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INSTALLATION OF A PARTICLE ACCELERATOR: FROM THEORY TO PRACTICE

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Abstract

The size and complexity of the LHC project at CERN calls for a strong co-ordination of all installation activities. The detailed installation planning has to take into account many constraints such as the component production rates, the installation contracts or the transport and handling requirements in a narrow tunnel with limited access points. The planning also needs to be flexible enough to cope with aleas that are unavoidable in such a large project that spans over many years. This paper describes the follow-up methodology, both in the field and in the office, adopted by the IC team to assist the groups involved in the installation of the LHC machine.

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1 INTRODUCTION

The LHC Technical Co-ordination Committee (TCC) has the mandate of defining the installation and hardware commissioning strategy for the LHC machine and its infrastructure. The TS-IC group manages tactical aspects of the installation, including the general co-ordination of LHC installation work. The TS-IC group covers activities of configuration management, integration studies, scheduling and co-ordination of the installation and of the hardware commissioning, site management, logistics, handling and transport. However, it is up to each CERN group to cater for the operational requirements for the installation of their equipment.

The organization of the LHC installation has been described, at the level of general principles, in several documents issued at the time the project was launched [1, 2]. We now have some experience in the field, and this paper presents the methodology of the IC team concerning the co-ordination of installation. It describes, with real life examples, the interactions between the different sections of the group and what they can do to cope with aleas.

2 PLANNING OF THE LHC INSTALLATION

All interventions are scheduled as soon as they are identified in the Work Breakdown System (WBS). The planning of the LHC has to deal with increased constraints on time and budget, which goes along with generalized external contracting practice. Contractual constraints are usually very rigid, and requests for modifications coming from the CERN side can lead to substantial over costs. The tendency is also to target for a just-in-time supply of components: this allows reducing cost by avoiding storage and early payments of buffer stock. Still, transport and logistics considerations in a narrow tunnel with limited access facilities add another level of complexity to the supply problems.

We describe briefly how the General Co-ordination Schedule and the Detailed Installation Planning are created and under which circumstances they can be modified.

2.1 General Co-ordination Schedule

The General Co-ordination Schedule is at mid-level between the Detailed Installation Planning and the Master Schedule which reviews the strategic goals and major milestones of the project. It gives a schematic of the different phases of the installation, indicates the main dates and shows the sequence of work in the different sectors of the LHC. The General Co-ordination Schedule is issued by the planning team of TS-IC with the aim to implement and control the flow of installation that is most effective in term of resources and time. It has to respect the main milestones of the Master Schedule (Ex: injection tests in TI8, tests of sector 7-8 with beam) and is endorsed by the Project Leader.

We have identified 12 phases for the installation activities [3] that have been grouped into 3 main periods: installation of general services, installation of the cryogenics line (QRL) and installation of the machine equipments. The present version of the General Co-ordination Schedule, revision 1.7 [4], was issued in March 2003. At that time, the installation planning of the general service was fully consolidated. The QRL installation, which is totally handled by the external contractor in charge, is rated by the contractual dates. The installation planning of the machine components was derived from previous experience with LEP, cross-checked with logistics studies concerning the transport of the cryo-magnets: it should be noted that the magnet interconnect work represents by far the most critical and time consuming activity of that installation period. Table 1 summarizes the corresponding dates, which are strategic constraints for the LHC installation planning. Completion of the machine up to colliding beams will furthermore include the hardware commissioning of each octant and the check-out of all systems working together on the entire ring, with the final access control.

Table I: Initial dates retained for revision 1.7 of the LHC installation planning

Sector	General services	QRL installation	Machine elements
7-8	Oct. 01 – May 03	Jun. 03 – Nov. 03	Dec. 03 – Apr. 05
2-3	Jan. 02 – Sep. 03	Nov.03 – Apr. 04	Apr. 04 – May 05
8-1	Jun. 02 – Feb. 04	Apr.04 – Aug. 04	Aug. 04 – Oct. 05
4-5	Apr. 02 – Feb. 04	Jun. 04 – Nov. 04	Nov. 04 – Feb. 06
3-4	Jan. 03 – Aug. 04	Sep. 04 – Feb. 05	Mar. 05 – Apr. 06
5-6	Aug. 03 – Nov. 04	Dec. 04 – May 05	Aug. 05 – Aug. 06
6-7	Aug. 03 – Feb. 05	Mar. 05 – Jul. 05	Jan. 06 – Oct. 06
1-2	Apr. 02 – Apr. 05	Jun. 05 – Oct. 05	Jun. 06 – Dec. 06

The installation of the General Services, which consist mainly in piping and cabling work but also includes the preparation of the floor for transport, survey, etc., is terminated in sectors 7-8, 2-3 and 8-1. It is presently ongoing in the other sectors, on schedule except close to point 5 where civil engineering work is not achieved.

The installation of the cryogenic distribution line has however accumulated a considerable delay and we expect the completion of the QRL in sector 7-8 by June 2004. The logistics for the supply of the component of the QRL in sector 8-1 will now force us to modify the sequence of installation: the pipe elements, which are 12m long, must be lowered through PX85 at point 8. They have to go through the experimental cavern onto a platform which allows their transport to the LHC tunnel. The installation planning of the LHCb experiment assumes that the platform is removed by August 2004, allowing to move the experimental magnet and to complete the spectrometer in place. We thus have to install the QRL in sector 8-1 before the sector 2-3 as originally planned: a new revision of the General Co-ordination Schedule will be issued as soon as we get reliable dates and rates for the installation of the QRL, with a view to propose a sound basis for the scheduling of the procurement of all machines components.

The details of the installation of the machine elements have been worked out and a scenario, covering the continuous cryostat in sector 7-8, is now available [5]. It includes local cabling and provision of the underground network, the installation and survey of the supporting jacks, the transport of the cryo-magnets to their final positions and their interconnect. With a view to partly recover the delays mentioned earlier, the planning team proposed to interleave these activities together with the cold tests of the QRL. This results in a very tight planning that requires an increased co-ordination and leaves almost no float. The provision of all the components required has been carefully studied and lists of requirement dates, items by items, have been issued and agreed with the providers.

Rescheduling of the installation, in the two examples given above, involves many parties. To obtain authorization for a schedule change, a Schedule Change Request is circulated to all the Group Leaders involved in the LHC Project for them to evaluate eventual implications on the installation of their equipments and on their contracts. When approved, the Project Leader declares the document as a Schedule Change Order and it is announced to all the Project Engineers.

2.2 Detailed Installation Planning and Short Term Planning Meetings

The Detailed Installation Planning derives from the details of the installation scenario and the knowledge of each individual installation work unit (activities, boundary conditions, resources, etc.). It is maintained with the MS-Project package, which updates automatically all the chronological relations between the different activities whenever a schedule change or a new task is introduced. It also provides a resource leveling function that is very useful to assess the feasibility of a new scenario.

The installation activities have to adapt through continuous feedback from the production sites and from the field. To this end, the detailed installation planning is actually reviewed, every 4 weeks, at the Short Term Planning Meeting whose aim is to confirm the activities to be carried over the 3 coming months. This is the forum where we get early warning of potential delays: interfaces between groups have not been identified or the task sequencing is incorrect, components or team are not available, preparation work or integration is not ready, time required to achieve a given task has been

miss-evaluated or unexpected technical difficulties were encountered. It is mandatory to limit the impact of such aleas, and we may envisage a rescheduling of activities or a redeployment of staff to optimize the usages of resources. In the decision making process, we start by trying solutions without consequences on other work units (co-activity if possible), then without consequences on work units under sub-contractors or vendors responsibility. Rescheduling can be accepted rapidly if the impact is limited to the domain of activity of the project engineers present or represented at the Short Term Planning Meeting and if the dates of the General Co-ordination Schedule are respected. We then get periodically a revised Detailed Installation Planning that takes into account the actual component production and installation contracts as well as the actual progress of the installation.

Such direct rescheduling can be a hazardous exercise. We have to be attentive to the logistics of the supply of the different work sites since activity in a shaft (cabling, piping or installation of cryogenics lines) forbids lowering material through this shaft for the entire duration of the work. We also must be very vigilant to all safety aspects: security rules have to be strictly enforced and the new procedures must be studied and documented in all details. This is anyway a mandatory step to assess the feasibility of the new scenario.

Still, if it appears that the change cannot be considered locally and that it has implication on the installation of other equipment occurring at different times and locations, the rescheduling must be known and accepted by all parties involved through a Schedule Change Request.

3 CO-ORDINATION OF LHC INSTALLATION

Different groups work closely together during the installation of the LHC, with a tight coupling between their activities since they often require services (Ex: electrical power, ventilation) provided by other teams. The work and co-activities are also constrained by the confines of the tunnel. There is thus a need to classify and group tasks by their position in the tunnel into Work Packages: these can also group several phases of the machine installation process with a detailed scheduling of activities which results from a single network of inter-dependency. This means that a punctual delay or an aleas may propagate onto a chain of activities within a given Work Package, thus resulting in additional delays and potential over costs. The role of the co-ordination is to limit the impact of such incident whenever decision can be taken on the field, and to give assistance to installation whenever minor interventions can unblock the situations.

We review now the content of the Work Package documents, the role of the Zone Coordinators and how they monitor the progress of the installation in the field.

3.1 Description of Work Packages

Because several protagonists can intervene in zones and during overlapping time intervals, it is necessary to make sure of the compatibility of all the works. It requires an overall view of what needs to be done, which in turn is possible only if the information is coherent across the installation of the whole project. For that very reason, the installation of services and LHC machine components has been broken down in Work Packages which cover a given period of the LHC installation and a given part of the underground areas. The Work Package documents contribute to the quality assurance process of the LHC project [6]. They are linked to the Detailed Installation Planning discussed in the previous paragraph, and this completes the information required for the chronology of the activities.

Beyond a summary description of the different works to be carried out, these documents give precise information on:

- The human and material resources required, contact persons…
- Specific logistics needs and means
- Specific access conditions
- Installation of surface barracks and storage areas
- Protective measures to implement if required
- Field utilities available over the work package time span

- Description of the initial environmental conditions if necessary

The description of installation Work Package is prepared together with the scheduling process, with the assistance of the Zone Coordinators (see §3.2). It is controlled by those involved in the field and approved by concerned Group Leaders and Heads of Department.

3.2 Co-ordination in the Field

The co-ordination in the field requires a very good knowledge, updated on a day-to-day basis, of the situation in each worksite, of the possibility of co-activities and of the transport conditions in the underground areas. The LHC ring is subdivided into 2 main zones with point 1 and point 5 as boundaries. The injection tunnels form a third geographical zone. Each zone is supervised by a Zone Coordinator who ensures that the installation activities are carried out as specified in the Work Package description, according to the defined strategy and in conformity to safety rules and regulations of CERN, INB and Hosts States. The aim is to stay aware of the advancement of every work site, and rapidly react to problems of all nature. To help in this mission, the TS-IC-AI Section can provide some assistance to installation and can carry minor works ranging from quick repairs to preparation of masonry, steel structures, electricity, etc. This allows in particular to handle orphan work sitting on the borderline of well identified responsibilities, and to unblock problematic situations in the field.

Experience indicates that getting a clear evaluation of the situation of each work site can sometimes proceed from an inquisitive investigation: people in charge may themselves be misled by their contracting party. They can also be quite reluctant to announce a problem that engages their responsibility, expecting that another incident will occur and mask their own difficulties. It is thus essential to balance a precise and professional attitude with good personal contacts, both in formal and informal situations. The emphasis is to be working together to implement the project as it has been planned. One can illustrate the importance of the knowledge of the advancement of an activity with the example of cabling work: laying down cables requires a free area, it does not allow for co-activity and may limit the transport condition in the tunnel. However, connecting work is very local and can be done in parallel with other activities. Solutions can thus often be found in the field, without modification of the Detailed Installation Planning, provided there is a good comprehension of the difficulties that all parties have to face.

3.3 Monitoring of the Installation Progress

The Zone Coordinators organize weekly meetings in the field with the aim to follow the advancement progress of every installation work, to identify potential problems and to propose corrective measures if necessary. The Work Supervisors of the groups involved, the Site Managers and the Safety Inspector participate in these meetings. On some occasions, ad-hoc meetings are organized with the teams involved in a specific area to study all the details of a delicate installation scenario.

Minutes of the weekly meetings in the field are available and the Zone Coordinators report to the Installation Follow-up Meeting that takes place every 4 weeks: this is a forum to share experiences and to check the homogeneity of the installation procedures on the different work sites. The Zone Coordinators also participate in the Short Term Planning Meeting that has been described earlier: the Engineers in Charge of the current work, the Safety Coordinators and the members of the TS-IC group thus have a coherent view of the situation of the installation every fortnight.

A synthesis of the Installation Follow-up Meeting and of the Short Term Planning Meeting is presented at the TCC and covers the following points:

- The work which has been achieved in the period elapsed since the previous report.
- The problems which have been encountered during that period and the corrective action taken with the consequences foreseen on other activities.
- The actual status of the project versus the planning materialized as a broken line on the train chart version of the General Co-ordination Schedule.

The status of the installation versus the planning is then published once a month on the home page of the LHC Project.

4 SUMMARY

The TS-IC group has adopted a pragmatic approach to the co-ordination of the LHC installation. What needs to be done and when it has to occur is described in the Work Packages documents and in the Detailed Installation Planning that are distributed via EDMS. The status of the installation is reviewed periodically, presented at the TCC Meeting and published once a month on the home page of the LHC Project. The schedule is updated to show the advancement of the installation process and the change with respect to the previous month.

Delays and incidents are unavoidable in a one-of-a-kind project of the complexity of the LHC and these may trigger a series of difficulties on several fronts. The co-ordination has to propose and implement measures to limit the impact of such aleas. These can be decided at different level of responsibility of the project:

- By the Zone Coordinators, in the field, when the solutions only imply a reorganization among the work sites but does not affect the planning;
- By the planning team, after a discussion at the Short Term Planning Meeting, if the rescheduling is limited to a few well identified activities and does not affect the General Coordination Schedule;
- By the Group Leaders involved in the LHC project, after a discussion at the TCC, through a Schedule Change Request that, if accepted, is endorsed by the LHC Project Leader.

However, this formal approach has to be backed by close interactions with all those who participate in the project, on the production site and in the field. This is the most effective way to understand all the difficulties people have to face and to propose alternative scenarios that can reach a consensus.

Finally, one must be aware that prompt reactivity is a potential source of accident. The installation of the LHC requires carrying heavy equipment and a huge variety of material in very confined underground areas. Many teams share the same access path and work sites, sometime working on different levels. All safety rules must be strictly enforced and there is no emergency that can justify any derogation.

5 REFERENCES

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