OMG and Distributed Object Database Issues in Detector Construction and Quality Control

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Abstract

The CRISTAL project will provide the quality control for a large number of parts to be produced in several countries for the CMS Detectors. Production will be controlled by specifying a set of workflows, which, as well as indicating the production sequence, specify Quality Control processes for identifying and correcting problems in production. Thus the system will be able to ensure that all parts are manufactured correctly and that they meet the standard required. Production specifications are provided centrally (Central System) but actual production will take place in so-called Local Centres distributed world-wide and loosely coupled with the central system. The data accumulated during manufacture are stored in a local object database and will be duplicated to the Central System when network conditions allow. CRISTAL will store all production history and the measurements permanently, providing free access to physicists and engineers for experiments and maintenance for many years to come. The complete process will occur across a number of sites in different countries, so an Object Oriented Database on the World Wide Web will be used to synchronise production.

1 Introduction

The CRISTAL system [1] is being developed to monitor and control the production and assembly process of the Electromagnetic Calorimeter (ECAL) for the Compact Muon Solenoid (CMS) experiment to be run at the Large Hadron Collider (LHC) facility at CERN from 2005 onwards [2], [3].

The initial phase of the CRISTAL (Cooperating Repositories and Information System for the Tracking of Assembly Lifecycles) project is concerned with the production and tracking of over 83,000 lead tungsten mono-crystals and their fast electronics to be installed in the CMS ECAL high energy physics detector. The CMS ECAL detector will ultimately be composed of around 1,000,000 parts of about 500 part types. The Crystal Detector is just one detector in the CMS experiment and the CMS experiment itself is just one of four to be used with the LHC. Each of these parts will have their physical characteristics individually measured and their associated technical documents will need to be stored and managed. Due to the number of crystals involved in ECAL construction and the very high standard to which each must be grown there will be a number of *Production Centres* located in Russia, China, and the Czech Republic. Assembly of the crystals with their associated electronics and mountings will take place in so called *Regional Centres* located in Italy, UK, Russia and at CERN which will also act as the co-ordination centre.

Since the overall costs and timescales of crystal production must be strictly controlled, the efficiency of the production process is paramount. It therefore follows that quality control must be rigidly enforced at each step in the fabrication process. The CRISTAL system must support the testing of detector parts, the archival of accumulated information, controlled access to data, on-line control and monitoring on all Production and Regional Centres.

This paper describes the specific database communication problems in the CRISTAL system showing the network and database issues that must be addressed and their interactions which require a special approach to communications within the CRISTAL project. CRISTAL must be able to interact with many other tools, ensure that data will never be lost across the network and it must ensure that production processes can be defined and redefined as necessary. These issues are discussed in more detail in [4].

2 Detailed requirements of CRISTAL

An Engineering Data Management System (EDMS) [5] will be used to manage, store and control all the information relevant for the conception, construction and exploitation of the LHC accelerator and experiments during their whole life cycle estimated to be more than 20 years. EDMS will define these systems in terms of product breakdown structures, assembly breakdown structures and manufacturing work breakdown structures. All the engineering drawings, blueprints, construction procedures, part definitions and part nominal values will be stored in EDMS. Since CRISTAL provides production management and workflow management facilities to control and track parts through the manufacturing life cycle up to the final construction and assembly of the crystal detector it must be able to interact with EDMSs, both now and in the future.

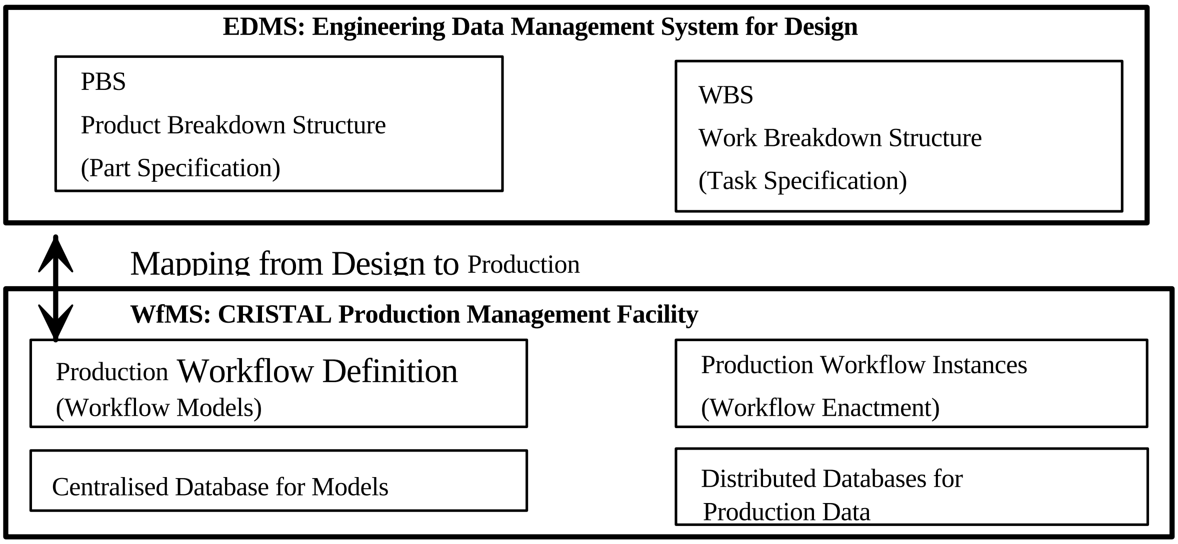

Figure 1:The EDMS consitutes a centrally available product description and the WfMS consitutes the actual processes required to produce the final product.

The EDMS will involve several components: a Product Breakdown Strucutre (PBS) (the graph decomposition of the Product providing the with Part Definition and Part Compostion relationships); an Assembly Breakdown Structure (ABS) (the tree generated from the PBS graph when navigating from the top holding the Items and their decomposition and a Work Breakdown Struture (WBS) (the graph decomposition of the workflow used to create and calibrate the parts). The relationship between CRISTAL and an EDMS is shown in Figure 1.

Effectively, CRISTAL will be used to design and build a distributed information management system to control crystal production across all centres and so it will become the central link in a distributed engineering information management and control system, controlling the production process of the crystal detector and providing secure access to calibration and production data.

A workflow system, derived from the PDM, will be used by CRISTAL to control production in each of the local centres as well as the shipping of parts between centres. Since the workflow system will be designed at the central site, and also since the production process will evolve over the lifetime of the project, CRISTAL must be able to communicate changes to all the local centres via the network communication system and the changed workflows will be stored on the local databases at each local centre.

3 Coping with dynamic change

The previous section alluded to the main difficulty faced by the designers of the CRISTAL system: that of dynamic change to the definitions of the components that it manages. The crystal detector is still very fluid in its design but being the inner most detector matters are made worse because it must start its production process first so that the CMS experiment can be assembled on time. It is envisaged that particularly in the early stage of production there will be many changes to the definitions of tasks and parts. If these definitions are kept statically in the database then problems of database dynamic schema evolution will result when definitions are changed and particularly when objects migrate from one centre to another.

This will inevitably lead to the problems of schema evolution in the database, with many objects needing to be stored under the old schema with long running transactions. These problems imply that a versioning system as discussed in [6], [7] and [8] is essential, but also, to cope with future developments of the engineering tools, we have introduced the concepts of meta-objects.

Meta-objects are descriptions of the objects which are managed by the database. Meta-objects are customisable without affecting the underlying database schema. The concept of meta-objects comes directly from the ideas of reflection [9] that is the ability for a system to manage information about itself and to change aspects of the implementation of the system on an object-by-object basis.

The object framework of CRISTAL is a dynamic structure which holds a description of itself which can be manipulated and configured whilst the system is running thus allowing incremental changes to be made. Within this framework all fundamental object classes are also are meta objects. In the current prototype these self descriptions have been done in an ad hoc way without any thought to descriptions being made available to other foreign systems which might wish to use CRISTAL in the future. If CRISTAL is to support a particular viewpoint such as Calibration, Maintenance or Experiment Systems Management it requires a corresponding Under-

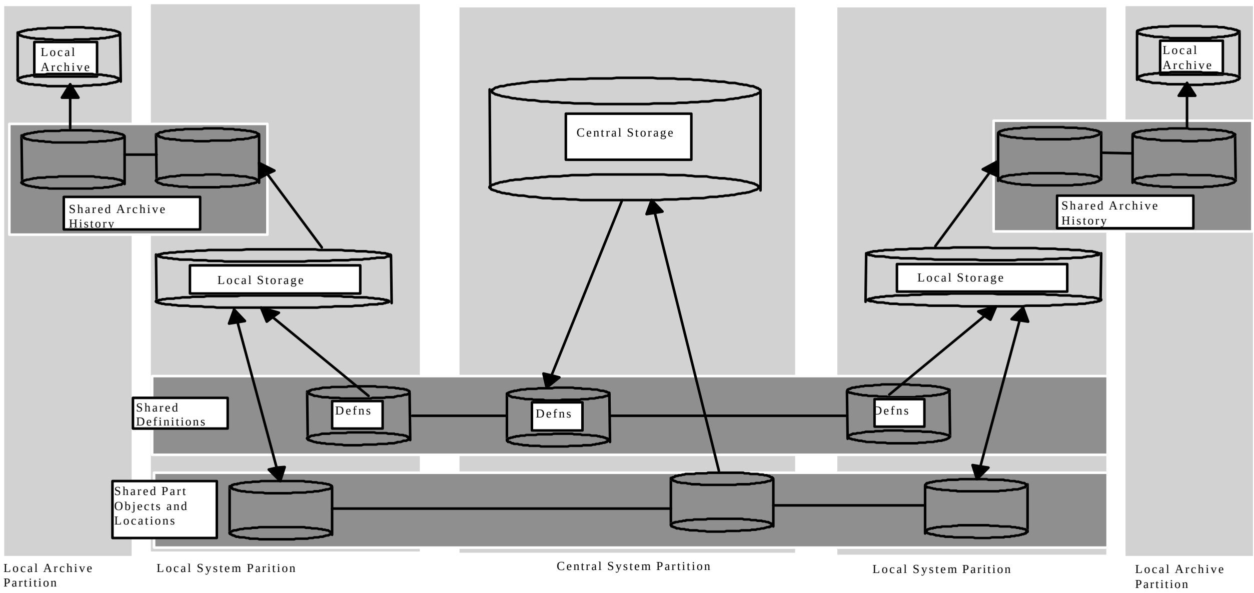

Figure 2: Partitions and data distribution in CRISTAL

lying object schema normalised to that viewpoint in order to successfully navigate and find relevant data.

4 Data distribution philosophy

The data handling and storage aspects of CRISTAL must be transparent to any users of CRISTAL wherever they are located. The main objective of the CRISTAL database system should be to provide maximum data availability with minimum local data storage. Part, task and production scheme data will be defined by the Coordinator at the central site (CERN) and captured in the central database. The Coordinator will determine when those definitions become active in the other centres and the CRISTAL software will distribute these definitions from the central site to outlying databases; thereafter the CRISTAL software will populate the new structures in those centres.

CRISTAL must ensure that no data can be lost between the centres so, a standard distributed transaction model is inappropriate, since a transaction can be blocked or it may abort due to unreliable or delayed network communications. Special software to handle the hand-over of data from one system will be written to ensure that these needs are met.

Data will be collected at each centre during the production/testing/assembly lifecycle and will reside at the centre for as long as the part resides at that centre. Data collected locally will be duplicated in the central CRISTAL system for security, for access from other centres and to act as input to the final Reference Database. Therefore an object duplication strategy is required in CRISTAL to provide transparent access across centres to part definitions and characteristics. Since the projected final amount of data in CRISTAL is of the order of 1 TeraByte, a fully replicated database approach with 10 centres (and therefore 10 TeraBytes of data) is not technically or economically feasible.

Dividing the database into autonomous *partitions*, each managing and controlling its own data and resources, allows concurrent access to information across the networks and reduces the impact of network failures. Availability of information, in the presence of failures, is achieved by replicating system resources such as hardware, software and data. This controlled replication eliminates any single point of failure in the distributed database. Data integrity is then maintained by parallel synchronous updates.

The Objectivity/Fault Tolerance option allows the creation of a widely distributed database environment. The CRISTAL database can be divided into autonomous groups, or partitions, which can be distributed across multiple platforms with access provided by local or wide area networks. An autonomous partition can continue to work independently of the availability of other autonomous partitions. Furthermore the Objectivity/Data Replication option allows replication of the database across multiple partitions. This replication mechanism again involves parallel synchronous updates.The CRISTAL database system has been built using Objectivity and has the following set-up. Each local centre is equipped with two autonomous partitions. One partition holds the local data and definitions and the other holds the local archive database (see figure 2) . The central system (at CERN) will have only one partition for the central database and associated definitions. The local centres store part information in the local base relevant for the parts currently located at that centre. If a part is to be shipped out to another centre for testing or assembly, the local archive base and the central database are updated to reflect new information and the part information is deleted from the local base. The central system's base always holds all current part information.

5 Conclusions

The above discussion shows the communication needs of the CRISTAL system. The conclusion of all these requirements is that the network and database must fit with interoperability standards, be self describing (and hence require the storage of the schema and meta-meta-data), guarantee no blocking or loss of data and store data for extensive periods of time using versioning to adapt to changing circumstances. OMG and ODMG standards are being used for the network objects and database respectively, with special versioning, and transaction models being written.

CRISTAL development was initiated in early 1996 at CERN and a prototype capture tool was developed using O2 and WWW to allow existing aspects of ECAL construction to be incorporated in an object database. The second phase of prototyping and technology evaluation was initiated in the summer of 1996 and development of this prototype is well under way and is based on the ECAL testing and construction programme in CMS. The OODBMS Objectivity™ is being evaluated as a repository during this second phase of CRISTAL research and development. At the time of writing the final version of the User Requirements Document for the CRISTAL Prototype 2 system is complete and the Software Requirements Document almost complete.

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References:

[1] J-M Le Goff et al., "CRISTAL: A data capture and production management tool for the assembly and construction of the CMS ECAL detector". CMS NOTE 1996/003

[2] The Large Hadron Collider Accelerator Project, CERN AC93-03 1993

[3] M Lebeau, P Lecoq & J-P Vialle, "Distributed Control and Data Base System for the Production of High Quality Crystals", CMS TN/95-024, CERN, 1995.

[4] R. McClatchey et al., "bject Databases in a Distributed Scientific Workflow Application'. In Proc. 3rd IEEE Basque Int.Workshop on Information Technology (BIWIT), Biarritz, France July 1997.

[5] A. P. Hameri., "EDMS - Concepts, Motivations and Basic requirements". Proceedings of the CERN School of Computing 96, CERN 96-08.

[6] M. Rusinkiewitz & A. Sheth., "Specification and Execution of Transactional Workflows". In W. Kim, ed., Modern Database Systems: The Object Model, Interoperability and Beyond. Addison-Wesley, 1994

[7] D. Lomet, B. Selzberg, Transaction Time Databases in Temporal Databeses, ed. Tansel, et al Benjamin Cummings

[8] W. Cellary, G.Jomier, Consistency of Versions in Object-Oriented Databeses, Proceedings of the 16th VLDB Conference, Brisbane, Australia, 1990

[9] J. Peters & M. T. Ozsu, Reflection in a Uniform Behavioural Object Model, Lecture Notes in Computer Science 823, R. A. Elmasri et al (Eds) Springer-Verlag, 1994,pages34-4