CERN ACCELERATORS TOPOLOGY CONFIGURATION: FACING THE NEXT LHC LONG SHUTDOWN

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Abstract

The Configuration and Layout (CL) team at CERN ensures that there is a clear and coherent representation of the status of the CERN underground facilities (about 60 km of equipment) and main accelerator projects at a given point in time.

In view of the major equipment changes to be carried out during the Year-End Technical Stop (YETS), the next Long Shutdown (LS2), and to facilitate the associated preparatory work of multiple CERN groups, the CL team has developed an immersive visualisation tool, displaying 360 degree panoramic images of CERN underground facilities. In addition, the CL team is launching a process to manage future layout configurations inside the CERN Layout Database in parallel to the current configuration.

This paper presents the 360 degree panoramic visualisation tool and the parallel configuration process, to view the past, current and future status of the CERN accelerator complex. It highlights their added value for the CERN groups in the preparatory phase for upgrade and consolidation modifications and discusses the potential future improvements.

INTRODUCTION

At CERN, the configuration and layout management of the accelerators is handled by a dedicated team of engineers working in the Engineering Department inside the Alignment, Coordination and Engineering (ACE) group. The so-called 'Configuration and Layout' (CL) section provides a clear and coherent representation of the LHC machine and its injectors at a given point in time. It controls, centralises and manages all the changes carried out in the CERN accelerators using the reference Layout Database (LDB) [1], [2] and the CERN Engineering Data Management Service (EDMS) [3].

The CL team registers, in the LDB, all data pertaining to the different CERN machines and transfer lines, including the sequence of their components, their layout (mechanical topology of functional positions or slots) and links to their design and manufacturing. The inserted data covers the mechanical, optical and electrical domains. The data managed in the LDB allows the generation of the optics sequence file for the nominal accelerator and the semi-automatic creation of 3D models and 2D drawings (conceptual and consolidated layout drawings). These models and drawings are needed by the CERN groups to visualise the accelerators areas and prepare equipment installation. In addition, the CERN integration team uses these models to study the feasibility of future projects.

In parallel, the CL team maintains, in EDMS, the long-term documentation describing changes or upgrades of the accelerators. All relevant documents produced throughout the life cycle of the accelerator's equipment are stored in the so-called 'accelerator hardware baselines' that reflect the hierarchy of classes, sub-classes and main item types. These documents might be functional specifications, engineering specifications, engineering change requests, installation change requests, installation procedures, technical reports, etc. The CL team ensures the technical quality of these documents, their check by the main stakeholders and their release (or not) by CERN executive committees.

For each change carried out in one of the CERN accelerators, it is the duty of the CL team to update the LDB, to manage the documents in the corresponding EDMS hardware baseline and to ensure the reliability and release of the documents. The CL team guarantees the coherence between the installed equipment, the data inserted in the LDB and the documents available in EDMS accelerators hardware baselines.

To further ease the preparatory work carried out by CERN groups and future projects such as the LHC Injectors Upgrade (LIU) and High Luminosity LHC (HL-LHC), the CL team decided to provide 360 degree panoramic images of the CERN accelerators, and parallel versioning of the layout and configuration (in LDB and in EDMS). These updates are important in view of the numerous changes to be carried out in the CERN accelerators during the coming Long Shutdown 2.

360 PANORAMAS

Throughout the lifecycle of the CERN facilities it has been useful to have photographic records of the machines, assemblies and installed equipment. Photographs have been used for a variety of reasons, from recording installations, to helping to plan modifications and upgrades when machine interventions are either not possible, or to comply with ALARA (As Low As Reasonably Achievable) principles by aiming to reduce incurred radiation doses.

Photographic records help to fulfil the wider aims of Configuration Management to provide a clear and coherent status of a facility at a given point in time, covering the past and present. The process for capturing images initially adopted by CERN was flawed in that they were captured informally, did not always cover the required areas, and were not formally versioned. To address these key issues and add further value for users, the 360 Panorama Project was conceived.

The primary aim of the project is to capture immersive 360 degree panoramic photographs of access restricted areas, including beam lines and underground service areas. These panoramas provide a fully navigable 360 degree view from a particular point, and are linked together to provide the possibility of undertaking virtual tours of the accelerators and other machines. Figure 1 shows a snapshot from a panorama taken in the LHC machine, and shows the navigation arrows used to move between panoramas.

Figure 1: Panorama snapshot from the LHC, showing the navigation arrow, date and location stamp, and the general viewer interface.

To ease navigation through the panoramas, the system is integrated with the CERN mapping tool (GIS system). Each panorama is given a location in the CERN coordinate system, and displayed on a clear top view map of the CERN machines and service areas.

To comply with Configuration and Quality management practices, each panoramic image has a time stamp, allowing versions of the same area to be stored. This gives the end user the possibility to view sections of the machines or service areas at a given point in time, and hence to view changes over time. In order to ensure that the most recent panoramas always represent the present, or real, situation, the configuration managers use the Engineering Change process [4], formally adopted across the CERN accelerators, to identify when and where new panoramas need to be captured.

The panoramas help all CERN users to undertake preparatory work for the Long Shutdown 2 (LS2), as they facilitate the visualisation of the real status of the machines and service areas. When combined with drawings, and other Configuration data, the information available is vastly increased.

For the future, studies will be undertaken to integrate the 360 panoramas with survey laser scans to enable distance measurements to be taken in a panorama. Additionally, to reduce the overhead for capturing images, investigations are underway to assess how to automate the capture. This includes the possibility of mounting the camera system onto moveable robots, and the 'monorail' robotic system used in the LHC machine.

PARALLEL CONFIGURATION

Today, the configuration versioning of the accelerators in operation is driven by the Year-End Technical Stops (YETS) and the Long Shutdowns (LS), as the majority of the changes are carried out during these periods. Four successive phases are needed to set-up an accelerator configuration, as shown in Figure 2:

1. The preparation or 'in work' phase during which the engineering specifications and change request documents are circulating;
2. The phase of review and validation of coherence between the foreseen changes and the current machine configuration ('under check' phase); the engineering change requests are approved at the end of this phase.
3. The implementation phase during which the changes are carried out in the accelerators;
4. The validity phase during the whole following run.

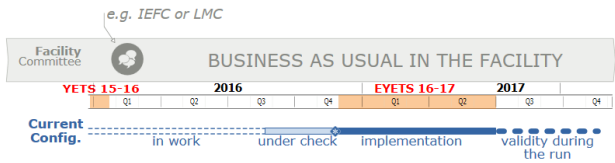

Figure 2: Phases to set-up an accelerator configuration.

CERN entered a phase of major upgrades on the injector chain (LIU Project) and on the main LHC ring (HL-LHC Project). These projects created a need for establishing project hardware baselines and a reference configuration to make sure the stakeholders and work package leaders are all working in line. The current versioning process does not match this request as it does not allow the project teams to know the machine configuration in advance. Configuration versioning today consists in archiving a copy of the 'current version' at a given point in time.

This drives the CL team to further implement time driven data, processes and tools in the LDB and EDMS. This new approach results in parallel configuration or versioning, allowing the management of multiple design versions of the same machine in parallel (see Figure 3) and the management of documents all along the equipment life cycle from its study phase to its installation.

The implementation of parallel configuration implies changes to be carried out in the EDMS hardware baselines and in the LDB structures. The EDMS hardware baselines need to be reorganised per machine/run/year. The validation of documents has to be reaffirmed for each configuration. The layout drawings have to be reorganised (separation to be able to individually manage them, identification and then generation of the missing ones). A fork structure has to be created in the LDB (one for each run - Figure 3).

The CL team just started this implementation with the ambitious aim to provide, by the end of 2017, the injectors chain LS2 configuration to be in time for the implementation of the LIU project.

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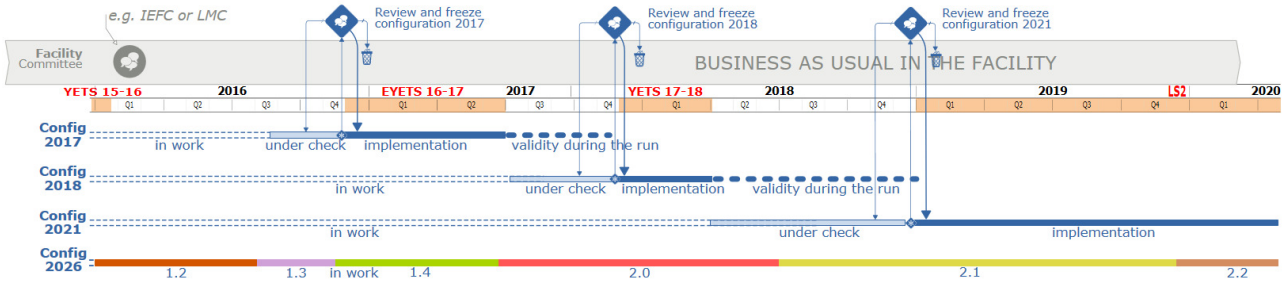

Figure 3: Parallel configuration in the Layout Database.

CONCLUSION

The upcoming upgrades on the injector chain (LIU project) and on the LHC accelerator (HL-LHC project) will imply major equipment changes to be carried out during the YETS 2017-18 and the LS2. A clear and coherent status of the CERN machine facilities will need to be ensured at any given point in time.

The configuration managers will continue to use the Engineering Change process, formally adopted across the CERN accelerators, to ensure that the changes are documented in the relevant version, to follow their implementation in the machines, to update the LDB and EDMS hardware baselines and to identify the regions where new panoramas will have to be captured.

The 360 degree panoramic photographs of underground areas are captured to facilitate the visualization of the machines and service areas, generally inaccessible during the runs, and to allow virtual tours of past and present configurations.

The CL team will manage the past, present and future configuration and layout versions of the accelerator's complex by means of the parallel configuration or versioning of the machines (reorganised per machine/run/year) and the management of the equipment documentation throughout its lifecycle using the LDB and EDMS tools.

In order to be able to provide the LS2 injectors configuration by the end of 2017, the CL team has started to implement specific processes and challenging updates in the LDB structure and EDMS hardware baselines.

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