# INFRASTRUCTURE WORKSITE COORDINATION LESSONS LEARNED FROM THE HL-LHC CASE STUDY

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*Abstract*

The High-Luminosity Large Hadron Collider (HL-LHC) project at CERN is a major upgrade LHC's today instantaneous luminosity by a factor of five and today total integrated luminosity by ten. This involves extensive new infrastructure, including underground galleries, access shafts, and surface facilities, pushing accelerator technology beyond current limits. Managing this complexity requires centralized coordination through a worksite hub that enables real-time communication, adaptive planning, and stakeholder support from conception to commissioning. A combined top-down and bottom-up planning approach ensures alignment with long-term objectives while addressing operational challenges. Dedicated planning tools support milestone tracking, resource management, and coordination of activities. Operational efficiency relies on safety, schedule adherence, and rapid response to technical issues. This paper highlights the importance of flexible on-site coordination, integrated planning, and advanced monitoring tools for large-scale projects. The approach demonstrates strong adaptability, reactivity, and collaborative problem-solving.

## INTRODUCTION

The Large Hadron Collider (LHC), one of the most complex scientific instruments ever constructed, requires a major upgrade to sustain and enhance its discovery potential. This upgrade aims to increase the LHC's instantaneous luminosity by a factor of five and its integrated luminosity by a factor of ten beyond original specifications. Given the LHC's high complexity, the upgrade demands meticulous planning and spans over a decade. The High-Luminosity LHC (HL-LHC) represents a significant advancement in accelerator technology. Its technical infrastructure includes civil engineering, electrical distribution, cooling and ventilation, access and alarm systems, technical monitoring, transport and logistics, storage, and operational safety. Key civil engineering elements include access shafts, underground galleries (distinct from the LHC tunnel), and surface buildings for compressors, ventilation equipment, electrical systems, and storage tanks for helium and nitrogen. Construction is divided between two experimental sites: Point 1 (for the ATLAS experiment) and Point 5 (for the CMS experiment). At each site, the underground work comprises a shaft, a cavern, a power converter gallery, service galleries, safety galleries, and vertical cores connecting the new infrastructure to the existing LHC (see Fig. 1) [1].

At CERN, accelerator coordination is managed by the Accelerator Coordination and Engineering group. For the case studies presented here, coordination involved two Facility Coordinators and one Safety Coordinator (*Coordination Sécurité et Protection de la Santé*, CSPS). The Facility Coordinators oversee co-activity management, short- and long-term scheduling, and serve as primary liaisons for stakeholders. Due to the high volume of working hours (Category 1), a Safety Coordinator is required to manage risks arising from interactions between tunnel maintenance and HL-LHC activities. The CSPS ensures compliance with safety best practices, reports on new activities, and provides expert guidance. All activities require approval from both coordinators before initiation.

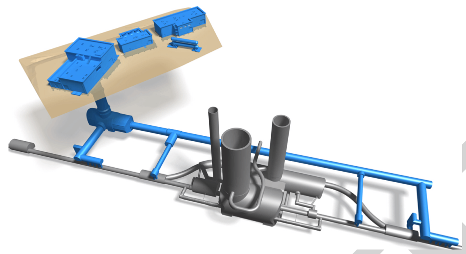

Figure 1: Overview of the HL-LHC infrastructure shown in blue. The existing LHC facility is shown in gray.

## COORDINATION CHALLENGES OF THE VERTICAL SHAFTS

Two case studies illustrate the coordination challenges encountered during the HL-LHC infrastructure phase. The project involves constructing surface buildings, along with new underground galleries located approximately 75 meters below. The shaft, serving as the sole access point to the underground, is a critical component of the project's infrastructure. Its central role in the critical path necessitated dedicated coordination efforts to address the challenges its installation posed.

### *Non-Conformity Within Shaft Commissioning*

The first case study examines a non-conformity during the commissioning of the shaft at Point 1. After completing the civil engineering work, the lift installation began. However, concrete debris falling during commissioning disrupted the process, threatening to delay infrastructure installation in the galleries. Given the shaft's critical role, both as a worker access point and a material delivery route, the initial plan to complete lift installation at Point 1 before moving to Point 5 would have caused cascading delays. The coordination team proposed a revised schedule to prioritize Point 5 despite the delay at Point 1, minimizing the overall project delay from 9 months to 3.5 months. A dedicated coordination team was subsequently established to supervise on-site activities and bridge the gap between the worksite and management (see Fig. 2).

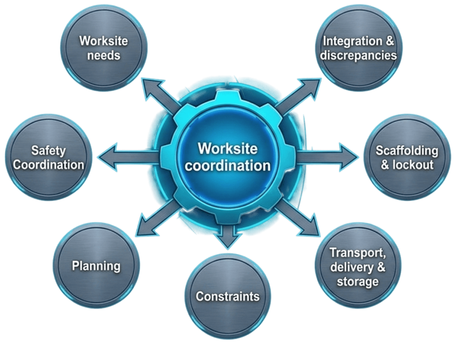


Figure 2: The coordination is a focal point with stakeholders.

### *Infrastructure Installation Within the Shafts*

The second case study addresses infrastructure installation challenges within the shafts. Beyond serving as a delivery route, the shaft must accommodate infrastructure such as pipes, cable trays, ventilation ducts, and smoke extraction systems. Temporary scaffolding within the shaft blocked deliveries, though the lift remained operational for gallery work. To ensure progress, the coordination team developed a six-month material delivery and storage strategy for the galleries, requiring a rigorous storage management plan aligned with activity progress. Due to some welding issues in the piping and assembly defaults in the smoke duct, the shaft on point 5 started to be delayed compared to the baseline. This forced the coordination to initiate worksite meetings that facilitate the communication and the reactivity to issues. The facility coordinator, overseeing all installation phases from conception to commissioning, acted as a conductor, linking the two sites and management. This approach enhanced schedule coordination and flexibility, enabling the review of the general schedule of both points. This allowed to start earlier the works on Point 1 in the shaft even if the Point 5 was not completed. To compensate for the delay on Point 5, the coordination had to find solutions to restock the galleries with materials deliverable via the lift. The centralization of the coordination team was useful to avoid delay by starting the activities of one site without waiting the milestones completed on the other site.

## COORDINATION METHODOLOGY

The methodology begins with the consolidation of inputs from the 3D Integration Service providing the 3D drawings and verifying the interfaces between equipments and from the Project Engineer responsible of the physical work and the contractors. This integration enables the worksite coordination team to gain a comprehensive understanding of the environment in which the worksite will operate. The Project Engineer provides essential information, including the duration, constraints, requirements, and prerequisites of the activity as defined by and/or agreed with the contractor. In the planning phase, these inputs are merged to propose an optimized sequence and timeline, ensuring the avoidance of co-activities. This creates a safer working place. Following this, a preparatory visit is organized to clarify specific needs, such as delivery logistics, storage requirements, and workshop arrangements. A Joint Safety Visit (VIC) is subsequently conducted to ensure the safety of all stakeholders and to guarantee compliance with safety regulations. Regular worksite meetings are held with Work and Service Supervisors (WSS) to support their activities, facilitate information exchange, and establish follow-ups. These follow-ups are reported from the activity lead to the coordination team and then to the planning team, ensuring a seamless link between the worksite and management. The methodology applied during the infrastructure phase is summarized in Fig. 3.

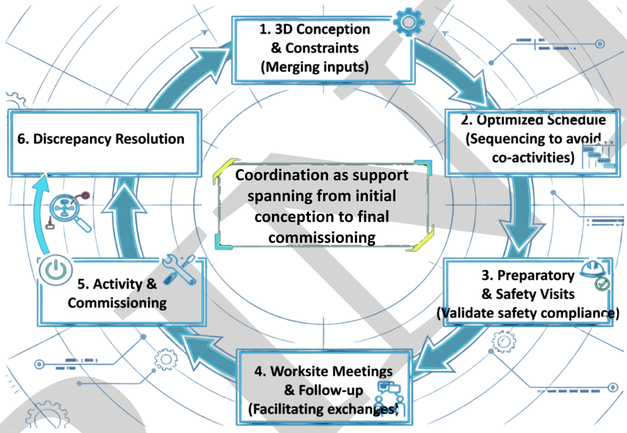


Figure 3: Follow-up methodology.

Schedule management for the HL-LHC infrastructure operates across multiple levels as illustrated on Fig. 4, each tailored to a specific purpose and audience. These schedules are ranked in order of importance from Level 1 to Level 4, with Level 5 introduced temporarily to manage particularly complex activities.

- Level 1 consists of the CERN accelerators schedule, primarily used for general CERN communication with a horizon of decades.
- Level 2 is the linear schedule for Long Shutdown 3 (LS3), providing a long-term overview for management to visualize major upcoming activities. It serves as the baseline for planning with a horizon of years.
- Level 3 offers a medium-term perspective and is intended for engineers, contract managers, and project leaders. It is updated and communicated to stakeholders on a monthly basis spanning several months.
- Level 4 is the primary tool for on-site coordinators, providing a short-term view, typically covering a five weeks horizon. Updated weekly and published in the weekly report, it is primarily aimed at technicians and on-site WSS. This schedule distils information from higher-level schedules to ensure daily coordination on-site and incorporates constraints from Levels 2 and 3.

It also feeds back field information to the higher-level schedules.

- Level 5 is used temporarily and exclusively in cases of force majeure, where precise daily planning is required for complex activities.

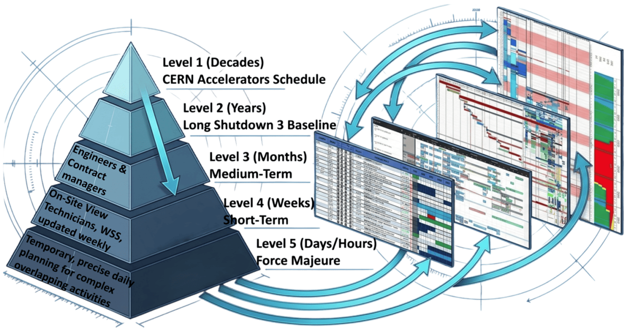


Figure 4: From Worksite schedule to CERN management schedule. Different schedules offer different views and granularity, targeted to different needs and audiences [2–4]

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## LESSONS LEARNED

Thanks to the issues encountered, of which the two case studies are examples, the coordination team's organisation and method have been continuously refined. During the project, the team needed to understand its strengths and weaknesses to achieve harmony between all stakeholders. Here are some key lessons learned that the coordination team would like to share. The first lessons is the essential role of worksite coordination as the central hub during the installation phase. This coordination acts as a bridge between all stakeholders, enabling rapid information sharing and prompt issue resolution. By facilitating seamless communication among groups, it ensures efficient information flow and timely responses to challenges.

The second lesson highlights the continuous improvement of coordination throughout the project's evolving complexity. The worksite coordination team was continuously adapted, employing a dual top-down and bottom-up approach to support worksite personnel. The process begins with high-level planning to define global activities and sequences. Once validated by management, worksite supervisors, and contractors, this planning is translated into a short-term format tailored to on-site needs. Worksite meetings confirm the feasibility of this planning, while technical and safety visits at the start of each activity address emerging needs such as compensatory safety measures, handling procedures, scaffolding, or lockouts. Follow-up meetings throughout the activity allow for reactive solutions, reassessment of co-activities, and adaptive planning.

The third lesson underscores the necessity for coordination to support stakeholders at every stage, seamlessly transitioning between long-term and short-term schedules, as well as abstract and concrete topics. The Facility Coordinator, plays a central role and comprehensive project knowledge, can resolve issues quickly. The coordination team's proximity to all stakeholders enables effective synthesis of information, which is vital for smooth project execution. To achieve this, the worksite coordination team must be involved in every phase, from integration to commissioning, providing scheduling and organizational support. By centralizing worksite knowledge, the coordination team delivers efficient, personalized support to stakeholders, empowering the Facility Coordinator to schedule, guide, and manage the worksite effectively.

Finally, a fourth lesson underscores the importance of strong safety organisation on worksites. The CSPS ensures rigorous co-activity risk analysis, protecting workers from hazards such as cryogenics, high voltage and radiation, while harmonising safety procedures across contractors. It enables safe coexistence of operations and complex handling tasks. As the central authority, the CSPS safeguards workers' integrity, supports decision-making, and helps prevent schedule disruptions. The systematic use of VICs further strengthens safety. They are centralised, validated before any activity starts and measures are shared with all stakeholders.

## CONCLUSION & FUTURE WORKS

Coordinating the installation of such a complex project requires flexible planning strategies, tailored to the stakeholders involved. A dual top-down and bottom-up approach, combined with real-time monitoring of day-to-day worksite issues, proved essential. The integration of short-term schedules with long-term planning was instrumental in achieving the project's objectives. Worksite efficiency is defined by safe operations, strict adherence to the schedule, effective management of co-activities, and organized coordination in response to challenges. The methodology adopted by the coordination team demonstrated its adaptability to stakeholder needs, reactiveness in resolving technical issues, and ability to foster collaboration among all stakeholders.

The facility coordination team experience found that increasing its own autonomy would greatly help the efficiency of working on-site, particularly in areas where different responsibilities are interfacing to each other. Assigning a modest budget to the coordination team, estimated as 0.8% of the activity value and designated exclusively to fund interface activities not correctly assigned and logistics needs, would be advantageous for all stakeholders in the project. Given the large workforce involved, the project experience also emphasized the importance of pairing the CSPS with the Facility Coordinator. This centralized coordination, supported by strong communication between the two roles, ensures rigorous planning while minimizing mutual interference. Additionally, the Facility Coordinator should lead worksite meetings to facilitate exchanges and participate in contracts management to propose claims based on delays observed.

## ACKNOWLEDGEMENTS

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