

THE SECOND LONG SHUTDOWN OF THE LHC AND ITS INJECTORS: FEEDBACK FROM THE ACCELERATOR COORDINATION AND ENGINEERING GROUP

A. L. Perrot, F. Baltasar Dos Santos Pedrosa, M. Bernardini, S. Chemli, J. - P. Corso, J. Coupard,
J. Etheridge, S. Grillot, J. M. Jimenez, K. Foraz, B. Nicquevert, S. Petit, J. - Ph. Tock,
E. Vergara Fernandez, CERN, Geneva, Switzerland

Abstract

The operation of the Large Hadron Collider (LHC) at CERN started in September 2008. Every 5 or 6 years, Long Shutdowns (LS) are programmed to execute time-intensive ordinary and extra-ordinary maintenance of the LHC and its injectors. The second LS (LS2) started in December 2018 and was completed end of 2020 for the injectors and early 2022 for the LHC. A huge number of maintenance, consolidation and upgrade activities, especially the upgrade of the injectors complex, were performed with challenges at various levels, from technical, to organizational and managerial.

This paper presents the applied methodology put in place by the Accelerator Coordination & Engineering (EN-ACE) group, in charge of the technical coordination of the activities for the interventions and changes to the LHC and its injectors, to ensure that the installation activities are performed safely, meeting the required high level of quality, while optimizing the schedule. It highlights key points of success and lessons learnt in terms of general coordination, quality assurance, configuration and layout management, spatial integration, planning and scheduling, operational safety, logistics and worksite coordination.

INTRODUCTION

The Accelerator Coordination & Engineering group (ACE) is part of the CERN Engineering Department (EN). They coordinate and optimise the interventions and changes implementation all along the CERN accelerators life cycle. Their expertise cover the configuration & layout management, the spatial integration studies and maintenance of the related 3D-CAD scenes, the organisation and scheduling of the programmed stops, the management of the mid- and long-term schedules, the worksites follow-up, the management of LHC sites, the LHC electrical lock-outs and the operational safety advices. In addition, the ACE group hosts the Accelerator & Technology Sector (ATS) Quality Service, providing support throughout the sector (see Fig.1). The group's priorities are Safety, Quality, Scheduling and Organisation. It is structured to respond to the main requirements for an efficient management of the interventions during accelerators programmed stops.

This paper describes the methodology followed by the EN-ACE group to face the LS2 challenges. It reports key successes and lessons learnt for the future.

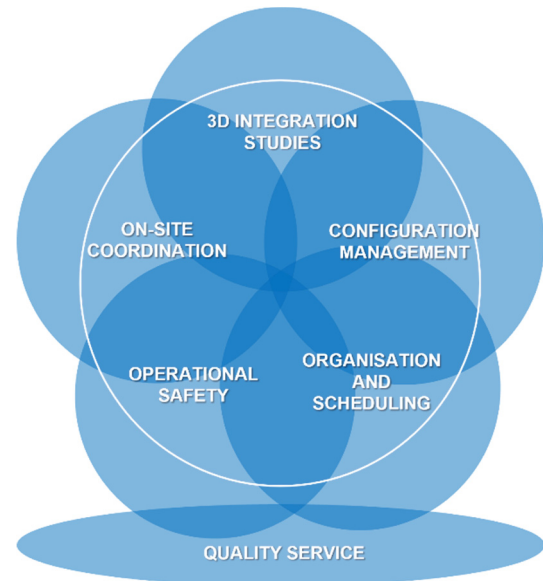


Figure 1: CERN EN-ACE areas of expertise.

METHODOLOGY

The preparation of the LS2 started in 2015, just at the end of the LS1 [1]. The methodology already implemented and recognised for its success during previous programmed stops [2, 3] was applied. From the early stage of the LS2 preparatory phase, strong links with the LS2 executive coordination team, with the main LS2 projects (LHC Injectors Upgrade (LIU), Consolidation, High Luminosity LHC (HL LHC) and Fire safety) and with the equipment owners were established. EN-ACE group members participated to the LS2 coordination team and also served as schedule officers for the main projects. They were giving regular status reports, identifying potential issues as early as possible. It allowed early warnings on difficulties and reactivity in solving them.

KEY POINTS OF SUCCESS

Safety

Safety is the highest priority at CERN and everybody is involved. The following points can be especially mentioned.

During the preparation phase, the Operational Safety Advisors (OSA) analysed the main activities with the relevant stakeholders to define the service to be provided in term of operational safety. This anticipation allowed placing dedicated contracts, to complement the existing team

to support the implementation of safe working conditions. The team was doubled to reach eight persons with some of them dedicated to some groups / projects to optimise the reactivity during the interventions. In addition, the OSA team participated to the review of critical CERN safety documents and performed joint safety visits, identifying potential safety issues and providing safety guidance.

The COordination, Consignation and Support (COS) team, in charge of the site management and coordination, appointed the work site supervisors a few years before the LS2, giving them time to acquire the technical knowledge of the areas under their supervision. They also manufacture and install light metal structures that are improving the safety level and/or are easing the work.

In 2016, the Organisation, Scheduling and Support (OSS) team started to work on the preparation of the LS2, delivering the first draft of the LS2 master schedule, covering the CERN accelerators and associated non LHC experimental areas. This early identification of the interventions contributed to perform a global optimization of the time, from 2016 to 2022, identifying and minimising the co-activities and thus increasing the safety level. One of the major challenges was to keep the simultaneous vision of the short, medium, and long term.

During the LS2 execution period, daily collaboration between all the sections was an asset. The OSA team improved and diversified its communication channels presenting ‘safety flashes’ in the accelerator’s weekly coordination meetings and improved its reactivity, thanks to new communication tools, to centralise all the requests and distribute them efficiently among its members. The OSA team took part in about 1400 joint safety visits providing safety recommendation reports for each of them.

The COS team gave an efficient support on site, facilitating all the interventions. They were the ones identifying unexpected onsite events such as power cuts, alarms, lift non-conformities, etc Their daily, fast, and effective reporting allowed fixing issues in due time by safety guidance and/or schedule optimisation.

Quality

The Accelerators Quality Service (AQS), the EN-ACE Integration (INT) and Configuration & Layout (CL) teams were drivers in ensuring/applying quality rules all along the LS2 changes process (see Fig. 1).

Several years before the LS2, the AQS team started its activity for LS2 being responsible of performing the technical auditing (i.e. chairing the specification committees) of the tendering documents for the supply contracts under the responsibility of the ATS.

The AQS team designed and piloted a new application ‘Track-It’ [4] implemented by the EN/IM group (in charge of Information Management) for aggregating and centralising information regarding interventions from their announcement at a committee to the actions that follow them. All along the LS2, ‘Track-It’ ensured an efficient follow-up of the production by INT of the layout drawings and 3D scenes and of the Engineering Change Requests (ECRs) managed by CL. It helped identifying and quantifying the

impact of the new drawings’ life cycle introduced by CERN CAD team just before LS2 on the Layout drawings release process. INT reported to the LS2 executive coordination team that was thus able to ensure that all necessary documents were available in due time.

The CL team launched before the LS2 the ‘Panoramas’ application [5] in collaboration with the EN-IM software developers. This tool was used during the preparation and the execution of the LS2 works. It helped with optimising machine interventions and producing integration studies by offering virtual tours of the accelerator’s facilities even when access is not possible, also minimising the personal radiation dose.

CL team launched in 2018 the ‘Layout meetings’ to discuss between optics physicists, surveyors, and configuration managers the update of databases in direct link with the equipment installation in site and the beams operation. This improved quality of the communication between teams resulted in timely effective updates with respect to the LS2 schedule and the beam operation

Schedule and General Coordination

The LS2 unique and central coordination covered the LHC and its injection chain. This structure was revealed to be effective, allowing to find optimum and global solutions to issues. The successful LS2 completion validated the methodology applied during the preparation and execution phases for scheduling and general coordination. The team managed the co-activities inside each machine, defined the logistics associated to each intervention and put in place mitigation measures to ensure the safety and anticipate any potential delay. [3, 6].

The LS2 Master schedule was built in collaboration with the coordination teams of the experiments and the experimental areas, with the Groups’ equipment owners, Works and Services supervisors of each CERN group, projects teams and the executive committees. The information of equipment readiness for installation, the analysis of co-activities, the overall resource levelling, the work package analysis reviewed by OSS with the equipment owners and OSA were key inputs. All these factors drove towards the construction of a solid baseline. The baseline of each Machine was approved via an official approval process, involving all the stakeholders [6].

The OSS team simultaneously managed several time-scales’ schedules daily, weekly, (bi-)monthly, yearly and on 5/7 years (between two LSs). This allowed reactivity and flexibility across the time. This was revealed to be very efficient in overcoming the sudden stop of activities linked to Covid 19 lock-down in March 2020.

Preparation and communication were of first importance during the preparation and execution phases. The OSS, INT and CL teams organised/chaired dedicated weekly meetings for their respective domains of expertise. There were continuous activity progress monitoring (through dashboards and broken lines), daily reports of the COS team (on site) and recurrent reporting to the LS2 executive coordination team.

LESSONS LEARNT

The EN-ACE team members, thanks to their central position during the LS2, contributed effectively to the identification of several points of improvements, studied at the ATS level for implementation for future technical stops and for the Long Shutdown 3, planned to start end of 2025.

Safety

The preparatory work by OSA to anticipate the requests and adapt its team size in advance should be kept for future use. The joint safety inspections should be anticipated as much as possible.

The Work and Services Supervisors (WSS) who monitor the compliance with the CERN Safety requirements in the execution of specific works and services performed a key role. They should be nominated by the projects/groups in advance to be trained on time. Their training may be tailored, and more sessions should be proposed.

Simplification and clarification of the numerous safety roles and functions would empower understanding and effectiveness. The procedures in case of breach of safety rules should be uniformly applied.

Quality

It is recommended to publicize basic quality rules, especially concerning the document production, and update them along the different project phases. The needed documentation, and especially the ECRs, should be provided in due time before the implementation.

Reviews should be organised to optimise the workflow between several sources of information (Layout database, Survey database, optics repositories, layout drawings) used for the equipment alignment on site and for the beam optics optimisation.

It is crucial to get the 3D environment before the start of a project. This would avoid time-consuming and costly reverse engineering.

The availability of survey scans for accelerators is crucial for the smooth advancement of integration activities.

‘Track-It’ and ‘Panorama’ applications should be maintained and upgraded for future stops.

Schedule

It is fundamental to establish a master schedule as early as possible considering the compatibility of resources and planning across the entire accelerator chain and the experiments. A unique central coordination for the LHC and its injectors was essential to guarantee a coherent approach across the CERN departments, and to smoothly resume the activities during the COVID-19 crisis; during the LS2 it was instrumental to ease the decision making of the CERN management and project leaders. This central coordination must be preserved during all future programmed stops.

Equipment deliverable dates should be known as soon as possible. The equipment readiness was essential to re-profile the activities. Dashboards were fundamental to monitor activity progress.

General Coordination

The methodology to prepare such long programmed stops is validated and proved. It is essential to retain the know-how in the ATS groups and in the EN-ACE coordination teams.

The technical stops scheduled between two LSs should be used to prepare or anticipate the next LS interventions.

The different meetings with the equipment owners and experts organised, respectively, by the INT, OSS, and CL teams (i.e., integration meetings, coordination meetings and layout meetings) should be maintained for future stops.

On-site meetings are mandatory towards intervention success. They allowed safety and co-activities optimisation as well as early identification of eventual 3D environment constraints.

Covid-19

The Covid-19 pandemic strongly impacted the LS2 execution. Nevertheless, the way of working did not need to be modified. The necessary major rescheduling of many activities followed the same guiding principles in a much shorter time thanks to the reactivity of the OSS team. New working conditions adapted to the Covid-19 safety constraints were defined. It has required many on-site or remote joint inspection visits by OSA to support and guide the teams for the implementation of the Covid-19 safety measures in addition to the other ones. To document it, the procedures had to be adapted and this was managed by the CL team.

The reaction to this unprecedented crisis can be seen as a successful validation of the robust methodology developed and mastered by CERN for the coordination of the programmed stops.

CONCLUSION

The ACE work carried out during the LS2 preparatory and execution phases resulted in an efficient and successful coordination of the LS2 activities. The group raised several points of improvement on which they have already started to work with colleagues of ATS in view of future programmed stops. The EN-ACE teams are already involved in the LS3 preparation which will be dedicated to the High Luminosity LHC upgrade, Consolidation and Maintenance activities.

ACKNOWLEDGEMENTS

The authors would like to thank the management and colleagues across the Accelerator and Technology Sector for their support and efficient collaboration.

REFERENCES

- [1] J. M. Jimenez, “Scope of the Long Shutdown 2, Optimisation of The Period 2015-2018, Chamonix 2014 Workshop on LHC Performance, Chamonix, France, Sep. 2014, pp. 270-272.
- [2] F. Bordry, S. Baird, K. Foraz, A.-L. Perrot, R. I. Saban, and J. Ph. G. L., “The First Long Shutdown (LS1) for the LHC”, in *Proc. IPAC'13*, Shanghai, China, May 2013, paper MOZB202, pp. 44-48.
- [3] M. Barberan Marin *et al.*, “Integration, Configuration and Coordination: from Project to Reality, at CERN”, in *Proc. IPAC'16*, Busan, Korea, May 2016, pp. 1407-1409. doi:10.18429/JACoW-IPAC2016-TUPMW003
- [4] S. Chemli *et al.*, “New Coordination Tools to Prepare Programmed Stops in the LHC and its Injectors”, in *Proc. IPAC'18*, Vancouver, Canada, Apr.-May 2018, pp. 200-203. doi:10.18429/JACoW-IPAC2018-MOPMF044
- [5] T. W. Birtwistle *et al.*, “360 Degree Panoramic Photographs During the Long Shutdown 2 of the CERN Machines and Facilities”, in *Proc. IPAC'21*, Campinas, Brazil, May 2021, pp. 3410-3412. doi:10.18429/JACoW-IPAC2021-WEPAB315
- [6] E. Vergara Fernandez *et al.*, “Processes and Tools to Manage Cern Programmed Stops Applied to the Second Long Shutdown of the Accelerator Complex”, presented at the IPAC'22, Bangkok, Thailand, Jun. 2022, paper WEPOTK009, this conference.