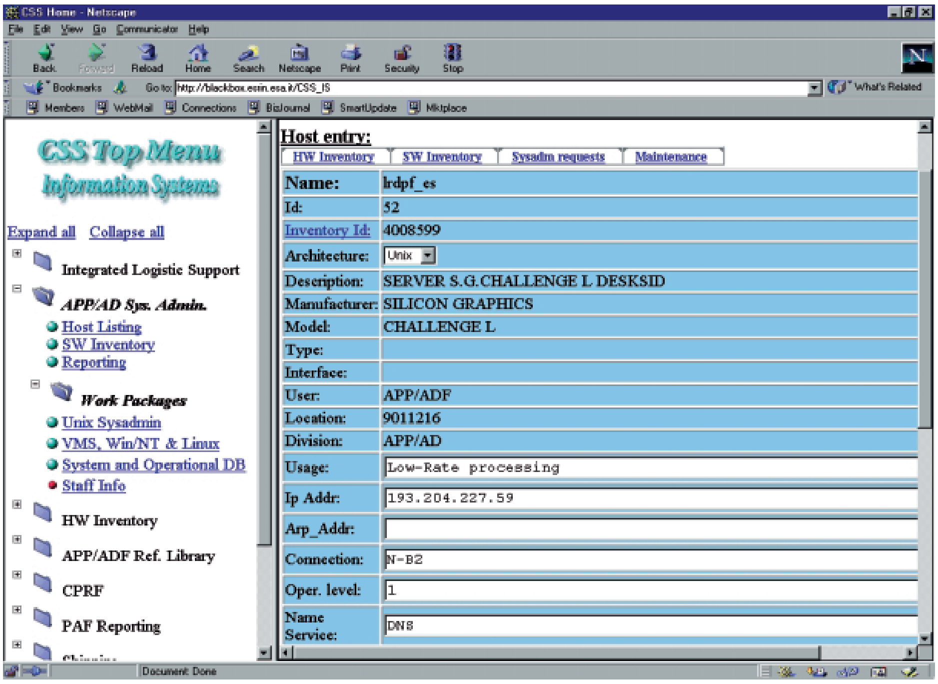


Figure 6. Integration of inventories and service activities

To measure performance, it is essential to thoroughly structure and model and to obtain clean and consistent data, with provision for performing effective plausibility checks. Cross-checks between data derived from different systems must be applied wherever possible. The database management system itself therefore provides valuable means for guaranteeing data integrity. Data need to be transformed and be prepared for use. Data can be collected automatically to avoid the effects of human error, with the collection of historical records being an integral part of the process. Data must be readily available and easily accessible to avoid that individual services create their own local and uncontrolled collection of information files. The use of private mailboxes for operational use must be discouraged and public means used instead. Comfortable user interfaces and query tools allow the best usage of data.

Within the CSS, data integration is facilitated by

– Enabling access to relevant information of the inventories (hardware and maintenance contracts) handled by the finance department, and linking them to the anomaly-handling system to ensure consistency.
– Cross-linking hardware and software inventory with the system administration activities and the maintenance contracts to identify systematic problems.
– Keeping the data model of the handover separate from the other inventories, resulting in two data worlds – a planned/requested and a nominal/actual world – to provide traceability of actual computer configurations back to their origins.

The CSS Web-page tree displays different information levels with the same look-and-feel:

– The request view tree only supplies Web pages that are of relevance to the inexperienced user who needs to make a request.
– The information system view tree contains Web pages for searching in production data and fetching reports (see Fig. 4)
– The internal view comprises pages with restricted access, for service-unit staff only.

Documentation Availability

A System Documentation Library was set up to maintain a master list of applicable documents for the operations environment, including reference systems, EO off-the-shelf software, prototypes and test documents. Documents can be requested directly via the Web within a search. For the reference systems, a compatibility check needs to be performed after hardware/software maintenance or anomaly de-bugging. The documented nominal system configuration items and the project history are therefore strictly linked to the system itself.

In order to have the correct level of information available for each system, the Handover-to-Operations procedure discussed above gathers information through the use of focussed questionnaires.

Human Factors

As already noted, well-motivated and well-trained staff are key to making quality management in an operational environment a reality. Roles and responsibilities need to be clearly defined and documented. The qualifications and training and assignment histories of the staff are also available on-line. Performance has to be maintained by continuously improving the working environment, implementing best working practices, communication and training. The CSS provides human-resource information transparency (work packages, assignments, responsibilities, reporting) to the staff and thereby helps to encourage a constructive working culture.

Use of IT Tools

The Linux operating system is both fast and reliable and the Alpha machines were chosen for their outstanding price/performance ratio. To ensure high system availability at reasonable cost, the fault-tolerant Linux cluster solution was adopted.

POSTGRESQL (also a freeware tool) was chosen as a low-cost solution for the Database Management System (DBMS), providing the performance, flexibility, scalability, distributed access, safety and physical independence required, and last but not least the powerful SQL (Structured Query Language) capability. POSTGRESQL can be easily accessed from PC office packages without disturbing day-to-day operations on the production database. PC query tools can be employed to elaborate, analyse and display the production data for reporting purposes.

A Web-based strategy was followed to guarantee a high level of information transparency. The chosen public-domain Web publishing system Zope has plug-in interfaces for the most common databases, and commercial adapters are also available. Most of the pages of the Web site tree are dynamically created and stored within Zope using its object-oriented functionality and thus guaranteeing consistency of links. Zope is linked to a Apache Web server, which hosts the static Web pages of guidelines, procedures, work instructions and other documentation. A synchronisation mechanism avoids concurrent production data extraction and database ingestion being performed on the operational machine whilst maintaining data integrity and consistency.

The benefits

After some months of operations using the new tools adopted and the application of the procedures imposed by the Information Management System, the benefits are very clear. The effort needed to manage the entire operational setup has been reduced and user satisfaction has increased, due to the overall improvement in efficiency. The staff directly involved in the operational process now feel part of an integrated system, with greater personal visibility in the operational process.

The Central Facility is certainly now more prepared to absorb the expected increasing workload, stemming mainly from the imminent start of Envisat mission operations, and to integrate the new services required by the growing market activity associated with Earth Observation payload data exploitation.

Conclusion

As highlighted above, operations should not be seen as just a repetitive sequence of routine work. In our environment, a predominant component is certainly represented by adaptation of the operational setup to the changing requirements and the evolution of the controlled infrastructure due to technology trends. That also means adjusting and controlling its dynamic reference in relation to the external and internal interfaces. This objective can only be achieved through the application of systematic quality-management methodologies.

Quality management implies fact-based reasoning to provide a solid basis for decision-making at all times. An integrated communication infrastructure is therefore essential and can only be provided by a centralised Information Technology system, based on common databases as core elements, thereby ensuring the meeting of the key objectives of:

- potential growth of the overall system within a controlled environment
- adaptability by controlled incremental adjustments
- rationalisation of human resources
- transparency of the decision process to service users
- increased overall system efficiency.

However, information technology and systematic methodologies alone do not necessarily ensure successful quality management. Optimised processes, good working practices and motivation cannot just be expected. The working culture and the behaviour of the staff involved must also evolve accordingly, and this evolution must be carefully planned and actively guided.