Department of Energy Mini-Review Report
on the
U.S. LHC Accelerator Project

DATE October 15-16, 2003
PLACE Fermi National Accelerator Laboratory

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PROJECT STATUS

Total Project Cost (TPC):	$110M	
Percent Complete:	Planned: 93%	Actual: 88%
Performance Indices[1]:	Cost Performance Index (CPI):	0.97
	Schedule Performance Index (SPI):	0.95
Project Completion Date:	Baseline: 9/30/05	Forecast: 9/30/05
CD-4 Date:	Baseline: 9/30/05	Forecast: 9/30/05

SUMMARY

There is good technical progress on U.S. LHC Accelerator components at each laboratory. Overall the project is slightly behind schedule; however the project plans to finish in September 2005, and plans to provide its deliverables within, or in advance of CERN need dates. Delay by CERN in sending Fermilab tested corrector magnets needed to complete the Fermilab quadrupole assemblies is a significant issue and concern. Cost is a concern due to remaining cost and schedule risks and limited amount of contingency ($2.04 million or approximately 17 percent of the remaining work).

[1]Cost and Schedule Performance Indices as reported in PARS are cumulative, project to date. Reported values for CPI and SPI are within the range characterized as expected to meet cost/schedule performance baseline and appear as “green” in the Monthly Project Status Report presented to the Deputy Secretary.

TECHNICAL PROGRESS AND ISSUES

Brookhaven National Laboratory (BNL)

Technical Accomplishments

The design effort at BNL is complete except for changes mutually agreed to by the responsible engineers. Progress on magnet production continues to be very good. Dipole production will be completed by the end of the year, and testing will be completed by June 2004. Shipment of the dipoles to CERN is planned to be completed by early 2005.

The current status of the required magnets is:

- D1—four of the five D1 dipoles have been delivered to CERN. The fifth magnet requires a re-test to evaluate a "soft short" between the main coil and the quench heater lead. This re-test should be completed as soon as possible to determine if a re-build is needed.
- D2—All nine of the D2 dipoles are fabricated and seven have been tested. The first is being readied for shipment to CERN.
- D3—all six of the D3 dipoles are wound, assembly into the cold masses (two per cryostat) is nearly completed.
- D4—all three of the D4 dipoles are wound, one is complete, the others are assembled into the cold masses, and one of these is being installed into the cryostat.

The required acceptance criteria and supporting documentation have been agreed to, and the first D2 dipole has been accepted by the CERN Magnet Review Board. (Four D1 have been previously accepted.) This task required more resources than originally planned. With the protocol developed, future magnet transfers are expected to require less effort.

Short sample cable testing has been hampered by very poor deliveries from CERN. Cable production is late by 6-12 months. This has lead to cost overruns and the need to reallocate resources that is typically an inefficient process. Out of 3,430 samples, 1,505 or 44 percent have been measured to date. Due to the uncertainties of the cable delivery schedule, this task is now considered a "level of effort" task. BNL will test as many samples as possible between now and March 2005. At that time, if any additional testing is required, it will be CERN's responsibility.

Cost and Schedule

BNL's magnet fabrication is scheduled to be finished by February 2004. Magnet testing will continue through June 2004. Cable testing, as explained, will be a "level of effort" task and is expected to match cable delivery schedules up to March 2005. BNL has responded to small design changes from CERN without any transfer of funds to cover these changes. Due to the limited funds remaining, this practice must be curtailed as the production period comes to a close.

Recommendations

1. Evaluate the schedule benefits and risks of running the BNL magnet test facility seven days per week. A shortened measurement schedule may offset the costs of the additional staff. Completing the measurement program early, determining that the magnets are an acceptable quality will allow the U.S. LHC Accelerator Project Management more latitude in contingency management.

2. Evaluate the overall benefits and risks of the U.S. LHC Accelerator Project Management offering to measure the correctors needed to complete the U.S. commitment to the LHC Program. Measurements of these correctors would be performed at BNL again on a seven day per week schedule. This would have to be funded separately.

3. Design changes requested by CERN estimated to exceed a limit established by the U.S. LHC Accelerator Project Management should be reviewed and approved prior to implementation.

4. Review the labor estimates proposed in ETC/BCR55 with the goal of reducing the total number of staff needed to support testing of both magnets and short samples. Cross training of staff should be considered in this review.

Fermi National Accelerator Laboratory (Fermilab)

Technical Accomplishments

Fermilab has made good progress on the production of magnets. They have received the first five of the KEK-built magnets. They are beginning assembly and testing components in cryostats. The testing of the first Q2 assembly went well. In the second assembly one of the two MQXB quadrupoles (Fermilab-built Interaction Region quadrupole cold mass) tested well, while the second reached a limit below the required field. The data are consistent with a conductor limitation at a specific location in the magnet, but the exact cause will not be known unless further detailed examination of the magnet is undertaken. The third Q2 assembly is on the magnet test stand.

Cost and Schedule

The Fermilab LHC Accelerator project is keeping costs under control. The touch labor costs on the magnet assemblies have been falling and the average meets the baseline target. Breaks in work are well managed. The cost variance has been constant over the last year and a half.

The diagnosis and repair of the second Q2 will require a call on contingency. The size of the contingency call depends on the scope of the repair. A decision tree and associated range of estimates has been created.

The schedule continues to erode. The Fermilab work has little schedule contingency left. The schedule is hostage to the delivery of corrector magnets from CERN. The manufacturer is now producing magnets and CERN has a magnet cold test schedule that is just-in-time to supply Fermilab's needs. The cold test program at CERN competes for limited resources and the committee is concerned about CERN maintaining adequate priority to deliver on their plan.

In addition, the schedule for cold testing completed inner triplet magnets at Fermilab in the magnet test stand—approximately nine weeks per magnet—has very little float. Fermilab is working to shorten the base test cycle by two weeks by not doing a second thermal cycle, moving preliminary measurements to the ICB production facility, and minimizing the cold measurements program. Nonetheless, this would still leave the schedule tight.

Recommendations

1. Communicate the implications of late delivery of the correctors to the program at Fermilab to CERN LHC management.

2. Investigate the possibility of BNL testing the correctors. This would have to be funded separately.

3. Eliminate the second temperature cycle from the magnet testing.

4. Work with Fermilab management to assure that the LHC magnets have a high enough priority in the Fermilab magnet test facility to stay on schedule.

Lawrence Berkeley National Laboratory (LBNL)

Technical Accomplishments

The TAS absorbers have arrived at CERN passed all visual inspections and are now ready for acceptance tests as soon as the TAS acceptance specifications have been approved. Two TAN beam tubes have been installed in their housings and are ready for shipment to CERN. The two other beam tubes have vacuum leaks and were returned to the vendor for repair, in the course of which one tube was severely damaged. As spare parts are available a new beam tube will be fabricated.

The damaged beam tube and all remaining subassemblies should be shipped to CERN, and to further repairs need be undertaken. Technical information concerning the provenance, properties, and fabrication details of the copper material used in the damaged tube should be obtained.

The procurement contract for the distribution feedboxes (DFBXs) was awarded to Meyer Tool and Machine (MTM) on March 22, 2003. The fabrication of the subassemblies required for eight DFBXs is progressing very satisfactorily: fabrication oversight activities and change control procedures are in place, and monitored closely. Ongoing reviews ensure speedy resolution of fabrication issues, scheduling priorities and timely transfer of government furnished materials (GFM) to the vendor. Critical assembly processes and inspection tests are witnessed by cognizant

project personnel. Forty high-temperature superconductor (HTS) leads, the procurement responsibility of LBNL, have been shipped to Fermilab for testing. As of October 15, 23 leads have been tested of which 11 have been found to be defective: four have wiring problems and seven have leaks from the helium space to air. The vendor, Pirelli, has been contacted and has promised to send a representative in November 2003 to assess the problems and propose and execute the appropriate repair procedures. The presence of these subtle defects in the structure and wiring make *ALL* HTS leads suspect. The qualification process before installation needs to be reexamined and protocols for the necessary repairs generated. One set of vapor cooled leads manufactured by American Magnetics Incorporated has been received by MTM on August 23, 2003; the remaining shipments are scheduled to be completed by the end of the year.

Cost and Schedule

The vacuum leaks in one TAN beam tube will be repaired by the electron beam welding vendor at his expense. The fabrication of a new beam tube from existing parts and subassemblies is estimated to cost approximately $15K as the beam fabrication tooling appears to be still in place at the vendor, the current schedule for the remaining two TAN absorbers should be minimally impacted, and an early 2004 shipping date is feasible. The absorbers are required to be at CERN by July 2004. In the absence of further information the impact of the repair of the HTS leads is currently unquantifiable. In the most optimistic scenario, i.e. one in which the repair(s) is trivial; the delivery schedule to MTM should remain unaffected. Participation in the repair process by LBNL and Fermilab personnel will have a small budgetary impact. If extensive repairs or even the highly undesirable need for a return shipment to England is indicated, a serious schedule impact can be expected. Obviously this process will also have a substantial budgetary impact as a complete re-test of the leads will be required.

Recommendations

1. Continue aggressive pursuit of the TAN beam tube repairs that should include the following steps:

    - Repair leaks in the weld(s) in one beam tube, at the vendor's expense, by November 15, 2003.
    - Fabricate a new beam tube using existing parts and subassemblies, by December 15, 2003
    - Ship the damaged beam tube and all remaining subassemblies to CERN. No further repairs steps are to be undertaken.
    - Obtain technical information concerning the provenance, properties and fabrication details of the copper material used in the damaged tube by November 1, 2003.

2. Require Pirelli, the HTS lead vendor, to send their representative to Fermilab without further delay and initiate the following steps:

    - Determine the cause of the leaks, the wiring defects and the extent of the shorting of the temperature sensors in conjunction with Pirelli by December 1, 2003.

- Develop a comprehensive repair and restoration procedure with Pirelli applicable to all 40 leads by December 1, 2003.
- Establish a detailed test protocol in conjunction with Pirelli by December 1, 2003.
- Repair defects. All repairs should be the responsibility of Pirelli but if not feasible, under his immediate supervision by cognizant LBNL and Fermilab staff. At least one pair of tested leads should be available by January 15, 2004.
- Ensure that the vendor of the DFBX is made fully aware of the HTS situation, and that the repair of the leads proceeds in a manner to minimize the impact on the DFBX fabrication schedule by November 30, 2003.
- Ensure that a representative from LBNL and/or Fermilab are present to witness the testing of at least one set of leads at American Magnetics, Incorporated, Oak Ridge, by December 1, 2003.

PROJECT COST AND SCHEDULE STATUS

Overall, cost and schedule performance since the February 2003 DOE review has been satisfactory due to aggressive efforts of the Project Management Office and the managers at BNL, LBNL, and Fermilab. The intimate level of understanding of cost and schedule issues is clearly demonstrated by the discipline used to maintain routine reporting, detailed risk analyses used to estimate and evaluate remaining contingency needs and the nature of the alternatives considered and mitigation strategies proposed and implemented.

The project completion date, DOE Critical Decision-4 (CD-4), for the U.S. LHC Accelerator project is September 30, 2005, and the project is approximately 88 percent complete, based on earned value. The Total Project Cost is $110 million, with an Estimate at Completion of approximately $108 million. The U.S. LHC Accelerator Project Manager and Level 2 laboratory managers have implemented an effective system for measuring, tracking, and reporting cost and schedule performance. The project management team maintains a good understanding of the cost and schedule variances and drivers at each Laboratory. This information is used constructively to adjust work plans or efforts where necessary, to work toward containing cost growth, and to help identify and assess contingency needs.

The U.S. LHC Accelerator Project Manager has worked with Level 2 managers at each of the contributing laboratories to conduct realistic contingency need assessments to establish a cost contingency range needed to address known problems and future uncertainties. The project is slightly below the lower level of that range; a situation that represents a serious concern given the nature of the remaining work and two remaining years in the project.

Baseline change requests are under preparation (and approved in the case of LBNL) to incorporate the revised Estimates at Completion for each Laboratory. These baseline budget changes essentially establish budgets at completion for each laboratory, capturing past experience, known changes, expected work adjustments, impacts of known schedule delays and estimated needed contingency. The U.S. LHC Accelerator Project Manager must continue to work closely with each laboratory's management, including CERN, to ensure that all viable cost reduction strategies and resources can be brought to bear.

The U.S. LHC Accelerator schedule performance has been satisfactory, but remains approximately five months behind the baseline (but well within CERN installation need dates). However, due to *minimal float* with respect to either DOE CD-4 or CERN installation dates in some instances (e.g., with initial quadrupole and final quadrupole or feedbox shipments) the schedule has become an increasing concern. Much of this concern arises from continuing CERN delays in providing corrector elements for the quadrupole assemblies, which has become critical path for completing U.S. quadrupole production, and creates a serious uncertainty. The U.S. LHC Accelerator project management has worked closely with CERN to identify and understand the impact of CERN delays on the U.S. production schedule, both with respect to CERN need dates and the DOE CD-4 date, and to press CERN for accelerated delivery of correctors. This is further addressed in the "Fermilab" and "Management" sections.

The detailed LHC component installation schedule that specifies CERN delivery milestones has been revised due to changes in the LHC installation sequence and plans. Some of these CERN delivery milestones are now scheduled beyond September 2005. This set of CERN delivery milestones has been used to establish U.S. LHC Accelerator Level 2 Project milestones for U.S. project completion. Since the U.S. LHC Accelerator project is to be completed by September 30, 2005, this tie between the CERN Delivery milestones and U.S. Level 2 Project completion milestones can no longer be held. Completing the U.S. work scope within the U.S. schedule remains the most effective use of project funds and so the Level 2 Project completion milestones need to be maintained to support the U.S. completion dates rather than the newly revised CERN installation schedule.

Recommendations

1. Finalize planned Baseline Changes to establish a revised Budget at Completion for each Laboratory by January 2004.

2. Continue to aggressively manage cost and schedule to complete the U.S. deliverables on the baseline schedule by CD-4 of September 2005.

MANAGEMENT

The U.S. LHC Accelerator Project Manager has managed cost and schedule aggressively. Management understands the project's cost and schedule and is taking appropriate action. The biggest threats to the project are from external forces including the timely delivery of correctors from CERN and adequate priorities at the laboratories. A full review of the Estimate at Completion (EAC) has been completed since the February 2003 DOE review. The cost risks were evaluated, and a curve for the required contingency for the remainder of the project has been developed. The available contingency based on the new EAC is approximately $2 million. This is slightly under the required contingency from the above analysis.

Cost and schedule are tight. Aggressive management of the project and at each laboratory will be required to complete the project within the current budget and schedule. Continued support of the three laboratory directors is required. Significant assembly and testing of components remain to be completed with the associated risk of added cost and delays.

Design changes requested by CERN estimated to exceed a limit established by the U.S. LHC Accelerator Project Office should be reviewed and approved prior to implementation. This procedure should be implemented before the end of 2003.

Recommendations

1. Continue to provide stringent management of cost and schedule and ensure that the Project has the support of the Fermilab, BNL and LBNL laboratory directors.

2. Investigate and implement ways to maintain the schedule such as alternates to testing the correctors at CERN and reducing the cold testing cycle at Fermilab.

LHC ACCELERATOR RESEARCH PROGRAM (LARP)

The presentation regarding the LARP program showed that it was very promising. The Committee was pleased to note that the program participants were very responsive in following the suggestions and recommendations of the June 2003 DOE review. In particular, there has been significant outreach to the university community and to other national laboratories that are not presently involved. A high level of interest by both of these latter groups was evident and it will be a challenge to find the funding support for these promising proposals.

The LARP collaboration had a meeting in Long Island in September 2003 to more firmly define their program for the next five years. An aggressive array of necessary activities was agreed upon and a distribution of responsibilities among the participants was explored.

The Committee was pleased with the scope and the rapid evolution of the research and development plans.

ACTION ITEMS

1. Conduct a project status meeting in January 2004.

2. Conduct a semiannual review of the U.S. LHC Accelerator Construction Project in April 2004.