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CONFIGURATION MANAGEMENT OF THE CERN ACCELERATORS COMPLEX ON THE ROAD TO LONG SHUTDOWN 3

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Abstract

The Configuration Management of the LHC and its injectors ensures a clear and coherent representation of the CERN accelerators at a given point in time. It has been evolving steadily. The methodology has been continuously improved, incorporating best practices and was also extended to the injectors to face the Long Shutdown 2 (LS2) with a set of rigorous and homogenised processes for the entire accelerator complex. Lessons learnt from the LS2 provide a strong basis to further improve the effectiveness of the change management process.

This paper describes the actions plan, concerning the processes and engineering tools, to further improve configuration management efficiency to face the numerous changes foreseen during the Long Shutdown 3 (LS3), with principally the equipment installation foreseen by the HL-LHC project. In addition, it reports on the smooth transition between the LHC and HL-LHC configuration teams to ensure the long-term operation and maintenance of the LHC.

INTRODUCTION

The Configuration Management (CM) team is part of the CERN Accelerators & Technologies Sector (ATS). The CM approach is based on the LHC Project CM plan, as described in the LHC Quality Assurance Plan. It is based on document traceability and information management [1, 2]. In ATS, the concept of 'Layout' is considered within the scope of the CM. It describes the sequence of functional positions within a facility or on a beam line. The CM team centralise and handles all the changes carried out in the CERN accelerators using databases and engineering tools covering mechanical, optical and electrical domains to provide clear, up-to-date and coherent representation of the CERN accelerators (LHC machine and its injectors). They guarantee the coherence between the accelerator life cycle documents, the installed equipment, and the data inserted in the Layout Database. Being the team in charge of the Accelerators Naming Service, they ensure a globally consistent and coherent naming across many distributed systems. In 2013, the CM team set-up the Panorama project offering a virtual tour of the accelerator complex, helping colleagues to optimise their preparatory work for interventions, in terms of precision, time and safety [3].

The CM team handles changes carried out in the accelerators and interacts with numerous stakeholders (see Fig. 1) through well-defined processes involving several engineering tools (as presented in Fig. 2). The data managed and provided by the CM team through the Layout Database are used by the optics physicists to generate the optics files for the nominal accelerator layouts, by the survey team to ensure the equipment alignment in the facilities and by the equipment owners to prepare their interventions. They are also the source for the 2D layout drawings and for the 3D positioning in CAD of the various LHC systems via the Digital Mock-up (DMU) tool.

The CM program scope evolved over time, starting with the LHC machine, and then progressively including the Injectors chain, and finally the fixed target experimental areas. Today several actors ensure the configuration management within ATS. The core configuration management team is hosted in the ENgineering department in the Accelerators Coordination & Engineering group (EN-ACE-CL). It oversees the primary beam lines covering about 50 km of accelerators and transfer lines. The configuration of the accelerators' experimental areas (without the LHC experiments) is managed by other groups being part of the BEams and SYstems departments. All the teams follow and use the same procedures, workflows and tools as set-up by EN/ACE-CL.

Figure 1: Main stakeholders working with the Configuration Management team.

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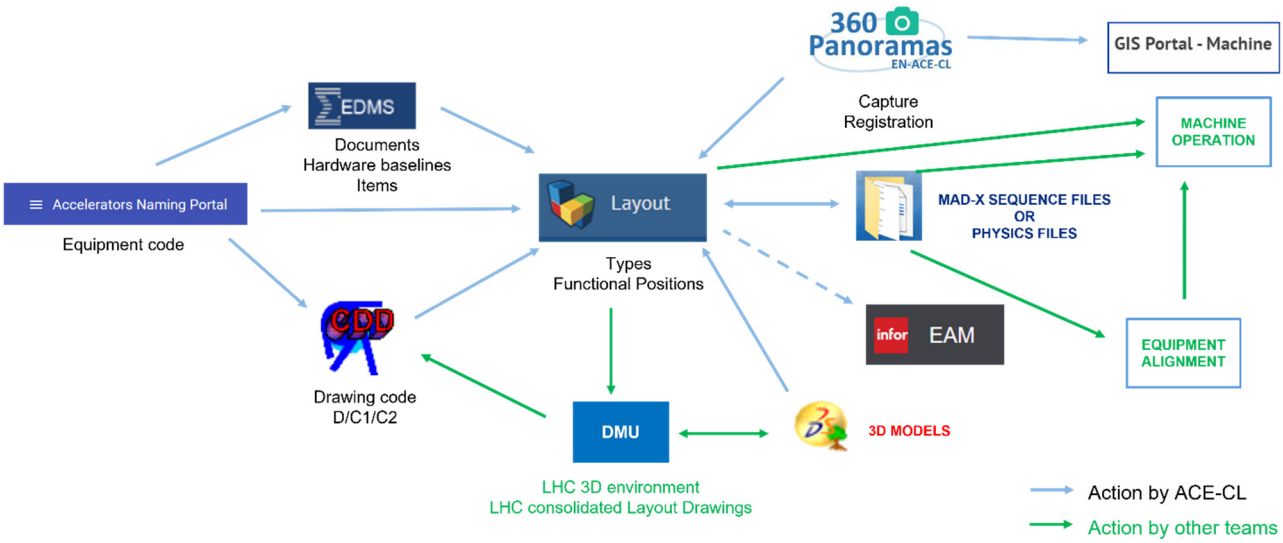

Figure 2: Configuration management process in ATS (EDMS: Engineering Data Management System; CDD: CERN Drawings Directory; DMU: Digital Mock-Up; EAM: Enterprise Asset Management; GIS: Geographical Information System).

LESSONS LEARNT FROM LS2

Processes

Efficient communication is a key factor for configuration management teams to optimise equipment installation on-site and beam operation parameters. For that reason, the configuration team launched, in 2018, collaborative meetings named 'Layout meetings' to review, with the optics physicists, surveyors and equipment groups, the data updates in the Layout database and the data consistency between the Layout Database, Survey database, optics repositories and Layout Drawings. The LS2 exercise identified some points of improvement in the workflow. The optics and mechanical data must agree at an early stage; a timing compromise shall be found between the optics data production and the Engineering Change Request (ECR) production; the data cross-check and confirmation by the optics physicists should be visible in the Layout database to ensure the surveyors import the validated (final) data when preparing for the alignment of equipment; the data consistency between the different databases should be reviewed.

About 300 ECR documents were produced for the LS2 activities carried out in the accelerators' primary beam lines. The ECRs granularity was not homogeneous, with some ECRs covering a huge part of a machine (e.g., an entire Long Straight Section of the SPS) while other ones reported the change performed at the equipment level. The necessary maturity level of the ECRs with low granularity was sometimes difficult and long to reach. One solution might be to split the document in sub-documents covering smaller areas of the machine. A case-by-case study is needed to find a good balance between document maturity and granularity. Discussion between the configuration managers and the authors is crucial to reach it.

The CM team received the majority of ECRs after the deadline pre-defined with the Technical Coordination. These late deliveries impacted the whole process (see Figure 2) with consequences for the integration studies, optics physics simulations, calculations and alignment preparatory work. A new status was created in the document management tool (EDMS) to allow integration studies and the ECR approval to progress simultaneously. In 2022, the CM team launched a campaign to raise awareness amongst the equipment groups on the impact of a late ECR beyond the configuration management scope.

The CM team managed the LIU project changes, the consolidation, and the maintenance activities simultaneously. It was requested to report the ECR status to numerous parallel meetings within the project framework and by the accelerators' technical coordination team. It would be useful and improve efficiency to have a committee able to cross-check the interfaces between projects, consolidation and maintenance and thus to reduce the numbers of reports and meetings.

Engineering Tools

A few months before the LS2 start, the Layout Database (key engineering tool in the configuration management process) was replaced by a new one offering new functionalities (such as parallel versioning) with a new methodology for data insertion. The deployment period was inappropriate, forcing the CM team to reinsert part of the LS2 data for the PS and SPS complexes and to face numerous inconsistencies.

Versioning tags were introduced in EDMS to link documents to machine versions (i.e., accelerators' run). This new functionality revealed to be not enough end-user oriented. It generated an enormous workload for the CM team as thousands of documents had to be reviewed and tagged manually, checking their validity during the different runs

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since 2015. The tags functionality should be improved to reduce the manual work and to improve usability.

Parallel structures in EDMS were implemented between the LIU project and the injectors operational hardware baselines. The purpose was to easily identify the project documents during the LS2 period. The strategy in view of the LS3 and the extensive changes in the frame of the HL-LHC project is being revisited, taking stock of the LS2 experience.

ROAD MAP TOWARDS LS3

Work on Processes and Tools

The E2A (Engineering to Alignment) project was launched in ATS at the end of the LS2 in answer to the improvement points identified through the Layout meetings. The ACE-CL team members contribute significantly to this programme. They are in charge of clearly defining the terms used throughout the process from ECR to alignment. In addition, the configuration managers are the main actors in the process dedicated to the cross-check of data consistency between the different databases and to the inconsistencies resolution.

A solution under study to face the late ECRs issue is to move from documents management to information management integrated within the existing CERN systems and databases. The implementation of this "document dematerialisation" would allow ECRs to be approved part by part by the executive committee, as data related to beam operations, environment and other aspects could be managed separately. The ACE-CL team has taken the lead of this project and collaborates with software developers for its implementation. In parallel, the ACE-CL team continues its awareness campaign towards the equipment groups.

The versioning tags process should be reviewed. The CM team requires a new feature to link the documents between them especially when tagging or reconfirming the documents validity. It does not exist today but is mandatory to face the huge workload coming with the HL-LHC era.

Communication between the scheduling, integration and configuration teams is instrumental for a successful LS3. The EN-ACE group deployed the Track-it tool to facilitate exchanges between the 3 teams for the LS2 [4].

The implementation of the HL-LHC during LS3 [5] will require the removal of the existing systems and their replacement by new equipment, covering a length of nearly 1.2 km. One of the challenges for the ACE-CL team will be to capture all the panoramas in a restricted time window (at the end of the LS3 before the hardware commissioning period) [2]. The capture process is being reviewed to be less time consuming.

Transition Towards HL-LHC

A major challenge for the ACE-CL team will be to ensure a progressive and smooth transition between the HL-LHC and the LHC configurations.

The work on the Layout is ongoing, as a parallel configuration was implemented since the beginning of the LS2 with the respective versions of the machine optics. However, only data linked to the optics were considered. A non negligeable part of the data required to ensure the 3D reconstruction of the LHC environment is still missing (e.g., the QXL cryogenic line, all the magnets' jacks, part of the vacuum equipment…etc). In 2023 the ACE-CL team will take over the responsibility of the data insertion in layout DB for HL-LHC.

A huge number of documents were produced since the beginning of the HL-LHC project. The ACE-CL team is collaborating with the HL-LHC configuration & quality manager to consult them and identify the ones to be merged, inserted, and tagged in the LHC hardware baseline. The impact of the major LHC upgrade that is the HL-LHC project on the documents describing the current LHC accelerator will be massive. This will require an expert analysis and a huge campaign of documents update to be carried out jointly by the HL project and EN-ACE CM teams.

The ECR process set-up by the project would have to be adapted to consider both the project and the machine sides. A staged approval workflow between the project team and then the LHC Machine executive committee will have to be set-up.

A tight collaboration with the HL-LHC project team is the key factor towards the success.

CONCLUSION

The unprecedented upgrade foreseen on the LHC accelerator with the HL-LHC project will imply major and numerous equipment changes to be carried out during the LS3. An efficient configuration management will be crucial towards smooth implementation in the machines to ensure a successful physics run 4. The lessons learnt during LS2 serve as a basis for improving the processes and engineering tools used currently by the configuration team and its stakeholders. The success of the E2A project and of the knowledge transition between the HL-LHC project and the ATS CM team is mandatory to face the LS3 challenges.

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