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LS1 "FIRST LONG SHUTDOWN OF LHC AND ITS INJECTOR CHAINS"

K. Foraz, S. Baird, M. Barberan, M. Bernardini, J. Coupard, N. Gilbert, D. Hay, S. Mataguez, D. McFarlane, CERN, Geneva, Switzerland

Abstract

The LHC and its Injectors were stopped in February 2013, in order to maintain, consolidate and upgrade the different equipment of the accelerator chain, with the goal of achieving LHC operation at the design energy of 14 TeV in the centre-of-mass. Prior to the start of this First Long Shutdown (LS1), a major effort of preparation was performed in order to optimize the schedule and the use of resources across the different machines, with the aim of resuming LHC physics in early 2015. The rest of the CERN complex will restart beam operation in the second half of 2014. This paper presents the schedule of the LS1, describes the organizational set-up for the coordination of the works, the main activities, the different main milestones, which have been achieved so far, and the decisions taken in order to mitigate the issues encountered.

INTRODUCTION

Fifteen months have passed since the beginning of the first major shutdown of the CERN accelerator complex. As defined by the directorate of CERN the LS1 aims to perform all activities needed for a safe and reliable operation of the accelerator complex at nominal energy, taking into account essential rules: safety first, quality second and schedule third.

ORGANIZATION

Preparation

Prior to the start of the first major shutdown, F. Bordry, project leader of the LS1, with the help of the technical coordination team established a prioritization between the activities requested by equipment groups and the projects, with respect to the goals, resources and time available [1].

Work package analyses of each of the selected activities have been performed, to identify constraints, resources, and safety aspects. The analyses result, for each facility, in an optimized and resource levelled schedule. The LHC schedule has been built around the main projects: Splices consolidation and Radiation to Electronics.

Coordination

The LS1 Committee (LSC) has been created as the executive committee concerned with all technical and organisational aspects of the Long Shutdown 1 (LS1) for the CERN accelerator complex. [2] In particular the LSC:

- monitors all the LS1 activities,
- examines and defines the safety conditions,
- follows up the Quality Control
- examines and decides change of activities and priorities,
- closely monitors the LS1 schedule, and evaluates the schedule delays,
- assesses any new proposal recommended by the LMC or IEFC which involves work during the LS1 in order to decide if this can be incorporated into the overall shutdown schedule and if, as a result, it is necessary to suppress or delay other activities,
- reports to the Directorate.

The technical coordination is part of the EN-MEF-OSS section, where a technical coordinator was designated for each facility within the CERN accelerator complex. The technical coordinators are organizing regular meetings, to manage activities in the short and medium term. These meetings following up the progress of activities and the main milestones, reviewing safety aspects and issues, are gathering all the stakeholders. Moreover the technical coordinators are following the Quality Assurance Process ensuring that 3D integration drawings are kept up to date, Engineering Change Requests are edited, and their follow-up is correctly implemented. Moreover from time to time, they provided ad hoc support to equipment groups in order to ensure a smooth progress.

Technical and organization aspects of each main project are fully deeply discussed weekly within the project coordination committees (SMACC, R2E, and collimation). The projects committees report to the LSC and the "facility" technical coordination.

Tools

The detailed schedules are maintained with the MS-Project package: while in the Injectors one schedule officer was designated, three schedule officers were responsible for the different types of area (service areas, Long Straight Section and arcs) and the different main projects (SMACC, R2E, maintenance, collimation). The linear schedules, showing a synthetized view in each facility, are the automated results of the different schedules (through excel vba). Key Performance Indicators were implemented, allowing visualising easily any deviations and delay, and implementing strategies for recovery [3].

The daily activities are managed with the Intervention Management Planning and Activity Coordination Tool (IMPACT [4], developed at CERN). Since the start of the LS1, the tool was upgraded, and is now linked with the radiation database (offering radiation dose planning), includes the electrical permit as well as the fire permits, the report of safety inspectionsand other essential safety forms (see Fig.1).

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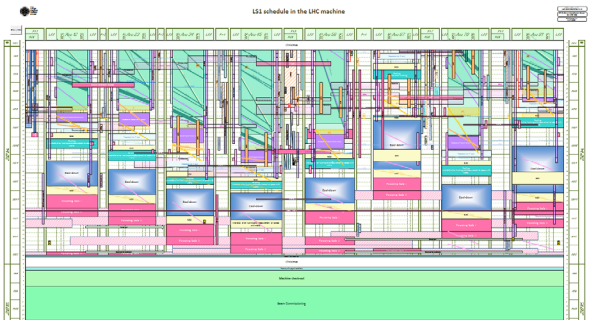

Figure 1: LS1-LHC dashboard.

MAIN ACTIVITIES

The Long Shutdown roadmap includes:

- a preliminary test phase in order to detect existing faults,
- a preparatory phase including lock-out,
- the work phase,
- the final phase up to the hardware tests.

LHC

The main activities and the time driver in the LHC machine are the SMACC and R2E projects:

- The SMACC project is one of the major projects including 260 persons, and is responsible, in particular for the splice consolidation which will enable the LHC to run at nominal Energy. The splice consolidation, including cryomagnets and Distribution Feed Boxes (DFBAs) is organized with a sequence of activities ("wagons"), allowing an efficient work, in terms of resources and logistics [5]. Moreover the SMACC project includes the replacement of 13 cryo-magnets which showed important default, as well as other consolidation works: DN200 installation and inner triplet copper braid consolidation. Regular electrical tests were performed and a specific Quality Assurance procedure was adopted to reinforce one of the LS1 pillars: Quality.
- The Radiation to Electronics project will enable to reduce the Mean Time Between Failure of the LHC machine. In order to reduce by a factor of 6 failures of controls electronics caused by radiation, it was decided to relocate sensitive equipment on five points of the machine, and to add shielding in strategic areas [6].

A considerable amount of other consolidation and maintenance activities are taking place: UPS, replacement of ducts of water cooled cables, collimation, beam instrumentation, water pumps, cryogenics…

Injectors

The Injector complex ran more than 3 years without long winter shutdowns, which were the norm in the past. Therefore the maintenance of all equipment is crucial. On top of these essential activities, major upgrade and consolidation are being /were performed:

- installation of a new accelerator access system on the Meyrin site,
- replacement of the PS ventilation system,
- upgrade of the RF and kickers systems,
- shielding,
- installation of 16 dipoles for e-cloud mitigation in SPS,
- replacement of 18kV transformers for the main power converters of SPS,
- replacement of irradiated cables in SPS (LSS1),
- On top of the LS1 scope, several LIU activities were implemented in order to ease LS2: preparatory work for 2 GeV upgrade in PSB, identification of obsolete cables etc.

Maintenance

As already mentioned, after 3 years of continuous operation leading to the discovery of the Higgs boson, all the equipment definitively need to be inspected and maintained: machine equipment as well as infrastructure equipment. For instance a complete maintenance of the 18kV transformers and electrical switches was performed in cooperation with EDF, SIG and EOS/Alpiq. The maintenance of the infrastructure equipment is a core point as the unavailability of the equipment concerns different facilities at the same time. Induced constraints were included and the schedule was regularly updated in order to best fit the progress of each facility.

ISSUES ENCOUNTERED AND SOLUTIONS

Additional Activities

The preliminary tests and inspections performed at the beginning of the shut-down showed faults that had to be corrected:

- As a result, the number of splices to be redone increased by a factor of 2 (from 15% to 30%).
- In addition to the 2 existing leaks on the cryogenic line, further tests (leak and YX-rays) identified damaged compensators and leaks, which result from welding non-conformities, worsening during the warm up process. The 27km cryogenic line was inspected, and a dedicated team was set up for the repair, in situ, of the 16 damaged compensators (out of 560 ~2.8%).

The full inspection of the main Distribution Feed Boxes (DFBA) showed the same failure process as for the cryogenic line. 4 gimbals bellows were found damaged. Two were repaired in situ, while the tight environment of the 2 others imposed a repair on surface (decision was taken after a risk assessment).

A deep re-management of resources was done: dedicated teams were set up rapidly in order to minimize the impact of these additional activities on the global schedule. While the QRL repair was transparent to the main milestones, the gimbal bellow repair delayed the

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readiness for cool-down of 2 sectors. The additional resources injected in the SMACC project minimized the delay of this extra-activity, and thanks to a close follow-up, the end of the activities is now in line with the original baseline.

In December 2013, it was decided to include further electrical tests in order to test the correct functioning of the dipole busbars and diodes: warm measurements and Copper Stabilization and Continuity Measurements.

Moreover, new mitigation measures were to be implemented at point 4, with respect to the Radiation to Electronics (R2E) studies performed in 2012. The relocation of the equipment is being performed in the shadow of other activities, without major reshuffling of the schedule.

Equipment Delay

Equipment delays are inherent to such a big project. But we would like to underline, that teams were very well prepared, and there were less delays than initially expected. Thanks to the regular follow-up, including the production follow-up, all the stakeholders were warned early of potential delays. Thanks to the strong involvement of all stakeholders: from the bottom to the top, ad hoc solutions were found in most of the cases. Additional contracts were set up to cope with the problem of quality and production of the quadrupole diodes, and part of the production was re-internalized. The readiness of equipment in all the different facilities was reviewed regularly. Unfortunately, some did not pass smoothly the last surface qualification tests, and induced delays on the following activities. A constant review of this schedule is being performed in order to optimize the dedicated resources along the machine. Moreover, it was decided in some cases, to postpone the installation of non-vital and late equipment to later programmed accelerator stops in order not to compromise the start-up of the different facilities.

A new version of the LHC schedule was approved in April 2014 [7], taking into account the mitigation measures. It is important to underline that this new version is not a new baseline, as it does not modify the readiness of LHC. This new road map is helping our partners to have a clear picture of the flowing steps.

STATUS OF THE LS1

More than 15 months have passed since the start of the LS1.

The LS1 activities and hardware tests finished in due time in the PSB and PS, and the machines were given back to beam operation. In SPS, the works are progressing very well, as shown on the dashboard [3]. The major consolidation works are now finished (upgrade of RF systems, 18kV transformers replacement, irradiated cables replacement...), and the re-installation of the beam line on the LSS1 will be ready in due time.

In LHC, at the edition time of the paper, the splice consolidation is finished, and leak tests are being performed. R2E works are progressing ahead of schedule. Accordingly to the schedule the first sector is being cooled down and all signals are green for a start of cold check-out in January 2015 as originally predicted.

CONCLUSION

The solid preparation done before the LS1 has paid off. The pre-Injectors are now in the hands of the operation team, and if no further bad surprises the SPS and LHC will be ready in due time.

The serious management and the deep involvement of CERN staff is certainly the key of success for the LS1 and a vital motor for the future projects and shut-downs.

Moreover, it is important to mention the low accident frequency and severity rates. The marathon is now in its last kilometres, and so far the activities have been performed respecting the key rules: Safety first, Quality second, Schedule third.

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