US LHC ACCELERATOR PROJECT

brookhaven - fermilab - berkeley

US LHC Accelerator Project

Jim Strait
Fermilab

DOE Review

15 October 2003

Outline

Project Technical and Schedule Status
Revised Delivery Milestones
Cost and Schedule Performance
EAC and Contingency Analysis
Expected Subproject Completion
Issues

Appendices:
Responses to February Review Recommendations
Table of Milestones

US LHC Accelerator Project

IR Final Focus Systems: Points 1, 2, 5, 8

- –US-built quadrupoles (FNAL)
- –Japanese-built quadrupoles (KEK)
- –CERN-provided correctors
- –Cryostats for all quadrupole assemblies (FNAL)
- –US-built beam separation dipoles (BNL)
- –US-built IR feed boxes (LBNL)
- –US-built specialized absorbers (LBNL)

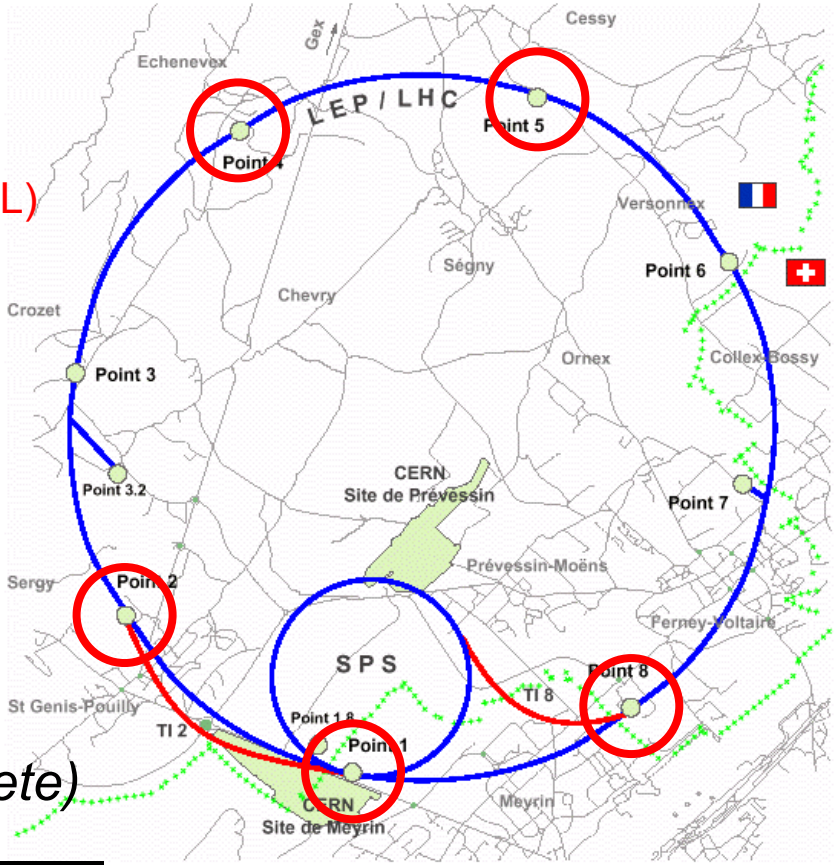
RF Region: Point 4

- –Beam separation dipoles (BNL)

Wire and Cable for Main Magnets:

- –Measurement of SC wire & cable (BNL)
- –Cable production support (LBNL - complete)

Accelerator physics (all 3 labs - complete)



Project management and oversight (FNAL)

US LHC Accelerator Project Status

IR Quadrupoles

IR Quadrupoles are well into production.

- 3 of 9 Q2 (2 MQXB magnets + CERN corrector) are complete.
  - First is ready to ship, pending CERN acceptance formalities.
- Third Q2 is being prepared for testing.
- 6 more MQXB complete . . . 12 of 18 total.
- 14 of 18 KEK quads (MQXA) complete . . . 5 MQXA at FNAL.
- Correctors now arriving from CERN – but we still project this to be the critical path.

BUT…

- One MQXB in Q2#2 fails to reach operating gradient (the other reaches the goal of 230 T/m without quenching).
  - *Looks like damaged superconductor, but cause is not known.*
  - *Location known within a few cm.*

US LHC Accelerator Project Status
IR Quadrupoles (continued)

Current plan:

1) Test Q2#3.
2) Disassemble Q2#2 to assess cause of fault (under consideration).
3) Pause assembly of FNAL magnets.
4) Proceed with cryostating of KEK magnets.

Potential impact of magnet fault:

- $0.3~0.45M depending on repair and retest strategy.
- ≤ 2 months schedule delay.
  All deliveries still ahead of installation schedule requirements.

. . . Assuming that this is a one-time fault.

US LHC Accelerator Project Status

Beam Separation Dipoles

Beam separation dipoles far into production.

D1 - 4 of 5 D1's are at CERN.
- 5th requires a re-test to verify quench heater integrity.

D2 - Construction of all 9 D2's is complete.
- 8th is being tested; first being readied to ship.

D4 - 1 of 3 D4's is complete.
- Other 2 cold masses are complete; one is being cryostated

D3 - 6 of 6 cold masses (2 per cryostat) are nearly complete.

Dipole production will be complete by the end of the year.

Dipole testing will be complete by June 2004.

Last dipole to be shipped by early 2005 (limited by round-trip time of 3 special shipping containers).

US LHC Accelerator Project Status
IR Feed Boxes and Absorbers

DFBX Production moving forward well.

- Production proceeding well at Meyer Tool . . . No significant issues.
- All HTS leads are at FNAL:
  - 8 of 20 pairs cold tested – 2 problems found;
    plus 3.5 pairs have failed warm tests.
  - Pirelli to visit FNAL in November to assess repairs.
- Vapor cooled leads are in production.
  - 1st set is at Meyer Tool; last set to be delivered by December.
- Lab-built subassemblies to be done this year.
- On schedule to meet installation schedule requirements.

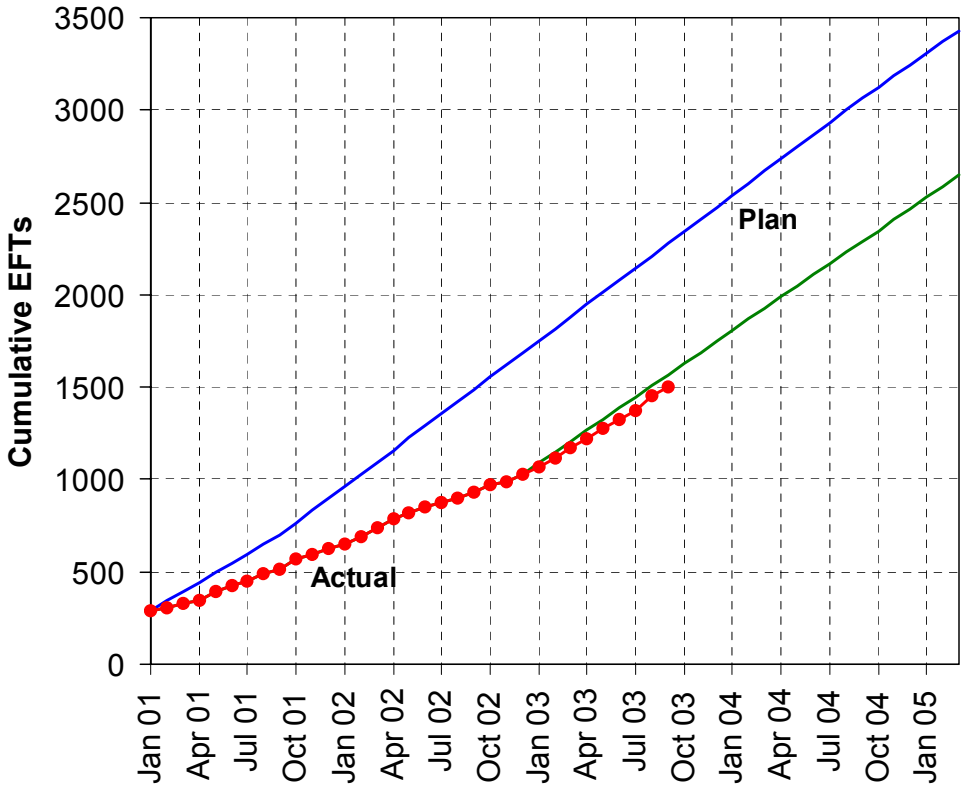
IR Absorbers production assembly nearing completion.

- 4 of 4 TAS are at CERN.
- 2 of 4 TAN is complete.
- Expect to ship all 4 TAN by end of the year => done.

US LHC Accelerator Project Status
Superconductor Testing

Production SC cable testing continues.

- Sample rate from CERN for past 6 months has been ~90% of planned rate. . . 115% in August.
- BNL testing is keeping up with CERN sample delivery.
- Test program is now tracked as a level-of-effort task.
- We will test as many samples as possible between now and March 2005 using the existing resources.



US LHC Accelerator Project Status
Schedule Summary

Schedule situation is becoming a concern . . . vigilance is required:

- Overall the project remains ~5 months behind our schedule.
- We remain ahead of schedule for installation in LHC.
  - Dipoles and absorbers are well ahead of CERN need dates.
  - Must watch quadrupole production:
    - Corrector deliveries are critical path.
    - 2-3 month float for first quad deliveries to CERN;
    - ~ 2 months float for final delivery to CERN.
    - Impact of recent quad test results is small (assuming it is a one time fault).
  - Must continue to watch feedbox production:
    - Typically 1-2 month float for most deliveries to CERN;
    - < 2 months float for final delivery to CERN.

Revised Delivery Milestones

CERN Delivery Milestones

A set of milestones is contained in the Implementing Arrangement, which specify when CERN needs sets of components for installation.

- Current set is based on obsolete installation schedule and must be updated to the current version (rev 1.7).
- Installation periods for the IRs on the current schedule are rather uncertain.
  => The new milestones will be 7 months before the start of hardware commissioning of each sector, whose dates are more certain.
- A change request is being prepared to update the CERN milestone table.

IR	Req'd Delivery
8L	24-Sep-04
2R	29-Oct-04
8R	11-Mar-05
1L	11-Mar-05
4R	22-Jul-05
5L	22-Jul-05
4L	23-Sep-05
5R	6-Jan-06
1R	9-Jun-06
2L	9-Jun-06

Delivery Milestones and Project Completion

DOE Milestones

Currently there is a set of Level 2 Project milestones that are identical to the CERN list.

- Project completion is defined by achieving these milestones.
- Three CERN milestones are after our end-of-project milestone of 30 Sep 2005.
- Any further delays in corrector deliveries will jeopardize our ability to deliver last quads by 30 Sep 2005.

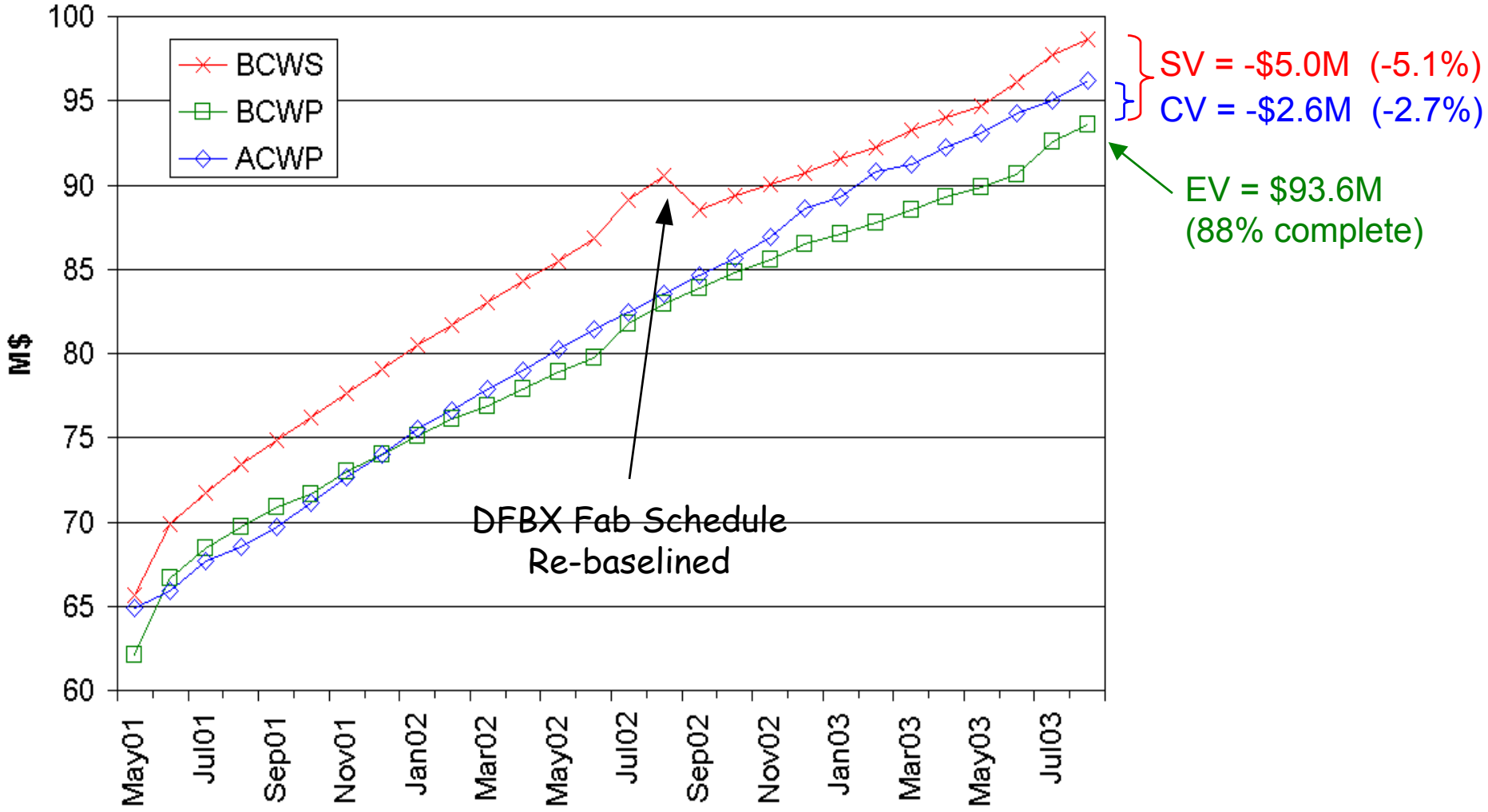
=> Break the tie between CERN and DOE milestones.

- New Level 2 milestone list to be defined by readiness to ship.
- BCR is being prepared to codify this.

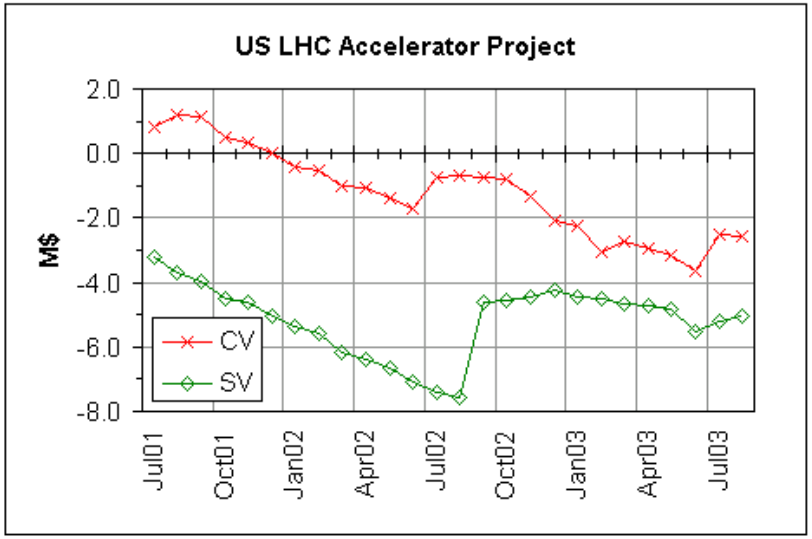
IR	Ready to Ship
8L	10-Aug-04
2R	14-Sep-04
8R	25-Jan-05
1L	25-Jan-05
4R	7-Jun-05
5L	7-Jun-05
4L	9-Aug-05
5R	30-Sep-05
1R	30-Sep-05
2L	30-Sep-05

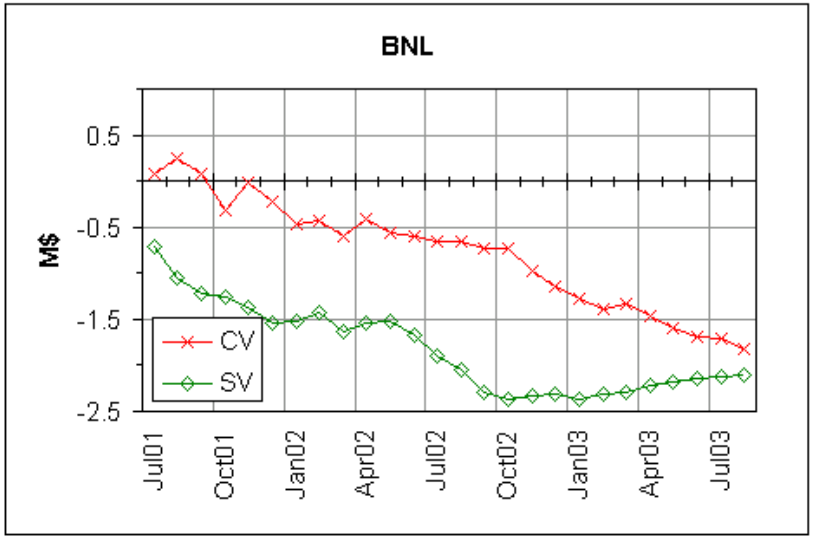
Cost and Schedule Performance

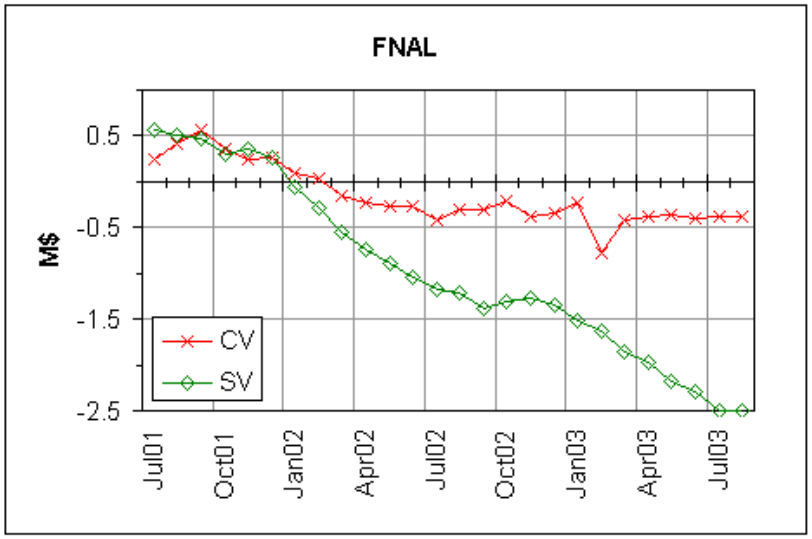
through August 2003

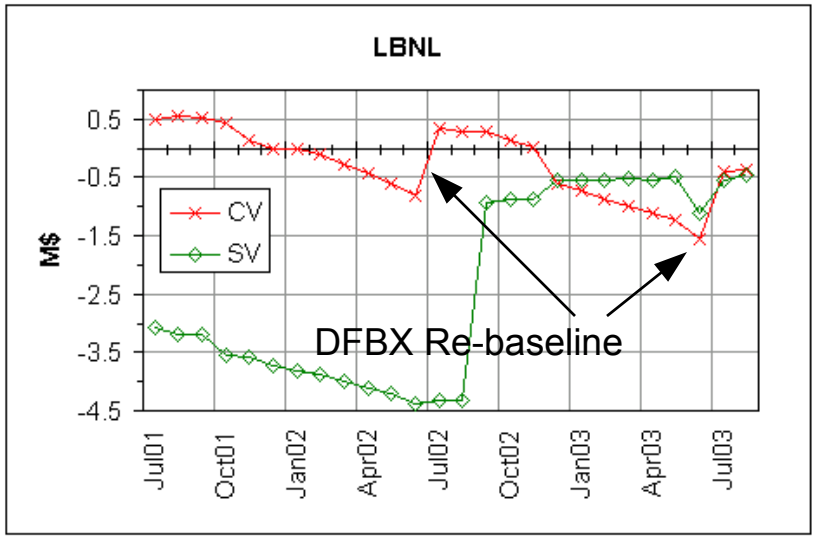


Cost and Schedule Performance









Cost and Schedule Performance

Principal causes of unfavorable cost trends:

- Magnet testing and acceptance effort at BNL.
- Higher than budgeted cost per SC cable test.
- Modest negative variances in FNAL quad production and testing.
- Partially offset by positive variances in DFBX fabrication and Project Management costs.

Principal causes of schedule trends:

- Slow delivery of correctors from CERN to Fermilab.
- Less than baseline rate for SC testing at BNL.
- Modest time delays in major DFBX milestone invoices.
- Partially offset by positive variances in dipole fabrication.

EAC and Contingency

Full review of Estimate at Completion (EAC) conducted by PMO with each lab during June and July, based on:

- Past cost experience.
- Known changes in effort required to complete planned work.
- Effect of schedule delays.
- Expected adjustments in work scope.

Also estimated needed contingency.

- Evaluated for each task at the cost accounting level or below.
- Includes uncertainty in EAC + allowance for "unplanned events."

Adjustments made for recent events:

- Need to rebuild 2nd IR quadrupole.
- Need to retest 5th D1 dipole.
- Additional D1 and D3 dipole parts fabrication.

Adjustments made for cost savings agreed by all 3 Labs.

Baseline Budget Changes

BAC as of Feb 03 Review		$105,741k
BCR 50 (change D3/D4 aperture separation)	+$136k	$105,879k
BCR 52 (FNAL to build DFBX instr. ducts)	+$76k	$105,954k
BCR 54 (increase dipole testing)	+$435k	
(offsetting cable test reduction)	-$435k	$105,954k
BCR 53 (Q3 configuration change)	$144K	
(offsetting cable test reduction)	-$144k	$105,954k
BCR 51 (rebaseline DFBX fabrication at LBNL)	$0k	$105,954k
(-$60k fab+shipping, +$60k EDIA)		
BCR 56 (Absorber fab. budget increase)	+$284k	$106,238k

BAC and EAC Changes Since February Review

		Baseline Budget				Estimate at Completion		
		Feb 03	Oct 03	Change		Feb 03	Oct 03	Change
1.1.1 + 1.1.5	IR Quads	28,818	28,933	116		29,279	29,597	318
1.1.2 + 1.2.1	Beam Sep Dipoles	20,177	20,643	466		21,084	22,232	1,148
1.1.3	DFBX	8,482	8,850	368		8,842	8,915	73
1.1.4	Absorbers	4,320	4,558	238		4,436	4,558	122
1.3.1	SC Testing	9,910	9,441	-469		9,414	8,726	-688
1.3.2	Cable Prod Support	936	936	0		947	936	-11
1.4	AP	2,626	2,626	0		2,627	2,625	-2
1.5	PM	10,746	10,746	0		10,780	10,597	-184
	G&A+Overhead	19,726	19,505	-222		19,647	19,776	129
	Total	105,741	106,238	497		107,056	107,961	905

2 BCRs in preparation will capture most of EAC increase over BAC:

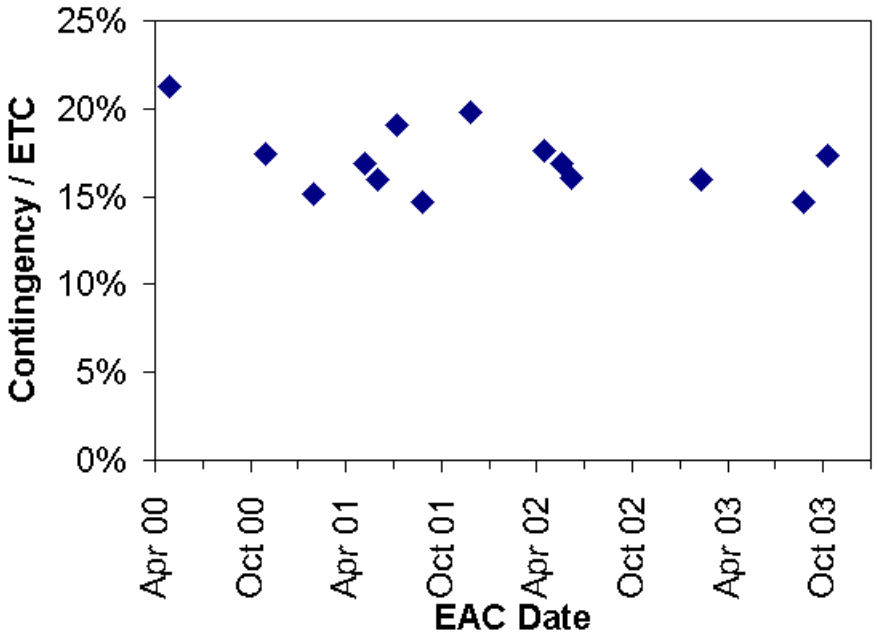
- BCR 55 – re-baseline BNL program
- BCR 59 – re-baseline FNAL program

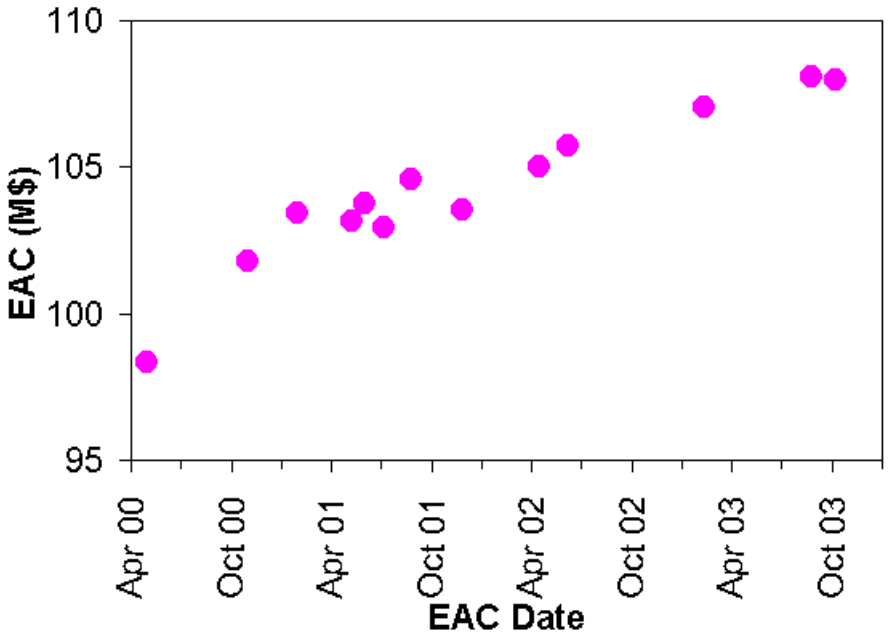
Remainder is impact of failed quad – to be handled by separate BCR.

EAC and Contingency History

	As of 31 Aug 03			Contingency Rqd		10Oct03	27Aug03	12Feb03	9Jun02	22May02
	BCWP	ACWP	BAC	K$	%		EAC	EAC	EAC	EAC
BNL	39,217	41,032	43,870	836	20%	44,941	44,823	44,434	44,469	44,469
FNAL	36,613	36,994	42,001	1,179	22%	42,653	42,617	42,353	41,720	41,150
LBNL	17,775	18,141	20,367	269	10%	20,367	20,651	20,268	19,559	19,963
Total	93,605	96,167	106,238	2,284	19%	107,961	108,091	107,056	105,748	105,582
TPC			110,000			110,000	110,000	110,000	110,000	110,000
%compl	88%	89%								
Contingency (TPC-EAC)						2,039	1,909	2,944	4,252	4,418
ACWP as of end of previous month						96,167	95,059	88,572	79,340	79,340
Cost to go (EAC - ACWP)						11,794	13,031	18,484	26,408	26,243
Congingency as a fraction of:										
Cost to go (EAC - ACWP)						17%	15%	16%	16%	17%
Required contingency in dollars						2,161	2,334	3,347	4,789	4,789
Rqd ETC reduction for 19% conting						122	425	403	537	372

EAC and Contingency History





Contingency computed from EAC continues to be in the 15-20% range.

- Accomplished through active management, with support of top management of all 3 U.S. Labs.
- Cost of rebuilding Q2 is included, but further evaluation is on-going.
- Have utilized agreement with CERN that changes generated by them must be offset by cost reductions elsewhere.

Contingency Need Analysis

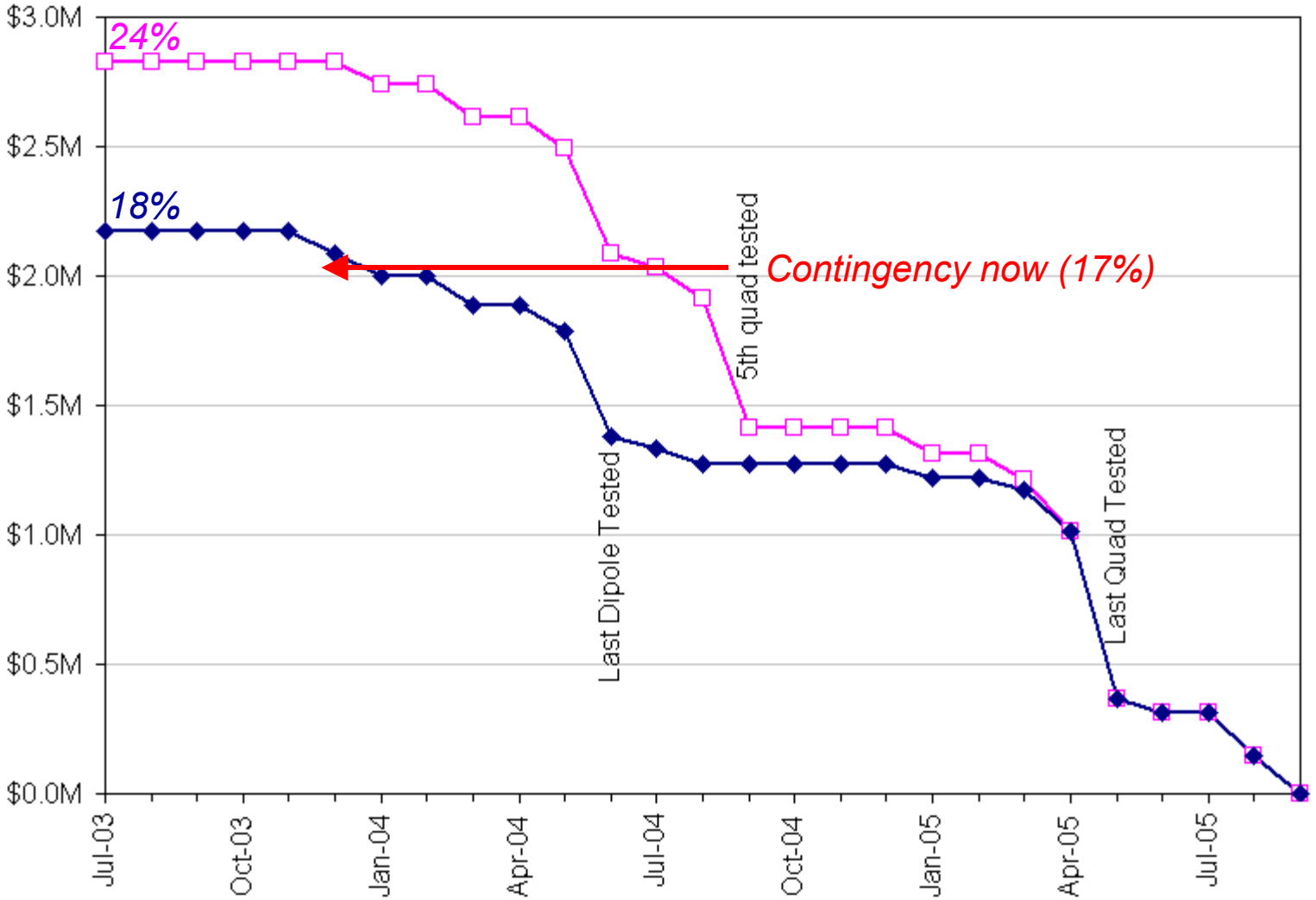
Risk Analysis Performed:

- List all plausible things that can go wrong, with associated cost.
- Determine time up to which contingency must be held against event.
- Apply judgment as to how many risks must be added linearly to determine required contingency fund.
- Example for quad program:

Program Element Event	Weight	Cost		Hold until…	Comments
1.1.1 + 1.1.5 IR Quads					
Unweighted sum			$1,625k		
Suggested contingency reserve			$1,038k		
Tooling failure	1	$50k		Apr-05	End of cryostat assembly
Minor assembly process failure	1	$50k		Apr-05	End of cryostat assembly
Major assembly process failure	0	$500k		Aug-04	Covered by "magnet rebuild" risk
Run out of cable	1	$100k		Feb-04	Completion of cold mass assembly
Substantial corrector delay	0.5	$100k		Dec-04	Assume at most one of these happens
Test system problems	0.5	$75k		Mar-05	
Slow quench training	1	$50k		Apr-05	Completion of cold testing
Magnet fails to meet acceptance criteria - accepted	1	$50k		May-05	
Magnet rebuild	1	$500k		Apr-05	
Magnet damage during shipment	1	$100k		Aug-05	Last magnet at CERN
Extended process to approve acceptance specs	1	$50k		Aug-05	

Contingency Need Analysis

Contingency required to cover plausible future problems.



Expected Subproject Completion
Dipoles

Remaining work:

- D1: Retest and ship the 5th (last) one.
- D2: Test last 2; attach QQS modules to 5; ship all 9.
- D4: Complete assembly, test and ship all 3.
- D3: Complete assembly, test and ship all 3.

- Production complete this year.
- Testing complete mid-2004.
- All deliveries expected well before CERN delivery milestones. . . Last shipment in early 2005.

Expected Subproject Completion
Quadrupoles

Quadrupoles are currently 9~11 months behind schedule.

- Still being delayed by slow deliveries of CERN correction coils.
- Production plan adjusted to minimize impact.
- Adding modest-cost cryostat tooling to maximize production rate.
- Simplifying test plan to minimize testing time.
- KEK quadrupole production rate => not a limiting factor.

Baseline schedule final deliveries to CERN:

Q2 = May 2004 -> July 2005

Q1/Q3 = September 2004 -> August 2005

Corrector + quad production schedules are consistent with new CERN delivery milestones . . . but just barely.

Expected Subproject Completion
Absorbers and Feedboxes

Absorber work nearing completion.

Expect to ship all absorbers to CERN by December 2003.

Feedbox fabrication proceeding on or ahead of schedule:

- First box complete April 2004.
- Ship first pair of boxes by August 2004.
- Ship last pair of boxes by July 2005.
- All shipments are consistent with need dates for LHC installation.

Project Completion Schedule Summary

- Large float relative to Project Completion milestone (30 Sep 05) exists for dipoles and absorbers.
- Cable testing will continue at maximum possible rate through March 2005.
- Minimal float for shipping of last quadrupole relative to Project Completion milestone.
  => aggressive monitoring of CERN corrector testing, and high priority to FNAL quad testing will be required.
- Minimal float for shipping of last DFBX with respect to Project Completion milestone.
  => aggressive monitoring and timely support of vendor will be required.
- Project completion to redefined to be based on readiness to ship, providing $1\frac{1}{2}$ months additional float w.r.t 30 Sep 2005.

Issues

CERN-induced cost pressures: "scope creep."

- We push back:
  - Accept minimum additional work consistent with LHC performance requirements.
  - Require additional work to be balanced by other scope reductions.
    - … SC cable test duration has been the main "fly wheel."
- Have started discussions with CERN about possible use of "CERN Direct" funds to cover some costs to U.S. labs.

CERN-induced schedule pressure: Slow delivery of correctors.

- We are pressing CERN to test rapidly.
- We plan to be able to use correctors immediately as they arrive.
- We are redefining the end of project milestones.

Issues

Internal cost pressures

- Local management at each lab is committed to manage to the agreed cost.
- A series of Baseline Change Requests (BCR) is in process to convert the individual lab EAC's to baseline budgets, which will define the remaining funding to be provided to each lab.
  - Process is complete for LBNL.
  - BCR 55 for BNL has been submitted to the PMO.
  - BCR 59 for FNAL is in preparation.
- Contingency will be allocated only for approved work scope changes.

Main technical issue is poor performance of 4th FNAL quad.

- Not believed to be a systematic problem.
- Next quad is on the test stand.

US LHC Accelerator Project Summary

- Technical progress is excellent, except for Q2 problem.
- Schedule is becoming a minor issue.
- Cost and contingency situation continues to require serious attention and action.

- Excellent and constructive working relations continue with CERN (and KEK).

- We remain fully committed to deliver on our commitments to CERN
  Full technical performance,
  On time,
  Within our budget,
  and every action is and will be taken to ensure success.

Appendix 1:
Response to Feb DOE Review Recommendations

IR Quadrupoles (WBS 1.1.1)		
1	Continue efforts to reduce the length of the magnet cold tests.	We are discussing with CERN the possibility of reducing the cold test to one thermal cycle. This would save two to three weeks.
2	Develop criteria, approved by CERN, by the end of March for acceptance of the Fermilab built magnets.	Acceptance criteria has been developed through several interations via meetings and e-mail exchanges with CERN. The resulting magnet acceptance plan has been submitted to CERN for formal approval and release.
3	Resolve the issue of the MQSXA placement by the end of March	The placement has been resolved. The a3-a4-b4 windings will be removed from the MQSXA corrector and mounted on the end of the MCBXA at the non-IP end of Q3.

Response to Feb DOE Review Recommendations

IR and RF Region Dipoles (WBS 1.1.2 and 1.2.1)		
1	The Project Management Office shall continue to work with CERN to develop standardized, agreed upon acceptance tests and documentation requirements by the end of March.	Agreement with CERN has been reached on the acceptance specifications for the D1 and D2 dipoles. The respective acceptance specification documents have been released in the CERN EDMS. The D4 acceptance specification will be essentially identical to D2,
2	The Project Management Office and CERN shall decide if quench tests should be performed on the three D2 magnets, for which no quench tests are currently planned, by the end of March.	We have agreed with CERN to quench test all D2 magnets.
3	The Project Management Office and CERN shall decide if minimum warm/cold correlation confirmation tests should be performed by the end of March.	We have agreed with CERN to do a minimal set of cold field measurements on all subsequent magnets, which will firmly establish warm-cold correlations.
4	Resolve and finalize the D3 interface specifications with CERN by the end of March.	The D3 Cooling Specification and D3 Interface Specification have been submitted to the CERN EDMS for formal review and approval.

Response to Feb DOE Review Recommendations

IR Feedboxes (WBS 1.1.3)		
1	Continue aggressive pursuit of the feedbox contract; the Best and Final Offer should include: - The latest set of drawings and specifications, - Revision to the delivery schedule to reflect shipping milestone date from the vendor to CERN, - Break-out prices for shipping via airfreight and ocean transport, - Removal of the Liquidated Damages provisions, - Addition of an Availability of Funds clause based on current funding profile.	The contract was awarded on March 27, 2003 with all the recommended provisions included.
2	Provide technical support to the vendor after award to maintain the schedule (and vendor efficiency).	We are in constant technical contact with the vendor. A weekly teleconference is conducted with the vendor by Fermilab and LBNL engineers where status is reviewed and vendor questions are addressed. A senior crygenics engineer from Fermilab visits the v

Response to Feb DOE Review Recommendations

IR Feedboxes (WBS 1.1.3)		
3	As currently planned, deliver the government furnished equipment (GFE) this fiscal year.	Major GFE items have begun to arrive at the vendor well in advance of the need date. The compete set of GFE is expected to reach the vendor by the end of 2003.
4	Finalize the DFBX acceptance criterion with CERN by end of April 2003.	Not done yet.
5	Identify and obtain Project Management Office and Laboratory management buy in, prior to issuing the award, for two or three fundamentally full-time cryogenically experienced individuals to aggressively deal with DFBX procurement tracking activities for p	LBNL has committed its DFBX project engineer and lead engineer, both of whom have cryogenic experience, to follow the DFBX procurement though completion. They will be supported by a designer at LBNL, and a senior cryogenic engineer and cryogenic designer

Response to Feb DOE Review Recommendations

Cost and Schedule		
1	Develop a minimum project contingency budget in dollars as a function of time for duration of the project by April 1, 2003. Once this minimum is reached; scope reductions would be required.	Contingency need, based on a risk analysis, is currently estimated at $2171K. Contingency available, after accounting for the cost of rebuilding the second Q2 quadrupole, is $2039k. Several actions are being evaluated to bring the contingency available in line with the need.
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.	We continue to hold the overall project completion date at September 30, 2005. All deliverables are scheduled to arrive at CERN ahead of the required dates based on the installation schedule. We continue to use schedule flexibility to minimize cost.
3	Ensure all Project Advisory Group members address the project endgame plans and secure support for these plans prior to the next DOE review.	The project end game has been discussed with PAG members individually and in meetings of the PAG (limited to the members from the 3 US LHC labs). There is fundamental agreement and support by all on the end game plan.

Response to Feb DOE Review Recommendations

Management		
1	Develop a minimum project contingency budget in dollars as a function of time, for duration of the project, by April 1, 2003. If this minimum is reached, scope reductions would be required.	Same as Cost and Schedule #1.
2	Continue to keep the three laboratory directors briefed quarterly of the remaining contingency status. It is absolutely essential that the U.S. LHC project be successfully completed on budget.	The Project Advisory Group met on 30 July 2003. The cost and contingency situation was discussed, as well as methods to control costs for the remainder of the Project.
3	Resolve with the highest levels of CERN management the documentation deliverables to facilitate smoother acceptance procedures by end of March 2003	The US PM has met on several occasions with the CERN LHC Project Leader to discuss the impact on the US Project of changes in interfaces and other requirements on our ability to complete the agreed upon work within budget. Specific issues addressed in th

Appendix 2:
Table of Controlled Milestones

US LHC Accelerator Project Controlled Milestones

Status Date: 3 Oct 2003

US LHC Accelerator Project Level 1 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
1 - 1		Project Start	1 Oct 1995		1 Oct 1995
1 - 2 C		Decision as to whether or not the U.S. Project includes RF region quadrupoles	1 Jul 2001		20 Jun 2001
1 - 3		Project Completion	30 Sep 2005	30 Sep 2005	

Table of Controlled Milestones

US LHC Accelerator Project Level 2 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
		WBS 1.1 Interaction Regions			
2 -1.1- 1		Begin 1st inner triplet quadrupole model magnet	1 Jul 1997		1 Jul 1997
2 -1.1- 2		Complete inner triplet quadrupole model magnet program phase 1	1 Dec 1999		28 Sep 1999
2 -1.1- 3		Complete inner triplet quadrupole model magnet program phase 2	1 Mar 2000		17 Mar 2000
2 -1.1- 4		Place purchase order for HTS power leads	1 Feb 2000		30 Aug 2000
2 -1.1- 5		Begin absorber fabrication	1 Nov 2000		30 Oct 2000
2 -1.1- 6		Complete inner triplet quadrupole prototype magnet program	1 Oct 2001		31 Aug 2001
2 -1.1- 7		Begin interaction region beam separation dipole production assembly	1 Oct 2000		25 Jul 2000
2 -1.1- 8		Begin inner triplet feedbox fabrication	1 Mar 2001		27 Mar 2003
2 -1.1- 9		Begin inner triplet quadrupole production assembly	1 Nov 2001		1 May 2001
2 -1.1- 10		Complete 1st inner triplet quadrupole magnet	1 Sep 2002		11 Mar 2003
2 -1.1- 12		Complete inner triplet feedbox fabrication	31 Aug 2005	31 Aug 2005	
2 -1.1- 13a C		Delivery of inner triplet magnets for IR8 left (MQX, D1, D2)	19 Dec 2003	31 May 2004	
2 -1.1- 13b C		Delivery DFBX for IR8 left	13 Aug 2004		
2 -1.1- 15		Complete absorber fabrication	1 Feb 2003	31 Jan 2004	
2 -1.1- 16a C		Delivery of inner triplet magnets for IR8 right (MQX, D1, D2)	8 Oct 2004		
2 -1.1- 16b C		Delivery DFBX for IR8 right	25 Feb 2005		
2 -1.1- 18		Complete interaction region beam separation dipole production assembly	1 Apr 2003	14 Jan 2004	
2 -1.1- 19a C		Delivery of inner triplet magnets and absorbers for IR1 left (MQX, D2, TAS, TAN)	6 Aug 2004		
2 -1.1- 19b C		Delivery of DFBX for IR1 left	25 Feb 2005		
2 -1.1- 23a C		Delivery of inner triplet magnets and absorbers for IR5 left (MQX, D2, TAS, TAN)	31 Aug 2005		
2 -1.1- 23b C		Delivery of DFBX for IR5 left	31 Aug 2005		
2 -1.1- 25a C		Delivery of inner triplet magnets and absorbers for IR5 right (MQX, D2, TAS, TAN)	29 Apr 2005		
2 -1.1- 25b C		Delivery of DFBX for IR5 right	31 Aug 2005		
2 -1.1- 26a C		Delivery of inner triplet magnets for IR2 right (MQX, D1, D2)	30 Apr 2004		
2 -1.1- 26b C		Delivery of DFBX for IR2 right	1 Oct 2004		

Table of Controlled Milestones

US LHC Accelerator Project Level 2 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
	WBS 1.2 RF Region			
2 -1.2- 1	Begin assembly of 1st dipole model magnet	1 Sep 1999		10 Jun 1999
2 -1.2- 2	Complete dipole model magnet program	1 Aug 2000		8 Nov 2000
2 -1.2- 3	Begin RF region beam separation dipole production assembly	1 Jan 2002		3 Dec 2001
2 -1.2- 4 C	Delivery of D3, D4 for IR4 right	24 Jun 2005		
2 -1.2- 5	Complete RF region beam separation dipole production assembly	1 Sep 2003	1 Jun 2004	
2 -1.2- 6 C	Delivery of D3, D4 for IR4 left	31 Aug 2005		
2 -1.2- 7	RF Region task complete	30 Sep 2005		
	WBS 1.3 Superconducting Wire and Cable			
2 -1.3- 1	All cable production support equipment delivered to CERN	1 Sep 1999		28 May 1999
2 -1.3- 2	Complete SC testing facility upgrades	1 Jun 1999		30 Sep 1999
2 -1.3- 3	Series wire and cable testing complete	31 Mar 2005	31 Aug 2005	
2 -1.3- 4	Superconducting Wire and Cable task complete	30 Sep 2005		

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
		WBS 1.1.1 Interaction Region Quadrupoles			
3 -1.1.1- 1		Inner triplet quadrupole (MQX) cold mass conceptual design review	15 Oct 1996		15 Oct 1996
3 -1.1.1- 2		Begin 1st quadrupole model magnet	1 Jul 1997		1 Jul 1997
3 -1.1.1- 3		Quench heaters for model magnet program phase 1 delivered, LBNL to FNAL	1 Jun 1998		1 Jun 1998
3 -1.1.1- 4		Cable and wedges for model magnet program phase 1 delivered, LBNL to FNAL	1 Jun 1998		1 Jun 1998
3 -1.1.1- 5		MQX cryostat conceptual design review	15 Dec 1998		21 Jan 1999
3 -1.1.1- 6a	C	MQXB to LQX Cryostat Interface Specification approved	15 Oct 2000		11 Jul 2001
3 -1.1.1- 6b	C	MQXA to LQX Cryostat Interface Specification approved	1 Jan 2001	1 Feb 2004	
3 -1.1.1- 7		Complete model magnet program phase 1	1 Sep 1999		28 Sep 1999
3 -1.1.1- 8		Cable and wedges for model magnet program phase 2 delivered, LBNL to FNAL	1 Mar 1999		15 Jun 1999
3 -1.1.1- 10a	C	MQXB Functional Specification approved	15 Oct 2000		23 Apr 2001
3 -1.1.1- 10b	C	LQX Functional Specification approved	1 Dec 2000		4 Jun 2002
3 -1.1.1- 10c	C	TAS2/3 Functional Specification approved	1 Dec 2000	1 Feb 2004	
3 -1.1.1- 11	C	Inner Triplet Corrector Interface Specification approved	15 Oct 2000		28 Aug 2002
3 -1.1.1- 12	C	Inner triplet compensation and correction scheme approved	1 Jul 1999		7 Mar 2000
3 -1.1.1- 13		Start production of cable and wedges for prototype and production MQXB	1 Jan 2000		29 Feb 2000
3 -1.1.1- 14		Complete model magnet program phase 2	1 Dec 1999		17 Mar 2000
3 -1.1.1- 15	C	LQX Tunnel Installation and Alignment Specifications approved	1 Jun 2001	1 Feb 2004	
3 -1.1.1- 16a	C	LQX (Q3) to DFBX Interface Specification Approved	15 Oct 2000		13 Jul 2001
3 -1.1.1- 16b	C	LQX Cold Bore Tube Interface Specification Approved	1 Jan 2001	1 Feb 2004	
3 -1.1.1- 16c	C	LQX to BPM Interface Specification Approved	1 Apr 2001	1 Feb 2004	
3 -1.1.1- 16d	C	LQX to LQX Interface Specification Approved	1 Jun 2001	1 Feb 2004	
3 -1.1.1- 16e	C	LQX (Q1) to Warm Beam Vacuum Interface Specification Approved	1 Jun 2001	1 Feb 2004	
3 -1.1.1- 17a		MQX Cold Mass Engineering Design Review	1 Apr 2000		13 Apr 2000
3 -1.1.1- 17b		MQX Cryostat Engineering Design Review	1 Nov 2000		7 May 2001
3 -1.1.1- 19		Complete prototype magnet program	15 Jul 2001		31 Aug 2001

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
		WBS 1.1.1 Interaction Region Quadrupoles			
3 -1.1.1- 20		MQX Production Readiness Review	15 Jul 2001		27 Mar 2002
3 -1.1.1- 21		Begin assembly of first MQXB	15 Jul 2001		1 May 2001
3 -1.1.1- 22		Complete production of cable and wedges for production MQXB	1 Jul 2001		12 Apr 2002
3 -1.1.1- 23	C	Delivery to FNAL of 1st MQXA	1 Mar 2002		7 Mar 2002
3 -1.1.1- 24	C	Delivery to FNAL of 1st correction coil	1 Nov 2001		22 Jan 2002
3 -1.1.1- 25		Begin assembly of first MQXA	1 Aug 2002	1 Dec 2003	
3 -1.1.1- 26		IR8 left MQX ready to deliver	1 Mar 2003	1 May 2004	
3 -1.1.1- 27		IR8 right MQX ready to deliver	1 Jul 2003	31 Aug 2004	
3 -1.1.1- 28		IR1 left MQX ready to deliver	1 Nov 2003		
3 -1.1.1- 29		IR1 right MQX ready to deliver	1 Dec 2003		
3 -1.1.1- 30		IR5 left and right MQX ready to deliver	1 Apr 2004		
3 -1.1.1- 31		IR2 left and right MQX ready to deliver	1 Aug 2004		
3 -1.1.1- 32		All spare MQX ready to deliver	1 Sep 2004		
3 -1.1.1- 33		Interaction Region Quadrupoles task complete	30 Sep 2005		

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
		WBS 1.1.2 Interaction Region Dipoles			
3 -1.1.2- 1		Beam Separation Dipole Conceptual Design Review (see Note 2)	1 Aug 1998		16 Jul 1998
3 -1.1.2- 2	C	D1,D2 field quality specifications approved	1 Feb 1999		10 Jun 1999
3 -1.1.2- 3a	C	Beam separation dipole functional specification approved	1 Jul 2000		15 Jun 2000
3 -1.1.2- 3b	C	D1 interface specification approved	1 Aug 2000		14 Feb 2001
3 -1.1.2- 3c	C	D2 interface specification approved	15 Sep 2000		31 Jan 2001
3 -1.1.2- 4		Superconducting wire for IR dipoles delivered by LBNL to BNL	1 Feb 2000		1 Oct 1999
3 -1.1.2- 5a		D1 engineering design review complete	15 Apr 2000		19 Sep 2000
3 -1.1.2- 5b		D2 engineering design review complete	15 Sep 2000		19 Sep 2000
3 -1.1.2- 6a		D1 production readiness review complete	1 Nov 2000		11 Dec 2000
3 -1.1.2- 6b		D2 production readiness review complete	1 Nov 2000		11 Dec 2000
3 -1.1.2- 7a	C	Delivery by CERN to BNL of all CERN-provided D1 parts	1 Dec 2000		31 Jan 2001
3 -1.1.2- 7b	C	Delivery by CERN to BNL of all CERN-provided parts for first D2	1 Aug 2000		31 Jan 2001
3 -1.1.2- 8a		D2 1st issue production start	6 Jul 2000		25 Jul 2000
3 -1.1.2- 8b		D2 series production start (balance)	17 Jan 2001		17 Jan 2001
3 -1.1.2- 9		D2 series production complete	1 Jan 2003	14 Jan 2004	
3 -1.1.2- 10		D1 production start	9 Oct 2000		10 Oct 2000
3 -1.1.2- 11		D1 production complete	1 Apr 2002	1 Apr 2004	
3 -1.1.2- 12		Interaction Region Dipole task complete	30 Sep 2005		

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.2.1 RF Region Dipoles				
3 -1.2.1- 1		Beam Separation Dipole Conceptual Design Review	1 Aug 1998		16 Jul 1998
3 -1.2.1- 2 C		D3,D4 field quality specifications approved	1 Feb 1999		10 Jun 1999
3 -1.2.1- 3a C		Beam separation dipole functional specification approved	1 Jul 2000		15 Jun 2000
3 -1.2.1- 3b C		D4 interface specification approved	31 Dec 2001		12 Aug 2002
3 -1.2.1- 3c C		D3 interface specification approved	15 Mar 2002	15 Dec 2003	
3 -1.2.1- 4		Superconducting wire for RF region dipoles delivered by LBNL to BNL	1 Feb 1999		1 Mar 1999
3 -1.2.1- 5		Begin assembly of 1st dipole model magnet	15 Jul 1999		10 Jun 1999
3 -1.2.1- 6		Complete cold test of 1st dipole model magnet	1 Dec 1999		7 Apr 2000
3 -1.2.1- 7a		D4 engineering design review complete	15 Apr 2001		28 Jun 2001
3 -1.2.1- 7b		D3 engineering design review complete	31 Mar 2002		5 Jun 2002
3 -1.2.1- 8		Complete model magnet program	1 Sep 2000		8 Nov 2000
3 -1.2.1- 9a		D4 production readiness review complete	15 Jun 2001		28 Jun 2001
3 -1.2.1- 9b		D3 production readiness review complete	15 Apr 2002		19 Sep 2003
3 -1.2.1- 10		D4 production start	3 Dec 2001		3 Dec 2001
3 -1.2.1- 11a C		Delivery by CERN to BNL of all CERN-provided D4 parts	1 Jan 2002		27 Nov 2001
3 -1.2.1- 11b C		Delivery by CERN to BNL of all CERN-provided D3 parts	1 Jan 2002		27 Nov 2001
3 -1.2.1- 12		D4 production complete	1 Mar 2003	1 Mar 2004	
3 -1.2.1- 13		D3 production start	4 Mar 2002		4 Mar 2002
3 -1.2.1- 15		D3 production complete	1 Jun 2003	1 Jun 2004	
3 -1.2.1- 16		RF Region Dipole task complete	30 Sep 2005		

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
		WBS 1.1.3 Interaction Region Cryogenic Feed Boxes			
3 -1.1.3- 1		Cryogenic Feed Box (DFBX) Conceptual Design Review	15 Dec 1998		21 Jan 1999
3 -1.1.3- 2	C	DFBX functional specification approved	1 Mar 1999		7 Feb 2000
3 -1.1.3- 3		DFBX interface specification review	1 May 1999		23 Aug 1999
3 -1.1.3- 4	C	DFBX interface specification approved	1 Jul 1999	1 Feb 2004	
3 -1.1.3- 5		Place purchase order for HTS leads	1 Nov 1999		30 Aug 2000
3 -1.1.3- 6		DFBX Engineering Design Review	1 Jul 2000		9 May 2001
3 -1.1.3- 7		DFBX Production Readiness Review	1 Nov 2000		24 Jul 2002
3 -1.1.3- 8		Begin fabrication of 1st DFBX	1 Dec 2000		27 Mar 2003
3 -1.1.3- 9a		IR1 Left DFBX ready to ship	15 Dec 2004		
3 -1.1.3- 9b		IR1 Right DFBX ready to ship	12 Jun 2005		
3 -1.1.3- 9c		IR5 Left DFBX ready to ship	15 Jul 2005		
3 -1.1.3- 9d		IR5 Right DFBX ready to ship	15 Jul 2005		
3 -1.1.3- 10a		IR8 Left DFBX ready to ship	1 Jun 2004		
3 -1.1.3- 10b		IR2 Right DFBX ready to ship	15 Aug 2004		
3 -1.1.3- 10c		IR8 Right DFBX ready to ship	15 Dec 2004		
3 -1.1.3- 10d		IR2 Left DFBX ready to ship	12 Jun 2005		
3 -1.1.3- 11		Interaction Region Cryogenic Feed Box task complete	30 Sep 2005		

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.1.4 Interaction Region Absorbers				
3 -1.1.4- 1	C	TAN and TAS functional specifications approved	1 Jan 1999		15 Jun 2000
3 -1.1.4- 2	C	TAN and TAS interface specifications approved	1 Mar 1999		18 Aug 2000
3 -1.1.4- 3		TAN and TAS Absorber Conceptual Design Review	1 Mar 1999		30 Apr 1999
3 -1.1.4- 4		Instrumentation Conceptual Design Review	1 Nov 1999		5 Oct 1999
3 -1.1.4- 5	C	ISR jacks delivered to LBNL	1 May 1999		12 Mar 1999
3 -1.1.4- 6	C	z-placement of TAN approved	1 Jul 1999		18 Sep 1999
3 -1.1.4- 7	C	TAS support design approved	1 Jul 1999		18 Aug 2000
3 -1.1.4- 8		Interaction Region Absorber Engineering Design Review	1 Jul 2000		18 Sep 2000
3 -1.1.4- 9		Interaction Region Absorber Production Readiness Review	1 Jul 2000		31 Jan 2001
3 -1.1.4- 10		Begin fabrication of TAN and TAS components	1 Aug 2000		30 Oct 2000
3 -1.1.4- 11		Begin assembly of TAN and TAS	1 Dec 2001		28 Feb 2002
3 -1.1.4- 14		Complete assembly of TAN and TAS	1 Nov 2002	31 Jan 2004	
3 -1.1.4- 19		Interaction Region Absorber task complete	30 Sep 2005		

Table of Controlled Milestones

US LHC Accelerator Project Level 3 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
	WBS 1.3.1 Superconductor testing			
3 -1.3.1- 1 C	Complete superconductor testing facility upgrades	1 Jul 1999		30 Sep 1999
3 -1.3.1- 2 C	Begin pre-series testing	1 Mar 1999		1 Oct 1999
3 -1.3.1- 3 C	Begin series testing	1 Mar 2000		10 Jul 2000
3 -1.3.1- 4 C	Series testing complete	31 Mar 2005		
	WBS 1.3.2 SC Cable Production Support			
3 -1.3.2- 1 C	Deliver 4 Cable Measuring Machines (CMM) to CERN	1 Oct 1997		1 Oct 1997
3 -1.3.2- 2 C	Deliver powered Turkshead to CERN	1 Jul 1998		1 Jul 1998
3 -1.3.2- 3 C	Deliver eddy current flaw detector to CERN	1 Jul 1999		28 May 1999
3 -1.3.2- 4 C	Deliver spare CMM measuring heads to CERN	1 Jan 1999		4 May 1999