Department of Energy/National Science Foundation
Mini-Review Report on the
U.S. LHC Accelerator Project

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PLACE Fermi National Accelerator Laboratory

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PROJECT STATUS

Total Project Cost (TPC):	$110 million	
Appropriations through FY02:	$92.25 million	
Percent Complete:	Planned: 81 percent	Actual: 75 percent
Project Completion Date:	Baseline: 09/05	Forecast: 09/05
CD-4 Date:	Baseline: 4th Q FY05	Forecast: 4th Q FY05

SUMMARY

There is good technical progress on key U.S. LHC Accelerator components at each laboratory. Fermi National Accelerator Laboratory (FNAL) magnet production is making good progress, components from Japan and CERN successfully arrived and minor problems with magnet production and testing are being resolved. Lawrence Berkeley National Laboratory (LBNL) has made good progress on the interaction region absorbers. Completing the distribution feedboxes (DFBX) design has been problematic causing significant cost and schedule issues, however, resources have been added to the DFBX team and progress over the past six months is improving. Brookhaven National Laboratory (BNL) design efforts are winding down, magnet production and testing are well underway, and initial planning has been started for the LHC Accelerator Research Program.

Overall the project is slightly behind schedule, however the project plans to finish in September 2005. The project is currently on track to meet CERN need dates.

Cost is a concern due to remaining cost risk issues and relatively small amount of contingency ($4.3 million or approximately 16 percent of the remaining work).

TECHNICAL PROGRESS AND ISSUES

Fermi National Accelerator Laboratory (Fermilab)

Technical Accomplishments

Fermilab is making good progress but has a negative cost and schedule variance. Production progress is good. Four inner triplet quadrupole magnets (MQXB) are complete, coil assembly on the fifth is underway and cable has been insulated for the sixth. However, problems encountered with various types of ground shorts in these magnets continue. Several different categories of problem have been identified and corrected, with long-term solutions implemented where possible in magnet collaring or final assembly procedures (e.g., increased inspection, additional insulation).

Inner triplet elements have successfully arrived from Japan (MQXA01 quadrupole) and CERN (MCBX correctors). Coldmass assembly of the first Q2 quadrupole (LMQXB) is nearly complete and cryostat assembly is underway. Cryostat tooling has successfully aligned Q2 elements with respect to each other. An Acceptance Plan for the Q2 element has been delivered to CERN for informal review.

Magnetic field harmonics in the quadrupoles have been measured, and an adjustment in a quadrupole coil position was made to provide additional correction where needed. Initial long-term mechanical stability measurements made during a magnet transport exercise indicates that the magnets are very stable mechanically. Fermilab is working very closely with CERN to resolve an open technical issue with the Q1 beam tube design, as well as other interconnect region interface issues.

The next major technical milestone will be the testing of the two quadrupole (MQXB) coldmasses in the final cryostat along with the correction package and instrumentation. This is scheduled for the **end of the summer. [August?]**

Schedule and Cost

The new CERN 2007 start-up schedule has shifted CERN required need dates. While this adds up to nine months potential float on the first required U.S. delivery date, maintaining the U.S. project schedule and completion by September 2005 must remain a priority.

Deliveries of CERN and KEK components appear to be under control, and there are no short-term schedule issues for Fermilab magnet production. The Fermilab project manager is working closely with CERN and KEK to track and coordinate deliveries, such as for the remaining correctors. Progress is being made on specifications and acceptance plans.

An unfavorable schedule variance has developed due to delays in the production program, but this should improve as the technical issues with production are resolved. Cumulative schedule variance for the Fermilab program remains small.

Cost variance has trended negative in the past few months, due to cold mass production labor as a result of technical issues, and additional EDIA effort needed to complete interconnect system integration tasks. Cumulative cost variance for the Fermilab program remains small.

Recommendation

1. Maintain a high level of management vigilance to keep the Fermilab program on cost and schedule.

2. Continue close interactions and support of CERN and KEK efforts.

3. Re-evaluate and optimize the overall program production schedule and end-game plan for the next DOE quarterly status review.

Brookhaven National Laboratory (BNL)

Technical Accomplishments

The five D1 magnets have been produced, four have been tested, and one is ready to ship. Six D2 magnets are complete; 2 cold masses are complete and the last one is in progress. All coils are complete. The D3 design is complete except for interface issues with CERN.

The first two D2 magnets have been tested; one has been completely tested and the second requires some re-testing with the improved cryogenic system. The D4 magnets are complete.

Magnet testing has, so far, been the major source of cost overrun at BNL. The cost model used by Brookhaven assumed three quenches per magnet. Experience indicates several more than this is required. Progress has been made in better understanding and refining the quench tests and improving the cryo test stand. At CERN's request the magnets are cooled by pool boiling helium. Because of the magnet's inability to clear the gas phase, the magnets have a low thermal margin and tend to quench early. Pool boiling tests of the D1 magnets indicated marginal cooling but they performed well without heat load from the warm bore field-measuring system. Comparison tests were performed with D2L101 with liquid helium bath cooling and no warm bore, forced flow cooling with no warm bore, and then the liquid helium bath cooling repeated. A series of 12 quenches were performed in total to train magnet. Based on these results, the cryogenic system was improved. It is expected that these changes will speed up the quench tests.

Three superconducting cable test stands are now in continuous operation. Samples tested so far have met minimum electrical requirements. On the negative side, however, the production schedule is expected to extend by approximately 12 months. Budget exposure, however, is limited for cable testing inasmuch as the plan is to test to budget.

Initial planning has been started for the LHC Accelerator Research Program. The program proposed is organized in four areas, involving the three U.S. LHC laboratories as team leaders: 1) Fermilab—developing high performance magnets for new higher luminosity Irs; 2) BNL—accelerator physics experiments and calculations; 3) LBNL—developing advanced beam diagnostics; and 4) hardware commissioning.

Schedule and Cost

Schedule and cost control continues to be problematic. Schedule variance is -$1.5 million and cost variance is approximately four percent since re-baselineing in January 2001. The primary reason is the much greater time spent in testing the magnets. Secondary contributors are higher technician construction labor and a two percent increase in fringe benefits, retroactive for FY 2002. Cable testing has a cost variance of $103.4 K, however, the schedule variance is -$268.1 K. This particular element is dependent upon deliveries of cable to CERN from their various vendors. The CERN deliveries are almost a year late at this time. The BNL cost per cable test is some 20 percent higher than their estimate but this may be due to economies of scale.

Recommendations

1. Magnet and cable testing costs and schedule needs to be closely monitored by both BNL and PMO to control costs and manage to budget to the maximum extent possible. Testing plans for the magnets needs to be re-examined to bring testing to "acceptance tests" only.

2. BNL management needs to examine its expense burn rate to ascertain when funds will be used up.

3. BNL management needs to show it is actively pursuing cost containment.

Lawrence Berkeley National Laboratory (LBNL)

Absorbers

Good progress has been made on the IR absorbers; assembly has started supported by three FTE's. Continuing lingering interface issues concerning the TAS & TAN remain to be resolved with CERN.

Since the effort was rebaselined twelve months ago, there is a positive cost variance but a large negative schedule variance (-$632 K) that originates from a six-month delay in starting assembly; this is a 25 percent reduction of what was showed at the December 2001 review. LBNL labor is available as needed. A Pre-Assembly review was held in February 2002. Preliminary assembly of the TAN has started. While this item still has float, space charges and labor cost will continue to consume funds until it is complete. Completion should be vigorously pursued.

Distribution Feedboxes (DFBX)

Real progress has been made on the feedboxes despite the six-month slip in the last six months. Major design errors were discovered during this period, very late in the project. Now the design is nearing completion; the drawing set for the entire set of feedboxes, which was expected to be complete in March 2002 has increased from 310 to 460 drawings, with the first revision complete. The U.S. LHC Accelerator project manager has added a senior Fermilab cryogenic engineer plus support staff to this task. This together with the changes made six

months ago by LBNL, adding a full-time senior project engineer, finally provides the core team that is needed to complete this task in a reasonable timeframe; this revised plan is appropriate for the complexity of the device.

Permission for the lead mass production of the 7.5 kA HTS was released to the manufacturer on May 1, 2002 and appears to be off the critical path.

Appropriately, the project continues to involve the cryogenic industry in the issue of feedbox manufacturability; the design has modified based on feedback from this process. Budgetary estimates have been received, and three interested, qualified vendors have been identified.

A new estimate-to-complete, which was to be submitted in February 2002 has now been broken into two parts. BCR-038 ($2,438 K for EDIA increase) has been submitted while the second change request for the fabrication will be submitted in November 0202 after receipt of bids. A Production Readiness Review was held May 7, 2002, a three-day working design review will be held June 18, 2002, and a second Production Readiness Review will be held in September 2002, with a success orientated goal to have the contract awarded by mid December 2002. Finalizing interfaces between project components, acceptance plan approvals, satisfying safety requirements, the procurement process, etc. all put this date at risk, as well as the CERN first article installation date. The revised target schedule is to deliver the IR 8-Left Feedbox to CERN in March 2004, with additional units about every ten weeks. The production schedule for the remainder of the feedboxes is realistic and well ahead of CERN needs.

It is highly desirable to obtain the services of a senior cryostat designer for the duration of this calendar year. As a minimum this person could be used as a "checker," an individual that verifies dimensions and ensure consistency between drawings.

The personnel requirements for DFBX procurement tracking for FY 2004 while only slightly less than shown in the December 2001 plan of two FTE's, consists of five fractionated individuals. This has been a root problem since the start of the project.

Recommendations

1. Aggressively work to shorten the absorbers' assembly schedule in order to minimize total costs. As a minimum the current baseline plan of assembly completion in March 2003 should be met.

2. Continue aggressive pursuit of the feedbox Request for Proposals (RFP) process, proceeding with the baseline plan to award a contract to a qualified vendor in December 2002.

3. Finalize the DFBX interfaces and acceptance criterion with CERN and other elements of the project. This continues to use up a significant fraction of the LBNL manpower that could be assigned to finalizing the design. The project office should try to either take over this responsibility or at least invest a major effort in accelerating the decision process.

4. Draft, as a high priority within the next two weeks, an existing Fermilab or LBNL senior cryostat designer for the duration of this calendar year.

5. Identify and assign, prior to issuing the request for proposals, two or three fundamentally full-time cryogenically-experienced individuals to aggressively deal with DFBX procurement tracking activities for FY 2003 through FY 2005. Impress upon LBNL management that it is imperative that these resources remain available as required by the project for its duration.

6. Proactively control cost and schedule. For each of the quarterly reports provide an update of the estimate-to complete.

PROJECT COST AND SCHEDULE STATUS

The U.S. deliverables include superconducting magnets and components for the interaction region final beam focus systems at LHC ring locations 1, 2, 5, and 8; beam separation dipoles for the LHC radio-frequency acceleration system at ring location 4; testing and production support for the wire and cable for the LHC main ring superconducting magnets; and a level of effort in accelerator physics. Most of the major elements of the project are now in production. The feedboxes are the only remaining items yet to start production. These are technically complex given the number of joints and welds.

The total project cost is $110 million and the project completion milestone is September 2005. As of June 9, 2002, the estimate-to-complete is $105.7 million and the project is approximately 75 percent complete. The contingency remaining is $4.3 million. As of April 30, 2002, the actual cost of work performed is $79.3 million with $23 million of work remaining. The contingency, as a percentage of the work remaining, is now roughly 16 percent. This percentage is slightly lower than that presented at the previous semi-annual reviews. The estimate-to-complete method of calculating available contingency projects a more realistic estimate of available contingency than the official baseline contingency (approximately 30 percent).

The remaining cost risk is primarily associated with potential cost growth with the distribution feedboxes program, unforeseen difficulties in magnet production including the possibility of a magnet rebuild, equipment failures with magnet test facilities, and more general schedule issues. A baseline change request was prepared to address a revised cost and schedule baseline for the feedbox program. The project office has not acted on this change based on a desire to understand more completely the most likely costs of fabrication. The Committee feels that this change should be acted on as soon as possible. Certainly the EDIA can now be addressed and the fabrication estimates should be updated to reflect the most current understanding and internal estimate of the fabrication costs. The revised baseline will enable the project to manage against a current estimate of the schedule and cost-to-complete.

There are no major schedule issues. The item with the least schedule float relative to the CERN need dates is the delivery of the first cryogenic feedbox with minimal float relative to the CERN LHC need dates. The rest of the U.S. deliverables are scheduled to arrive at CERN well

before the LHC need dates. The testing of superconducting cable at BNL is well behind the original plans due to delays in the delivery of cable from CERN. The completion of cable testing must be managed to assure that the overall project completion date of September 2005 is not impacted.

The project is approximately five months behind schedule based on the budgeted cost of work performed compared to the work scheduled. This variance is mainly due to schedule delays with the feedboxes and absorbers with some contribution from delays in magnet production at Fermilab and BNL. Milestones for required delivery dates to CERN, tied to LHC installation schedule, are current. In general, the project remains ahead of schedule for delivery of equipment to CERN by the required installation dates.

The Committee received a presentation from Tom Taylor, the CERN contact for the U.S. contribution to the LHC accelerator. Lyn Evans, LHC Director, also participated in the review. The LHC machine schedule has been revised based on a technical review of the schedule including production of superconducting cable for the main ring magnets. The new schedule calls for first beams in April 2007 with collisions and the physics program in August 2007. This schedule and the finances for the entire CERN program will be presented to the CERN Council in June 2002 for approval. Tom Taylor stated that the U.S. scope of work and schedules should not be impacted by the changes to the CERN schedules.

Completing the U.S. work scope on schedule is the most effective use of project funds. Contingency is forecast to be less than the committee and the Project Manager believe will be necessary and therefore it is essential that the Project Manager work with the three collaborating laboratories to restore contingency to at least 20 percent of the cost to go. It is recommended that the Project Manager address all pending baseline change requests and meet with laboratory managers to review project endgame plans for each laboratory. The project plan for ramping down work at each laboratory must be transparent and understood by the entire project team including senior laboratory managers. The Project Manager must control adequate contingency to address the project's remaining cost risk.

Recommendations

1. Increase the project contingency budget to at least 20 percent of the cost-to-go through cost savings and scope adjustments, where possible, and present the status of these efforts at the next quarterly status review.

2. Complete the U.S. deliverables on the baseline schedule or better, i.e., do not use the schedule float relative to the CERN schedules. Hold the overall project completion date of September 2005.

3. Review, modify as necessary, and approve pending change requests, e.g., BCR #38 by July 15, 2002.

4. Develop an endgame plan that includes specific strategies for completing work on cost at each of the three collaborating laboratories and present these plans at the next quarterly status meeting.

5. Convene the Project Advisory Group to address the project endgame plans and secure support for these plans prior to the DOE quarterly status review.

MANAGEMENT

The major challenge for PMO is to successfully complete the U.S. LHC project within budget. Given that the present level of contingency is only 16 percent and that potential significant calls on contingency exist at all three labs, this will require extremely careful management and control. At Fermilab, insulation failures have resulted in cost overruns. At BNL, magnet testing has been the major source of cost overruns. At LBNL, the DFBX has been the major source of schedule delays and cost overruns. Of the three, the DFBX at present is the greatest risk.

The PMO works on Contingency Analysis and Risk Management with all three laboratories on an ongoing basis. The generic major risk factors they have identified are delays in completing designs and starting production, late delivery of key components, unforeseen magnet production difficulties, and magnet failures. Production related risks are controlled at present, since all systems except the DFBX are in production, key components are in house, and technical problems have been successfully dealt with. In the last six months, PMO has focused on the DFBX, which is a major cost risk exposure with a BAC of $5.8 million. Recently the DFBX has been negatively impacted (an approximate three-month delay) by an error in a thermal stress analysis. This error is currently being addressed, however, there is concern that this error had not been identified in previous design reviews. A senior cryo engineer at Fermilab, Tom Peterson, has been assigned to work with Joe Rasson at LBNL to accelerate this effort. The strategy with the DFBX is to work towards completion of design, procurement, and production as rapidly as possible. A plan has been developed to release the request for proposals in September, sign the contract in CY 2002, and deliver the first box to CERN by March 2004.

One problem area PMO identified is interfaces with CERN. In some cases, CERN has made changes to approved specifications that required significant design changes that incurred additional costs. In other cases, information required is not available on a timely basis. The PMO has tried unsuccessfully to rectify this; consequently, their plan is to ship components to the formerly agreed upon specification unless offset funding is provided.

Recommendations

1. It is absolutely essential that the U.S. LHC project be successfully completed on budget. Develop a plan to accomplish this in conjunction with the laboratory directors of all three laboratories by the next quarterly review.

2. Discuss the CERN interface issues with the highest levels of CERN management to develop a more satisfactory resolution to this problem by September 2003.

ACTION ITEMS

1. Conduct a Quarterly Status Review of the U.S. LHC Accelerator Construction and present the end-game plan on September 18, 2002.

2. Conduct a full review of the U.S. LHC Construction Project on January 21-22, 2002.