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HOW TO FILL A NARROW 27 KM LONG TUBE WITH A HUGE NUMBER OF ACCELERATOR COMPONENTS?

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Abstract

As in large scale industrial projects, research projects, such as giant and complex particle accelerators, require intensive spatial integration studies using 3D CAD models, from the design to the installation phases. The future management of the LHC machine configuration during its operation will rely on the quality of the information, produced during these studies. This paper presents the powerful data-processing tools used in the project to ensure the spatial integration of several thousand different components in the limited space available. It describes how the documentation and information generated have been made available to a great number of users through a dedicated Web site and how installation nonconformities were handled.

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As in large scale industrial projects, research projects, such as giant and complex particle accelerators, require intensive spatial integration studies using 3D CAD models, from the design to the installation phases. The future management of the LHC machine configuration during its operation will rely on the quality of the information, produced during these studies. This paper presents the powerful data-processing tools used in the project to ensure the spatial integration of several thousand different components in the limited space available. It describes how the documentation and information generated have been made available to a great number of users through a dedicated Web site and how installation nonconformities were handled.

INTRODUCTION

In order to guarantee the correct installation of each LHC machine equipment and also to avoid the interferences during installation phases, handling and transport, the integration studies have been an essential step in this project realization.

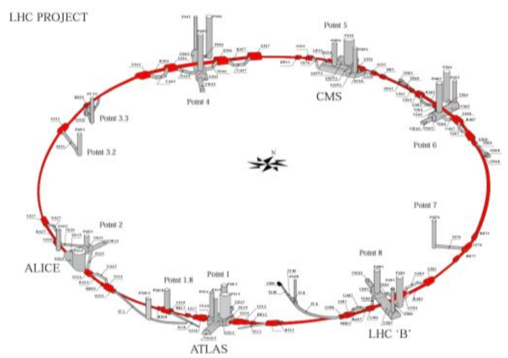

Figure 1: LHC underground installations.

The thousands of elements needed for machine operation are installed in a 27 km circumference tunnel (Fig.1). The machine has been divided in eight octants (8 x 3375 m) each one made up of a long straight section (600 m) and two half arcs (1387.5 m).

Depending on their localisation along the collider, long straight sections house experiments or specific machine function devices:

- Point 1 ATLAS experimental area
- Point 2 Alice experimental area and beam 1 injection
- Point 3 Momentum cleaning
- Point 4 Acceleration and beam instrumentation
- Point 5 CMS experimental area
- Point 6 Beam extraction
- Point 7 Betatron cleaning
- Point 8 LHCb experimental area and beam 2 injection

Standard arcs are made up of cryo magnets (Dipoles, quadrupoles) and services (Cryogenic line, cable trays, piping tubes, etc.).

The first integration analysis showed that:

- The space occupied by LHC machine and its services in the standard arc was much more important than that occupied by the previous LEP machine.
- None of the 150 underground service caverns were identical.
- Computer-Aided Engineering (CAE) tools would be a powerful help in the management of space available for the large quantity of equipment to be installed.

The experience gained during the years of operation of the LEP machine showed that it was absolutely necessary to have a centralised documentation with a high level of reliability and quality.

This paper presents the methodologies used to carry out the integrations studies of all the equipment necessary for the LHC machine operation coming from the various engineering and design departments working on this project in so different fields as civil engineering, metallic structure, electricity, ventilation, piping, cryogenic and accelerators mechanical equipments.

These integrations were performed for the study phase, but they will become a precious help during the installation phase and will absolutely be necessary as a documentation tool during the operation period.

WORKING ORGANIZATION

In September 1999 a weekly work meeting ICL (Integration cellule LHC) started with representatives from all design offices working for the LHC project in order to have a better consistency of integration studies but also to ensure that a 3D model will be supplied for each machine component.

The first step was a 2D approach, using the schematic layouts showing the longitudinal arrangement of the machine elements alomg the LHC ring [2].

Integration studies have been split in two parts: the main tunnel (standard arc) integrated by half-cell, and the long straight sections integrated by underground caverns.

Main tunnel integration

After having analysed which LEP services could be kept, the first typical 2D cross section (Fig.2) showing the LHC machine and its services were issued. The minute space available between equipments in their theoretical position required that exact tunnel concrete walls and ground measurements have to be made in order to verify the feasibility of the future installation.

At the same time, a “manual” 3D integration of a half cell with all its services was performed to ensure that no equipment was forgotten and, in parallel, a Digital Mock-Up tool (DMU) was developed in order to position automatically 3D models relative to each other. This DMU is built around the LHC Reference Database[3].

The cable tray and piping installation drawings were created after validation of the typical cross section drawings and 3D half cell.

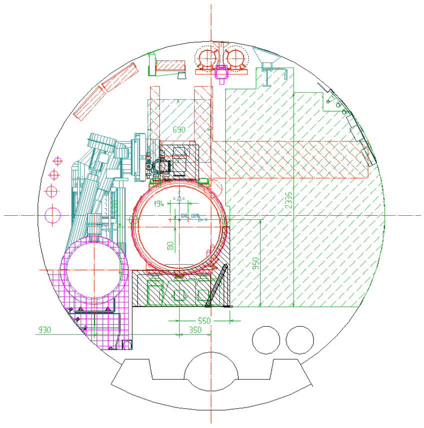

Figure 2: Typical main tunnel cross section.

Long straight section Integration

From the first long straight section integration studies, it turned out that it was absolutely necessary to have a tool to centralize all documentation. The ICL Web site [1] was therefore developed. This site is the repository for all the information used by the design offices and is a major communication tool for the engineering communities (Fig.3).

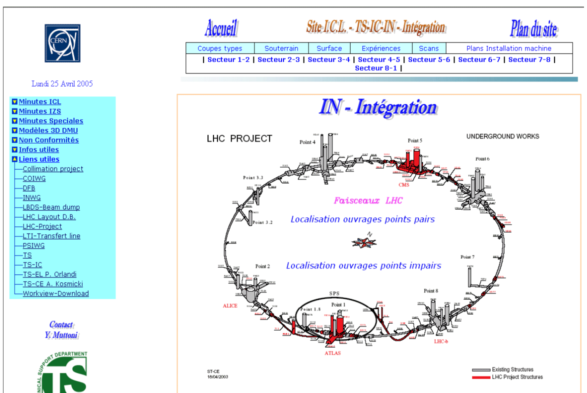

Figure 3: ICL Web Site

The following document types are available for each underground service cavern integrated:

- Photo database.
- Screen shots showing 3D integration.
- Summary tables indicating the 3D Model names .
- Integration drawings.
- 3D VRML Model (Fig.4) (Virtual Reality Model Library).

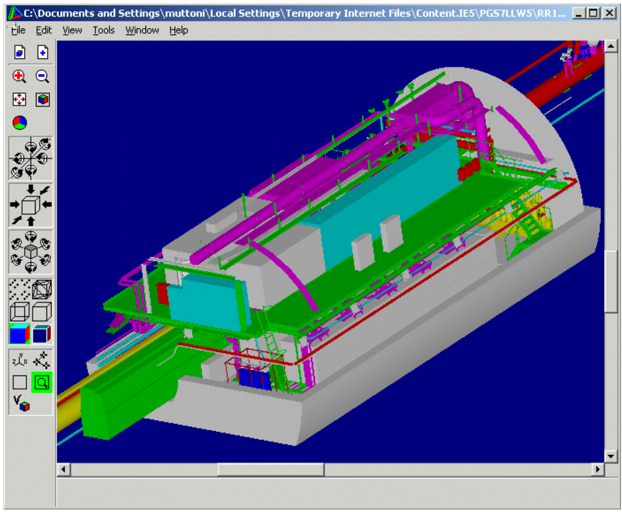

Figure 4: 3D VRML model

Almost permanent modifications led to a large number of iterations and it quickly became impossible to generate time-consuming full integration drawings.

3D integration models became the tool to validate integration studies and all the related documents have been recorded in an EDMS [4] (Electronic database management system) document before the start of an approval process.

After validation, the 3D models are frozen and recorded in database standard and then they are used to produce installation drawings.

INTEGRATION AND INSTALLATION

Space management is a permanent preoccupation and checking the installation quality is essential.

A procedure to issue and manage nonconformity installation reports has been therefore created.

It distinguishes between two types of nonconformities, the first one is considered as critical because it relates to the form, the dimension, the position, the function or any other characteristics of a nature which could compromise the installation or the operation of another equipment. The second one is called “use as is” and leads only to a documentation update.

Two methods are used for checking the equipment or the services installed:

- In situ, by using a portable PC in which the ICL Web site has been fully loaded thus being usable in a standalone mode. Visual comparisons between the theoretical 3D models and real installation can be done, allowing the detection of major geometrical discrepancies.
- A laser scanner allows generating points files, real installation photos in 3D [5]. After uploading these points in CATIA® software, a 3D model is obtained by meshing, and is compared with the 3D theoretical models of the future adjacent installations (fig. 4). One can verify if an equipment or a service is in the right position, as theoretically defined and that no future conflict will take place.

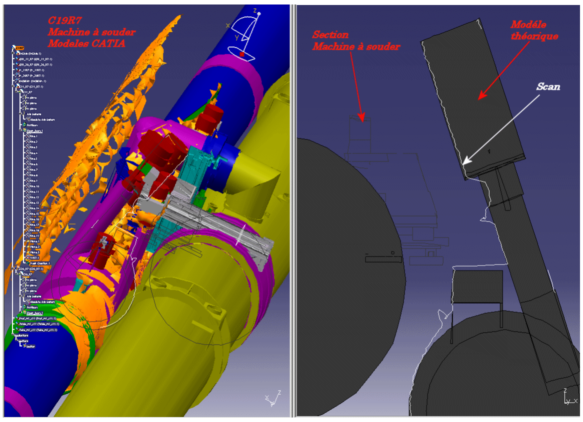

Figure 5: Interference check with CATIA

A non conformity installation report is written to identify the equipment or services, its location, the responsible project engineer, the description of the problem and the corrective action to be taken.

The System Manufacturing and Test Folders Travellers (MTF) are used to manage the follow up treatment of critical non conformities, but also to update the as-built 3D models.

THE ICL SITE AND ITS FUTURE

The documentation available on the ICL site can be summarized as follows:

- Main tunnel: 70 standard tunnel cross sections drawings, 100 definition drawings (Machine layout, piping synoptic, QRL etc.), 3500 standard 3D models, 900 installation drawings (Cable trays, metallic structure, piping, etc...), 544 machine installation drawings.
- Underground caverns: 150 models VRML, 50 integration drawings, 2500 photos.
- Surface buildings: 100 models and integration figures.

Why and how to manage the documentation in the future?

After some years of operation, the radiation levels of the LHC machine will only allow brief human interventions inside the tunnel. This will consequently require to keep all the documentation up to date with a high quality level to allow the best knowledge of the installations in order to reduce intervention times.

The project engineers and the design offices who will study the machine upgrades should be able to find easily the correct CAE data before any shut-down.

During the machine life and after every shut-down, it will be absolutely necessary to update all the documentation.

CONCLUSION

During the Study phase, almost concluded, and the current installation phase, started since few months, the ICL Web site became the central point where everyone could find all information available about his own equipment and its entire neighborhood. For the future LHC machine evolutions, a large, complete and up to date amount of data will be available, at a level never reached by the previous machines at CERN and all this accessible worldwide.

ACKNOWLEDGMENTS

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REFERENCES

[1] ICL Web site http://lhc-div-miwg.web.cern.ch/lhc-div-miwg/Main_Pages/frame%20miwg_icl.htm

[2] S. Chemli, C. Hauviller, R. Messerli, Y. Muttoni, E. Van Uytvinck, , “A Virual CAD Model of the LHC”, EPAC2000, Vienna, June 2000, p. 2139.

[3] P. Leroux, S. Chemli, A. Jimeno Yepes, B. Maire, H. Prin, A. Vergara-Fernández, M. Zerlauth, “LHC Reference Database : Towards a Mechanical, Optical and Electrical Layout Database”, EPAC2004, Lucerne, July 2004, p. 1882.

[4] EDMS Web site URL http://www.cern.ch/CEDAR

[5] T. Dobers, M. Jones, Y. Muttoni, “Using a Laser Scanner for the Control of Accelerator Infrastructure during the Machine Integration”, IWAA2004, Geneva, October 2004.