2^{nd} CERN MAC Cost Review Report on the LIU and HI-LUMI Upgrade for the LHC

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Introduction and General Description

The review began with a plenary session providing an overview of CERN activities and plans, a presentation of the LIU and HL-LHC project as well as a general overview of the CERN planning and budgeting process. After breaking up into five subgroups for the next day and a half the review finished with a close-out presentation on the afternoon of Wednesday, October 19, 2016. The detailed program can be found in: Appendix 2: Agenda.

The goal for this review was to assess the development of the baseline since the first Cost Review, which was performed in March 2015. Subject of the review were again the LHC Injectors Upgrade (LIU) and the High Luminosity LHC upgrade (HL-LHC). Previous as well as updated documentation was provided to the review in advance of the meeting, which was very helpful to the committee. The presentation and the documentation can be found at: https://indico.cern.ch/event/542864/. Neither the ongoing consolidation project (CONS), nor the upgrade of the detectors for LHC were part of the scope of the review, which is consistent with the previous review.

The Charge

The charge was given to the review team by Frederick Bordry, Director Accelerators at CERN. The following items were addressed:

1. Is the projects' status and progress, in particular the identification of critical pieces of hardware, on schedule and within cost as foreseen?
2. Are the baseline changes since the previous C&S review and the reasons for these changes, as well as their impact on scope, schedule and cost, commensurate with the project proposal from 2015?
3. Are the change-management methods and their implementation since the previous C&S review (i.e. tracing and validation of these changes) appropriate for managing this project?
4. Is the level of risk appropriately addressed and does the global evolution of the cost and schedule of both projects still stay within the original intent of the project?

The review team was requested to give an oral presentation of the findings, comments and recommendations by the end of the third day. The chair of CMAC was invited to the SPC to present its preliminary findings. A final report will be prepared within the following four weeks.

Executive Summary

The review committee again is very impressed with the enormous amount of work that was presented. Both, the LIU team and HL-LHC team continue to perform at a very high level and an enormous amount of work has been accomplished since the last review. Both teams addressed the recommendations from the last review as well and dealt with new challenges which developed over the last eighteen months.

After the 2015 Cost & Schedule review, the schedule for the Long Shutdown 2 and 3 were affected. LS 2 was delayed by 6 month and extended by 6 month. LS 3 was delayed by one year while maintaining the duration. The decision to delay LS2/LS3 was taken right after the 2015 C&S review, due to several reasons. The main reason was the need to reduce the cumulative budget deficit of CERN. It was not linked to WP17 cost increase that became apparent in spring this year.

The management team of HL-LHC has been increased and strengthened while focusing on the major issues the project had to deal with since the last review. Most prominently detailing the layout of the civil construction identified schedule and cost increases which the HL-LHC team effectively dealt with. This work package has made significant progress and the maturity of the design is at a comparable level. Cost increases were addressed by de-scoping the other work packages which maintained the Total Project Cost (TPC).

During a detailed discussion on the global schedule, it became clear that the LS2/LS3 shifts allowed accommodating some of the delays that started to appear in the other work packages of LIU and HL-LHC. Nevertheless, it became also clear that further delays will negatively impact e.g. maintenance schedules for cryo-plants, detector upgrade schedules, increase standing army costs etc, and therefore would have to be carefully assessed before implemented.

For Civil Engineering scope of work, which now has to be executed quite a bit earlier, namely almost completely during LS 2, timely preparation and execution of the tender for Infrastructure contracts demand highest priority and regular oversight of the LIU/HL-LHC Executive Committee.

Throughout the review it became clear, that manpower has to be added to both projects in order to allow them to stay on schedule. In many cases the expertise required does/will not exist (anymore) at CERN and must be recruited as soon as possible, be trained and brought into the projects. For the LIU project an assessment was performed and a request submitted that the review team agrees with. Cost management includes the recommendation to find efficiencies elsewhere in the project to support this request.

Acknowledgement

The members of the MAC are indebted to the CERN management, the LIU and HL-LHC team for following up thoroughly on our last report. We want to thank especially Frederick Bordry for his hospitality and Evelyne Delucinge, Malika Meddahi, Benoit Delille, Lucio Rossi and Frank Zimmermann for their support and excellent preparation.

The Breakout Sessions and Individual Comments

In the following chapter, the subgroups summarize their findings, comments and recommendations. In addition, each subgroup provides answers to the charge questions. An overview of the common conclusions will be given in the chapter, "General summary of comments from the subgroups and conclusions".

The LHC Injector Upgrade Plan (LIU) and LINAC 4

Findings

The LHC Injector Upgrade (LIU) was re-baselined in 2016 realizing cost savings of 6 MCHF (in 2015 prices). LIU has now a total cost of 180.2 MCHF (in 2015 prices). The project is 32% complete with a reported Cost Performance Index (CPI) of 84% and a Schedule Performance Index (SPI) of 93%. Some of the CPI and SPI deviation from 100% are due to delayed reporting of earned value.

In the present baseline LIU needs 791 FTEy of CERN staff, and 285 FTEy of Fellows and MPA representing an increase of 100 FTEy of CERN staff and 91 FTEy of Fellows and MPA over the last cost and schedule review. Of the 285 FTEy of Fellows and MPA, 56 FTEy of fellows are planned to be recruited: 22 already funded in the project and 34 presently not accounted for in the project, requesting an additional funding 3.5 MCHF to the LIU project.

Since the last review Linac4 (which budget is not part of LIU) has made significant progress towards reaching design parameters. Linac4 has accelerated 20 mA to 105 MeV and 5 mA to 155 MeV, while the design current and energy are 40 mA and 160 MeV respectively. Operations to date were limited to shifts of typically 8 h per day.

LIU-PSB has a total cost of 66.4 MCHF (in 2015 prices), and is 31.4% complete with a CPI of 99% and a SPI of 84%. The goal of the PSB upgrade is to reduce the emittance by a factor of 2. Old unused cables were disconnected and will be removed in the upcoming Extended Year-End Technical Stop (EYETS). In preparation for the connection to Linac4, a half sector test (HST) has been set up to verify the H^- charge stripping. The PSB scope was changed to replace all cavities with Finemet cavities, and separate the TT2 cooling from the PSB. The failure of a POPS capacitor requires a re-evaluation of the POPS-B building and power converter.

LIU-PS has a total cost of 23.5 MCHF (in 2015 prices), and is 35.6% complete with a CPI of 95% and a SPI of 93%. The PS has demonstrated reliable operation with 2×10^{11} ppb, with a LIU goal of 2.6×10^{11} ppb. Two fellows will join the PS team to advance the investigation of intensity limits and mitigations. The modification rather than replacement of the injection kicker yielded cost savings of 500 kCHF. However, a supplier for a needed HV cable using SF6 has not yet been found, and alternatives are under investigation.

LIU-SPS has a total cost of 72.2 MCHF (in 2015 prices), and is 18.8% complete with a CPI of 83% and a SPI of 79%. The SPS has demonstrated 2×10^{11} ppb at injection with 20% beam loss. The LIU goal is to deliver 2.3×10^{11} ppb to the LHC after 10% beam loss.

The ions Work Package was re-defined as PS Injectors (i.e. Linac3 and LEIR). LIU-ions have a total cost of 2.6 MCHF, and is 18.5% complete with a CPI of 92% and a SPI of 81%. The LIU ion parameters have been demonstrated up to PS extraction. The remaining tasks to be demonstrated are slip stacking and acceleration in the SPS, in order to double the number of bunches in the LHC. With the elimination of the fast (100 ns rise time) SPS ions injection kicker, 3.9 MCHF cost savings were realized.

Comments

The reported EV is behind during the year and EVM measures are most accurate at year-end. The cost estimates for the defined scope are largely based on existing equipment or received bids. The LIU management and WP leaders are confident that the schedule can be met if the missing staff is provided. There is concern over insufficient personnel resources for RF, LLRF and beam dynamics work.

Although significant progress has been made in commissioning Linac4, the design parameters have not been reached. The LIU beam parameters needed for the HL-LHC can be demonstrated with 30 mA, less than the 40 mA design current, providing performance margin for HL-LHC. After the switchover to Linac4 the reliability needs to match the present Linac2 reliability in order to maintain the LHC availability. A spare RFQ module can reduce the time of an RFQ replacement to three weeks.

The disconnect of unused old cables in the PSB was very well prepared and executed, with only one cable disconnected in error. For the success of the PSB upgrade continuous and reliable beam dynamics support is necessary.

There is still a significant risk of not reaching the LIU proton intensity goal in the PS and SPS and further studies are required. In the PS this could be studied with beam by the end of 2017. One possible mitigation in the PS is the installation of a Landau cavity. The cost and schedule for the construction and installation of such a system has not been estimated.

The full LIU beam performance parameters can only be demonstrated after LS2 when all upgrades are installed and commissioned. The mitigation of some performance risks in the PS and SPS may require additional installations in LS3 (e.g. impedance reduction measures, additional RF systems and feedbacks, aC coating).

The LIU ion parameters made significant progress since March 2015 with intensity increases in Linac3 and LEIR. The only outstanding demonstration is slip stacking in the SPS to double the number of ion bunches in the LHC. The remaining work in the injector chain is to improve the operational robustness, particularly important because of the short LHC ion runs.

Recommendations

- Allocate the missing 3.5 MCHF to fully finance the request for additional fellows.
- Ensure that sufficient RF, LLRF and beam dynamics personnel resources are available for the LIU machines including commissioning.
- Develop a strategy to mitigate the remaining performance risks in reaching the LIU beam parameters in the PS and SPS.

Answers to charge questions for LIU project:

1. Is the projects' status and progress, in particular the identification of critical pieces of hardware, on schedule and within cost as foreseen?

Yes. LIU has presently a two-month delay, but is on track to finish by the end of LS2 if identified but missing personnel resources are provided. Cost estimates are now in the −3% to +5% range (Class 1).

2. Are the baseline changes since the previous C&S review and the reasons for these changes, as well as their impact on scope, schedule and cost, commensurate with the project proposal from 2015?

Yes. The LIU scope has been slightly reduced and the total cost was reduced from 186 to 180 MCHF (in 2015 prices). This has no impact on the performance goals, which were also aligned to the HL-LHC goals. The schedule changes take advantage of the delayed and extended LS2.

3. Are the change-management methods, and their implementation since the previous C&S review (i.e. tracing and validation of these changes) appropriate for managing this project?

Yes. The impact of all significant changes on scope, cost and schedule were evaluated and presented to the review committee. Project documents are version controlled and ECRs are reviewed.

4. Is the level of risk appropriately addressed and does the global evolution of the cost and schedule of both projects still stay within the original intent of the project?

Yes. The LIU cost risk for the defined scope is low. Some schedule risk remains, in particular in the SPS, since not all personnel is committed yet and LS2 is not yet fully planned out. Mitigation measures to address the possible performance risks in the PS and SPS amount up to approximately 10 MCHF, which is not included in the LIU budget.

HL-LHC – Magnets, powering and cryogenic systems - HL-LHC project

Findings

A number of scope changes and reductions have been implemented since the last review, resulting in significant cost savings.

The new baseline for the 11T dipole has fewer magnets and considerably reduced the workload between LS2 and LS3.

Simplification of the powering circuits and the reduction of the current in the magnets have drastically reduced the cost of the power converters.

A new quench protection scheme was presented (OLH and/or ILH/CLIQ excluding the extraction energy system for the main circuits) and will be decided after the prototype tests.

A new cold mass for Q4 will utilize an existing magnet with a 70 mm aperture (MQY) rather than continuing development and production of a larger bore version.

A full Inner Triplet string test is planned at SM-18 as a single installation and operation phase instead of two installation and operation phases.

A 60 m prototype MgB_2 superconducting link assembly in its flexible transfer line will be tested at SM-18. The current plan is that all MgB_2 superconducting link assemblies in their flexible transfer lines will be tested before installation.

The project includes a number of potential in-kind contributions (U.S., Japan, Spain, Italy, France, Sweden + others).

Initial guidance for the United States' contribution to HL-LHC has been established with funding expected to be disbursed from FY17 to FY24, with peak funding in FY20. Deliverables from the U.S. to HL-LHC have been discussed and tentatively agreed upon between the HL-LHC Project Leadership (CERN) and the U.S. Project Management: 10 Cryoassemblies of Q1/Q3 focusing quadrupoles (out of a total of 20 Cryoassemblies of Q1/Q2/Q3 for HL-LHC) and 10 Dressed RFD Crab Cavities (out of a total of 20 Crab Cavities for HL-LHC) Preliminary Functional Specifications for the Q1/Q3 focusing quadrupoles are under approval by HL-LHC.

The United States' contribution to HL-LHC has achieved "Mission Need (CD-0) Approval" on April 13, 2016. The new project has been named HL-LHC Accelerator Upgrade Project (HL-LHC AUP). HL-LHC AUP is scheduled for an Independent Cost Review (ICR) by DOE- PMOA in the time frame of January – April 2017 and for CD-1 Approval ("Alternative Selection and Cost Range ") by early Summer 2017. FNAL is scheduling a "CD- 1 HL-LHC AUP Director Review" in late-March 2017. DOE has nominated a Federal Program Manager and a Federal Project Director in charge of HL- LHC AUP. Bi-weekly meetings of the IPT (Integrated Project Team) between DOE Managers and U.S. Project Management have been established. On the technical side, the first 150 mm aperture short model magnet (MQXFS1) has been tested and demonstrated quench performance up to and beyond ultimate HL-LHC currents. The US HL-LHC AUP contribution remains on the critical path.

KEK (Japan) presented plans for the D1 separation dipole, CIEMAT (Spain) is developing the MCBX corrector and INFN (Italy) is working on higher order corrector magnets. The Japanese contribution of the D1, along with a number of other in-kind contributions to the HL-LHC project is not authorized yet.

A one-year shift of LS3 has created some extra margin for the WP3 schedule. Critical paths for the installation are the 11T for LS2, then the modified Q5, then D1 and the QXF. The previous review comments on the test station activities have been taken into account and the overall risks are reduced in terms of schedule.

The choice of two different suppliers for Nb_3Sn wire was definitely chosen for strategic reasons to keep one manufacturer in Europe and to reduce risk in case of failure of one supplier wire despite the cost increase.

A strategy for magnet production was presented that included "critical steps." Risks for magnet production have been identified and mitigation plans were presented. A centralized and harmonized management of components is being set up to support internal contract preparation and follow-up, QA, stock and logistics and reporting. Support for personnel through collaboration agreements with external institutes have been or are in the process of being negotiated. CERN activities are supported between CERN employees and industry-provided manpower (M4P), which is included under Materials. Additional space for the magnet and cable activities has been negotiated with CERN management. The cold powering system involves HTS current leads, and MgB_2 superconducting links integrated into flexible cryogenic transfer lines. Designers are evaluating the option of transfer lines with and without incorporation of a thermal shield. Both options will be tested. The installation plan for the magnets was not shown.

Plans for providing infrastructure, including cryogenics, are proceeding for the crab cavity test in the SPS. Cryogenics for this test is on a tight schedule.

Comments

The response to the recommendations from the last review was excellent. Each one was explicitly addressed during the review. The excellent progress seen in this review indicates an extraordinary amount of work has been done.

The project should, to the limit of their ability, develop firm commitments for in-kind contributions. All provide value to the project and cancellation or even delay will have a negative impact. The D1 is a challenging 150 mm aperture NbTi dipole requiring significant design effort and would be a valuable contribution to HL-LHC. The committee urges finalization of a commitment as soon as possible. The MCBXF prototype is not yet developed and tested and the mechanical design of the end parts and nested collars are relatively complex. The committee suggests considering a second model for MCBXF to mitigate the technical risks.

Other in-kind contributions to HL-LHC magnets have not yet been approved and can endanger the overall schedule. It was not clear to the committee how risks and costs are shared between CERN and the contributor in each case. It is important that the project develop a "Plan B" for each case with clear decision milestones.

The committee recognizes and endorses the strategic and risk mitigation strategy of using two different suppliers for Nb_3Sn wire.

Costs for magnet installation and interconnection were not clearly visible in the cost breakdown presented but were clarified in a separate communication during the review.

The proposed strategy for the 11T and QXF magnet production is convincing, with a mix between CERN in-house production and industry involvement.

The mitigation plan to reduce the risks during the magnet production was presented and is convincing.

Testing all the final link assemblies has value in verifying integrity of superconductor.

The Pt 4 refrigerator not only unloads the main LHC cryogenic plants, but provides options for future upgrades and tests of SRF. The choice of a new cryogenic plant or upgrade of the existing refrigerator depends not just on presently predicted heat loads, but also on considerations for future options.

The SPS refrigerator for crab tests provides "test facility" for cavities with beam. It has use for future tests even if crab cavity tests come later and do not provide early enough input to production crab cavities.

Thermal shield in MgB_2 links provide insurance against unexpected heat load, but at the cost of increased stiffness of link assembly.

Review of magnet circuits leads to changes and simplifications, but opens issues on the calculations of over current due to failure scenarios that may require modification of the circuits.

The accounting and reporting for the manpower is confusing and reported data on manpower are not as well-aligned with actual needs as it could be.

Recommendations

- Prepare and present the installation plan.
- Prepare a mitigation plan in case of cancellation, or delay of the in-kind contributions (cost and schedule impact).
- Clarify the sharing of risks between CERN and magnet in-kind contributors.

Answers to questions in the charge to the committee

1. Is the projects' status and progress, in particular the identification of critical pieces of hardware, on schedule and within cost as foreseen?

Overall, yes.

2. Are the baseline changes since the previous C&S review and the reasons for these changes, as well as their impact on scope, schedule and cost, commensurate with the project proposal from 2015?

Yes, there has been substantial streamlining and cost reduction while still meeting the requirement.

3. Are the change-management methods and their implementation since the previous C&S review (i.e. tracing and validation of these changes) appropriate for managing this project?

Yes, in the context of the magnet, powering and cryogenic systems changes were explicitly mentioned along with impact on cost, schedule and technical risk.

4. Is the level of risk appropriately addressed and does the global evolution of the cost and schedule of both projects still stay within the original intent of the project?

Yes, but there are still aspects of the project that have been identified as having a high level of risk and they are actively looking for solutions.

SC cavities and rf systems - HL-LHC project

Findings

Four U.S. prototypes were being fabricated by a Niowave/US-LARP cooperation as part of an SBIR program. The fabrication was to demonstrate the crab cavity structural feasibility which showed limited traceability and therefore the quality control standards were not sufficient to deliver "beam ready" cavities. CERN took over the production of SPS prototypes with a crash program that started in Autumn 2015. The two design concepts of DQW and RFD have been well-established with harmonized cryomodule designs. A detailed production plan including cost and schedule was developed. Previous experience with superconducting cavities at CERN was available, and made these plans more reliable.

Following the previous recommendation, the baseline for the SPS test involves now testing of both types of cryomodules in the facility SM18, each before its installation in the SPS. The test of the DQW cryo-module with beam in the SPS is planned before LS2, the test of the RFD cryomodule after LS2. The modification of the SM18 facility to host the cryomodule preparation, assembly and cryogenic test is being performed and should be ready on time.

The preparation of the SPS infrastructure to host the DQW cryo-module test with beam is progressing (cryogenic refrigeration & distribution, transfer table, electrical connection), but is still on the critical path.

Comments

The test with beam of both types of cryomodules in the SPS is absolutely required, even after LS2. The test is necessary to assess the capability to efficiently crab the beam without affecting the beam quality over longer running periods, to tune and optimize the LLRF and cavity control, and to ensure reliable operation under realistic conditions.

In addition, performing this test before LS2, is obviously desirable to obtain experimental feedback before the start of the series production of the 4+1 DQW cryomodules. Only in this way one has the possibility to introduce modifications with a minimum additional risk in terms of cost, schedule and technical reliability of the system.

The committee supports the work sharing between CERN / UK and US. The same vendor should be assigned for prototype and series production. The pre-series cavities should ideally be usable as a backup in addition to the production cavities and ordinal spares for further redundancy. The committee supports acquiring raw material with 30% reserve for various practice prior to and backup purposes during the production stage, as it was proposed by the team.

The production plan for cavities is robust, integrating a prototyping phase for tech transfer to industry and then the series production, with an adequate contingency on cost and schedule

Even if the US prototypes are not qualified for the SPS test, they are and will be of highest value to gain experience on cavity fabrication steps, to set-up preparation procedure (chemical etching, clean room assembly, heat treatment, how to meet the frequency goal …)

Recommendations

- Develop a plan with reasonable margin in schedule to ensure a successful test before LS2 and submit the plan to the LIU / HL-LHC Executive Committee.
- Perform the cryo-module test in SM18 in due time relative to the start of production, independently of the test with beam.
- Develop a plan to accommodate a realistic cavity and cryomodule yield in SM18 (integrate reprocessing time).
- Start now the crab cavity production plan in order to secure the planned start date of series production in 2019, regardless of the SPS test

Other HL-LHC Accelerator systems

Findings

Detailed technical information, cost, schedule and manpower plans were presented on the work packages WP5 Collimation, WP7 Machine Protection and Availability, WP8 Machine Experiment Interfaces, WP12 Vacuum, WP13 Instrumentation, WP14 Beam Transfers. All WP's have clear scopes and detailed plans to achieve the goals. The process of reviewing/reducing the scope has led to a more stringent focusing on the important aspects.

Comments

Machine protection and availability: This work package covers aspects related to the technical safety of LHC as well as the overall reliability of LHC operation. The new superconducting magnets require quench protection systems and the plans for those are well advanced. On the other hand the failure scenarios of crab cavities were not studied in detail. These transverse deflecting cavities can cause fast beam losses and can also affect the reliability of operation.

Collimation: The experiments with artificially introduced beam losses for testing the quench limits of the machine (recommended at last review) delivered very valuable results to allow a more reliable extrapolation to HL conditions. The need for collimators in the dispersion suppressor region was confirmed. The committee welcomes the simplification of the systems by eliminating 11T magnets around IR2 and by planning the use of a collimation bump in IR1/5 for ions. In general, the work package collimation is planned well. Some risks remain in the production schedule of collimators with advanced materials, an area where not much experience exists.

Instrumentation: The work package is well-planned and prototype tests were conducted with critical components. Long range beam-beam compensation schemes may become important for this work package in order to mitigate risks associated with the crab cavity program. If the hollow electron lens is added also to this work package, planned budget and manpower will likely be insufficient.

Vacuum: The work package is well-structured and planned. The presented new movable interconnects are innovative but bear some operational risk. The new method of laser engineered surface treatment is a good alternative to carbon coating.

Injection/Extraction: At conditions of high intensity there exists a risk of overheating the beam dump beyond the sublimation temperature of graphite. The problem can be avoided by a proposed upgrade of the dilution kickers, but since this measure is not yet contained in the baseline planning, it presents a financial risk for the project (3.6MCHF).

Experiment Interface: At high luminosity conditions significant activation by debris from the collisions is expected at absorbers in the interaction regions. Possible dose rates of several 10mSv/h were mentioned. At this level remote handling of critical components is required. The implications of remote handling are possibly underestimated by the project. The complex space situation for cable routing and other installations requires good coordination in the detector area.

Recommendations

- **Machine protection and availability:** Analyze these risks associated with crab cavities and study possible mitigation measures:Fast losses triggered by CC failure and their impact on the technical safety of LHC. CC failure mechanisms that affect the overall availability of LHC.
- **Collimation:** Besides installing new collimators ensure a high level of availability for installed systems as well. Develop crystal collimation and hollow e-beam as supporting measures.
- **Vacuum:** Ensure thorough testing of new solutions (e.g. interconnects) to avoid later operational problems.
- **Instrumentation:** no specific recommendation.
- **Injection / extraction:** Clarify the need for additional dilution kickers as soon as possible to reduce the financial uncertainty for the HL upgrade project.
- **Experiment Interface:** Analyze the exact requirements for remote handling in more detail and prepare solutions early. Resolve the mentioned risk of late cabling definition by more intense coordination between the involved groups.

Answers to questions in the charge to the committee

1. Is the projects' status and progress, in particular the identification of critical pieces of hardware, on schedule and within cost as foreseen?

Yes, all critical hardware and in general the planned resources are adequately allocated. The presented budget seems to be comprehensive and sufficient. In all WP's a clear concept, scope and schedule was presented. However, the so called "success-oriented schedule" for the SPS test of crab cavities is critical. If the test is important for the project more resources should be allocated and some margin included in the schedule. The plan for the series production is robust.

2. Are the baseline changes since the previous C&S review and the reasons for these changes, as well as their impact on scope, schedule and cost, commensurate with the project proposal from 2015?

Yes, the presented scope reductions are supported by the committee and are compatible with the goals of the upgrade project. The scope reduction resulted in lower cost while the manpower estimates were not reduced in general, due to more precise estimates.

3. Are the change-management methods and their implementation since the previous C&S review (i.e. tracing and validation of these changes) appropriate for managing this project?

Yes, the consequences of each scope reduction were discussed and presented to the committee. The presented information did not indicate a lack of missing coordination on the consequences of the changes.

4. Is the level of risk appropriately addressed and does the global evolution of the cost and schedule of both projects still stay within the original intent of the project?

Yes, cost and schedule stay within the original frame. Risks are generally addressed appropriately. Backup solutions (e.g. flat beam collision in connection with long range bb compensation) should be prepared without affecting or delaying the baseline activities.

HL-LHC – Technical infrastructures, integration and (de)installation

Findings

HL-LHC

In the March 2015 review there was concern from the review committee that the definition of the necessary civil engineering and technical infrastructure was of low maturity, and therefore there was very high risk associated with the cost and schedule. Additionally, the issue related to vibration of the LHC Machine induced by construction activities was highlighted by the review team as being of significant risk since it was not clear that excavation activities for the shafts and galleries could proceed without causing serious disruption to the LHC machine.

The Session 4 Review Panel considers that since the previous review CERN has made significant progress in addressing all the issues raised and the maturity of the civil engineering and to a lesser extent the other technical infrastructure is now considered to be a level of maturity commensurate with that required for the project. Of particular note are the following key areas where CERN is to be commended on the progress made.

Schematic layouts for the underground works at points 1 and 5 have now been developed and frozen. The new layouts are based on the so-called “Double Decker” arrangement whereby the new caverns and galleries are located several metres above the LHC tunnel thereby allowing secondary lining and infrastructure installation works to be carried out while the LHC is operating. The underground structures have been rationalized to reduce scope and cost. The review team notes that the designs of the underground structures generally reflect those of the LHC and LEP with temporary ground support (shotcrete and rock bolts) coupled with a permanent reinforced concrete lining.

The frozen layouts for the underground works have enabled CERN, in conjunction with external consultants (Amberg Engineering) to develop cost estimates for this work scope. These estimates have to some extent been cross-checked with known costs from the LHC era. However, CERN staff stated that such cross-checking was not reliable due to the time difference and the difficulty in attributing contractor claims to specific structures. As such, the costs were largely based on the work of the external consultants.

The impact of ground vibration on LHC machine performance has been largely addressed through a comprehensive study that aimed to correlate the characteristics of the excavating machinery with the induced vibration of the LHC machine. The study represents a significant improvement in understanding when compared to the situation at the last review and gives more confidence that with judicious choice of excavation machinery, the shafts can be excavated while the LHC machine is running. Indeed this is the underpinning basis of the resulting construction schedule and thereby critical to the whole project. It is noted that the physical in-situ tests carried out did not replicate precisely the actual machinery, geology and machine configuration that would actually be encountered during the works at points 1 and 5.

Contract strategies have been developed and largely frozen since the last review. Following the LHC model, two large consultancy contracts and two large construction contracts will be placed for the civil work at points 1 and 5 respectively. The underground and surface works at each of these two points will be designed by a single consultant and constructed by a single contractor. The FIDIC model conditions of contract will be used (as was done for LHC) and it is noted that CERN has engaged the same legal expert to develop the standard FIDIC model in order to comply with CERNs status as an International Organization.

The consultants for the design and construction oversight of the civil works for Points 1 and 5 started work in July 2016 and initial deliverables were expected by end October. The review team noted that these external consultants have been working on an older layout and that they need to undertake some re-work to align themselves to the new, rationalized layouts.

An adjudication panel has been set up in accordance with standard FIDIC practice. The panel will adjudicate on all disputes between CERN and the Contractors and/or between CERN and the consultants. It was noted that the panel is made up of five members, two lawyers, two engineers and one architect. CERN expects the panel to visit the site four times per year during the construction period.

The contractor selection criteria are based on Best Value for Money using a two envelope system. This means the contract will be awarded to the cheapest technically compliant bid. A contracting entity will not be awarded both major construction contracts. Calls for Tender are planned to be issued in June 2017 with responses due back in August 2017 in order that the finance committee in December could be achieved.

In the area of infrastructure other than the underground civil engineering, the Session 4 Review Panel considered that progress was less well-advanced and noted the following:

Surface buildings are less mature than the underground works and layouts appear to be no more than basic height, width and length dimensions for each building. These dimensions are based on user estimates of the likely space they may require and future changes to user requirements may mean dimensions need to be changed. It was noted that as plant and equipment details are not yet known, users may tend to over specify their requirements.

Electrical, cooling and ventilation infrastructure have been estimated and costed based primarily on experience to date with LHC. Although this has resulted in robust designs, there was no indication that any in-depth rationalization or "value-engineering" has been carried out to try to reduce scope and/or cost in these areas which represent a significant portion of overall infrastructure costs.

Contract strategies for cooling and ventilation are based on a large (five) number of possible future contracts. This was explained as being due to a limited number of large contractors in the area capable of undertaking the full scope.

The civil engineering and infrastructure schedules were presented as separate schedules. It was apparent that in some cases these were not coherent.

General

Data provided to the Session 4 Review Panel on risk illustrates that the civil engineering works is currently the largest risk to the project. The primary reasons for this are the high cost 150 MCHF) coupled with the “high risk” rating still applicable to both cost and schedule.

Comments

Design Maturity

The Session 4 Review Panel was generally pleased to see a significant improvement in the maturity of Work Package 17, in particular 17.1 for the civil engineering. The review team considers that the maturity of the underground civil engineering is at the correct level for this stage of the project. Although the costs of infrastructure have increased significantly since the March 2015 review, CERN was able to demonstrate that they have made significant efforts to reduce scope in order to compensate for this increase in civil engineering costs. Efforts to reduce civil engineering scope were also demonstrated, but the Session 4 Review Panel considers some additional effort may be worthwhile in order to help create some cost margin.

Building and other infrastructure design maturity is clearly lagging behind the underground works. While understandable given that the buildings and associated infrastructure will not start to be constructed for a number of years, the level of design maturity needs to be improved in order to increase the level of confidence in the cost estimates and also to ensure that cost effective solutions are implemented.

It was noted by the Session 4 Review Panel that the interface documents for each building consisted of a rather basic text document containing a mixture of user requirements and user-determined solutions. For example users had specified a requirement for a concrete building without considering that with modern construction solutions a steel-framed building with suitable acoustic insulation could possibly satisfy the sound insulation requirements of the project.

Cost Estimates

The cost estimates are appropriate for the current stage of the project. The Session 4 Review Panel would have expected more effort to have been made to utilize the previous LHC costs or at least use them for a systematic comparison of the costs estimated by the external consultants. However, new and more detailed estimates will be provided by the engineering consultants currently retained for the detailed design and these should help to increase the confidence of the cost estimates.

Cost estimates for the surface buildings are based on square meter costs, and therefore vulnerable to increase if user requirements become excessive (for example, demanding a higher than necessary floor bearing capacity).

The costs as presented contained no contingency to cover scope increase or underestimating of the current baseline scope. For a project that involves a substantial amount of underground civil engineering this is of some concern. The problem is further acerbated by the fact that a substantial amount of de-scoping in other areas of the project has already taken place, making it all the more difficult to find further areas for building contingency.

Schedule

The schedule as presented appears reasonably robust but there are risk areas. The overall project success relies on a timely start of shaft construction in order to ensure that all underground excavation works can be completed within the two-year LS 2. Although a few months float is currently shown for this excavation activity, this can quickly be eroded as underground works are notorious for schedule slippage mainly due to the fact the process is very linear and generally based on three-shift work, thus making it difficult to recover any slippage. In addition, the current schedule assumes that the shafts can be excavated without impacting the LHC machine. If this turns out not to be the case and the shaft excavation has to stop, this will jeopardize the ability to complete all excavation works during LS 2.

The work done on the issue of construction-induced vibration on the LHC machine has alleviated to a great extent the schedule risk and to some extent it is this issue that has driven the need for a complete rethink by CERN on the overall schedule, timing of shutdowns etc. Although this is now considered a residual risk, the fact that the various tests were not done with the same parameters of geology, machinery and LHC configuration as will be encountered at points 1 and 5 means that there remains a small risk that the full depth of the shaft may not be able to be excavated before disruptions to the LHC occur. In this respect it is noted that the CERN civil engineering team are planning to put in place a contract mechanism to enable excavation to be “swapped” from hydraulic rock breaker to hydraulic milling. While this will come at a cost and certainly a reduction in excavation rates, it is a positive proactive risk mitigation move.

In the schedules provided during the presentations, the CERN Finance Committee Decision on contract award is shown to be in December 2017 or March 2018. The Session 4 Review Panel understands that CERN would like to obtain a Finance Committee decision in December 2017. The March 2018 date is a fall-back option in case contract negotiations take longer. The review committee, while encouraging CERN to start shaft construction as soon as possible, considers that the time provided to contractors to prepare their offers should not be sacrificed in order to achieve the December 2017 Finance Committee decision. This would likely result in poor quality offers with subsequent increased risk of claims and cost over-runs.

Session 4 Review Panel noted that some members of the technical teams considered that other stakeholders within the CERN Organization have work priorities that may not support the schedule for civil works. While this is to be expected in an organization as large as CERN, it is important that priorities are set by senior management and communicated effectively to all project stakeholders. Where priority conflicts arise these need to be managed at the senior management level.

Recommendations

On the basis of the comments above, the Session 4 Review Panel recommends the following actions to be undertaken by the CERN Management in order to build on the excellent work carried out over the previous 18 months.

- As part of the overall recommendation to increase the human resources available to the HL-LHC Project, ensure that the in-house team leading the civil engineering and infrastructure works are adequately resourced with experienced staff having the necessary technical and administrative skills and knowledge to deliver the Work Package 17 within the context of an International Organization.
- Ensure that an integrated schedule is prepared that links, at a minimum, all activities interfacing with the civil engineering works. This is critical in order to identify and resolve any serious mis-match in activity schedules prior to the commencement of the civil engineering. Ideally the Project should target to develop the integrated schedule prior to issuing the calls for tender for the construction works, i.e. mid-2017.
- Ensure that robust detailed requirements for the buildings are developed and documented. These requirements should be included in a formal configuration control management system to ensure that changes affecting cost and/or schedule receive the appropriate attention from senior management.
- Consider undertaking “value engineering” exercise for all aspects of the civil works and infrastructure. Such an exercise should critically review all requirements and aim to develop alternative cost effective solutions. This exercise should give special focus to the surface buildings as the Session 4 Review Panel found some evidence where building users were over-specifying their needs to low maturity of their own systems.
- It is recommended that 16 weeks should be given to the construction companies to prepare their bids for the civil engineering works at points 1 and 5. Underground civil engineering requires significant studies to be done during the tendering period in order that companies can select and price the correct equipment and calculate correctly their advance rates. The international nature of the project and the high likelihood that joint ventures will be formed only reinforce the need to provide sufficient time for proper bid preparation.
- Senior management must follow up closely the procurement of the civil works and ensure that priorities are shared and agreed with all internal and external stakeholders.
- Concerning the ground vibration issue, consideration should be given (if technically feasible) to undertaking additional testing at point 1 with the actual equipment that will be used for the shaft excavation. It is unlikely this can be done prior to the start of excavation by the selected contractor but it could be targeted to be done early in order that potential issues can be identified and addressed early in the construction process.
- Given the “risky” nature of the works to be carried out, CERN should aim to start civil engineering construction with an available contingency of at least 20%. Once contractor’s offers are received CERN will be able to determine if this contingency is available or whether it needs to be created through de-scoping or other means.

- To address the previous point, CERN is advised to start building a contingency or at least possible alternative or de-scoping option if the need arises.
- Lastly, given that the civil engineering works are currently the highest risk to the project and are likely to remain so at least until the excavation works are completed, it is recommended that a direct communication between the LIU/HL-LHC Executive Committee and the civil engineering team is established. This will provide senior project decision makers with up to date and pertinent information on cost and schedule and enable them to make rapid decisions to cope with any unexpected events that may arise.

Answers to questions in the charge to the committee

1. Is the projects' status and progress, in particular the identification of critical pieces of hardware, on schedule and within cost as foreseen?

Yes. There has been substantial progress since the previous review 18 months ago. In particular, the underground layouts have been finalized and design consultants have started working on the specifications and drawings for the construction calls for tenders. Significant cost increases have been incurred in this area of the project but this has been offset by savings in other areas.

2. Are the baseline changes since the previous C&S review and the reasons for these changes, as well as their impact on scope, schedule and cost, commensurate with the project proposal from 2015?

Yes, modifications to civil works were necessary in order to make them compatible with the preferred (optimized) layout of the machine and supporting services at points 1 and 5. Findings related to the vibration issue have led to schedule changes that will minimize impact on LHC operations and should allow sufficient time to complete the excavations during LS-2.

3. Are the change-management methods and their implementation since the previous C&S review (i.e. tracing and validation of these changes) appropriate for managing this project?

Change management was not addressed in detail for WP17. The CE underground layouts are now frozen and any modifications will require approval by senior management. However, at this stage there does not appear to be a formal configuration management system in place.

4. Is the level of risk appropriately addressed and does the global evolution of the cost and schedule of both projects still stay within the original intent of the project?

Yes. Risks registers are being maintained and the schedule and cost for civil works, although significantly different, are closer to the original intent than the scheme in place at the time of the last review. Risk registers are being updated by the external consultants responsible for the design and construction oversight

HL-LHC/LIU – Cost, schedule and change management methods

Findings

The budgets for LIU and HL-LHC are baselined at 180 MCHF and 951 MCHF respectively. As already mentioned in the executive summary, the budget for the HL-LHC was formally approved by the CERN Council in June 2016. Both budgets do not include cost contingency and cost overruns must be managed by scope adjustments.

LIU

During the first CSR a cost baseline of 186 MCHF was presented. Nevertheless, by October 2015 the baseline was set at 180MCHF implementing some of the scope reduction options that were discussed during the review, while at the same time increasing the team size to make sufficient manpower available.

HL-LHC

Following the previous CSR the CERN team immediately developed a more detailed plan for the execution of the civil construction. This was an important but not the only driver that lead to the decision to delay LS2 by six months and extend it by six months. Also LS3 was delayed by one year as compared to the schedule, which was shown during the first CSR.

During the development of a more detailed design, it became clear that major cost growth in WP 17.1 (Civil Engineering) was to be expected. The cost growth was offset by scope reductions in several other work packages and the CERN team stated that the performance goals and key performance parameters were not affected. Accordingly, in preparation of the second CSR, a re-baselining of the HL-LHC was carried out and formally endorsed by the LIU/HL-LHC Executive Committee of the 3 August 2016. In addition the HL-LHC became a “landmark project” in the ESFRI roadmap.

General

The LIU and HL-LHC EVM show cost and schedule variances only one month into the new baseline. This seems mostly due to accounting issues and late reporting of earned value and accomplishments.

Neither LIU nor HL-LHC cost of the CERN staff is tracked through the cost baseline. This leads to difficulties in tracing back the origin of schedule/cost variances, especially for those activities that heavily depend on CERN staff.

Since 2015 CSR, the HL-LHC schedule has taken advantage of the new overall Accelerator Complex schedule (LS2 / LS3).

Comments

Both the LIU and HL-LHC project have made excellent progress since 2015 CSR. The LIU EVM performance and the decreased cost uncertainty are both good indicators and support this statement.

The LIU is in the midst of the execution phase, but still has to achieve a major ramp up in man power to not fall behind the present baseline.

The HL-LHC approval by the CERN Council as construction project and its integration into the Medium Term Plan for budgets in September 2016 was an impressive achievement. Over the last 18 months, the HL-LHC team has demonstrated its capability to manage the scope of the project and deal with major construction project issues as cost and schedule variance appear across the project. Creating contingency from scope reduction to manage cost overruns within the cost baseline of the project has been done effectively. However, this will become more difficult as project moves into the execution phase and designs are frozen.

The Project Management tools used at CERN (APT, EVM, etc.) are state-of-the-art and are well-utilized by the team. In some cases the implementation of the EVMS to the baseline diminishes its use as a project management tool, especially when there is a mismatch between linear assumption from start to end of a particular activity ("level of effort") versus actual establishing a schedule baseline with actual milestone payments, deliveries, and invoicing.

Although substantial progress has been made in WP 17.1, Civil Engineering still stands out as, by far, the activity that poses the main cost and schedule risk

Recommendations

- Create tracked milestones for significant steps in WP17 during the procurement process.
- Add an "event risk" to the cost uncertainty calculation until the commitment of DOE/LARP is solidified.
- Prepare an integrated schedule and show the critical path
- Develop a new list of scope contingencies that could be deferred if necessary, of sufficient value to cover your risk.

Answers to questions in the charge to the committee

1. Is the projects' status and progress, in particular the identification of critical pieces of hardware, on schedule and within cost as foreseen?

The LIU and HL-LHC status and progress is generally on schedule and within cost showing nevertheless variances partially due delayed reporting of EV

2. Are the baseline changes since the previous C&S review and the reasons for these changes, as well as their impact on scope, schedule and cost, commensurate with the project proposal from 2015?

Changes to LS2 and LS3 schedule as well as scope adjustments recommended at the 2015 CSR have been beneficially adopted by the LIU and HL-LHC projects

3. Are the change-management methods and their implementation since the previous C&S review (i.e. tracing and validation of these changes) appropriate for managing this project?

Appropriate change control measures (LIU-PLI and HL-LHC TCC) are in place. Some improvements are necessary for WP17. Detailed requirements management is necessary.

4. Is the level of risk appropriately addressed and does the global evolution of the cost and schedule of both projects still stay within the original intent of the project?

Risks are appropriately addressed but reflected as cost uncertainties. The global evolution matches the 2015 CSR plan except that the completion date is about one year later.

General summary of comments from the subgroups and conclusions

From the input of the subgroups, a risk profile for the two projects is being assembled (see next two paragraphs).

What are the areas of high risk for scope, schedule or cost overrun?

Similar the methodology applied in the first CSR , the committee characterized the cost and schedule risk resulting from the maturity of the design, by project, at a summary level. Risks can vary from Low, Medium to High and Design Readiness from: Conceptual being <10% ready, Advanced Conceptual 10-30%, Preliminary 30-60%, Detailed 60-90%, Final >90%. Compared to the last review significant progress has been made in both projects. Most notably the quality of the estimate has changed for LIU from Class 2 to Class 1. In HL-LHC the most substantial progress could be seen in the civil engineering design. As details became clearer, the cost of this package rose to the top. In fact a strong value engineering effort was undertaken to minimize the cost growth while at the same time scope/cost reductions in the technical areas were pursued in order to stay below the cost ceiling.

The review committee was told that all of these changes and scope reductions could be implemented without significant changes to the performance of HL-LHC. The review committee did not verify that this is correct while at the same time, there was no evidence to the contrary. It was proposed and it is planned to confirm this statement during the next LHC performance workshop in January 2017.

LIU Status

Table 1: List of Linac4 and LIU projects, their design readiness, the cost and the schedule risk.

Syb-system	Design Readiness	Cost Risk	Schedule Risk
LIU			
Linac 4	final	Low	Low
PSB	final	Low	Low
PS	final	Low	Low
SPS	final	Low	Med
Ions	final	Low	Low

In summary and referring back to Table 1, LIU is now considered a class 1 estimate as compared to being class 2 during the last review. The summary for the project is listed in Table 2 below.

After initial cost reduction for LIU since the review in March 2015 from 186MCHF to 180MCHF, no major changes in the work packages appeared since October 2015. Only the WBS element, which captures cost in management and manpower, increased somewhat.

As of the time of the review the additional request stands at 3.5MCHF. Performance risks identified as "High", while unlikely to all come through, might require an additional ~ 10MCHF.

Table 2: Summary table for the LIU status

Total cost / MCHF	**180***
Uncertainty / %	**-3 / +5**
Uncertainty / MCHF	**-5 / +9**
Uncertainty	**Class 1**
% complete	**32%**
Total FTEy / CERN	**791**
Total FTEy / MPA	**285 (198+87)****

* Does not include LINAC4; **mostly Fellows and Project Associates

The additional 3.5MCHF requested is for more manpower, mostly fellows. Scope reductions to curtail cost growth include the SPS ion injection system and simplifications and improved designs addressed the SPS dump, the beam loss control systems and the electron cloud mitigation. A cost transfer to other part of the laboratory (General services) had a minor impact. On the schedule side the steepest part of the significant manpower ramp is still to come and should be carefully monitored.

HL-LHC Status

Similar to the LIU project, the HL-LHC project was characterized by work packages. The highest cost work package is in Civil Engineering / Technical Infrastructure which is different from the last CSR where Interaction Region Magnets were the highest single cost item of the packages. This work package increased from ~180MCHF to 254MCHF and subsequently drove scope reductions that included reducing the number of 11T dipoles, reduce the number of crab cavities by a factor of two and implement smaller Q4 quadrupole apertures to lower magnet costs. Simplifications in some of the designs, like the “double decker solution”, changes within the Quench protection system, new converters, reuse of components, and laminated structure instead of solid quadrupoles further reduced costs and both together allowed reducing some of the scope of the infrastructure work package.

In addition a small number of personnel, mostly workshop labor, were transferred into the consolidation project. While a lot of changes then happened within the packages the baseline remains at 951MCHF.

A positive observation from Table 3 includes the fact that for the high value packages either the design is “detailed” already, or cost / schedule risks are medium or low. Only a few cases remain, where the design is not as advanced but the cost and schedule risks are well understood. As a consequence overall cost and schedule risk for the HL-LHC are reasonable for the stage of the project and the uncertainty is small.

In summary and referring back to Table 4, the HL-LHC project is considered on average a class 3 estimate.

Table 3: The table lists the HL-LHC work packages in the order of cost from high to low. The first seven work packages listed comprise 75% of the total cost. Compared to the last review, the civil engineering work package became the most expensive one.

Sub-System	Design Reasiness	Cost Risk	Schedule Risk
Civil Engineering	preliminary	High	High
Technical infrastructure	preliminary	Med	Med
Magnets for IRs	detailed	Med	High
Cryogenics	detailed	Med	Low
Crab Cavities	detailed	Med	High
11 Tesla dipoles	detailed	Med	Med
Cold powering	detailed	Low	Low
Collimation	detailed	Med	Low
Σ = > 75% of HL-LHC cost			
Vacuum	detailed	Low	Low
Warm powering	detailed	Low	Low
MPS	preliminary	Med	Low
Beam Diagnostics	detailed	Low	Low

Table 4: Summary table for the HL-LHC status

Total cost / MCHF (new estimate)	951
Uncertainty / %	-14 / +18
Uncertainty / MCHF	-135 / + 174
Uncertainty	On average Class 3
% complete	Construction phase = 5%
Total FTEy / CERN	1823
Total FTEy / MPA	1137

Appendix 1: The Review Team and Organization of the Review

The review team consists of resident experts from the CERN MAC and was complemented in some areas with additional experts.

Name	Institution
CMAC Members:	
Fischer, Wolfram	BNL
Gourlay, Stephen	LBNL
Holtkamp, Norbert (Chair)	SLAC
Oide, Katsunobu	KEK
Qin, Qing	IHEP (excused)
Seidel, Mike	PSI
Vedrine, Pierre	CEA - Saclay
Invited Experts	
Bai, Mei	FZJ
Bousson, Sébastien	IPNO-IN2P3
Neumeyer, Charles L.	PPPL
Watson, Timothy	ITER
Yamamoto, Akira	KEK
Scientific Secretary	
Zimmermann, Frank	CERN

The review is divided into plenary and break out session focusing on the various aspects of the LIU and HL-LHC projects. The assignment for the break out sessions and the CERN point of contact are listed below.

Session 1: LIU

Convener:W.Fischer, CERN lead: M. Meddahi - Reviewer: K.Oide, M.Bai

Session 2: HL-LHC – Magnets, powering and cryogenic systems

Convener: S. Gourlay, CERN lead: J.-M. Jimenez - Reviewer: T. Peterson, P. Vedrine,

Session 3: HL-LHC – Superconducting RF and other accelerator systems

Convener: M. Seidel, CERN lead: P. Collier - Reviewer: J.-S. Bousson, A. Yamamoto

Session 4: HL-LHC – Technical infrastructures, integration and (de)installation

Convener: T. Watson, CERN lead: L. Tavian - Reviewer: N. Holtkamp, C. Neumeyer

Session 5: HL-LHC/LIU – Cost, schedule and change management methods

Convener: N. Holtkamp, CERN lead: M. Meddahi, L. Rossi, F. Zimmermann- Reviewers: C. Neumeyer, T. Watson

Appendix 2: Agenda

Monday 17 October 2016

Plenary Session - 30-7-018 - Kjell Johnsen Auditorium (08:30-14:00)

-Conveners: Frederick Bordry

time	[id] title
09:00	**[2] Welcome and Introduction** *Presenter: BORDRY, Frédérick* LHC status and last results LIU-HL-LHC from the 1st Cost & Schedule review (March 2015) HL-LHC formal approval by CERN Council (June 2016) Recall of the CERN planning, budgeting and controlling rules Operation budget and consolidation project Charge of the review Review sessions
09:40	**[3] Status of LIU Project** *Presenter: MEDDAHI, Malika* General overview of the LHC injectors upgrade project for the proton and ion accelerator chains Changes since March 2015 in: Organisation of the project, Work packages breakdown, overall cost-to-completion, overall resources (budget, manpower), overall planning, critical path Beam parameters: status in March 2015 and path since then to the Sept. 2016 updated baseline beam parameters Baseline project activities: any changes since March 2015? Additional baseline changes to be proposed? List of mitigations.
10:20	Coffee break
10:50	**[4] Status of HL-LHC Project** *Presenter: ROSSI, Lucio*
11:30	**[5] Status of HL-LHC Technical Infrastructure** *Presenter: TAVIAN, Laurent Jean*
12:10	**[6] HL-LHC Collaboration Status** *Presenter: BRUNING, Oliver*
12:40	Lunch break

Session 1: LIU Project - 60-6-015 - Room Georges Charpak (Room F) (14:00-18:30)

Reviewers: M. Bai, W. Fischer, K. Oide

Outcomes of the 2015 Cost and Schedule review; Baseline beam parameters (changes since 2015); Machine layout; Status of work progress; Mandatory CONSolidation items; Risks and mitigation; Budget, manpower, EVM; Schedule

-Conveners: Malika Meddahi

time	[id] title
14:00	**[7] Linac4 status and outlook** *Presenter: LOMBARDI, Alessandra*
14:45	Questions
15:00	**[9] LIU-PSB** *Presenter: HANKE, Klaus*
15:45	Questions
16:00	Coffee break
16:30	**[20] LIU-IONS PS injectors (source, Linac3, LEIR** *Presenter: SCRIVENS, Richard*
17:15	Questions
17:30	**[10] General discussion**

<u>Session 2: HL-LHC Magnets, Powering and Cryogenic Systems</u> - 30-7-018 - Kjell Johnsen Auditorium (14:00-18:30)

Reviewers: S. Gourlay, P. Vedrine

-Conveners: Jose Miguel Jimenez

time	[id] title
14:00	**[21] Overview IR magnet system and budget** *Presenter: TODESCO, Ezio*
14:45	**[22] Nb3Sn IT quads Q2a/Q2B** *Presenter: FERRACIN, Paolo* Nb3Sn technology Low-beta quadrupole magnets
15:15	**[23] Nb3Sn IT quads Q1/Q3** *Presenter: Dr. AMBROSIO, Giorgio* Nb3Sn technology, low-beta quadrupole magnets
15:45	**[24] Beam separation dipole (D1)** *Presenter: NAKAMOTO, Tatsushi* Beam separation dipole, first 2m long model magnet, heat exchanger hole
16:05	Coffee break
16:30	**[25] INFN contribution: D2** *Presenter: FABBRICATORE, Pasquale* Separation/recombination dipole D2 Engineering design Short model construction Full length prototype
16:50	**[26] WP3 - Status of MQYY** *Presenter: FELICE, Helene* NbTI quadrupole, short model, QUACO PCP
17:10	**[27] CIEMAT contribution: MCBX** *Presenter: TORAL, Fernando*
17:30	**[28] INFN contribution: High order correctors. Status and perspective** *Presenter: SORBI, Massimo* Corrector magnets
17:50	**[29] Magnet circuits & protection** *Presenter: RODRIGUEZ MATEOS, Felix*

Session 3: HL-LHC Superconducting RF and other Accelerator Systems - 180-1-N51 (14:00-18:30)

Reviewers: N. Holtkamp, C. Neumeyer, T. Watson

-Conveners: Paul Collier

time	[id] title
14:00	**[40] Overview of Crab Cavities (CC) sytems** *Presenter: CALAGA, Rama* HL-LHC crab cavities, compact deflecting cavities, Piwinski angle, luminosity levelling
14:30	**[68] CC RF systems** *Presenter: MONTESINOS, Eric*
15:00	**[41] SPS CC tests and validation** *Presenter: VANDONI, Giovanna*
15:30	**[42] CC construction plan at CERN** *Presenter: CAPATINA, Ofelia*
16:00	Coffee break
16:30	**[43] U.S. Contribution for Crab Cavities: Status of prototypes and plans for production** *Presenter: CARCAGNO, Ruben Horacio* Crab cavities, RFD crab cavities, dressed RFD cavities, US contribution
17:00	**[67] Machine protection and availability** *Presenter: WOLLMANN, Daniel*
17:30	**[44] Collimation** *Presenter: REDAELLI, Stefano*
18:00	**[45] Vacuum & beam screen** *Presenter: BAGLIN, Vincent*

Full Committee Executive Session: Preparation of questions to project - 30-7-018 - Kjell Johnsen Auditorium (18:30-19:00)

Tuesday 18 October 2016

Session 3: HL-LHC Superconducting RF and other Accelerator Systems - 180-1-N51 (08:30-12:00)

Reviewers: N. Holtkamp, C. Neumeyer, T. Watson

-Conveners: Paul Collier

time	[id] title
08:30	**[46] BI for HL** *Presenter: JONES, Rhodri*
09:15	**[47] Beam transfer** *Presenter: BRACCO, Chiara*
09:45	**[48] Collider-experiment interface** *Presenter: SANCHEZ GALAN, Francisco*
10:30	Coffee break
11:00	**[49] Options to the LHC baseline (common talk to session 2 and 3)** *Presenter: BRUNING, Oliver* Q4 Full CC system Sub-harmonic RF system Higher-harmonic RF system LRBB compensation Hollow e-lens Other options (BT & BI)

Session 1: LIU Project - 60-6-015 - Room Georges Charpak (Room F) (08:30-11:30)

Reviewers: M. Bai, W. Fischer, K. Oide

Outcomes of the 2015 Cost and Schedule review; Baseline beam parameters (changes since 2015); Machine layout; Status of work progress; Mandatory CONSolidation items; Risks and mitigation; Budget, manpower, EVM; Schedule

-Conveners: Malika Meddahi

time	[id] title
08:30	**[11] LIU-PS** *Presenter: DAMERAU, Heiko*
09:15	**[65] Questions**
09:30	**[13] LIU-SPS** *Presenter: GODDARD, Brennan*
10:15	**[66] Questions**
10:30	Coffee break
11:00	**[14] General discussion**

Session 2: HL-LHC Magnets, Powering and Cryogenic Systems - 30-7-018 - Kjell Johnsen Auditorium (08:30-12:00)

Reviewers: S. Gourlay, P. Vedrine

-Conveners: Jose Miguel Jimenez

time	[id] title
08:30	**[30] Cold powering of the HL-LHC magnets** *Presenter: BALLARINO, Amalia* Current leads, superconducting links, superconductor, superconducting circuit, MgB2, HTS
09:15	**[31] Power converters for HL-LHC** *Presenter: BURNET, Jean-Paul* Power converters for superconducting magnets, magnet power supplies, high-precision current control
09:45	**[32] HL-LHC cryogenics** *Presenter: CLAUDET, Serge*
10:30	Coffee break
11:00	**[33] Options to the LHC baseline (common talk to session 2 and 3)** *Presenter: BRUNING, Oliver* Q4 Full CC system Sub-harmonic RF system Higher-harmonic RF system LRBB compensation Hollow e-lens Other options (BT & BI)

Session 4: HL-LHC - Technical infrastructures, integration and (de)installation - 30-7-010 (08:30-12:00)

Reviewers: N. Holtkamp, C. Neumeyer, T. Watson

-Conveners: Laurent Jean Tavian

time	[id] title
08:30	**[55] Transport** *Presenter: FERAL, Bruno*
09:10	**[56] Logistics and storage** *Presenter: MUFFAT, Patrick*
09:40	**[57] Operational safety** *Presenter: FORAZ, Katy*
10:10	Coffee break
10:40	**[58] Installation** *Presenter: FESSIA, Paolo*
11:20	**[59] Alignment and internal metrology** *Presenter: MAINAUD DURAND, Helene* Internal metrology, alignment, adjustment, fiducialisation, monitoring

Session 2: HL-LHC Magnets, Powering and Cryogenic Systems - **180-1-N51 (13:30-18:30)**

Reviewers: S. Gourlay, P. Vedrine

time	[id] title
13:30	**[34] Magnet cryostats** *Presenter: DUARTE RAMOS, Delio* Concerns all cryostats for magnets under the scope of work packages 3 and 11 as well as bypass cryostats and connection cryostats
14:00	**[35] Magnet test plan** *Presenter: BAJKO, Marta*
14:30	**[36] 11 T dipole for LS2** *Presenter: SAVARY, Frederic*
15:15	**[37] Upgrade and consolidation of the superconducting test facility in SM18** *Presenter: MERTENS, Volker* RF, magnets, tests, cryogenics, infrastructures, upgrade, consolidation
15:45	Coffee break
16:15	**[38] IT string overview** *Presenter: BAJKO, Marta*
16:45	**[39] Production scenario - Magnets, superconductors and cryostats** *Presenter: BOTTURA, Luca* Review material to be produced, quantity and schedule (dashboards) Recall LHC maintenance works and parallel R&D Baseline production scenario, required infrastructure and logistics (in-house work, collaboration work, industry work) Conclusions

Session 5: HL-LHC/LIU: Cost, Schedule and Change Management Methods - 30-7-018 - Kjell Johnsen Auditorium (14:00-18:40)

-Conveners: Lucio Rossi; Malika Meddahi

time	[id] title
14:00	**[16] Overall cost summary (material, manpower), EVM and CET** *Presenter: PRODON, Sylvie* Overall LIU Earned Value Management data (incl. Cost Performance Index and Schedule Performance Index); LIU data from CERN Expenditure Tracking application; Manpower (CERN and Associates); Material to Personnel; Parameters impacting the LIU-Cost to Completion (CVI, exchange rate…); Outlook wrt Mid-Term-Planning
14:30	**[17] Planning, layout and installation organization and updates** *Presenter: COUPARD, Julie* Organisation of the LIU Planning, Layout and Installation activities Space Reservation Requests, Engineering Change Requests, drawings, layout, integration status Work planning for (Extended)Year End Technical Stops and Long Shutdown 2 Concerns
15:00	**[18] Safety aspects and documentation** *Presenter: FUNKEN, Anne* Safety organisation of the LIU project Status of the documentation Waste (radiological and not) handling Next steps towards shutdown installation and beam permit
15:30	**[19] Overall risk analysis, mitigation, change management methods** *Presenters: MEDDAHI, Malika, RUMOLO, Giovanni* Compilation of the major risks (equipment, schedule) Budget with risk level class Manpower concerns Mitigations Change management practices
16:00	Coffee break
16:30	**[60] HL-LHC project cost summary, EVM, manpower and costing uncertainty** *Presenter: DELILLE, Benoit* HL-LHC costing methods Comparison with 2015 cost&schedule review 2016 Re-baselining, impact on cost Integration in CERN Activity Planning Tool (APT) and Earned Value Management (EVM) systems Manpower distribution Costing uncertainty
17:10	**[61] From LARP to HL-LHC AUP in US** *Presenter: APOLLINARI, Giorgio* LARP, HL-LHC Accelerator Upgrade Project (HL-LHC AUP), US deliverables, Critical Decision (CD) Process in DOE, Funding profile, Schedule for US deliverables, Risk management
17:40	**[62] HL global planning** *Presenter: TAVIAN, Laurent Jean*
18:00	**[63] TDR, ECR, QA and Documentation** *Presenter: BEJAR ALONSO, Isabel*
18:20	**[64] Safety and conformity for HL-LHC** *Presenter: OTTO, Thomas* Fire safety, evacuation, pressure vessels, safety studies, safety file, radiation

Wednesday 19 October 2016

Report writing and preparation of close-out - 60-5-012 (09:00-13:30)

time	[id] title
10:00	Coffee break
12:00	Working lunch

Fact check-subcommittee with Project Team - 61-1-017 - Room D (09:00-12:30)

time	[id] title
10:00	Coffee break