

## Cost and Schedule Review Committee Report 1 December 2002

### Summary and Recommendations

The Cost and Schedule Review Committee (CSRC) met at CERN from the morning of 21 October through mid-morning on 23 October. During the first two days, the project team presented the status of the LHC Project and a description of the management tools that they are using to track project cost and schedule performance. Prior to the meeting, we received copies of the LHC Project Status Report, 13 June 2002 (CERN/CC/2443); LHC Project: Cost-to-Completion, 26 June 2002 (AC-DI/BP 2002-09); and The Large Hadron Collider Conceptual Design, 20 October 1995 (CERN/AC/95-05(LHCL)). The Charge to the CSRC and the meeting agenda are presented in the enclosure. We briefed the Director General and the Project Director on our findings and recommendations on the morning of the third day.

The Committee was asked to respond to the following three issues; 1) to determine whether the LHC Project: Cost-to-Completion could be used as a baseline cost estimate for tracking project cost performance; 2) to determine whether current project schedule could be used as a baseline schedule for tracking project performance; and 3) to evaluate the tools that project team currently uses and plans to use to monitor the cost and schedule performance. On the basis of our review, we make three recommendations as follows:

- We recommend that CERN Management adopt the LHC Project: Cost-to-Completion estimate (hereafter Cost-to-Completion) of \$3,220M CHF, as the project cost baseline for tracking the project cost performance for the remainder of the project.<sup>□</sup>
- We recommend that CERN Management adopt the current project schedule that forecasts the start of commissioning on April 2007 for tracking the project schedule performance for the remainder of the project.
- We recommend that the LHC project team continue to use the project tools that are currently in use and that they quickly move to complete and deploy the proposed earned value system (EVM), since it will provide additional tools to closely monitor cost and schedule performance.

The Committee reviewed the methodology that the management used to develop the Cost-to-Completion. The budget holders used a bottoms-up-process to prepare it and they are committed to building their systems within the cost estimate. We conclude that the methodology is sound. Slightly more than 80% of the 3,220M CHF Cost-to-Completion is in the form of signed industrial contracts and special contributions. We note that the figure of 3,220 MCHF includes 143 MCHF that was expended on R&D. We reviewed five systems that we believe are representative of the whole project. We chose to review superconducting magnets, the cryogenic system, RF, power converters, and beam transfer and concluded that the scope of work of each of these systems is well defined and that the divisions responsible for the work understand what needs to be done.

The procurements for superconducting magnets and the cryogenic system, which are the most complex and demanding procurements, are almost entirely under contract. These

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<sup>□</sup> The Project Director informed the Committee that two cost overruns had occurred since the Cost-to-Completion had been prepared. These were 9 MCHF in civil engineering and 7 MCHF in magnet cryostats.

contracts present the greatest risks and it is likely that the costs of executing these contracts will exceed the contract values. The Project Director informed the Committee that an overrun of 7 MCHF had occurred in the cost of magnet cryostats because one of the vendors had become insolvent. Nevertheless strong management can avoid significant cost increases. Much of the remaining 20% of the work described in the Cost-to-Completion is for systems such as RF, power converters and beam transfer equipment. In most instances, successful prototypes have been built and in some instances the big-ticket items are under contract. The fact that the remaining work is either captured in contracts or is familiar to the project team reduces the risks of overruns, but it does not eliminate the risks. Since CERN has successfully managed the fabrication and commissioning of these systems in the past, there is no reason to expect that they will not be completed within the estimates. We discuss these points in more detail later in the section entitled **“Analyses of the Estimated Cost and Schedule of Five LHC Systems”**.

The cost and schedule of the deep underground construction and the subsequent outfitting of the tunnels and caverns with electrical, water and ventilation systems, has traditionally been difficult to control. The estimated cost of this work in the Cost-to-Completion is 592 MCHF and it represents an overrun of 130 MCHF relative to the 1996 budget allocation. The work is very nearly complete and the anticipated claims are largely included in the project cost estimate. During the meeting, the Project Director reported that the conventional construction costs have increased by 9 MCHF relative to the Cost-to-Completion. We conclude that any further growth in conventional construction costs should be very small.

We note that the Cost-to-Completion is also at risk because CERN staff costs are not included in the project cost estimate, although an estimate of the required number of staff FTE's is included under tab C. While the Divisions plan to provide the needed level of effort through their authorized staff complements this can only be done if they have the right number of people with the right skills. This approach has worked very well for CERN in the past, but it may not work for the LHC project because a large number of critical positions are not filled. The Division Leaders stated that with their current resources many positions in the LHC project are unfilled and these unfilled positions correspond to approximately 220 man/years. If these positions cannot be filled by CERN staff the cost, which will be in the range of 30M CHF, will have to be born by the project as an unbudgeted expense. The Morges III Management retreat is expected to address this issue. It is important that a solution to this problem be found.

The Committee did not review the project schedule in detail, although we did review the schedules for the five representative systems and we also reviewed the planning and organization for installation. We concluded that the installation schedule, while it is very challenging because of its scale and complexity, is achievable. We present our finding in more detail in the section entitled **“Baseline Schedule”**.

We reviewed the management tools that the managers are using to track cost and schedule performance. The existing tools, which have been used effectively at CERN for many years, allow cost and schedule to be monitored independently. The project needs tools that can simultaneously monitor cost and schedule and provide management with an early warning of problems. The earned value methodology (EVM) when properly used it can spot trends before they erupt into serious crises. The software and computer based report forms that were demonstrated during the review appear to be effective and easy to use. This is essential if they are to gain acceptance across the entire project. We note that EVM is not a

substitute for the existing tools; it complements them. The project also needs a high level resource loaded schedule to assess the cost of delays created by resource shortages. We note that good project Management tools require a significant investment to bring them into being and sufficient staff to use those tools to provide management with the needed information.

As noted in our third recommendation, we strongly support the decision of the LHC Project Director to incorporate EVM into the LHC Project Management System. Finally we note that it will be crucial to begin formally reporting the Project Cost Performance to all levels of management on a frequent basis.

In the remainder of our report we present our findings on the subjects that we reviewed in greater detail as well as further recommendations.

### **Cost to Completion**

The LHC Project: Cost-to-Completion document provides a very detailed breakdown of the costs that either have been or are expected to be incurred. The CERN Divisions responsible for delivering the required systems prepared it by using a bottom-up analysis of the project requirements. It was not part of the charge of the Committee to check the accuracy of the estimates and in any case the volume of data would have made this impossible during such a short review. However, we are pleased to note that, apart from a few isolated examples, the Cost-to-Completion estimates and time-scales are still accepted to be valid by those responsible for the work some 6-12 months after their initial preparation. Therefore, the Committee believes that the Cost-to-Completion document provides a stable basis from which future changes to cost or schedule can be tracked.

There have been small cost increases since the Cost to Completion was prepared. While small cost increases are normally managed with a contingency fund, there is no contingency within the estimate. Furthermore, there is little scope for savings to arise from the contracts that remain to be placed since the vast majority (80-85%) of the total project expenditure has already been committed. Any increase in cost is likely to appear as an increase in the Cost to Completion. It is therefore vital that the project now places emphasis on ensuring that the contracts are completed to time and to cost. This will require:

- Sufficient and timely monitoring of work at suppliers;
- Minimising changes to the scope and scale of contracts (including the exercise of options);
- Ensuring that items provided by CERN are delivered to suppliers when contractually required.

We are satisfied that the project staff realize the importance of these issues and are pleased that extra individuals have recently been identified to monitor the contracts that are currently most critical. We conclude that many, if not all, of the prudent cost effective steps to mitigate these risks have been taken by the project team. However, we are concerned that there are resource shortages within the project. The preparations for the Morges III meeting should hopefully allow the scale of the shortages to be fully defined. The means by which extra effort can be found and/or the consequences of re-scheduling tasks to match the existing effort needs to be assessed urgently since either solution has potential adverse consequences on the external costs of the project. Ideally the information generated for the Morges III meeting should be used to create a resource-loaded project plan including both the

CERN and contract effort required. This would provide a mechanism for resource shortages to be identified before they cause delays to the project.

The Cost-to-Completion, the recommended baseline for the cost estimate, has been essentially stable since it was created nearly a year ago. Moreover it is the best available basis for monitoring cost performance.

### **Earned Value Management for the LHC Project**

The Project is in the final phase of setting up an earned value system based on a WBS structure, essentially at the system level, and split up into Work Units, typically of three months duration. The variance calculations are performed at the cost account level and can cover several Work Units. A more detailed variance breakdown requires additional effort by hand. Work Unit definitions are becoming available from many groups and data loading in the system in progress.

The Committee considers the software tools, which are an extension of a system in use for the past several years for ATLAS, to be excellent and particularly flexible. In view of this flexibility, we suggest that some thought now be given to defining what generic monthly reports will be made available to the various layers of management. When fully implemented, the Earned Value Management (EVM) system should greatly assist the project management to identify cost and schedule variances on contracts.

The Project hopes to start reporting on many (hopefully all) systems in January 2003. The Committee considers it important to start on this date, even if the initial reporting is less than complete, since this is a new management tool for CERN and the earlier both the users and developers gain experience the better.

The Committee believes that the ability of the earned value system to capture cost information is good. We find its ability to determine the degree of completion of technical tasks (and thus determine schedule variances) to be less well advanced. We consider the ability to monitor schedule variance at this stage in the Project to be as important as costs as the installation and commissioning phase begins since delays risk increasing external labour costs. Assigning earned value to significant technical milestones, in addition to Work Units, should help to provide a more comprehensive picture.

The Committee notes that 'reality checks' of the schedule variances will be provided by major system tests such as the cool down and powering of an Octant. The use of such technical milestones is encouraged. Over the next several years the schedule will become increasingly complex and challenging. The ability of the system to report schedule variances in a timely fashion will be crucial in providing useful management information. The system administrators should verify this aspect of the earned value reporting.

We found resource loading of the plan with manpower estimates to be lacking, as was the ability to capture the actual manpower. We believe that manpower roll-ups, including by skill types, will be necessary for management to plan Project activities especially in view of the perceived shortages of CERN staff, which are projected to become more acute in the next several years. Hence, manpower reporting (including contract labour usage) should be a high priority for the system developers.

We are less certain that the EVM system will be the best tool for the project management to assess the effect of any delays to the delivery of equipment on manpower costs since the duration of the installation tasks and the number of individuals required may have to be re-optimised to reflect the revised availability of components. We recommend that the project

considers establishing a simple, high-level, resource loaded project plan for the installation phase to allow the effect of delays on the total external cost to be assessed and the total external cost to be minimized by the optimal re-scheduling. Where possible, the contractual terms for the on-site works should attempt to retain sufficient flexibility to minimize the financial effect of component delays.

### **Engineering Change Request System**

Over the period 1996-1999, any requested technical changes affecting the machine were reviewed by the committee(s) responsible for the system concerned (MARIC, LEMIC, PLC, TCC etc) and then presented to the Technical Committee for validation. This system was inadequate for two main reasons. Firstly, no single document provided a straightforward summary of all the technical changes made. Secondly, the procedure for the validation of the proposed changes focussed on technical arguments and hence those proposing modifications were not systematically obliged to make an in-depth study of the probable additional costs associated with their technical proposals.

From October 1999 onwards, the Project Management modified its technical change management system and implemented a revised Engineering Change Request (ECR) system, which defines three levels of decision-making depending on the estimated impact of the requested ECR on costs, schedule and performance.

<b>Class</b>	<b>Description</b>	<b>Person responsible for the decision</b>
None	Purely a change in the form of the technical documents. No impact on costs or schedule.	Project Engineer
Class II	Change in component without impact on costs or schedule	Parent Project Engineer
Class I	Change with impact on costs, schedule or interfaces with other systems	Project Management

This is a significant improvement compared to the previous arrangements since an estimate of its impact is required as soon as an ECR is submitted, which enforces better cost and schedule awareness. The Committee considers that this is a good procedure that fits the project needs. The Project Management have concluded that there would be no benefit to be gained from comparing the actual impact on cost and schedule with the original estimates because of both the difficulty of the task and the low added value of the comparison (since the decision would already have been made). The Committee does not disagree with this conclusion. However, the Committee believes that this can be done starting with the Cost-to-Completion as the project cost baseline.

According to the data supplied by the Project Management, 115 ECRs were raised over the period October 1999 to October 2002, the majority of which concerning civil engineering (22 in 2002). It is probable that the number of ECR will strongly decrease as systems enter their production phase. The cost change estimates associated with these ECRs amount to a cumulative saving of 5.1 to 8.1 MCHF. This 3 MCHF range comes from the fact that the expected savings are often expressed as a range.

The Committee believes that the ability of the earned value system to capture cost information is good. The ability to determine complete technical progress in the Project (and thus determine schedule variances) we find to be less well advanced. Assessing earned value to significant technical milestones in addition to Work Units might help to provide a more

comprehensive picture. We consider the ability to monitor schedule variance at this stage in the Project to be as important as costs as the installation and commissioning phase begins.

### **Baseline Schedule**

The Committee reviewed the planning and organization for the installation, which, to a large extent, will control the baseline schedule. As noted earlier, the committee looked at the schedules for five of the systems, although we did not review the Baseline Schedule in detail. Moreover, we did not review the cost of installation as presented in the Cost-to-Completion, since it is contained in the estimated cost of all of the separate systems. We note that the EST Division is reviewing the costs of these activities in parallel with creating the LHC Installation Coordination Group. For this reason, we limit our comments to the Installation Organization and Planning.

The LHC Installation Coordination group is being formed in the EST Division and it will come into existence on January 2003. The intent is to draw people who are currently working on the same activity in several divisions into one unit for better coordination. It will provide the missing link between the individual installation activities of technical groups such as the power converter group or cryogenics group. It will also provide coordination of the installation of the LHC machine, its injection lines and the infrastructure in the experimental halls, and hardware commissioning of the LHC sectors. Its responsibilities and purpose were described to the Committee during the presentations. The group will play a vital role in the LHC installation and its creation was not premature

Its immediate priorities are integration, databases and configuration management for the equipment in the machine, and the organization of logistics and transport. In addition, the LHC Installation Coordination group supports the installation work of other groups and provides assistance in unexpected emergency situations as well as site management. The mandates of the different subgroups of LHC Installation Coordination group were found very essential for a smooth installation of the LHC components in the tunnel.

We note that the planning of the sequence of steps for the LHC equipment is quite advanced. An extensive installation plan and schedule for the main components was presented to the Committee and it appears quite satisfactory. The Committee and the presenters are in agreement that the installation and commissioning of the magnet system, including related equipment such as power converters, present the greatest challenges. The Committee also believes that the installation of the cryogenic distribution line (QRL) 'just in time' without any stock to cope with delays in the fabrication process manifests a risk. The development of an auxiliary control system with limited capabilities to test the QRL might be time critical and should be monitored. Ultimately the very demanding schedule for magnet fabrication drives the installation schedule.

The Committee tried to step through the complete path of transporting accelerator components into the tunnel and tried to identify potential bottlenecks of the installation procedures. Experience obtained from the installation of other accelerators has shown that the availability of low-technology equipment and associated procedures is often not properly addressed and their impact on the schedule is frequently underestimated. We recognize that the LHC Installation Coordination group is aware of these facts and gained considerably experience during the dismantling of LEP. In particular, the installation of magnets could effectively stop if the big mobile crane were not available (N.B.: only one mobile crane is

available on site). Similar, problems could arise due if one of the stationary shaft cranes or one of the various specialized transport trucks or vehicles were out of service. Fortunately, installation and transportation are done during the night making repair possible during the next day to recover the delay. However, we learned that considerable amount of preparatory work must still be carried out to define the full complement of equipment that is needed to move the equipment into and within the tunnel.

The Committee learned that the LHC Installation Coordination group has started activities to define different routines as well as non-routine installation procedures and the corresponding handling tools. We encourage the group to thoroughly examine all steps in the installation and transportation processes, as they are doing with magnet installation. This will identify potential weak points and will make provision for non-routine situations such as accessing the QRL line after magnets are already in place. In addition, safety issues should be addressed in advance to allow magnet installation and test of the QRL in parallel in case of a major delay of the QRL installation or unexpected initial problems.

The LHC Installation Coordination group must also review the cost estimates for installation of the various systems. They expect to complete the full definition of their scope of work and a revised cost estimate for this work early next year, while continuing to provide coordination for the work in the LHC tunnels that is already underway. The Committee did not explore how the group plans to use the earned value methodology to track its performance, since the group must first establish cost and schedule baselines for its work within the overall project baselines for cost and schedule.

We conclude that this portion of the schedule is well planned, although there is much to do to fill in the details. Similar to other groups, the lack of manpower (10 out of 55 staff members scheduled) has to be addressed.

### **Analyses of the Estimated Cost and Schedule of Five LHC Systems:**

We reviewed the status of five major systems including their cost and schedule. We selected the magnet system and cryogenic system because they represent nearly two thirds of the total Cost to Completion and because they present the greatest risk to completing the project within the Cost to Completion and on schedule. We also selected RF, Power Converters, and Beam Transfer, since the work is representative of the type of work done by the SL-Division. Our findings on the estimated cost and schedule of the five LHC subsystems are contained in the following paragraphs:

#### **The Magnet Program**

The main dipole production, together with the short straight sections, represents a significant fraction of the Project cost to complete. The start of magnet production was preceded by a major and successful R&D effort that has enabled the magnet system group to develop excellent, high performance magnets and adapt their fabrication to industrial production. The 143 MCHF cost of this program is included in the Cost-to-Completion. A hugely significant milestone has been the good technical performance of the magnets and at this point the Committee concludes that, barring unforeseen circumstances, this has now been satisfactorily established. All construction contracts are placed so the ability to maintain cost and schedule within these contracts is crucial to the Project. The fabrication and testing of the superconducting magnets presents the greatest risk and the work at the vendors and at

CERN must be monitored closely, since the production of magnets is a very complex manufacturing process. We congratulate the CERN management on taking steps to fill the positions that are needed to monitor these activities. The Committee commends the additional manpower recently provided for contract maintenance as a sensible move in these circumstances. The contracts are complex with many components to be supplied by CERN. While industry has successfully produced dipole cold masses, the Committee notes that the short straight sections have not yet been fabricated industrially and contain demanding tolerances.

The Committee believes that the Project is well aware of the issues involved in magnet production and is taking all reasonable steps to ensure a successful construction phase. Nonetheless, we note that cable production has yet to achieve the desired rate on a sustained basis. This has been masked by the fact that the low rate of magnet production in the pre-series stage has limited demand. The dipole production rate is scheduled to increase dramatically in the next few months so this may cause a critical situation if the cable production rate is not increased correspondingly even though a significant buffer of cable has been built up by the Project.

Until production of a significant number of magnets has been demonstrated, the Committee believes that there will remain a non-negligible cost and schedule risk in this area. We commend the aggressive steps taken by the Project to address this fact and in view of the upcoming in-depth review of this program we choose to offer no advice at this time. The Committee does however find it unrealistic to expect that in excess of 1500 complex magnetic elements will be produced without encountering problems of one form or another. The challenge will be to minimize the cost and schedule impact of these problems when they occur.

During our meeting, we learned that the production targets for the main dipole magnets that were set a year ago have not been met. The reasons range from the failure of equipment at the vendors, which was provided by CERN, to the recent insolvency of several vendors. The project team has responded rapidly to each of these crises and has prevented them from causing significant overruns. Nevertheless, these problems will delay the ramp-up of magnet production and testing to the level planned for series production by several months. The project team does not believe that this will delay the completion of the series magnet production and/or the installation of magnets. If this is the case it will not affect the April 2007 date for commissioning

### **Cryogenic Distribution Line and Cryogenic System**

The committee recognizes that the fabrication and installation process for the cryogenic plants is well advanced and the installation activities are in a good shape. The cryogenic components are either provided on a contract basis as turnkey systems from industry or are re-used from LEP.

The cryogenic transfer line (QRL) will be constructed, delivered and installed on a “just-in-time” bases by the vendor. The committee could imagine that this might cause problems for the schedule in the case of unexpected occurrences such as strikes etc. In addition, a single vendor is supplying the whole system increasing risk to the costs-to-completion and the schedule.

A detailed scheme for the QRL installation and testing has been developed taking into account interleaved periods of work on other sub-systems. Parts of the transportation chain of

the QRL modules into the tunnel remain as a CERN responsibility. The issue of organizing the joint transport task between CERN and the vendor remains to be addressed. Critical items on the CERN as well as the vendor's side have been identified. The committee was told, that despite of some small delays in the deliveries of some components or the completion of some activities no impact on the overall schedule is expected. Likewise delays in the delivery of the feed-boxes for the magnet test stands should not impact the anticipated schedule for testing the magnets.

The QRL contract management system looks very advanced. The vendor can directly access the CERN EDMS database. Periodical progress reports are generated in a structured and detailed way. The actual status of the procurement process or of the agreed specifications is listed as well as summary charts for project tracking. Engineering Change Requests are managed in a well-defined way and communicated between CERN and the vendor. Financial data are transparently accessible and the costs are controlled. There are no cost overruns reported to date. Presently, no link to the EVM system has been established. However, the committee is convinced that the follow-up of the cryogenic contracts is an easy task to be integrated in the EVM system.

### **Power Converters**

The LHC power converters consist of modules, which are bought from industry, that are integrated into power supply units at CERN. The number of different industrial converter types needed has been minimized by using sets of parallel-connected converters to meet several different requirements, e.g. 8V at 2kA, 4kA or 8kA is supplied by parallel connected 8V, 2kA modules. Redundancy, and hence high reliability in operation, is built in by incorporating one spare module in each set. This approach maximizes the desirability of the contracts to industry (i.e. mass production of a few different converter types), and hence costs, whilst minimizing risk by allowing CERN to undertake the technically demanding control and integration of the power converter units into power supplies. The risk has been further reduced by CERN undertaking the design and construction of the power converter types that are not suited to industrial development.

The presently expected availability schedule of the power supply units has a small amount of contingency. The contract signature milestones and the number of delivered converters will be used to provide Earned Value data for each different type of unit; some data has already been entered into the EVM system. The integration of the power converter modules into power supply units at CERN raises some concerns. Firstly, the contract with the only available supplier of DCCT units is currently subject to a delay of several months. Secondly, the much-reduced electrical effort available at CERN following recent retirements will result in longer design, engineering, production and evaluation times. The Committee urges that CERN management proactively assesses the consequences of the resource shortages and that appropriate Work Units should be included in the EVM system to allow progress on such tasks to be monitored. We also suggest that the choice of individuals to work on the various aspects of the power supply implementation should be made carefully to maximize the amount of knowledge retained in those staff who will be still at CERN during the operation of LHC.

### **The Beam Transfer System**

The different parts of the system are at very different stages of their production: the resistive magnets are complete whereas injection stoppers and shielding, transfer line collimators, extraction septa and diluters are still in the preliminary design phase. However, the fabrication of the injection and extraction kickers, which are the most technically challenging items, is now starting production, and the prototyping phase of the dilution kickers has been completed. Overall progress is consistent with the schedule and no major technical problems have been reported. According to the group leader, the main technical principles are validated and the prototyping phase is going as planned.

The group's budget to completion amounts to 49.4 MCHF, including 3.6 MCHF of in-kind contributions. This represents a 16% increase in the budget initially allocated to the group in 1996. It appears that at this time, a significant portion of the budget to completion is still based on estimates rather than contract actuals. Consistent with the varying levels of technical design maturity of the components, some of the cost estimates are still rather conceptual. The Group Leader brought no specific concerns for potential cost increases to the attention of the Committee, but we note that in case overruns occur, there is no explicit contingency in its budget to accommodate them. In this context, evolution in the cost to completion would mainly depend on the level of accuracy in the cost estimates produced by the group and attention should be given to changes at the contracting stage. It is the opinion of the committee that the analysis carried out to prepare for EV reporting will enhance the accuracy of the more conceptual cost estimates estimated to be around 20 MCHF at this time.

The Group Leader reported concerns about projected manpower shortages, mainly due to staff retirements. Without any intervention, the missing staff represents an important fraction (49%) of the manpower needed for 2002-2006. This question will be addressed in the Morges III meeting by the CERN management. However, in case the missing posts are not filled from the laboratory's staff, then this manpower shortage could have an impact on the Cost-to-Completion as the group would have to resort to purchasing additional external manpower.

The Group has transmitted data to the EVM Project Leader. Roughly 160 work units have been identified. Some tuning is still to be done but the work seems to be progressing well. The Committee notes that several of the sub-system schedules span over the whole time available and as a consequence there is limited schedule contingency. The introduction of EVM will be of great help in monitoring these tight schedules.

The Committee notes that the construction budget to completion only includes 8 dilution kickers out of the full complement of 20. Project Management took the decision to defer the installation of twelve of the dilution kickers (4 MCHF) until after 2006. They assumed that the LHC will deliver no more than half its full design intensity during commissioning. This phased approach is entirely reasonable for commissioning and initial operation; however, ultimately all no more than half its nominal intensity 20 kickers will have to be installed as the operating intensity increases.

## **RF System**

The main 400 MHz RF-system cavities (capture, acceleration and storage) have been tested at low power. Furthermore prototypes of the high power system, such as a klystron power amplifier, circulator and load have been tested. Minor problems, which have been encountered to date, with the load at high power should be solved before the end of the year. There is still some risk connected with the high power coupler, after a series with cracks

developed in the ceramic copper brazing around the windows. After some technical modifications the last two windows have performed well with no cracks. If this reflects an established improvement the problem should be solved. The tunnel layout and infrastructure for cavities and supporting infrastructure have been designed and no problems have been encountered after the changes required for the new optics version 6.4.

Special attention has to be given to the full acceleration chain tests in SM18 under transient and high power conditions since they seem to be crucial for the definition of the final electronics.

Staging of the 200 MHz capture and acceleration system has been considered in case of cost overruns or manpower shortages. A staged implementation could benefit from subsequent knowledge on longitudinal emittance and injection losses gained from initial, low intensity operation.

More than 50% of the budget has been committed and is consistent with the technical progress to date. The budget seems to be solid. No critical items could be seen in the preliminary planning as presented to the Committee.

In preparation for the EVM implementation the definition of the work units is progressing well and ought to be ready soon. The Committee encourages this implementation as soon as practical.

## **Conclusions**

The project team must meet many challenges before the LHC is successfully completed and commissioned. These challenges have and will introduce a great deal of risk in completing the project within the recommended baseline cost estimate of 3,220M CHF and starting the commissioning with beam during April 2007. The Committee concludes that the basic plan is sound and moreover, it is possible to reach these goals. Nevertheless CERN should be prepared for small costs increases and small delays, given that there is no contingency in the cost estimate and the schedule has no room for delays.

Submitted by the CSRC Committee  
John Peoples, Chair  
Reinhard Bacher  
Martin Cox  
Michael Harrison  
Marc Pannier  
Albin Wrulich

# **Enclosure**

CERN/DG/DI/LRE/jf

9<sup>th</sup> October 2002

## **Cost and Schedule Review of the LHC Machine and Experimental Areas**

CERN, Geneva, 21-23 October 2002

### **Charge to the committee**

To understand the basis of the cost-to-completion (CTC) of the LHC machine and experimental areas and to agree to a baseline from which future deviations of cost and/or schedule can be tracked.

To analyse the tools available to project management to track cost and schedule and to make recommendations on improving their efficiency.

To understand the proposed schedule for completion of the LHC project and to comment on its feasibility.

## Cost and Schedule Review of the LHC Machine and Experimental Areas

CERN, Geneva, 21-23 October 2002

### Provisional Agenda

#### Monday 21 October - Building 30

c o n f r o o m 6 - 0 4 1	10.00	Executive session
	11.00	Meeting management
	12.00	Current status of the LHC (L. Evans)
	13.00	<i>Sandwich lunch</i>
c o n f r o o m 7 - 0 1 2	14.00	Earned Value Management – WBS (P. Bonnal, J. De Jonghe, J. Purvis)
	15.00	Quality Assurance – Engineering Change Requests (R. Saban)
	15.20	<i>Tea</i>
	15.45	Main Superconducting magnets (L. Rossi)
	16.15	Cryogenic Distribution Line (QRL) (L. Taviani)
	16.45	RF (T. Linnecar)
	17.05	Power Converters (F. Bordry)
	17.30	Continued discussion of the previous four presentations
	17.50	Executive Session
	19.00	<i>Dinner COOP “Glass Box” (by invitation)</i>

#### Tuesday 22 October – Building 30

c o n f r o o m 7 - 0 1 2	09.00	Beam transfer (V. Mertens)
	09.30	Installation – Planning (P. Bonnal)
	10.00	Installation – Organization (P. Ciriani)
	10.30	<i>Coffee</i>
c o n f r o o m 6 - 0 4 1	11.00	Questions and Answers
	13.00	<i>Sandwich lunch</i>
	14.00	Executive Session
	19.00	<i>Dinner</i>

#### Wednesday 23 October - Bldg. 61-017, 1<sup>st</sup> fl, “Salle A”

08.30	Executive Session
09.00	Closeout Discussion with Management
10.00	Adjourn

