ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-TUPA154

PROJECT MANAGEMENT STRUCTURES, PROCESSES, AND TOOLS FOR THE HL-LHC PROJECT

G. Vandoni†, O. Brüning, B. di Girolamo, P. Fessia, H. Garcia Gavela, L. Jensen, M. Modena, C. Noels, L. Tavian, M. Zerlauth, CERN, 1211 Geneva 23, Switzerland

Abstract

At its restart after a major shutdown in 2029, the LHC will see its performance improved by the installation of the HL-LHC equipment, with new Nb_3Sn triplets and cold and warm powering system, new machine protection, crab-cavities for crossing angle compensation and luminosity levelling, an upgraded collimation system, and fully remote alignment for the final focusing region. New technical galleries and surface buildings will host the infrastructure needed by the overhauled machine, including a novel cryogenic refrigeration and distribution, cooling and ventilation plants and an upgraded electrical distribution. In the following operational runs, the LHC will aim at a tenfold increase of the integrated luminosity, as compared to the original design.

The HL-LHC project features a light project management (PM) structure, with strong delegation of PM tasks to the 19 work-packages structuring the project by expertise areas. Centralized processes and shared tools are applied to all PM domains, including configuration, schedule, quality, budget, procurement and risk. The paper describes the project organization and the external and internal committees operating for the project; it details the responsibility share between project and work-packages, explains the procedures ruling decision and change management in configuration and schedule, and explains how quality standards build a common language across the project. A second paper in these conference proceedings treats budget, procurement, and risk management.

INTRODUCTION

The HL-LHC project (the Project) [1] covers a major upgrade of the LHC machine, aiming at a nominal peak luminosity of 5×10^{34} cm^{-2} s^{-1} with levelling, to reach an integrated luminosity of 3000 fb^{-1} after 10 years of operation. The Project follows a major LHC injector's chain upgrade (LIU) [2], concluded in 2021, allowing delivery of beams with the challenging HL-LHC parameters. The Interaction Regions (IRs) of the high luminosity experiments ATLAS and CMS are modified with new Nb_3Sn quadrupoles for final focussing, corrector magnets and recombination and separation dipoles, all powered via HT superconducting cables. SRF crab-cavities allow luminosity levelling and crossing angle compensation. A fully remote alignment system enhances the accelerator's performance and allows for more frequent realignment and minimizing radiation dose to personnel. Moreover, a full upgrade of the collimation system to match the luminosity increase will be implemented, including halo cleaning in IR2 and 7.

The machine upgrade is completed by novel infrastructure, hosted in new underground galleries and surface buildings. Amongst these, the installation of 2 cryogenic plants is accompanied by a new sectorization of the cryogenic distribution, to separate the arcs from the IRs. Cooling and ventilation plants, an upgraded electrical distribution, safety sectioning and alarms complete the HL-LHC scenario. While some equipment was already installed in the Long Shutdown 2 (LS2, 2018- 2021) and Technical Stops, most of the project's machine equipment will be installed during the next Long Shutdown, LS3, in 2026-2028. Civil engineering works are almost completed. A parallel upgrade of the two main experiments ATLAS and CMS, out of the scope of the HL-LHC Project, is in preparation.

The HL-LHC technology and infrastructure landmarks are summarized in Fig. 1.

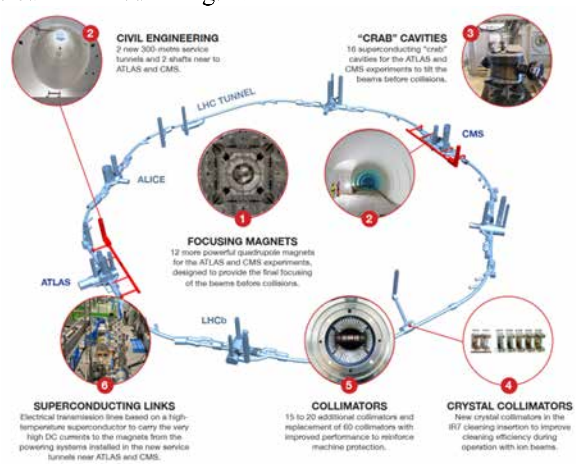

Figure 1: The HL-LHC technology landmarks along the LHC ring.

With a total targeted Budget-At-Completion of 1,140 MCHF, HL-LHC is today the major project at CERN. This budget covers all material and manpower, required to complete the project, with the exclusion of CERN staff cost: all machine equipment and spares, new infrastructures, up to the installation and hardware commissioning. It also includes the value of an important in-kind contribution. After a multi-year design study phase, the Project was approved in 2015, its budget and timeline defined in 2016, thus entering the prototyping phase. Presently, after validation of the prototypes, most sub-projects are moving into the industrialization phase. Following covid, the Long Shutdown 3 was postponed twice and is finally scheduled to start in December 2025.

This paper describes the Project Management structures, committees and links, applied to this major project. Further, it illustrates the Configuration and Schedule management. A second paper [3] completes the PM description of

† Giovanna.Vandoni@cern.ch

ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-TUPA154

HL-LHC with Budget, Procurement and Risk management.

PROJECT ORGANIZATION

The Project Management (PM) of HL-LHC relies on a light Project Office (PO) and a strong delegation of PM tasks to sub-projects, or Work-Packages (WP). Like all accelerator studies and projects at CERN, HL-LHC is attached to the office of the Director of the Accelerator and Technology Sector (ATS). The project management is organized in a Planning pole and a Technical Coordination pole, referring to the Project leader and his deputy and distributing management tasks amongst 8 coordinators. Management domains are Configuration, Budget, Schedule, Collaborations, Procurement, Documentation, Quality, Risk Monitoring, Communication and Safety. Integration and (De-) Installation are covered by a dedicated work-package centralized as well in the PO. Due to its importance and large variety of competences, the New Infrastructures WP is also integrated in the PO.

The work-packages structure the Project in a Work Breakdown Structure (WBS) by technical expertise domains, from Accelerator Physics to Control Technologies. The organization structure and upmost level of the WBS is illustrated in Fig. 2. There is no full overlap of the WBS with the organic structure of CERN: the relationship between organic groups and WPs is not univocal. As an example, vacuum activities will be found in several WPs, while a Vacuum WP covers the most cutting-edge vacuum upgrades.

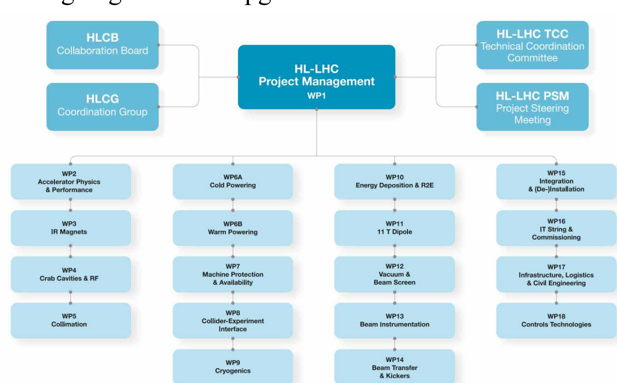

Figure 2: Project structure with committees and the highest level WBS.

An important part of the Project scope is received as in-kind contribution, with 38 institutes from all around the world contributing with material and personnel to 9 WPs, making the HL-LHC a truly international project.

Highest level strategy and coordination with the parallel upgrade of the LHC experiments is managed in the Executive board, bringing together CERN extended directorate with the ATLAS and CMS experiment's spokespersons and the HL Project leader and deputy. A management board including only the ATS department heads with the ATS director and deputy and the HL-LHC Project leader and deputy discusses executive decisions and strategies.

The ATS Director summons an international panel of experts for a regular cost and schedule review, led by CERN's Machine Advisory Committee chairperson. Since 2016, 5 reviews have been held, issuing recommendations to the ATS Director and the Project.

Collaborations are grouped by national funding agencies, in regular Collaboration Steering meetings. A HL-LHC Coordination group to harmonize the experiments and machine upgrade, a Collaboration board gathering representatives from all collaborating institutes and countries, and a Steering Committee for Site and Civil Engineering (SCE) bringing together the Project management and the SCE department, complete the picture.

Budget and Schedule are treated by WP, in tri- to quadrimestral advancement Project Steering Meetings (PSM). The PSM gathers the WP Leader and sub-task engineers, the hierarchical responsibility holders, and the Project Leader and coordinators. Managerial actions are defined and followed; upcoming major procurement presented; risk evolution analysed. Earned Value Management (EVM) metrics is presented and examined together with schedule updates. All upcoming changes in budget and schedule are presented for approval, or compensation and mitigation actions. Internal interfaces, both within the Project and to the facilities and units within CERN, are checked for issues. Collaborations status, schedule and progress are presented. A particular attention is given to safety questions in relation to the ongoing activities, and to safety management within the WP's scope.

CONFIGURATION MANAGEMENT

The Project's technical baseline configuration is captured in the Technical Design Report, issued in 2020 [4]. Major changes since 2016 include the descoping of a part of the crab-cavities, the introduction of the fully remote alignment system, a reduction of the number of orbit correctors and the inclusion of several machine elements following the entry of Russian institutes in the Project. A Hollow-electron lens for enhanced halo-cleaning and additional dilution kickers of the beam dump system have been recently descoped to compensate insourcing of cancelled contributions from Russia. Other layout changes include crab-cavity interchangeability between the two main IRs, update of the triplet magnetic lengths, as well as changes in the cooling and LHC cryogenic sectorization schemes.

The technical baseline configuration and related changes are presented and debated in the bi-weekly Technical Coordination Committee (TCC). This is the main forum for defining and maintaining a coherent set of parameters and the associated hardware lay-out for the HL-LHC. Changes in the technical baseline are documented and presented via Engineering Change Request (ECRs), checked by the TCC members, the WP Leaders, and engineers, and approved by the Project Leader, before being integrated in a new configuration baseline. More than 105 ECRs have been issued since the beginning of the Project, with 30 new ones issued between November 2021 and November 2022. These cover also minor technical configuration changes, definition of parameters and the identification of interfaces.

ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-TUPA154

SCHEDULE MANAGEMENT

Managerial processes and structures are adapted to the Project's lifecycle. Thus, the organization and methods applied during the present production phase might be modified during the 3-yearly installation phase starting in 2026, see Fig.3.

Figure 3: HL-LHC timeline.

Two schedules are therefore maintained independently: one, for deliverables production, and one, for installation. The first one ultimately produces readiness-of-equipment milestones for the highest-level deliverables of each WP. These milestones are tracked via a trend analysis; all changes above an appropriate threshold are checked and documented via Schedule Change Request documents, approved both by the Project Leader and the Group Leader of the team responsible for the deliverable. The installation schedule produces needed-for-installation milestones, for the same highest-level deliverables. The time lag between the readiness-of-equipment and the needed-for-installation milestones represents the schedule margins.

In both schedules, activities durations are estimated from previous experience and internal and external expert's advice. Production schedule is managed by each WP for its own deliverables, with different managerial processes for those deliverables which link different WPs to each other. For external procurement, duration estimates include the tendering process and the learning curve in industry, while internal procurement is estimated with resource loaded team schedules. While estimate uncertainty is naturally included, no risk contingency is taken, following the general CERN policies. More on risk for HL-LHC is presented in [3]. Collaboration's contribution schedules are managed according to the institute's principles and procedures and communicated to the Project via the corresponding WPs and at the Collaboration Steering committees.

Installation schedule is worked out in collaboration with the Planning team of the EN-ACE group and all technical and equipment teams, considering constraints like infrastructure completion, team resources, and coactivity in installation phases. Presently, Installation schedule version 2.0 is under study.

Both schedules are constructed and maintained using the Scheduling tool described in [5]. The graphical schedule presentation, isochrone line of progress, deliverables milestones trend, are all generated from this tool.

QUALITY MANAGEMENT

Quality management provides a common language to the whole community. In a transparent and collaborative approach, all technical information must be accessible to all members. Collaborating institutes apply their internal quality plan, but all deliverables to the Project must be compatible with the Project quality plan. Hardware baseline documents are managed and stored via EDMS [6], while all fabrication records are handled via MTF [7]. Finally, the corporate image of the Project is always present, wherever the Project is presented.

All procedures, policies, templates, plans and guidelines have been developed to comply with ISO 9001:2015. The same standards are applied coherently during the whole life-cycle of the Project, from requirements definition to operation and maintenance, through the engineering, production, and installation phases.

Several tools are in use at CERN to check and issue technical drawings (CDD), check, approve and store documentation (EDMS), and manage assets (EAM-MTF). These are also used for the HL-LHC Project. For all high-level deliverables, EAM-MTF identifies all assets, traces all subcomponents, stores inspection plans and manufacturing data and links the equipment to the installation slot (functional position) in the LHC Layout Database. Non-conformities are also managed in the same way.

Besides Engineering Change Requests (Technical Baseline) and Schedule Change Requests (Schedule), Decision Management Reports document any managerial decision not impacting configuration. Examples are the insourcing of a part of scope or changes in WBS. Budget Change Requests capture all minor budget changes.

The audit process is also part of the Quality Plan, defining the technical reviews needed to ensure adequate tracking and execution. Reviews are held in engineering phase: Conceptual or Detailed Design Reviews (CDR/DDR); Specification Committee Reviews (SCR), if applicable, and Production Readiness Reviews (PRR). During fabrication, Manufacturing Reviews (MR) are held, and before installation, Installation Readiness Reviews (IRR). The End of Manufacturing Reviews (EMR) are held when equipment is completed or installed.

CONCLUSION

Now fully entering the industrialization phase, the HL-LHC features a light PM structure, allowing for coherent yet flexible treatment of all managerial processes, with dynamical re-baselining and stringent quality rules. The whole project community shares the same PM culture, and applies the same procedures and rules, which thus contribute to keep together and align the pace of this complex and articulated project and all its actors, both internal and from collaborating institutes.

REFERENCES

[1] O.Brüning, M.Zerlauth, "Overall Status of the HL-LHC Project", presented at IPAC'23, Venice, Italy, May 2023, paper TUYG1, this conference.

[2] M. Meddahi, "Performance with the upgraded LHC injectors", presented at IPAC'23, Venice, Italy, May 2023, paper MOXD1, this conference.

[3] G.Vandoni *et al.*, "Budget, Procurement and Risk Management for the HL-LHC Project", presented at IPAC'23, Venice, Italy, May 2023, paper TUPA155, this conference.

ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-TUPA154

[4] I. Béjar Alonso *et al.*, "High-Luminosity Large Hadron Collider (HL-LHC): Technical Design Report", CERN Yellow reports Vol.10, `doi.org/10.23731/CYRM-2020-0010`

[5] E.Vergara Fernandez *et al.*, "Processes and Tools to Manage CERN Programmed Stops Applied to the Second Long Shutdown of the Accelerator Complex", in *Proc. IPAC'22, Bangkok, Thailand, June 2022*. `doi:10.18429/JACoW-IPAC2022-WEPOTK009`

[6] T. Pettersson *et al.*, "The CERN EDMS: An Engineering and Equipment Data Management System", in *Proc. EPAC'02*, Paris, France, Jun. 2002, paper TUPDO027, pp. 2697-2699.

[7] C.Delamare *et al.*, "Manufacturing and Test Folder: MTF", in *Proc. EPAC'02*, Paris, France, Jun. 2002, paper TUPDO026, pp. 2688-2690.