US LHC Accelerator Project
Progress Report, 1st Quarter FY 1999
12 February 1998
J. Strait, Project Manager

I. Summary

Good technical progress is being made on all fronts. However, the quench performance of the interaction region quadrupole models is still not satisfactory. Two Conceptual Design Reviews were conducted this quarter and the affected subprojects were given the go-ahead to proceed to develop detailed designs. The Project Advisory Group met twice with members of the Project, and the main topic was the IR quadrupole R&D program. The second DOE review of the project was conducted in October, and the Project was found to be making good progress. The Project Management Plan was signed. The mechanical safety MOU with CERN has been finalized and will be routed for signature in January. The cost performance reporting system is now fully operational and shows that the project has an unfavorable cost variance of $0.8M and an unfavorable schedule variance of $4.0M. Based on the earned value of $21.2M, the project is about 24% complete.

A partially rebuilt third model interaction region quadrupole was tested. The test, which was intended to determine the effect of locking the collared coil to the skin through the yoke, showed no significant improvement in quench performance. Model number 5 was moved ahead of model number 4 in the fabrication and test schedule. Model 5 includes collar packs, end cans, G10 end parts, and closely matched properties in the inner and outer coils. Model 4, which includes end cans but is otherwise similar to model 3, will be available for testing in the future if required.

Conceptual design reviews were conducted in December on the distribution feedbox for the interaction region and the cryostat for the quadrupoles. The reviewers raised several issues in each case for the designers to address. None of the issues were believed to be show stoppers and each concept was given the go-ahead to proceed to detailed design.

Progress continues on the separation dipoles. The cross section and longitudinal piping layouts for all four cryostat types were determined. The method for helium filling and level control was specified. Several purchase orders and purchase requisitions for the D2 and D4 magnets were released. Rapid progress is being made on the design of the tooling, and information is being gathered with respect to the possibility of acquiring the R&D cryostat insertion tooling from CERN and having the manufacturer of the tooling modify it for our use.

Good progress continues to be made on the absorbers. The functional specification for the TAN was finalized and will be submitted to CERN in January. The specification will be reviewed, modified as required, and entered in the CERN electronic document management system (EDMS) as a controlled document. This is the first engineering specification from the US Accelerator Project and will serve as a prototype for working out the process. The functional specification for the TAS and the interface specifications for both the TAS and TAN are in preparation and will soon follow.

Progress on the upgrades to the superconductor test facility at BNL has been slower than planned due to shortages of skilled manpower because of the RHIC startup. However, this shortage is expected to be alleviated soon, and the upgrades are still projected to be complete by the milestone date of 1 July 1999. Installation of the second magnet is complete and the second cryostat is ready for the cryogenic safety review before cool-down. CERN has yet to start delivery of pre-series wire and cable samples, so there was little testing activity during this

quarter. The prototype eddy current edge flaw detector system is complete and will be tested next quarter. Test cable runs for CERN to understand manufacturing tolerances continue.

CERN released the KEK quadrupole field error table in October and asked the US LHC Accelerator Physics group to evaluate its impact on the dynamic aperture. The field has a large b_{10} component which reduces the dynamic aperture by about 2 sigma. The strength of a magnet sufficient to correct the large b_{10} is unrealistically large. Analysis is proceeding at FNAL and BNL to determine significance of the impact and possible solutions. Work continues on the design of the instrumentation for the IR absorbers and on quantifying the electron cloud effect in LHC.

The October Lehman Review concluded that the project was doing well at this early stage. They found that the project had maintained its momentum and that previous recommendations had been implemented. There were several recommendations to be considered by the project but the only action item was to schedule a one-day review in April. This has been done and the review will be held on April 8, 1999.

The cost performance reporting system (CPR) is fully operational and cost/schedule reviews using the CPR will be held at each of the three labs beginning next quarter. Through December 1998, the project has an unfavorable cost variance of $0.8M and an unfavorable schedule variance of $4.0M. The schedule variance is dominated by the difficulties in the IR quadrupole R&D program and by later than scheduled purchase of parts and materials for the dipoles. Scenarios exist to recover schedule float in the IR quadrupole program if required, and the dipole materials ordered later than scheduled are not on the critical path. The cost variance is expected to grow due to the extended quadrupole R&D program, but the overall schedule variance is expected to stabilize as the dipoles recover schedule but the quadrupoles continue to require more development.

Several Baseline Change Requests will be processed in the coming quarter to establish the accelerated schedule as the baseline and quantify its cost advantage, adjust several milestones, and codify cost increases in the IR quadrupole program. The Project Management Plan was signed in October, and the MOU with CERN on mechanical equipment safety is ready for signatures.

II. Program Planning

The Project Advisory Group (PAG) met twice during the quarter. In both meetings the member of the PAG discussed at length the development results and plans for the interaction region quadrupole magnets. The PAG endorsed the plan to conduct a technical review by experts from outside the project. In addition, John Peoples created a Director's internal review committee consisting of Paul Mantsch and Alvin Tollestrup to help him review the technical progress of the quadrupole program on a regular basis. They met with leaders of the quadrupole development program and Project Management on November 25 and December 22.

The technical review of the interaction region quadrupole program is scheduled for March 18-19, 1999. The review committee consists of magnet experts mostly from outside the project. Arnaud Devred of Saclay will serve as the chairman. The other reviewers will be Ranko Ostojic (CERN), Daniel Leroy (CERN), Pierre Vedrine (Saclay), Mike Anerella (BNL), and Bob Schermer (consultant).

The Cost Performance Reporting system (CPR) is operational at all three laboratories and for the overall project. Demonstrations were conducted in December for level 3 managers and others at FNAL and LBNL. A similar demonstration will be conducted at BNL in January. Cost and schedule reviews utilizing the CPR will be conducted monthly at each of the laboratories beginning next quarter.

Several Baseline Change Requests (BCRs) have been identified and are in preparation for submission next quarter to the Change Control Board. Two of the BCRs will revise milestone dates for cable production support at LBNL and the absorber instrumentation conceptual design review. Two BCRs will revise cost estimates for the heat exchanger test conducted by FNAL at CERN and for test stand leads at FNAL. One BCR will revise cost estimates downward due to the overall acceleration in project schedule. A BCR to raise the cost estimate and extend the time for the interaction region quadrupole development will be submitted.

R. Ostojic, our official point of contact for the LHC insertion regions, has advised us that it is highly likely that the TOTEM experiment will be approved, and that the US project should anticipate it in the designs. Implementation of TOTEM will require independent powering of the magnets in each triplet. This affects the number of buses passing through the magnets and the number of high current power leads in the distribution feedbox. We have been told that the TOTEM experiment would cover incremental costs to the LHC machine, but we do not know how that will occur. Meanwhile we are asking the affected task managers to identify cost increases that might result if TOTEM were to be added.

T. Taylor, the official liaison person at CERN for the whole US LHC Accelerator Project, has relinquished his position as head of the Insertions, Protection and Correctors Group of the LHC Division, but retains his position as Deputy LHC Division Head. This change does not affect his role vis-a-vis the US Project.

The MOU with CERN concerning the safety of mechanical equipment provided by the US laboratories for LHC was finalized and will be routed for signature in January. It has evolved from a document concerned only with pressure vessels to one, which defines the procedures for reviewing US-provided equipment with respect to mechanical safety and certifying them for use in LHC. Its most important features are that it permits the use of the ASME code and allows most of the safety reviews of each device or system to be done by the US laboratory responsible for the item following its own standard procedures. M. Bona, head of the Technical Services and Environment group of the CERN Technical Inspection and Safety Commission (TIS) and P. Pfund, US LHC Accelerator Project Engineering Manger visited BNL and LBNL in November to review each lab's safety review procedures. They found them compatible with the requirements of CERN.

III. Technical Progress

<u>WBS 1.1.1 Inner Triplet Quadrupoles</u>

Detail plans were developed for the production and test of magnets HGQ03A through HGQ06. Procurement of end parts for the return end of HGQ06, of the new design, began, as did production of new cable and wedges. The magnets use a series of different longitudinal restraint mechanisms, including collar to yoke interference (HGQ03A), aluminum end cans at both ends (HGQ04 and HGQ05), and G10 end parts (HGQ05) to increase the rigidity of the coil ends and to limit motion in the ends under the Lorentz load which has to be reacted by the coil end.

HGQ03A is a rebuild of model HGQ03, in which the only change was the locking of the collared coil to the yoke through the addition of shims placed between the collaring keys in each quadrant. The result is an interference between the collar and yoke laminations such that longitudinal load is transferred to the skin along the length of the magnet, rather than just through the end saddles. This change was expected to address whether the poor quench performance is associated with external constraints or is more deeply rooted in the magnet. The test showed no change in quench performance at 4.5K, and only a small improvement in initial 1.9K training, reaching the same plateau just above 12kA as HGQ03 had.

It was decided to place higher priority on magnet HGQ05, which incorporates collar packs, end cans and G10 end parts, and coils that have been recured to match inner and outer coil properties more closely. HGQ04, which is very similar to HGQ03, was given a lower priority, as it incorporates fewer new design features which are currently believed to offer an improvement in quench performance. Construction of HGQ05 continued, and procurement and fabrication of new design end parts for HGQ06 are well underway. Winding for HGQ06 will commence in February after all parts are received and a set of practice coils is completed which confirms the cured coil size and properties.

New inner cable with optimized cross-section has been fabricated at LBNL and cable short samples have been tested at BNL. The cable was received at FNAL in December. The work on the development of the copper distributed quench heaters continues at LBNL. A heater design with heating/shunted lengths equal to the cable transposition pitch was selected for fabrication at LBNL. This heater, to be installed in HGQ05, was delivered from LBNL to Fermilab in December.

The cryostat CDR was completed December 3, with 7 'conceptual' and 10 'detail' action items noted. Continued detailed design has been given the go-ahead. The final review report will be issued in January. A FNAL engineering design review (EDR) of the feed box which will connect the heat exchanger test cell to the CERN cryogenic system occurred at the end of October. FNAL also conducted an EDR for the feed can for the quadrupoles at the Magnet Test Facility in December, which generated an action item list which will be addressed before quotes are requested in February. Again, the go ahead for final detailed design was given, though the effect of TOTEM on the number of buses running through the system and the effect of the production schedule and order of production on the test schedule were noted as items for continued vigilance.

<u>WBS 1.1.2 Interaction Region Dipoles / 1.2.1 RF Region Dipoles</u>:

A decision was made to use magnetic steel rather than stainless steel keys in the D1 and D3 magnet yoke collars. This helps to control the field distortion due to saturation at the highest fields. The inventory of spare RHIC magnet parts was reviewed and items were identified that could be used in the construction of the LHC magnets.

The baseline plan to make a common spare magnet for D2/D4b was re-evluated in the light of a change in the cooling scheme of the D4b and more detailed understanding of the technical requirements for both types of magnets. The engineering complications involved in manufacturing a common spare are solvable. The use of a common spare is more cost effective than constructing an entirely separate D2 spare assembly, thus confirming the decision in this regard made in developing the baseline program plan and cost estimate.

The cross section longitudinal arrangements of the piping located in the cryostat for D1, D2, D3, and D4 were completed. The method for filling the magnets with helium and maintaining the level in steady-state operation was specified.

We are working through CERN to contact IDESA, the Spanish firm that designed the tooling CERN uses to insert D2, D3, and D4 cold masses into their cryostats. We have opened discussions with IDESA to inform them of our interest in obtaining their design drawings and possibly having them fabricate tooling for us.

Plans were made for New England Electric Wire to perform incoming inspection, sorting and storage of the spools of leftover SSC wire currently at LBNL. NEEW would manufacture the wire into cable.

The sizes and positions of all features of the D2/D4 yoke laminations were finalized. The field quality remains good even with revised bus slot positions to accommodate the interface to CERN designs.

A purchase order was placed for stainless steel for the D2 and D4 collars, including prototypes. The delivery schedule supports the master schedule, and material cost is within the budgeted value. A purchase requisition for yoke steel for the D2 and D4 magnets has been released. Bids are due from potential vendors in January. Material for the prototypes is already on hand. Purchase requisitions for collar and yoke laminations for D2, D4, and the prototype were released. Potential vendors to whom Request for Quotations were sent were all pre-screened during site visits by BNL Engineering and QA representatives.

Detailed design work was completed on the shell welding fixture, and cold mass lifting beam. Finite element stress analyses in support of the designs were completed on the shell welding fixture beam and cold mass lifting beam. Preliminary design work was completed on the cradle alignment/weld fixture, including a finite element stress analysis. Final tooling design reviews were held on the D2/D4 collaring press design, and on the shell welding / rotating end plate and end volume welding fixtures (Cold Mass Fixtures 1 and 2), with the exception of details for end plate alignment bushings and cradle alignment tools. Final design of these elements awaits further development of magnet designs. Preliminary tooling design reviews were held on the prototype coil curing tooling, cold mass lifting beam, and cradle alignment/welding fixture.

WBS 1.1.3 Interaction Region Feed Boxes

The DFBX conceptual design was reviewed at FNAL on December 2. The reviewers raised 9 issues regarding the concept and 14 issues regarding design details for the designers to address. None of the issues were believed to affect the validity of the concept so the designers were given the approval to proceed with detailed design. Several concerns of the review committee involved the effects of radiation on the DBFX components. The final review report will be issued in January. Design information was provided to Nikolai Mokhov at FNAL for inclusion in his modeling of the LHC interaction region. Preparation of the Functional Specification has started.

WBS 1.1.4 Interaction Region Absorbers

The Functional Specification for the TAN was completed and submitted to the US-LHC Project Office for final review and transmission to CERN for approval. The first draft of the Functional Specification for the TAS was completed.

The TAN will weight approximately 30 tonnes. It is still uncertain whether it is to be installed as a single unit or assembled in place from eight subassemblies weighing less than 5 tonnes each. We have wording with CERN on this and have provided them with the necessary information to develop the installation scenario, but have not yet reached a resolution.

The TAN location will move closer to the IP by no more than 4 m due to TOTEM elastic detectors. CERN will follow up on a possible interference between the TAN and the monorail stay clear region. A ConFlat flange on the TAN beam tube facing the IP has been eliminated to increase vacuum reliability of the TAN. The number of ISR jacks needed for the TAN absorbers and the DFBs was defined and CERN agreed to ship them to LBNL in the next several weeks.

A slot has been added in the TAS copper absorber 25 cm behind the front face to accommodate the option of adding detectors to the TAS. Engineering calculations have been carried out for forced air cooling of the TAS with a 1 cm diameter cooling manifold. Bakeout calculations for the TAS were also updated. Work still continues at FNAL on radiation deposition, activation and shielding calculations for the TAN and TAS for v6 optics including more realistic geometric details of the TAS and TAN.

Design work for the ATLAS and CMS forward shielding is getting underway. Tentative agreement was achieved on the size of the shielding blocks that support the TASs. The TAS cooling air requirements were discussed – the need for compressed air has been included in the utility requirements for IPs1 and 5. Interface details were discussed for the air cooling and bakeout of the TASs. Work on the TAS support drive was started.

WBS 1.1.5 Inner Triplet System Design

We are continuing to organize the inner triplet system design effort. We created a detailed list of IR design tasks: inner triplet cryogenic system design, inner triplet mechanical system design, electrical system design, instrumentation layout and planning, beam vacuum, insulating vacuum, alignment, interfaces, system safety documentation, magnetic system oversight, and radiation issues.

It has been tentatively decided that the US Project would provide the bus work for the inner triplet quadrupoles. It is important to define the geometry and composition of these bus bars, as it will have an impact on the size of the bus slots and expansion loops through the MQX magnets made both by the US and by KEK, as well as the heat load through the lambda plate. While the bus bars proposed for the main arc quadrupole circuits may be used as a template, they are considerably oversized for the inner triplet. Preliminary calculations indicate that a cross section of quadruple inner cable stabilized by 1 or 2 equivalent cross sectional areas of copper should be sufficient. The electrical wiring for the inner triplet was updated reflecting our present knowledge of the type and quantity of correctors, instrumentation wires and bus bars.

WBS 1.3.1 Superconductor Testing

Installation of the second magnet in its cryostat is complete. The second cryostat will be ready for a cool-down in January after the cryogenic safety review. Instrumentation work in the control room is in progress. The design work for the modification of the inner vessel of the third cryostat has been completed and released to the shops. Completion is expected by mid-February 1999. The six 25 kA leads with the stainless steel jackets have been fabricated and now are in the process of final assembly. Work started on assembling the third 4.2 K sample holder with the three high current leads. The assembly of the third test magnet is complete. Cold testing has been delayed due to lack of manpower and is now scheduled for the end of January 1999.

Plans have been made for additional helium storage capacity to be installed during the third quarter of FY 1999. This will substantially help in the scheduling of cable testing in those years when other magnet testing will be an on-going parallel activity.

Software to analyze the V-I curves numerically in a Windows environment and store the various calculated parameters in the BNL database was completed and is in the process of being upgraded after initial end-user trial runs. It is intended to have the database software in its final revision before the start of Phase 0 cable tests, which are scheduled to begin during the third quarter of FY 1999.

Slower than planned progress has been made on the upgrades, due to a shortage of skilled technicians, who have been diverted to RHIC installation. As RHIC installation is nearing completion, this situation is expected to be alleviated soon, and the test facility upgrades are still expected to be completed by the milestone date of 1 July 1999. In its current state, the facility is ready to support the pre-series testing, which is scheduled to begin later this year.

WBS 1.3.2 Superconducting Cable Production Support

Wire from EMI was received at the end of December. This wire will be re-spooled together with the wire from Alsthom and IGC for an experiment to verify the uniformity of performance and dimensions for LHC dipole cable made from different wire sources.

The eddy current flaw detector for detecting cable edge defects has been completed by SE Systems. This unit will be acceptance tested at LBNL and then sent to CERN if the operating specifications are met. SE Systems has started work on the new sensor arrangement for a wide face detection system, and a proof of principal test run will be conducted during one of the cable runs in late January or early February. If the results are satisfactory, a BCR will be submitted to expand the scope to include the purchase of a prototype wide face system. The cable sharp edge tests and specification range tests were begun in late November; these tests will continue in January.

WBS 1.4 Accelerator Physics

During the LHC Accelerator Physics Workshop, held at Fermilab on October 19-20, CERN released version 1.0 of the KEK MQX field error table. At CERN's and KEK's request, extensive dynamic aperture tracking studies have been performed using this and a revised error table, version 1.1. The field error analysis and compensation results indicate that, compared with FNAL quads, the KEK quad field errors further reduce the dynamic aperture by about 2 sigma, to a level about 4 sigma below the CERN target value. The leading source of impact is from b_{10}, and secondly from b_6. Local corrections including b_{10} can meet the target, but the needed strength appears impractically large. CERN has requested additional studies involving several alternate magnet configurations and further modified KEK error tables with lower b_{10} to help guide CERN's and KEK's decision regarding a possible modification of the KEK coil cross-section.

Some conclusions have been reached concerning the specification of alignment numbers in the Standard eXchange Format (SXF). A Study on the fractional tune dependence of dynamic aperture for LHC at collision energy concluded that the collision DA can be increased by about 3 sigma if the working point can be moved away from the current value (near third order resonance) by as little as 0.03.

A preliminary study was completed addressing technology choices for absorber instrumentation. It was concluded that a gas ionization chamber is the most promising when considering radiation tolerance and time response. A seminar on instrumentation for the TAS and TAN absorbers was prepared and given at CERN on November 16, 1998. Ensuing discussion indicated that there is agreement that instrumentation somewhat expanded beyond the baseline configuration would be useful and desirable to include in the LHC beam instrumentation.

The study of the electron-cloud effect in the PEP-II positron ring, an important normalizer for the code that is being used to evaluate the effect in LHC, was thwarted by unexpected commissioning problems in the machine. One high-statistics simulation for the PEP-II case was run in order to have a better estimate of the growth rate of the instability as a function of bunch position along the train.

IV. Budget and Schedule Status

The cost performance reporting system is fully operational. The budget data are correct, the earned value data represents the schedule status provided by the responsible individuals, and the actual costs are reconcilable to the individual laboratories' accounting systems. The historical schedule and actual cost data used to establish trends from June 1998 are also correct, at least to the extent that schedule status was properly reported during that period when the CPR system was not yet operational.

The Cost Performance Report (CPR) for December 1998 and three trend charts (cumulative performance, cost/schedule variance, and bull's-eye) are included as attachments. The bottom line numbers for the entire US LHC Accelerator Project are as follows:

BAC	89.4M
BCWS	25.2M
BCWP	21.2M
ACWP	22.0M
Schedule Variance (SV)	-4.0M (-16%)
Cost Variance (CV)	-0.8M (-4%)
Contingency (110M – BAC)	20.6M
Contingency adjusted for CV	19.8M
Adjusted Contingency as a % of Budget to go	29.0%

The unfavorable schedule variance has two primary causes: about 60% is due to later-than-scheduled ordering of material for the IR and RF region dipoles at BNL, and about 30% is due to the time it is taking to resolve the quench problems of the IR quadrupoles. All of the dipole material was entered in the schedule as being ordered in the first month of the fiscal year, while in fact the orders are spread over several months. None of the unordered material affects the critical path to the first prototype assembly milestone on 15 July 1999. This variance should reduce over the next few months. The schedule variance related to the IR quadrupoles will continue to increase until the problem is resolved or a BCR is approved for additional model magnets.

The major contributors to the unfavorable cost variance are the model magnet R&D program (-475K) and the inner triplet heat exchanger test unit (-350K) under the IR Quadrupole task WBS (1.1.1) at FNAL, and the G&A rates applied in FY 1996 and FY 1997 at LBNL (-220K). The quadrupole R&D program cost variance is due to the problems encountered resolving the quench problems and will continue to increase until the problem is resolved or a BCR is approved for additional model magnets. The heat exchanger test cell cost variance is due to an under-estimate of the scope of the test and will probably increase to about $400K by the time the unit is completed. The G&A cost variance is due to funding in FY 1996 and FY 1997 being provided as operational funds rather than equipment funds as was estimated. Operation funds G&A rates at LBNL are higher than the rates for equipment funds, therefore the variance. This variance is not recoverable.

We expect that the schedule variance will probably stabilize at around its current –$4M value as the recovery of schedule at BNL is overtaken by the loss of schedule at FNAL. The cost variance will get worse as the IR quadrupole model magnet program continues until the quench problems are resolved.

In this quarter, DOE advised us of a new funding profile that makes more funds available to the US LHC Accelerator Project earlier in the program. The new profile is contained in the chart entitled, "US LHC Accelerator Project Funding Profile" which also shows each laboratory's funding requirements (without contingency) for comparison. The difference between the allotted funding and the required funding is the contingency for each year. It will be noted that this year (FY 1999) shows a contingency shortfall. However, that shortfall is covered by contingency carry-over from previous years.

The next chart, "US Financial Tracking Data", shows how the project is doing against the funds available and the projected need for funds. Through Dec 98, the expenditures plus open commitments are running below the projected need due to the schedule variance noted previously. However, the slope of expenditures plus open commitments suggests that by the end of the fiscal year actual funds usage will catch up to the projected need, leaving a little over $2.3M as carry-over to FY 2000.

V. Milestone Status

The status of the level 2 and level 3 milestones are summarized on 6 charts at the end of this report. The open symbols show the baseline dates and the filled symbols indicate the actual dates. No level 2 milestone were scheduled and none were achieved during the reporting period. Two level 3 milestones were scheduled during this quarter: MQX (IR quadrupoles) Cryostat Conceptual Design Review and Cryogenic Feed Box (DFBX) Conceptual Design Review, both on 15 December 1998. These conceptual design reviews were held on 2 and 3 December, but achieving the milestones requires that the review report be complete and approved by the Project Manager. Reports exist in draft form and have been circulated to the review committee. We expect to achieve both milestones in January. Thirteen level 3 milestones are scheduled for the upcoming quarter. We are currently developing a Milestone Dictionary which will define precisely what constitutes achievement of each milestone and expect to have this complete by the end of the next quarter.

VI. Evaluation

Good technical progress is being made on all the subtasks. The primary technical problem is the development of the interaction region quadrupoles, which continue to demonstrate unacceptable quench performance. Considerable effort is being directed at solving this problem, and as a result there will be increased cost and delays in completing the phase 1 and phase 2 model magnet programs. The schedule variance will probably stabilize at –$4M as the recovery of schedule at BNL is overtaken by the loss of schedule at FNAL. A simple rearrangement of the IR quadrupole production schedule would allow us to generate as much as a year of schedule float, so the apparent loss of schedule on the quadrupole task is not yet a serious problem. The cost variance will probably get worse due to the additional costs for the quadrupole magnet program. However, the cost increase due to the expanded quadrupole R&D program is modest so far, and overall Project contingency remains adequate to cover any foreseen cost variances.

COST PERFORMANCE REPORT
FORMAT 1 - WORK BREAKDOWN STRUCTURE

DOLLARS IN Thousands

1. CONTRACTOR	2. CONTRACT		3. PROGRAM	4. REPORT PERIOD
a. NAME US LHC Accelerator Project Office	**a. NAME** US LHC		**a. NAME** US LHC Accelerator Project	**a. FROM** *(YYMMDD)* 981201
b. LOCATION *(Address and ZIP Code)* P.O. Box 500 MS 343 Batavia, IL 60510	**b. NUMBER** 1 **c. TYPE** FPI	**d. SHARE RATIO** 100/0 100/0	**b. PHASE** *(X one)* x **RDT&E** x **PRODUCTION**	**b. TO** *(YYMMDD)* 981231

5. CONTRACT DATA

a. QUANTITY	b. NEGOTIATED COST	c. EST. COST AUTH UNPRICED WORK	d. TARGET PROFIT/ FEE	e. TARGET PRICE	f. ESTIMATED PRICE	g. CONTRACT CEILING	h. ESTIMATED CONTRACT CEILING
0/0/0	89,417.8	0.0	0.0 / 0.0%	89,417.8	89,417.8	110,000.0	110,000.0

6. ESTIMATED COST AT COMPLETION

	MANAGEMENT ESTIMATE AT COMPLETION (1)	CONTRACT BUDGET BASE (2)	VARIANCE (3)
a. BEST CASE	89,417.8		
b. WORST CASE	89,417.8		
c. MOST LIKELY	89,417.8	89,417.8	0.0

7. AUTHORIZED CONTRACTOR REPRESENTATIVE

a. NAME *(Last, First, Middle Initial)*	b. TITLE
Jim Strait	US LHC Project Manager
c. SIGNATURE	**d. DATE SIGNED** *(YYMMDD)* 990115

8. PERFORMANCE DATA

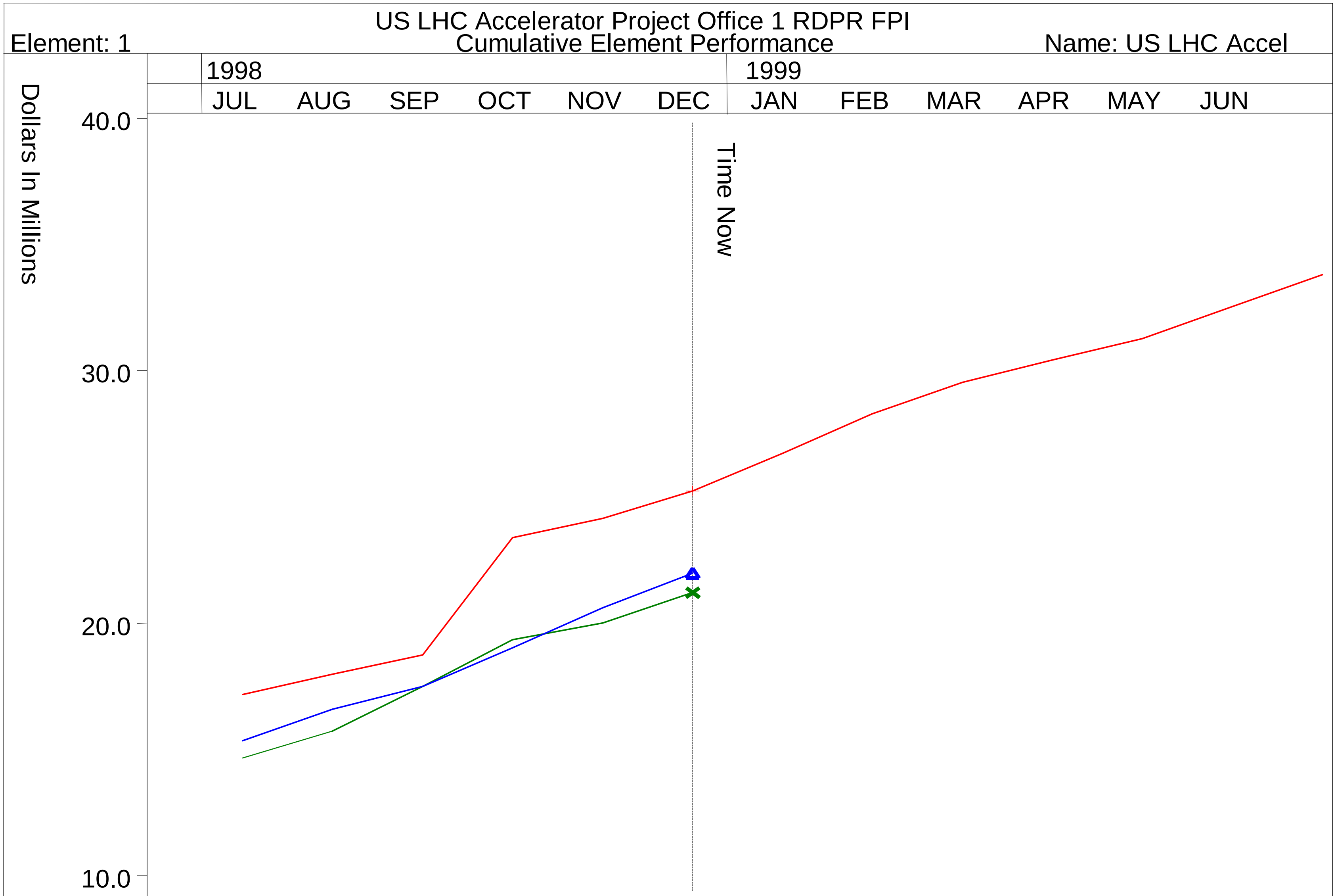
ITEM		CURRENT PERIOD					CUMULATIVE TO DATE					REPROGRAMMING ADJUSTMENTS		AT COMPLETION		
		BUDGETED COST		ACTUAL	VARIANCE		BUDGETED COST		ACTUAL	VARIANCE						
		WORK SCHEDULED	WORK PERFORMED	COST WORK PERFORMED	SCHEDULE	COST	WORK SCHEDULED	WORK PERFORMED	COST WORK PERFORMED	SCHEDULE	COST	COST VARIANCE	BUDGET	BUDGETED	ESTIMATED	VARIANCE
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
a. WORK BREAKDOWN STRUCTURE ELEMENT																
1.1 - Interaction Regions	2	362.1	400.9	638.2	38.8	-237.3	10,014.4	8,045.1	8,652.1	-1,969.2	-607.0			35,919.7	34,557.4	1,362.3
1.1.1 - Quadrupoles	3	181.5	210.1	327.0	28.6	-116.9	7,278.3	6,302.3	6,789.3	-976.0	-487.0			21,904.7	21,415.7	489.0
1.1.2 - Dipoles	3	128.8	167.2	274.4	38.4	-107.2	1,733.5	901.6	1,077.1	-831.9	-175.5			5,150.6	4,494.2	656.4
1.1.3 - Cryogenic Feedboxes	3	26.0	7.7	8.8	-18.3	-1.1	412.8	280.0	407.6	-132.8	-127.6			4,580.5	4,575.3	5.2
1.1.4 - Absorbers	3	17.0	7.1	15.4	-9.9	-8.3	383.4	354.8	217.0	-28.6	137.8			3,288.2	3,121.8	166.4
1.1.5 - System Design	3	8.8	8.8	12.6	0.0	-3.8	206.4	206.4	161.1	0.0	45.3			995.7	950.4	45.3
1.2 - RF Region	2	275.6	300.1	244.5	24.5	55.5	3,517.3	2,264.4	2,080.8	-1,253.0	183.6			11,685.9	10,249.3	1,436.6
1.2.1 - Dipoles	3	275.6	300.1	244.5	24.5	55.5	3,517.3	2,264.4	2,080.8	-1,253.0	183.6			11,685.9	10,249.3	1,436.6
1.3 - Superconducting Wire & Cable	2	66.8	99.3	103.4	32.5	-4.1	3,570.7	3,368.4	3,563.1	-202.3	-194.7			9,833.1	9,825.6	7.6
1.3.1 - Superconductor Testing	3	57.1	73.8	84.2	16.7	-10.4	2,840.1	2,689.7	2,786.8	-150.3	-97.0			8,854.1	8,800.8	53.3
1.3.2 - Cable Production Support	3	9.7	25.5	19.2	15.8	6.3	730.6	678.6	776.3	-52.0	-97.7			979.0	1,024.7	-45.7
1.4 - Accelerator Physics	2	38.4	38.4	54.1	0.0	-15.6	829.9	829.9	815.7	0.0	14.2			3,809.4	3,795.2	14.2
1.4.1 - BNL Accelerator Physics	3	19.4	19.4	22.2	0.0	-2.9	282.5	282.5	319.4	0.0	-36.9			1,705.8	1,742.7	-36.9
1.4.2 - FNAL Accelerator Physics	3	14.0	14.0	18.9	0.0	-4.9	297.7	297.7	261.2	0.0	36.5			1,196.5	1,160.0	36.5
1.4.3 - LBNL Accelerator Physics	3	5.1	5.1	12.9	0.0	-7.9	249.7	249.7	235.2	0.0	14.6			907.0	892.5	14.6

COST PERFORMANCE REPORT
FORMAT 1 - WORK BREAKDOWN STRUCTURE

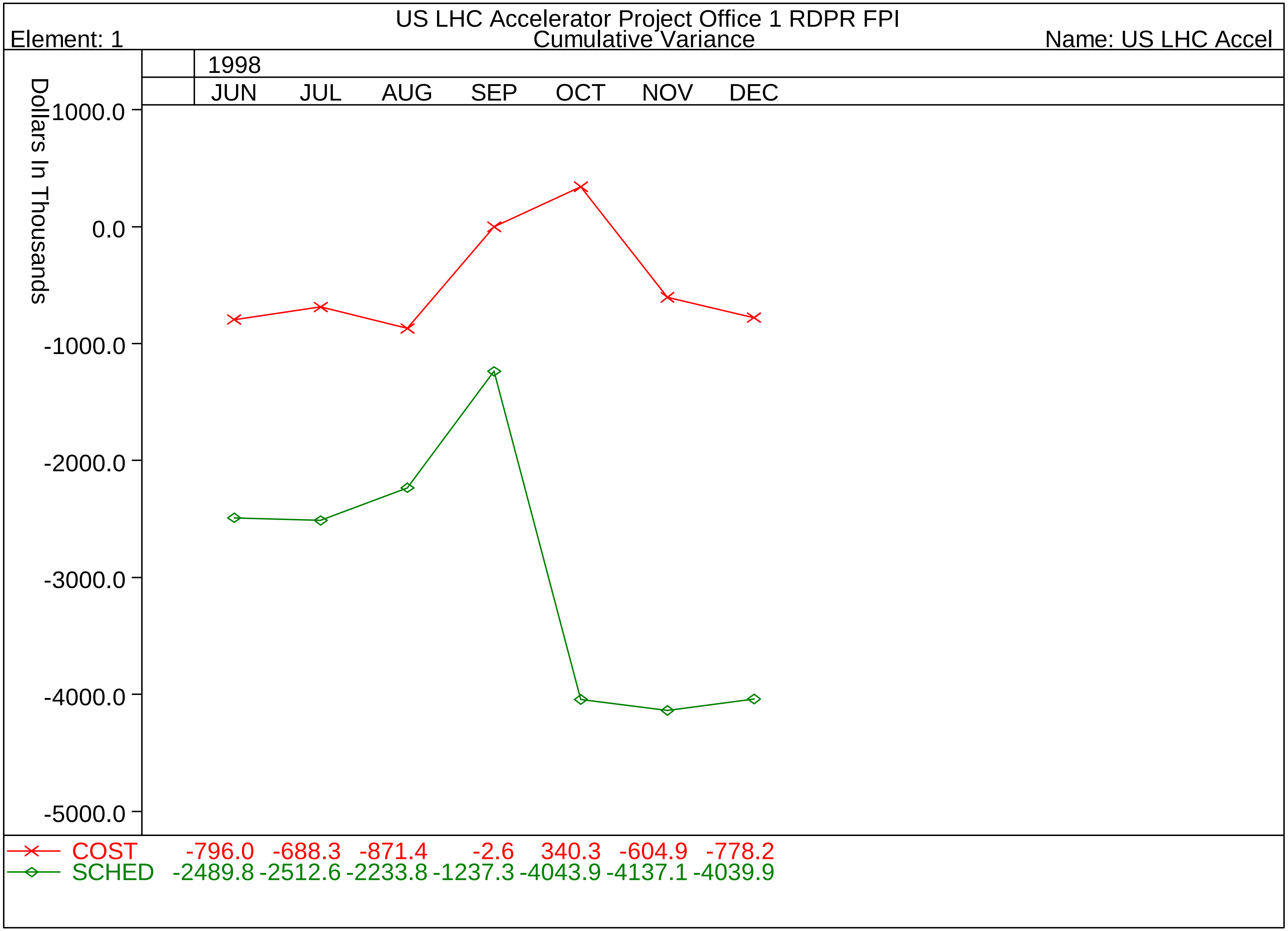
DOLLARS IN Thousands

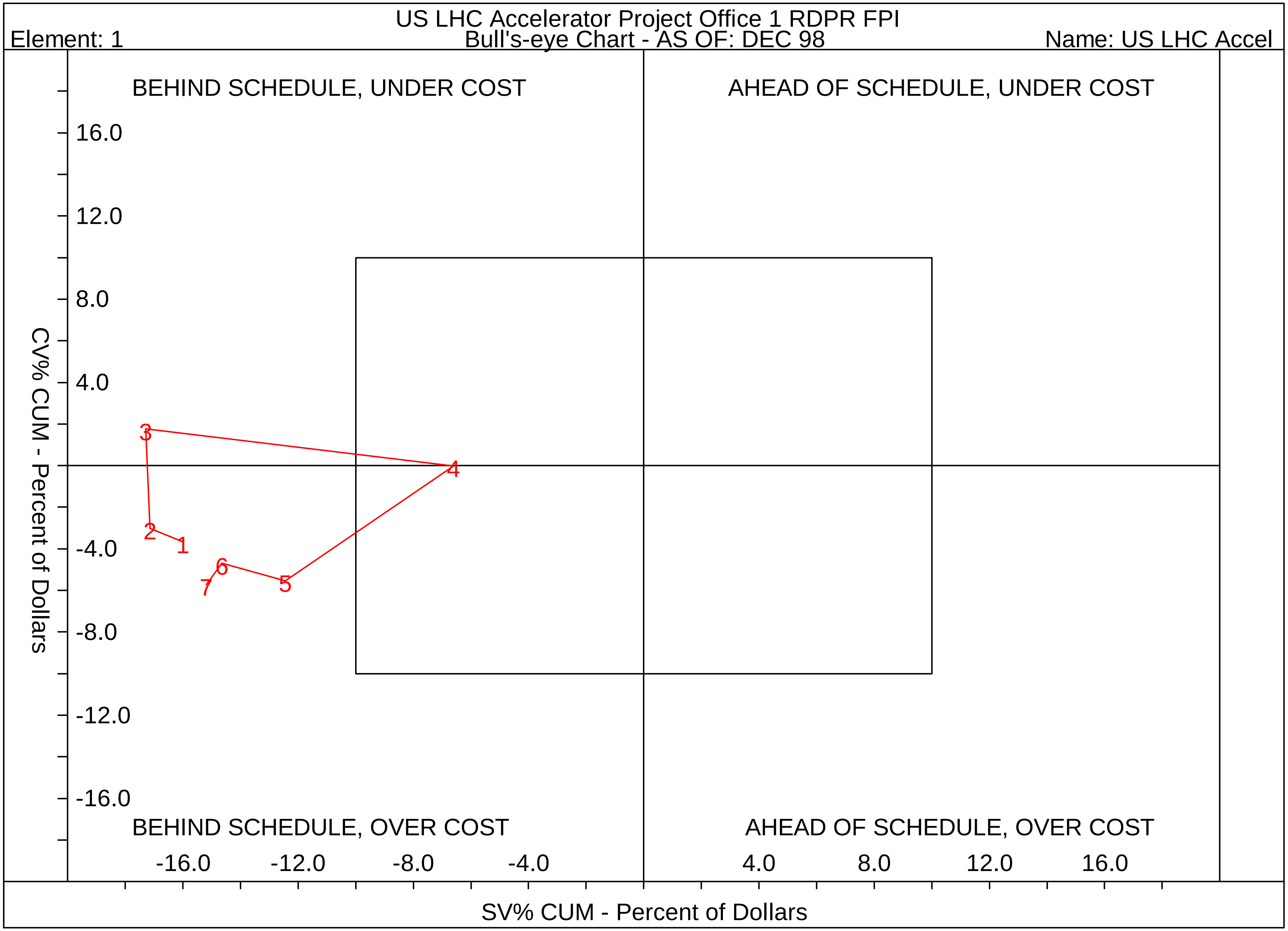
8. PERFORMANCE DATA

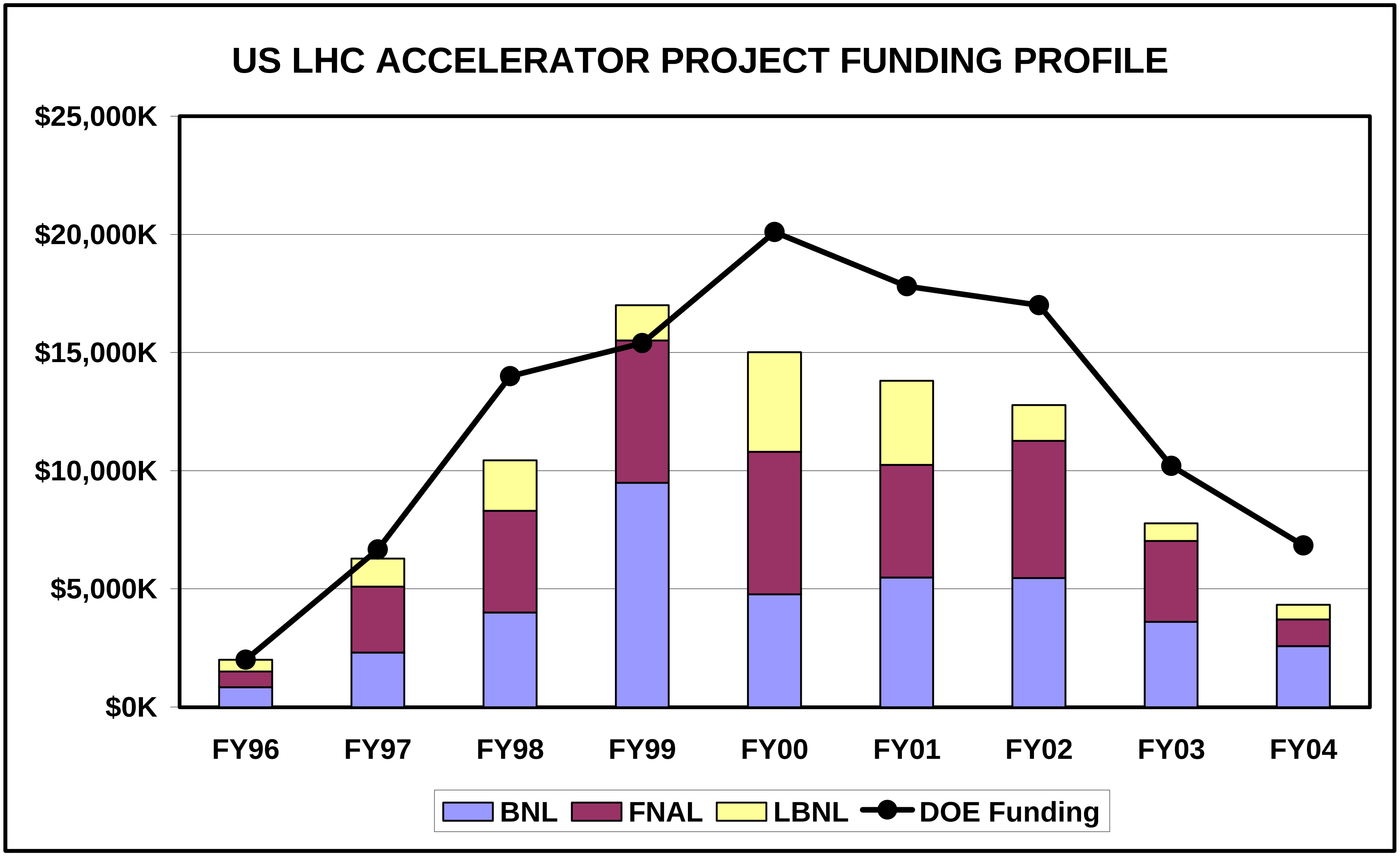
ITEM		CURRENT PERIOD					CUMULATIVE TO DATE					REPROGRAMMING ADJUSTMENTS		AT COMPLETION		
		BUDGETED COST		ACTUAL	VARIANCE		BUDGETED COST		ACTUAL	VARIANCE						
		WORK SCHEDULED	WORK PERFORMED	COST WORK PERFORMED	SCHEDULE	COST	WORK SCHEDULED	WORK PERFORMED	COST WORK PERFORMED	SCHEDULE	COST	COST VARIANCE	BUDGET	BUDGETED	ESTIMATED	VARIANCE
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
a. WORK BREAKDOWN STRUCTURE ELEMENT																
1.5 - Project Management	2	148.2	148.2	135.8	0.0	12.4	2,679.3	2,679.3	2,528.3	0.0	151.0			12,261.4	12,110.3	151.0
1.5.1 - US LHC Project Management	3	25.1	25.1	27.0	0.0	-1.9	484.8	484.8	639.5	0.0	-154.6			2,549.0	2,703.6	-154.6
1.5.2 - BNL Project Management	3	85.1	85.1	73.2	0.0	11.9	1,350.3	1,350.3	1,340.0	0.0	10.3			6,028.5	6,018.3	10.3
1.5.3 - FNAL Project Management	3	17.7	17.7	24.7	0.0	-7.0	363.5	363.5	240.7	0.0	122.8			1,808.4	1,685.6	122.8
1.5.4 - LBNL Project Management	3	20.2	20.2	10.9	0.0	9.3	480.7	480.7	308.1	0.0	172.6			1,875.4	1,702.8	172.6
OV - OVERHEAD	2	76.3	74.9	85.2	-1.4	-10.3	1,723.7	1,452.2	1,422.8	-271.5	29.4			6,118.1	5,817.2	300.9
b. COST OF MONEY	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0
c. GENERAL & ADMINISTRATIVE	2	124.2	127.0	100.9	2.8	26.0	2,901.6	2,557.7	2,912.5	-343.9	-354.8			9,790.2	9,801.1	-10.8
d. UNDISTRIBUTED BUDGET	2													0.0	0.0	0.0
e. SUBTOTAL *(Performance Measurement Baseline)*		1,091.6	1,188.7	1,362.1	97.2	-173.4	25,236.9	21,196.9	21,975.2	-4,039.9	-778.2	0.0	0.0	89,417.8	86,156.1	3,261.7
f. MANAGEMENT RESERVE	2												0.0	0.0		
g. TOTAL		1,091.6	1,188.7	1,362.1	97.2	-173.4	25,236.9	21,196.9	21,975.2	-4,039.9	-778.2	0.0	0.0	89,417.8		
9. RECONCILIATION TO CONTRACT BUDGET BASE																
a. VARIANCE ADJUSTMENT										0.0	0.0					
b. TOTAL CONTRACT VARIANCE										-4,039.9	-778.2			89,417.8	86,156.1	3,261.7



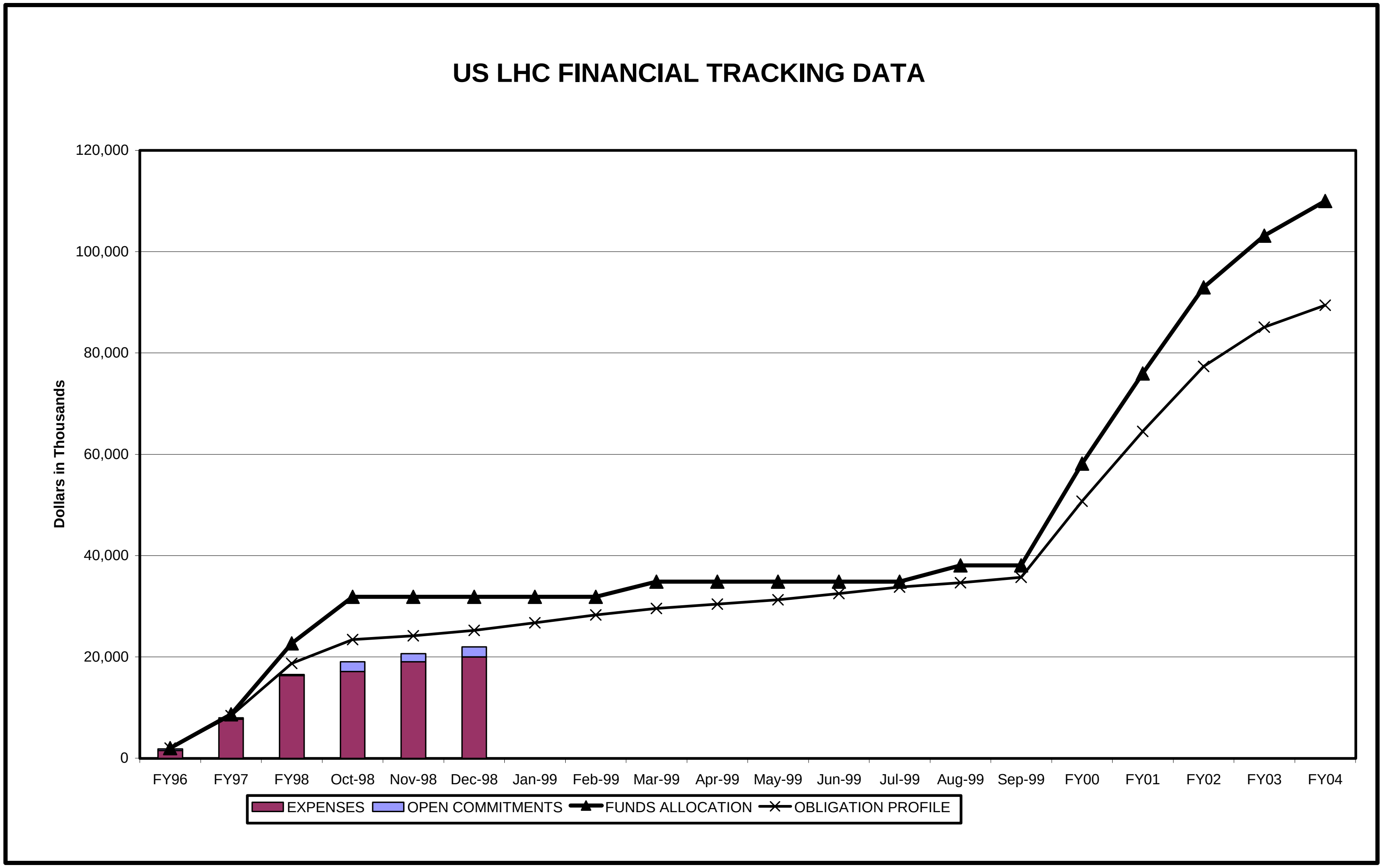
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
BCWS	17.2	18.0	18.7	23.4	24.1	25.2	26.7	28.3	29.5	30.4	31.3	32.5
BCWP	14.6	15.7	17.5	19.3	20.0	21.2						
ACWP	15.3	16.6	17.5	19.0	20.6	22.0						


US LHC Accelerator Project Office 1 RDPR FPI
Cumulative Variance
Element: 1
Name: US LHC Accel
1998
JUN JUL AUG SEP OCT NOV DEC
Dollars In Thousands
1000.0
0.0
-1000.0
-2000.0
-3000.0
-4000.0
-5000.0
COST -796.0 -688.3 -871.4 -2.6 340.3 -604.9 -778.2
SCHED -2489.8 -2512.6 -2233.8 -1237.3 -4043.9 -4137.1 -4039.9


US LHC Accelerator Project Office 1 RDPR FPI
Element: 1
Bull's-eye Chart - AS OF: DEC 98
Name: US LHC Accel
BEHIND SCHEDULE, UNDER COST
AHEAD OF SCHEDULE, UNDER COST
BEHIND SCHEDULE, OVER COST
AHEAD OF SCHEDULE, OVER COST
16.0
12.0
8.0
4.0
-4.0
-8.0
-12.0
-16.0
CV% CUM - Percent of Dollars
-16.0
-12.0
-8.0
-4.0
4.0
8.0
12.0
16.0
SV% CUM - Percent of Dollars
1
2
3
4
5
6
7

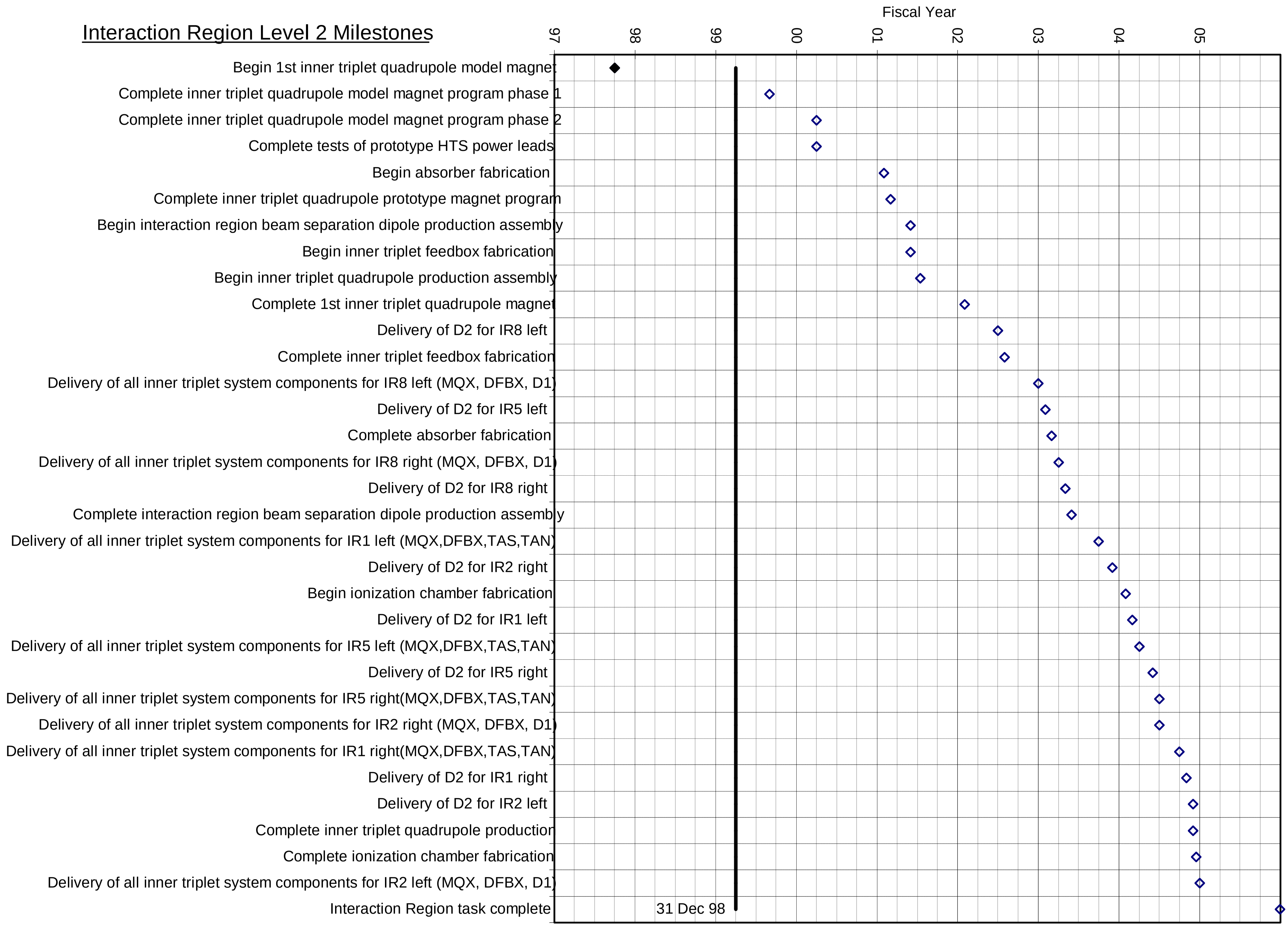


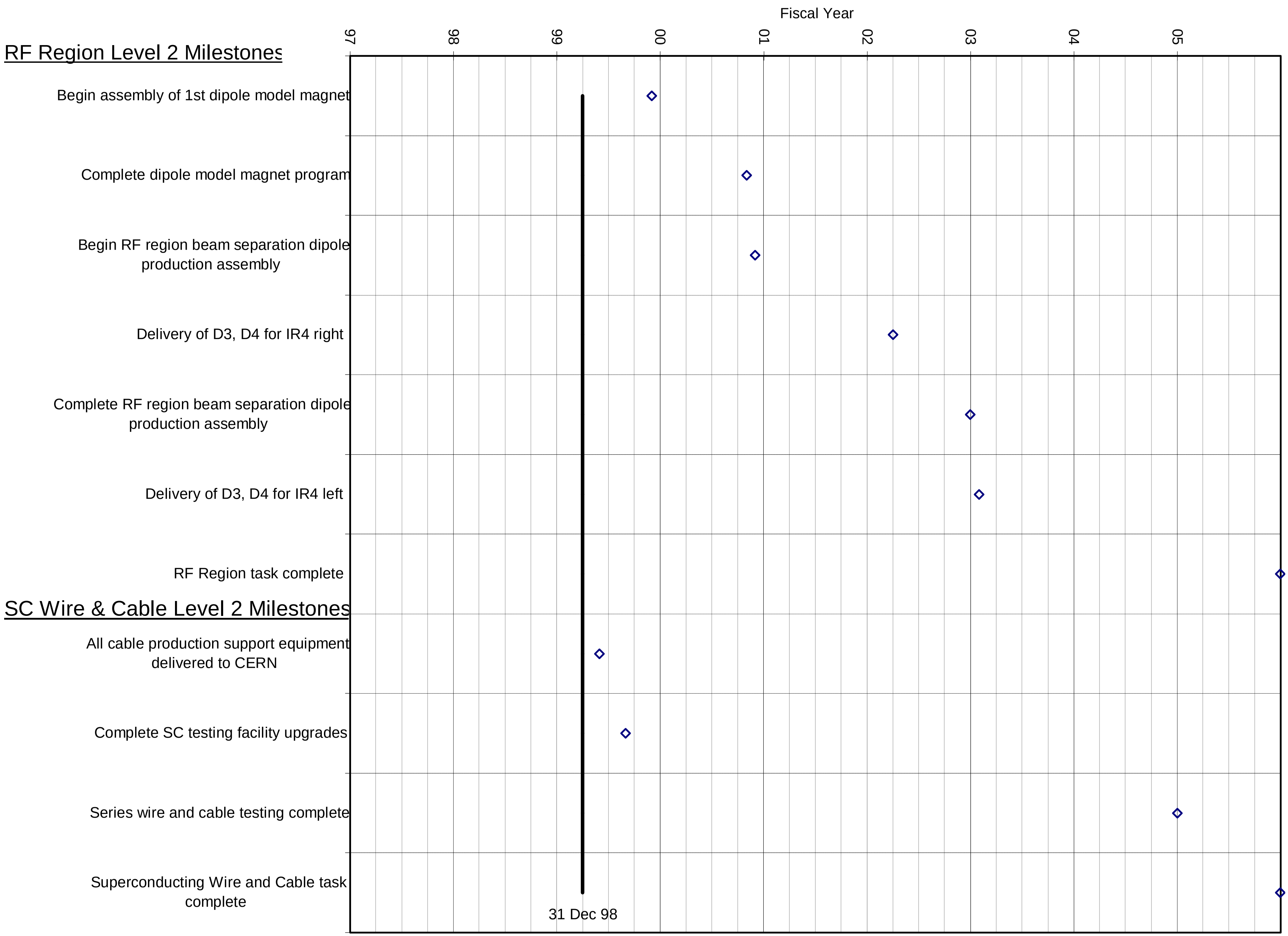
	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	TOTAL
BNL	$840K	$2,300K	$3,999K	$9,494K	$4,769K	$5,474K	$5,453K	$3,609K	$2,574K	$38,510K
FNAL	$660K	$2,800K	$4,304K	$6,014K	$6,033K	$4,769K	$5,814K	$3,418K	$1,126K	$34,939K
LBNL	$500K	$1,185K	$2,140K	$1,491K	$4,208K	$3,561K	$1,513K	$750K	$622K	$15,969K
Contingency	$0K	$385K	$3,558K	-$1,598K	$5,090K	$3,996K	$4,220K	$2,423K	$2,508K	$20,582K
DOE Funding	$2,000K	$6,670K	$14,000K	$15,400K	$20,100K	$17,800K	$17,000K	$10,200K	$6,830K	$110,000K
Operating	$2,000K	$6,370K	$2,865K	$900K	$600K	$1,900K	$2,400K	$2,400K	$2,200K	$21,635K
Capital	$0K	$300K	$11,135K	$14,500K	$19,500K	$15,900K	$14,600K	$7,800K	$4,630K	$88,365K



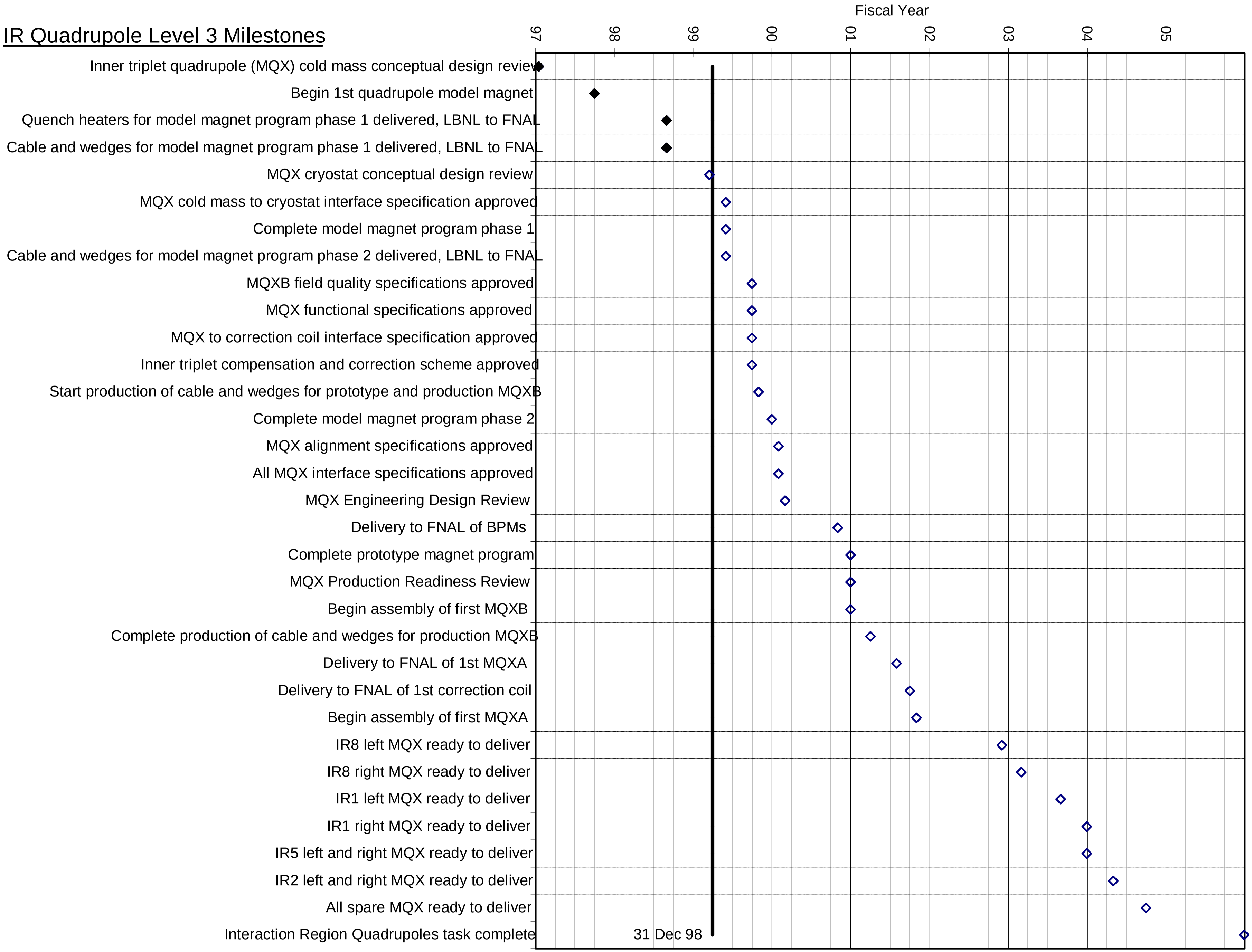
	FY96	FY97	FY98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	FY00	FY01	FY02	FY03	FY04
INCREMENTAL																				
FUNDS ALLOCATION	2,000	6,670	14,000	9,170	0	0	0	0	3,010	0	0	0	0	3,220	0	20,100	17,800	17,000	10,200	6,830
OBLIGATION PROFILE	1,962	6,427	10,337	4,662	756	1,092	1,479	1,578	1,239	882	841	1,267	1,265	842	1,096	15,010	13,804	12,780	7,777	4,322
EXPENSES	1,515	6,186	8,594	817	1,905	966														
OPEN COMMITMENTS	296	-43	-31	1,671	-297	396														
CUMULATIVE																				
FUNDS ALLOCATION	2,000	8,670	22,670	31,840	31,840	31,840	31,840	31,840	34,850	34,850	34,850	34,850	34,850	38,070	38,070	58,170	75,970	92,970	103,170	110,000
OBLIGATION PROFILE	1,962	8,390	18,727	23,389	24,145	25,237	26,716	28,294	29,532	30,414	31,255	32,522	33,787	34,630	35,725	50,735	64,539	77,320	85,096	89,418
EXPENSES	1,515	7,701	16,296	17,112	19,017	19,984														
OPEN COMMITMENTS	296	253	222	1,893	1,596	1,992														

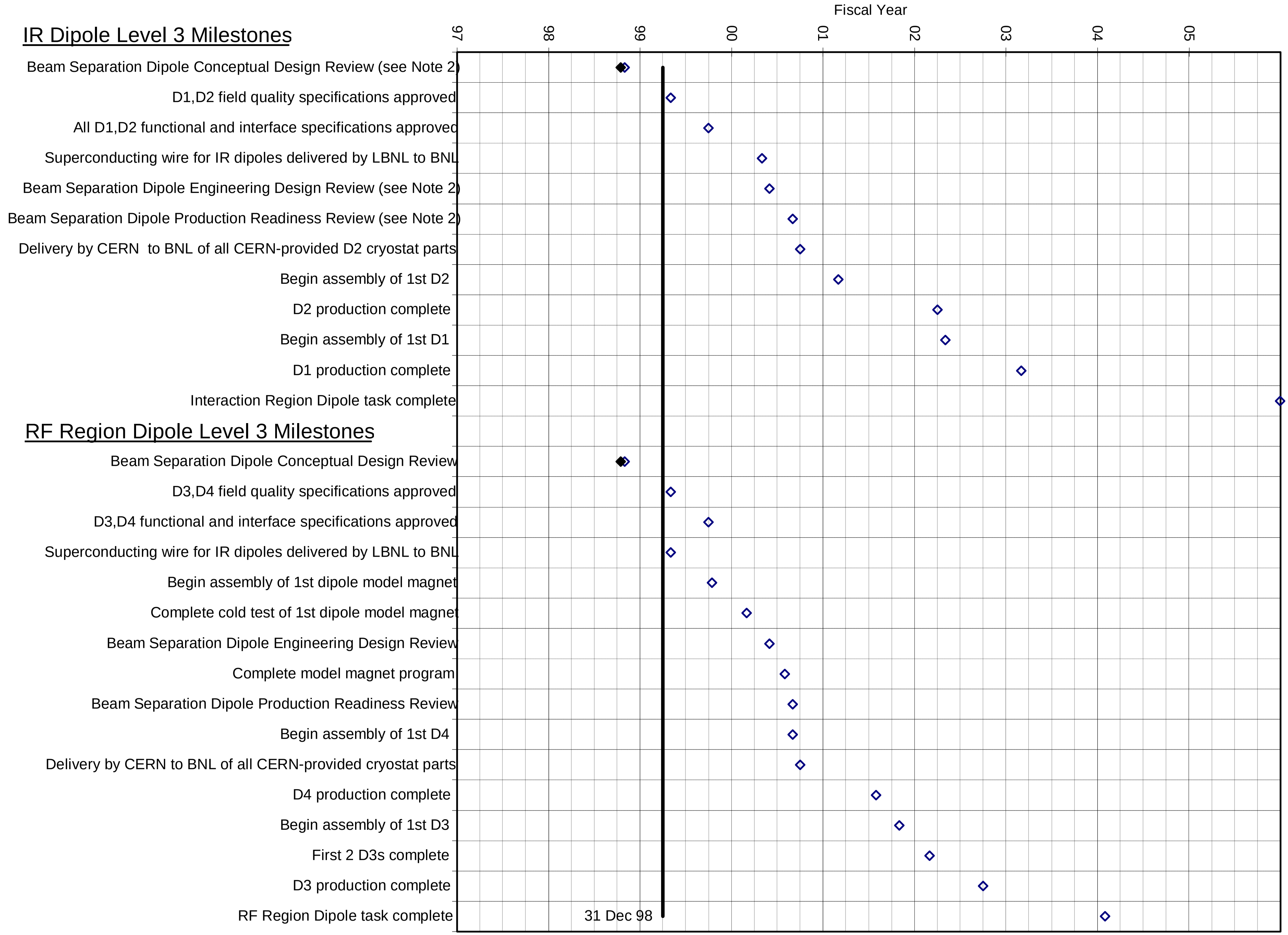
Interaction Region Level 2 Milestones

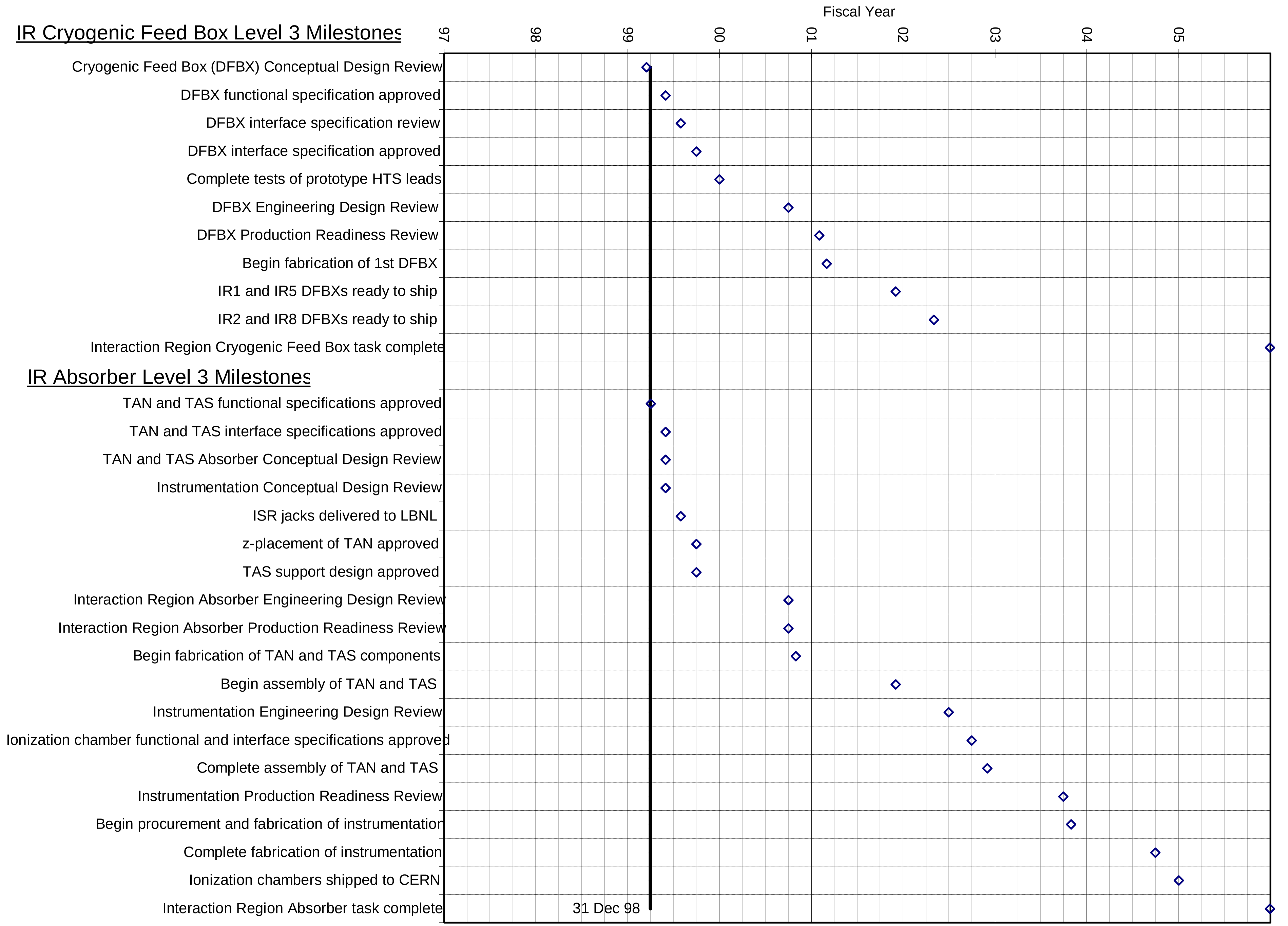



RF Region Level 2 Milestones
Begin assembly of 1st dipole model magnet
Complete dipole model magnet program
Begin RF region beam separation dipole production assembly
Delivery of D3, D4 for IR4 right
Complete RF region beam separation dipole production assembly
Delivery of D3, D4 for IR4 left
RF Region task complete
SC Wire & Cable Level 2 Milestones
All cable production support equipment delivered to CERN
Complete SC testing facility upgrades
Series wire and cable testing complete
Superconducting Wire and Cable task complete
Fiscal Year
97
98
99
00
01
02
03
04
05
31 Dec 98

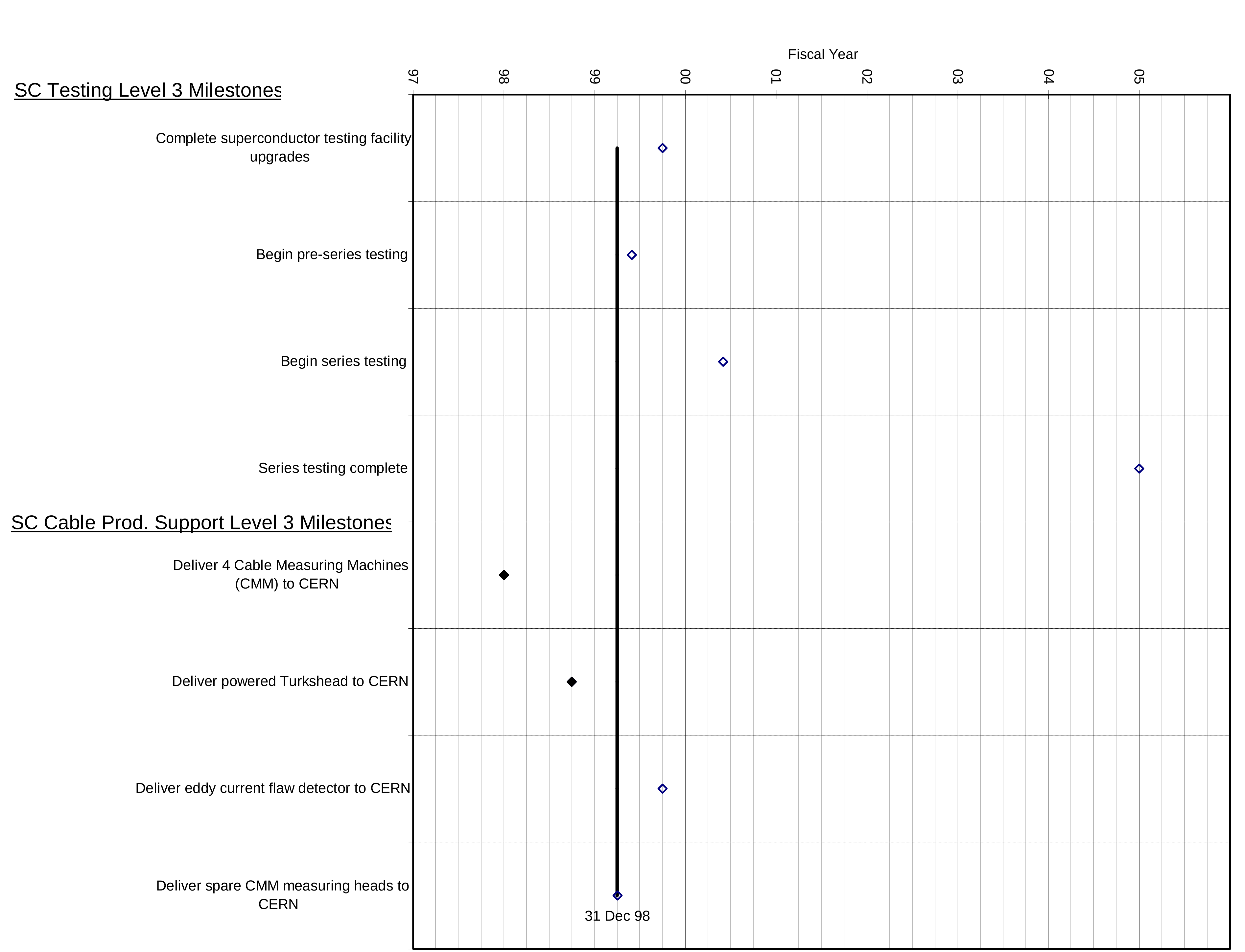
IR Quadrupole Level 3 Milestones




Fiscal Year
97
98
99
00
01
02
03
04
05
IR Dipole Level 3 Milestones
Beam Separation Dipole Conceptual Design Review (see Note 2)
D1,D2 field quality specifications approved
All D1,D2 functional and interface specifications approved
Superconducting wire for IR dipoles delivered by LBNL to BNL
Beam Separation Dipole Engineering Design Review (see Note 2)
Beam Separation Dipole Production Readiness Review (see Note 2)
Delivery by CERN to BNL of all CERN-provided D2 cryostat parts
Begin assembly of 1st D2
D2 production complete
Begin assembly of 1st D1
D1 production complete
Interaction Region Dipole task complete
RF Region Dipole Level 3 Milestones
Beam Separation Dipole Conceptual Design Review
D3,D4 field quality specifications approved
D3,D4 functional and interface specifications approved
Superconducting wire for IR dipoles delivered by LBNL to BNL
Begin assembly of 1st dipole model magnet
Complete cold test of 1st dipole model magnet
Beam Separation Dipole Engineering Design Review
Complete model magnet program
Beam Separation Dipole Production Readiness Review
Begin assembly of 1st D4
Delivery by CERN to BNL of all CERN-provided cryostat parts
D4 production complete
Begin assembly of 1st D3
First 2 D3s complete
D3 production complete
RF Region Dipole task complete
31 Dec 98



Fiscal Year
97
98
99
00
01
02
03
04
05
IR Cryogenic Feed Box Level 3 Milestones
Cryogenic Feed Box (DFBX) Conceptual Design Review
DFBX functional specification approved
DFBX interface specification review
DFBX interface specification approved
Complete tests of prototype HTS leads
DFBX Engineering Design Review
DFBX Production Readiness Review
Begin fabrication of 1st DFBX
IR1 and IR5 DFBXs ready to ship
IR2 and IR8 DFBXs ready to ship
Interaction Region Cryogenic Feed Box task complete
IR Absorber Level 3 Milestones
TAN and TAS functional specifications approved
TAN and TAS interface specifications approved
TAN and TAS Absorber Conceptual Design Review
Instrumentation Conceptual Design Review
ISR jacks delivered to LBNL
z-placement of TAN approved
TAS support design approved
Interaction Region Absorber Engineering Design Review
Interaction Region Absorber Production Readiness Review
Begin fabrication of TAN and TAS components
Begin assembly of TAN and TAS
Instrumentation Engineering Design Review
Ionization chamber functional and interface specifications approved
Complete assembly of TAN and TAS
Instrumentation Production Readiness Review
Begin procurement and fabrication of instrumentation
Complete fabrication of instrumentation
Ionization chambers shipped to CERN
Interaction Region Absorber task complete
31 Dec 98


SC Testing Level 3 Milestones
Complete superconductor testing facility upgrades
Begin pre-series testing
Begin series testing
Series testing complete
SC Cable Prod. Support Level 3 Milestones
Deliver 4 Cable Measuring Machines (CMM) to CERN
Deliver powered Turkshead to CERN
Deliver eddy current flaw detector to CERN
Deliver spare CMM measuring heads to CERN
Fiscal Year
97
98
99
00
01
02
03
04
05
31 Dec 98