CONTROL OF THE GEOMETRICAL CONFORMITY OF THE LHC INSTALLATION WITH A SINGLE LASER SOURCE

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Abstract

A large and complex accelerator like LHC machine needs to integrate several thousand different components in a relatively limited space. During the installation, those components are installed in successive phases, always aiming to leave the necessary space available for the equipment which will follow. To help ensure the correct conditions for the installation, the survey team uses a laser scanner to measure specific areas and provides this data, merged together in a known reference system, to the integration team who compare the results with the 3D CAD models. This paper describes the tools and software used to rebuild underground zones in the CATIA environment, to check interferences or geometrical non conformities, as well as the procedures defined to solve the identified problems.

INTRODUCTION

The LHC machine is a complex and giant particle accelerator. It contains thousands of equipments to be installed in a narrow tunnel with a circumference of 27km circumference located more than 80 meters underground. For this purpose, the installation of all those elements is foreseen in several steps, the tunnel being filled consecutively in layers of equipments until the last phase which is the machine itself aligned on the beam.

After the first months of installation, it appeared relevant to control the elements right after their installation to ensure that the next elements could be correctly installed. The Survey group proposed to use a laser to scan needed slices of the tunnel. This information could then be analysed to:

- Check installation non conformities
- Update the CAD data (as-built models)

This paper presents the methodology used to complete these actions, the tools chosen to optimize the results and the perspectives for the future life of the machine.

THE LHC MACHINE

The Large Hadron Collider uses the existing tunnel constructed for the LEP Accelerator. Several additional caverns and special tunnels were added to fit with the particularities of the LHC. Nevertheless, most of the 27km of tunnel match with the following Typical Section, a 3,8m diameter tunnel with its Services (Pipes, Cables trays, Monorail, Safety Elements, the Cryogenic main line [QRL]), the machine (Magnets, Vacuum Equipments, Beam Instrumentation) and the various spaces reserved for Survey and Transport.

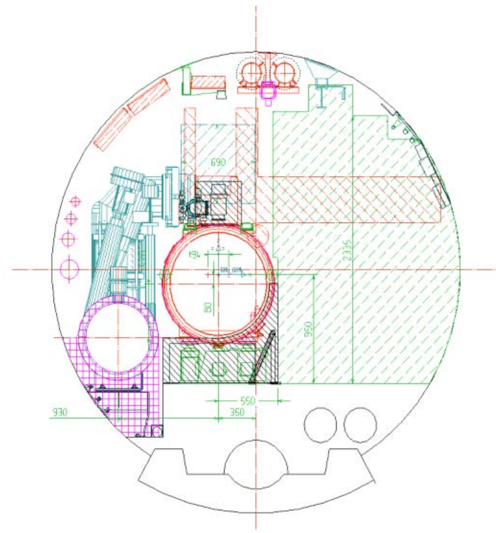

Figure 1: Typical Section of the LHC Tunnel.

In order to properly complete the installation of the machine, all those components arrive in sequential phases, starting by the Services (a), then the QRL (b), and finally the Machine itself (c), this last phase keeping the area free for the transport (d).

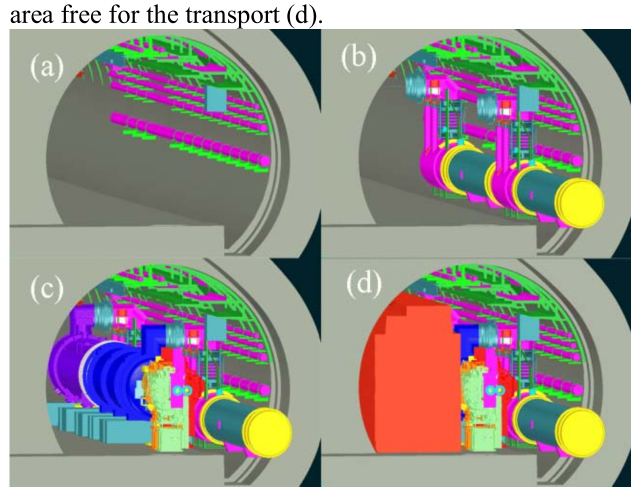

Figure 2: Phases of the LHC Machine Installation.

THE LASER TOOL

In order to sequentially control the correct installation of the elements added into the tunnel, the Survey Team chose a *LEICA HDS3000* laser scanner. This tool is able to measure up to 1800 points per second, in a vision range of 360º horizontally and 270º vertically. It measures points from 1 to 100 meters with a precision of 6mm at 50m.

Figure 3: Leica laser HDS3000 and its accessories.

Some characteristics of this tool like the instantaneous availability of the point cloud for the modelling or measurement or the high precision of the details are not specifically necessary for the LHC. On the contrary of the following features are particularly useful for this machine:

- No contact measurement of the objects
- Operation time reduced
- Measurement of inaccessible equipment
- Non-perturbation of the traffic
- Archive for subsequent controls in the same area

THE CONTROL PROCEDURE

Initiated while the installation of the LHC was already taking place, the control procedure with the laser scanner was defined to respond quickly to the first problems encountered in situ.

Prior to the installation, all the equipments foreseen for the accelerator were modelled in 3D, and then integrated altogether to avoid interferences and allow the correct assembly.

The following scheme (see Fig. 4) shows the place of the laser scanner in the process. After the completion of an installation campaign, the area is scanned.

Then, the measurements are compared to 3D models including the models still to be installed. Three different situations then appear:

- Measurements fit with the 3D integration: the installation can proceed
- Measurements do not fit with the 3D integration without consequences for the neighbouring elements: the installation can proceed and the 3D models are modified to become “as-built” models.
- Measurements do not fit with the 3D model and interfere with the equipment still to be installed: modifications must be made to the equipment and as-built models created before proceeding further in the installation process.

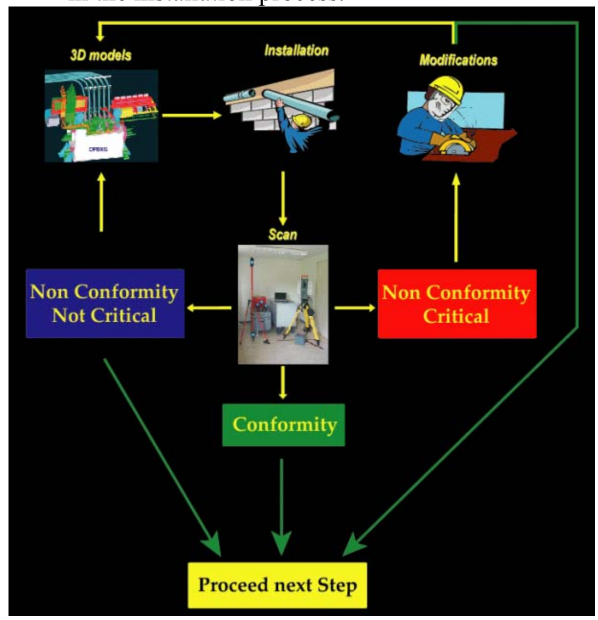

Figure 4: Scheme of the procedures of control.

The last two cases described before start up a process of Non Conformities following the Q.A.P. in use at CERN. It opens a Non Conformity Document detailing the problems (text, photos and any document relevant). The NC is then classified *Critical* or *Use-as-is* and is circulated to the concerned people. Critical issues generate actions to be done to solve them. Non-Critical issues, as Critical ones, require updating of the information stored in the database, by making ‘as-built’ models. Each non conformity is strongly followed until its solving and it is then close. Some statistics of the LHC Machine: 540 non conformities were opened to date, 322 Critical and 218 Use-as-is.

DATA ANALYSIS

Once the laser scanner has measured the targeted area, all the measurements are entered in the Cyclone application where the information rom each instrument set-up are treated by Survey operators to obtain a cloud of points in a specific geodetic reference system.

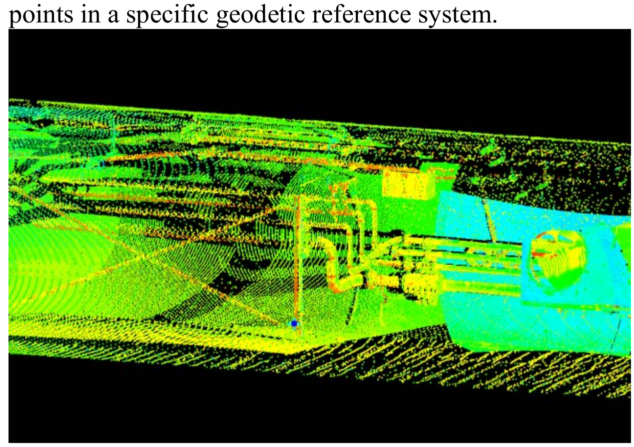

Figure 5: Points Cloud with Cyclone.

The Integration team then load these points into CATIA, create a mesh and compare it to the 3D models loaded from EUCLID.

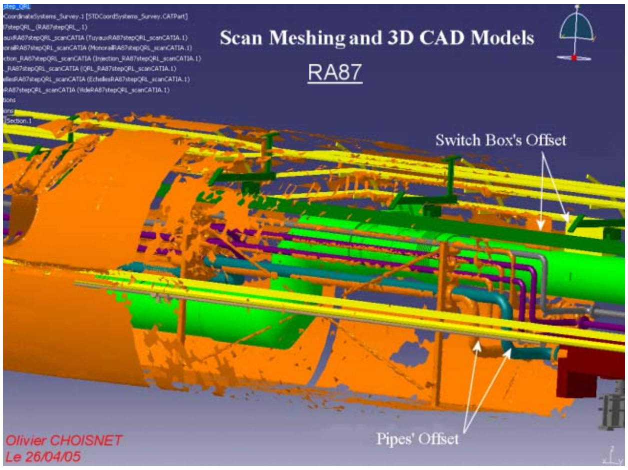

Figure 6: Meshing and 3D models superimposed in the CATIA CAD tool.

CONTROL RESULTS

The analysis of the laser scanner work has several implications for the Integration team.

The first one highlights the non conformities of the equipment installed and the consequences on the neighbouring elements. Modifications can be described and quantified before being made in situ. A final check can then be made before proceeding with the installation.

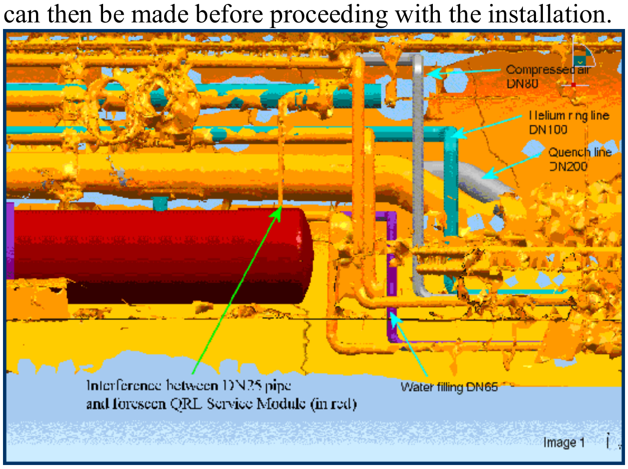

Figure 7: Interference identification.

The second is the opportunity to create "as-built" models with a good accuracy to complete and update the huge data sets available in the CAD software.

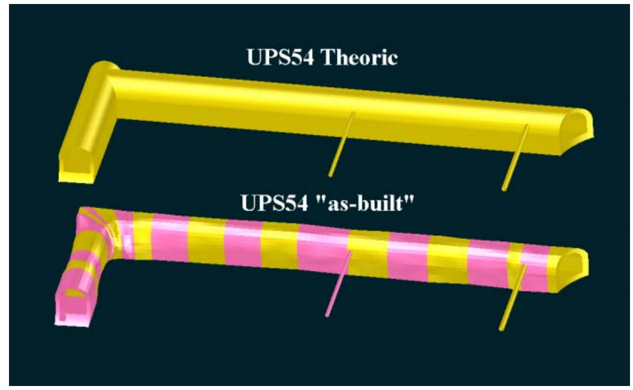

Figure 8: Tunnel as-built model from scanned points.

CONCLUSIONS

LEP installation and more importantly all successive evolutions of this accelerator showed that a good knowledge of the real situation in the machine is crucial to avoid interferences during the installation and as a consequence lost time and money. When adding new equipment, the imperfections in situ, not obviously predictable with only 3D theoretical models, should be taken into account.

The use of the laser scanner gives the Survey and Integration teams the possibility to complete as much data as possible concerning the machine really installed in the underground areas, in caverns and tunnels that are not accessible during operation phases or even during shutdowns in areas with remanent radiations.

All future evolutions of the accelerator could be checked like this and stored in the database. This would require only limited access and still provide a good level of accuracy.

ACKNOWLEDGMENTS

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