Department of Energy
Review Committee

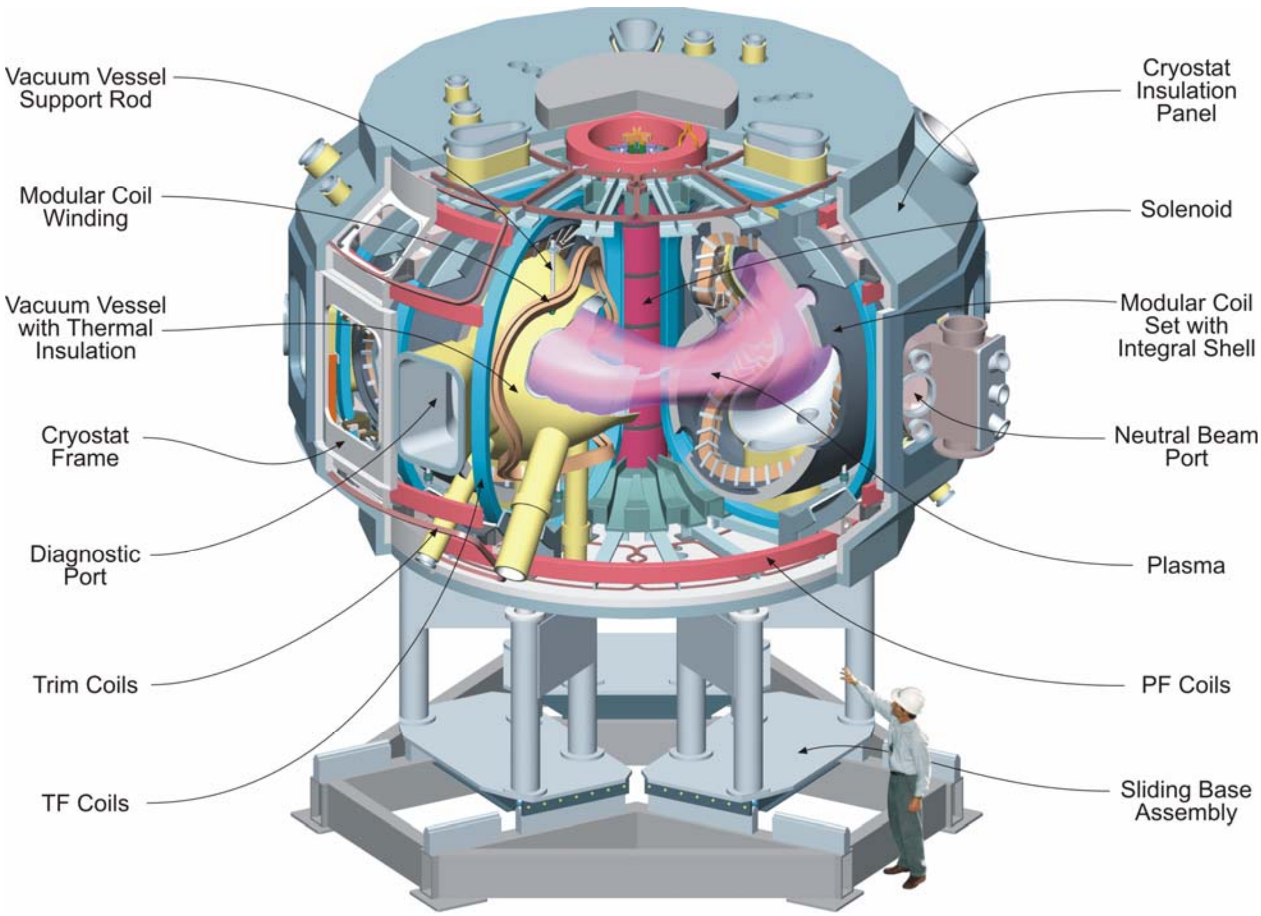
for the

Technical, Cost, Schedule,
ES&H, and Management Review

of the

NATIONAL COMPACT STELLARATOR EXPERIMENT (NCSX) PROJECT

December 2006



NATIONAL COMPACT STELLARATOR EXPERIMENT (NCSX) PROJECT

EXECUTIVE SUMMARY

As requested by Thomas Vanek, Acting Associate Director for Fusion Energy Sciences, Office of Science (SC), a Department of Energy (DOE) Independent Project Review of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment was performed at Princeton Plasma Physics Laboratory (PPPL) on December 19, 2006. The main purpose of the review was to assess credibility of current cost and schedule estimates, including adequate contingency for the remaining work; and to determine if the project is being managed properly.

Overall, the Committee found that the project is making good technical progress. Also, the NCSX management team is committed and is actively working the issues. However, the probability of successfully completing the project within the $92.4 million Total Estimated Cost, which includes approximately $4 million in contingency (approximately 14.8 percent of remaining work) appears to be low. Although several significant project risks have been retired, the Field Period Assembly is just initiating and several major risks remain.

The project presented a $12.4 million cost increase in order to add a "high-confidence" level of contingency to the cost baseline and a corresponding amount of contingency (two months) to the schedule baseline. The additional cost and time required are based on a subjective evaluation of remaining risks by the PPPL project team. The project needs to develop a bottoms-up estimate-to-complete and updated resource-loaded schedule estimates to substantiate adding cost and schedule contingency to the NCSX baselines.

The NCSX project is an innovative magnetic fusion plasma configuration consisting of a stellarator core that has three field periods and is surrounded by eighteen modular coils (six per field period). A vacuum vessel fills the internal volume of the modular coils to provide the maximum space for plasma shape flexibility. The modular coils are supplemented by toroidal field, poloidal field, and trim coils. Diagnostic systems provide the detailed measurement of the plasma parameters that are critical to the research goals of NCSX. The project is scheduled for completion in July 2009 and includes four and a half months of schedule contingency. The Committee's major recommendations to the project include the following:

- Prepare a bottoms-up estimate-to-complete and update the resource-loaded schedule after more data on field period assembly is collected (i.e., summer 2007).
- Re-baseline the project as appropriate, based on the above information, in order to include adequate contingency for achieving Critical Decision (CD) 4, Approve Start of Operations.

There was one action item resulting from the review—DOE/SC will conduct a progress review in approximately six months.

.

CONTENTS

1. INTRODUCTION

The National Compact Stellarator Experiment (NCSX) is a fusion research project initiated in the Department of Energy (DOE) FY 2003 budget at the Princeton Plasma Physics Laboratory (PPPL). The compact stellarator is one of several innovative magnetic fusion plasma configurations supported by the DOE Office of Fusion Energy Sciences (OFES) and has the attractive potential of operating continuously and without plasma disruptions. Also, when extrapolated to a fusion power plant, the compact stellarator is projected to require low operating power compared with that produced by the power plant.

The mission of NCSX is to acquire the scientific and technological knowledge needed for understanding the behavior of a compact-stellarator plasma, evaluating the attractiveness of this fusion concept, and advancing the state-of-the-art, three-dimensional analysis of fusion plasmas. In 2001, a panel of plasma physicists and engineers conducted a Physics Validation Review of the NCSX design. The panel concluded that the physics approach to the NCSX design was appropriate and that the concept was ready for the next stage of development, namely proof-of-principle. The Fusion Energy Sciences Advisory Committee endorsed the panel view. Critical Decision (CD) 0, Approve Mission Need, for NCSX was approved by OFES in May 2001. A May 2002 DOE Conceptual Design Review panel found that the NCSX design concept and project plans provided a sound basis for engineering development. Approval of CD-1, Approve Alternative Selection and Cost Range, was obtained in November 2002.

The NCSX project involves the design, fabrication, installation, and integrated system tests of a compact stellarator core device consisting of a highly shaped vacuum vessel; surrounding coil systems; enclosing cryostat and various auxiliary power; cooling, vacuum, cryogenic, and control systems; as well as a set of startup diagnostics. All of this equipment plus a control room will be located in existing buildings at PPPL that were previously used for other fusion experiments. Further, many of the NCSX auxiliary systems will be made available to the project from equipment used on the previous experiments. The project is being led by PPPL with Oak Ridge National Laboratory providing major leadership and support as a partner.

Because the project involves the fabrication of new equipment and considerable re-use of existing facilities and hardware systems and minimal civil construction, DOE designated the project as a Major Item of Equipment and included it as such in the FY 2003 budget. The cost initial cost range of NCSX, based on the pre-conceptual design, was between $69-83 million. The Total Estimated Cost (TEC) of the device based on the conceptual design was $73.5 million with a completion in June 2007. Due to the continuing resolution at the beginning of FY 2003 that was not resolved till February 2003, the project did not start until April 2003 instead of the planned October 2002 start. With this later start and additional design and cost information, PPPL estimated the TEC of the device to be $81 million with a completion in September 2007. PPPL assembled an outside committee to perform a preliminary design review in October 2003. Upon completion of the review and after analyzing the impacts from recommendations of that committee, the project team estimated the NCSX TEC to be $82 million with a completion date of November 2007. In addition, the preliminary design review committee concluded that the project was ready to proceed to CD-2, Approve Performance Baseline (signed in February 2004 with a baseline TEC of $86.3 million and a completion date in May 2008 after incorporating recommendations from the November 2003 Performance Baseline Review and updated DOE funding profile).

After various reviews, CD-3, Approve Start of Construction, was obtained in September 2004, with a TEC of $86.3 million and a completion date in May 2008. In 2005, the NCSX funding profile was modified by OFES in response to budgetary constraints. A new baseline was developed and approved by the Deputy Secretary in July 2005. This new baseline established a TEC of $92.4 million and a July 2009 completion date.

2. TECHNICAL SYSTEMS EVALUATIONS

The NCSX project appears to be well managed in terms of technical requirements. Technical accomplishments and progress to date are exemplary. Due in part to time restrictions, much of the technical discussions focused on the activities at hand such as the Modular Coil fabrication and test, and on the upcoming Field Period Assembly work. Some of the remaining technical issues involving design and assembly details of the Toroidal Field and Poloidal Field coils and final integration into the Stellerator Core received less attention. However, based on current performance it is expected that these issues will be addressed in a timely and satisfactory manner.

2.1 Modular Coil Winding Forms and Modular Coil Winding Process

2.1.1 Findings

Eleven of the eighteen Modular Coil Winding Forms (MCWF) have been machined and delivered to PPPL (five type "C", two type "B", and four type "A"). The remaining seven MCWFs are in progress at the vendor and are projected to be delivered ahead of schedule and well before the critical need date. These MCWF are a difficult three dimensional component and the delivery of these components from the vendor represents a significant success.

Nine modular coils have been wound (five type "C", three type "A", and one type "B"). Seven of these coils have been epoxy impregnated using the Vacuum Pressure Impregnation Process (VPI) (five type "C" and two type "A"). This work involves difficult winding operations due to the size and complicated geometry of the coils. In addition to the successful completion of the work it is reported that feedback from inspection data has been used to make corrections to conductor position prior to coil impregnation, thereby improving the as-built quality of the coil from what would otherwise have been achieved based on manufacturing tolerances of the MCWF. This effort is impressive and is to be commended.

One modular coil (C1) has been successfully cold tested without incident. It was noted that prior to cold test, electrical testing revealed an electrical short between the chill plate and the coil leads due to a weakness in the design. The weakness was corrected on the tested coil and the correction implemented on all future coils, with one previously completed coil scheduled to be repaired in the near future.

2.1.2 Comments

"A" coils were completed in approximately 30 percent (four weeks) less time than "C" coils, but with approximately ten percent (200 hours) more labor. Comments regarding events at the time include: staffing was added to increase rate and overtime was increased (98 → 116 hours) for a few weeks during September through November to catch up. This suggests that work has become less efficient as a result of these actions. Although there was not enough time to explore these issues during the review, some considerations are: Is work performed on overtime less efficient (due to fatigue, relaxation during standard hours, etc.)? Are the new staff members less efficient due to not being adequately trained? Has the work force become overstaffed?

It should also be noted that both winding stations were used for winding "A" coils, after five "C" coils were wound. (The remaining "C" coil is to be fabricated after MCWF delivery from the vendor.) The present plan is to wind two "B" coils before the "A" coils are complete. This sequence is driven in part by MCWF deliveries and in part by the field period assembly schedule. However, as there is a tooling changeover associated with this switching to different coil types, this represents wasted labor. Furthermore, gains in efficiency through the repetition of identical tasks are lost when like coils are not completed in series by the same individuals.

It is agreed that cold power cycling of additional individual coils does not provide adequate benefit to justify the cost. It has been explained that the coil insulation system is robust and further that coils are not fully stressed until final assembly is complete. Consider instead if there is benefit, due to differences in design or manufacture of different coils, in subjecting one "A" and one "B" coil to thermal cycling while monitoring electrical integrity and thermal uniformity. It is expected that the above testing could be completed at significantly less cost than previously identified and yield the most valuable risk abatement.

2.1.3 Recommendations

1. Restrict the use of overtime to only when necessary for continuity of work.

2. Work to optimize the limited amount of repetition available in production to realize efficiency through learning, reduced tooling changeovers, etc.

3. Review staffing plan. Verify that new staff is adequately trained, staffing levels are not excessive, work is consistently planned, etc.

2.2 Toroidal Field Coil Procurement

2.2.1 Findings and Comments

The contract to fabricate Toroidal Field (TF) coils has been awarded to Everson Tesla. Everson has built a clean room for coil winding per PPPL recommendation. Close proximity between PPPL and Everson has permitted good communication through direct weekly meetings. The first TF coil winding is underway. Everson is a quality vendor with strong technical capability (note that Everson was previously a RHIC magnet vendor).

2.2.2 Recommendation

1. Continue to provide direct oversight throughout the contract to ensure that Everson is aware of and supporting all technical and schedule requirements.

2.3 Poloidal Field Coils and Trim Coils

2.3.1 Findings and Comments

Drawings exist for Poloidal Field (PF) coils and trim coils, but no contracts have been placed and no active plans exist for fabrication of coils at PPPL. PF-1 through PF-3 are not part of the CD-4 scope. Two each of PF-4, PF-5, PF-6, and trim coils are required for CD-4. Half of these coils (lower coils) must be complete before final machine assembly can begin.

NCSX is relatively unconcerned about the fabrication of these coils due to the relative simplicity of the designs. However, there are considerations underway to revise the PF conductor design from the existing 2 cm solid copper with cooling hole to the “QPS” conductor (stranded copper around a cooling tube) for ease of assembly and reduced costs. Furthermore, a vendor with capability to fabricate the largest of these coils (which has an outer diameter of eighteen feet) has not been identified.

Completing design and engineering of the PF coils (and trim coils if necessary) and investigating potential vendors for PF coils will require resources and time. Failure to develop a commercial vendor could introduce risk to the overall program schedule.

2.3.2 Recommendation

1. Complete the investigation of a commercial vendor in time to build capability in house if necessary without adversely affecting the overall program schedule.

2.4 Field Period Assembly

2.4.1 Findings

All three vacuum vessel subassemblies are received and inspected.

A Field Period Assembly (FPA) Peer Review was conducted, resulting in many recommendations for improvements or corrections that were or are being implemented.

Work has started in the first two of five work stations.

A manpower loading projection for the five FPA work stations showed widely varying month-to-month labor requirements and partial FTE requirements each month in each work station.

Changes to TF coil structural support are being considered to reduce cost.

2.4.2 Comments

It was agreed that an assortment of shims of various thicknesses, to be selected at assembly based on inspection data, is much preferable in terms of significant cost savings and improved reliability over custom grinding of stainless steel shims.

The present need to ream holes in MCWF mating flanges is understood to be problematic. The proposed method of selecting offset bushings and filling voids with Stycast epoxy has promise but is unproven on the actual assembly. The same comment applies to the plan for using Stycast epoxy as part of the new inboard shear plate assembly.

2.4.3 Recommendations

1. Validate all proposed technical changes off critical path.

2. Develop integrated daily manpower assignments including all workstations to smooth out manpower requirements to an achievable level and to ensure that labor will be available when needed.

2.5 Final Assembly

2.5.1 Findings and Comments

Changes to PF coil structural support are being considered to reduce cost.

2.5.2 Recommendation

1. Validate the proposed technical changes off critical path.

Intentionally Blank

3. COST ESTIMATE

3.1 Findings

The NCSX baseline TEC remains at $92.4 million and the project reported that $58.6 million of work had been performed through November 30, 2006. This equates to 70 percent of the project having been completed, compared against 71 percent planned. The Cost Performance Index at that point was 0.97, which was calculated from April 2003 onward (when the project initially baselined and includes the directed baseline change in July 2005). The project presented approximately $5 million in contingency (18 percent); however if unavoidable costs are considered, there is approximately $4 million remaining in contingency (14.8 percent).

To obtain "high confidence" the project has identified the need for an additional $12.4 million of contingency. The estimate for the additional cost contingency is mostly subjective, with new cost numbers based on past NCSX project experience and an external peer review conducted in October 2006. The $12.4 million cost estimate is not based on a bottoms-up approach.

3.2 Comments

Considering the complex assembly work ahead and past project history, contingency is marginal at this stage of project. To obtain "high confidence" the project has identified the need for an additional $12.4 million of contingency. The estimate for the additional cost contingency is mostly subjective and is not based on a bottoms-up approach. The reasonableness of the additional $12.4 million request cannot be determined at this time because of the subjective nature of the estimate and the field assembly work is just being initiated.

3.3 Recommendation

1. Develop a bottoms-up estimate of the project's work to complete that is integrated into the project schedule and identifies required contingency by the next review.

Intentionally Blank

4. SCHEDULE and FUNDING

4.1 Findings

By the end of November 2006, the project was 44 months into a 76-month long schedule. The NCSX project schedule calls for an early finish in early March 2009. Actual performance is a half-month behind that goal, thus leaving about 4.5 months of schedule contingency to the baseline date for CD-4 (Approve Start of Operations) in July 2009. This reflects a little over one month of schedule slip since the May 2006 DOE review. The Schedule Performance Index as of November 30, 2006 was reported at 0.99. The project critical path has remained constant. It runs through the remainder of MCWF production and MC winding, then through field period assembly (starts in July 2007), and finally through cryostat installation, pump-down, and integrated system testing. All R&D is essentially complete, and over 85 percent of all Title I/II design work has been finished.

The MCWF vendor's schedule performance has been good and Princeton University's intervention with the vendor to offer financial schedule incentives has paid dividends. Recent history indicates that MCWF deliveries will exceed the project's early finish schedule requirements (last MCWF is projected for delivery in May 2007). A third winding fixture is being added to optimize the overall winding process, which now uses two winding stations. This leaves the option of establishing a third MC winding station by adding trained staff to accelerate the MC winding process. A decision on whether to exercise that option will have to be made in the next couple of months. MC winding operations are running two shifts per day with weekends reserved for re-work if needed. The current schedule calls for all MC winding to be completed by November 2007.

Although the project presented its case for $12.4 million of additional contingency, NCSX management still plans to maintain the July 2009 CD-4 date.

Field period and machine assembly operations are still planned using a single shift per day. The project has a fall-back plan to run two shifts per day, and there appears to be adequate staff resources to do this provided that the extra personnel can be trained in time to support the schedule.

The current PARS status indicator for NCSX is "Yellow" due to steady erosion of cost contingency. As reflected in Table 4-1, most of the available contingency falls in FY 2008. As noted in the previous section and below, the actual cost contingency is about $4.0 million after accounting for $1.0 million of "unavoidable risks" that are not yet in the project cost baseline.

Table 4-1. NCSX Funding Profile and Contingency Distribution as a Result of BCWS ($M)

	FY03	FY04	FY05	FY06	FY07	FY08	FY09	Total
BA	7.9	15.9	17.5	17.0	15.9	15.9	2.3	92.4
Contingency				0	1.4	3.5	0.1	5.0

4.2 Comments

Given the nature of the critical path schedule that requires producing the MCWFs, winding the MCs, and then assembling them with the Vacuum Vessel Sub-Assembly into the Stellarator Core, the project's 4.5 months of schedule contingency is becoming tight. The cost situation may soon preclude the option of buying the project's way out of schedule difficulties.

Looking at the project's funding profile, the budget authority levels for FY 2007 and 2008 are essentially fixed. Thus, if contingency is to be added, it would have to come in FY 2009 (and FY 2010 if CD-4 should slip more than three months). The prospect of a year-long Continuing Resolution in FY 2007 should not affect the NCSX funding profile, and so schedule should not be impacted.

Given about $1 million of "unavoidable risk," much of which is in FY 2007, the use of substantial cost contingency this year will force work to be deferred into FY 2008. Considerable non-critical path activities have already been deferred into FY 2008.

While the near-term (i.e., FY 2007) project schedule appears to be adequately detailed, the remainder may not be detailed enough to judge whether schedule contingency will be sufficient. If the project is to undergo a Level 0 rebaselining, it would be prudent to provide an updated resource-loaded schedule to make sure that a realistic CD-4 date is included with adequate schedule contingency.

4.3 Recommendation

1. Develop an updated resource-loaded schedule to complete the project as part of any Level 0 rebaselining proposal. It needs to be consistent with the amount of additional cost contingency being proposed.

5. MANAGEMENT

5.1 Findings

Management has been diligent in their oversight of the project.

At the current rate of contingency usage the project will have negative contingency of about $6 million at its termination. An analysis has been underway to assess both unavoidable additional costs (risks) and potentially avoidable costs (risks). While numbers have been assigned to these items they appear to be subjective and soft. At present the available contingency is
14.8 percent of the costs to go. All of the potential additional work, fabrication, and contingency on these two items have been lumped into a new overall contingency figure of 64 percent of the cost to go. This is a total increase in the project cost of $12.3 million.

Management has been active in trying to control in house fabrication costs although they remain higher than the original estimates. Resource loading has been driven by the perceived need to meet the current CD-4 date rather than cost minimization. Much of the outside procurement for the highest risk items such as the modular coil formers and the vacuum sections has been delivered. However, some of the most difficult fabrication remains to be accomplished such as the FPA assembly and assembly of the vacuum container.

Management has been working on a high confidence cost estimate to completion that was presented as additional contingency. Based on the presentation it was difficult for the Committee to ascertain the distribution of additional work and additional contingency.

The project appears to have strong support from Princeton University. They have backed incentive payments to the modular coil form vendor.

Depending on a new funding profile there may be little or no schedule contingency. There is a potential extension of the project to late 2009.

The project strongly feels that the in-process testing is adequate. Suggestions were made to only cryogenically test types “B” and “A” coils to confirm mechanical models. Full current testing of an individual coil does not simulate the force loading in operation and is not being considered. The decision process is strongly motivated by cost and schedule considerations rather than technical considerations.

5.2 Comments

In many cases fabrication procedures are a work in progress and in development. As such, each of these represents potential additional risk.

One of the unknowns are the costs for the PF coils that still need to be fabricated. A make/buy analysis is in progress. The project is considering a design change to a new conductor similar to that used in the modular coils. Once design work is completed vendor selection needs to be done.

As presented to the Committee, the project is just now developing procedures for these tasks. As a result, the cost estimate-to-complete is viewed as subjective (less than rigorous) by the Committee and needs additional support and analysis. For a new baseline a new bottoms-up estimate with well defined contingency is required. The earliest time to receive new funds appears to be in FY 2009.

5.3 Recommendations

1. Make a final decision regarding the cryogenic testing of the modular coils.

2. Refine the estimated cost to complete including a rational contingency estimate in preparation for a re-baseline in the summer.

APPENDIX A

CHARGE MEMORANDUM

Department of Energy
Washington, D.C. 20585

November 14, 2006

MEMORANDUM FOR DANIEL R. LEHMAN, DIRECTOR
OFFICE OF PROJECT ASSESSMENT

FROM: THOMAS J. VANEK, ACTING ASSOCIATE DIRECTOR
FOR FUSION ENERGY SCIENCES /signed/

SUBJECT: Cost and Schedule Review of the National Compact Stellarator Experiment (NCSX) at the Princeton Plasma Physics Laboratory (PPPL)

I would like to request that your office organize and lead an Office of Science (SC) review of the NCSX project.

The purpose of this review is to evaluate the project's latest cost and schedule performance. This information will help SC determine whether the NCSX Project is meeting the SC performance goals, and provide recommendations to address any issues you may discover.

The review is planned to be held on December 19-20, 2006, at PPPL. In carrying out its charge, the review committee should evaluate the following:

1. Are the project's current cost and schedule estimates credible and realistic for the remaining work?

2. Is there adequate cost and schedule contingency to address the risks inherent in the remaining work and is it being properly managed? Is the contingency supported by and consistent with an appropriate project-wide risk analysis? How much additional contingency would be required to achieve a high level of confidence in completing the project successfully?

3. Evaluate the NCSX Project Team's transition-to-operations plan. Have facility and infrastructure improvements been identified and planned to support first plasma at CD-4?

4. Is the project being managed (e.g. properly organized, adequately staffed) at this point and are future staffing plans adequate? Is there adequate support from PPPL and ORNL management?

5. Has the NCSX Project Team responded to the findings and recommendations from the May 10, 2006 Lehman Review? Does the Committee agree with the responses from the Team?

Barry Sullivan, the NCSX Program Manager, will work closely with you as necessary to plan and carry out this review. I would appreciate receiving your Committee's report within 30 days of the conclusion of the review. This review will play an important role in ensuring that the NCSX project can be completed within cost and on schedule.

Thank you for your help in this matter. If you have any questions or need additional information, please contact Barry at (301) 903-8438.

cc:
J. Decker, SC-2
G. Nardella, SC-24.2
B. Sullivan, SC-24.2
J. Makiel, SC-PSO
J. Faul, SC-PSO
R. Goldston, PPPL

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy Review of the
National Compact Stellarator Experiment (NCSX)

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Daniel R. Lehman, DOE/SC, Chairperson
Kin Chao, DOE/SC, Chairperson

Consultants

Mike Anerella, BNL
Jeff Hoy, DOE/SC
Bruce Strauss, DOE/SC
Stephen Webster, DOE/FSO

Observers

Barry Sullivan, DOE/SC
Jeff Makiel, DOE/PAO
Greg Pitonak, DOE/PAO

APPENDIX C

REVIEW
AGENDA

Department of Energy Review of the
National Compact Stellarator Experiment (NCSX)

AGENDA

<u>Tuesday, December 19, 2006—Lyman Spitzer Building, Room 318</u>

8:00 am	DOE Executive Session	D. Lehman
8:45 am	PPPL Welcome	R. Goldston
8:50 am	Project Overview and Management	H. Neilson
9:50 am	Stellarator Core Design, Procurement, Testing, and Verification	M. Cole/W. Reiersen
10:45 am	Break	
11:00 am	MCWF Procurement	P. Heitzenroeder
11:10 am	TF Procurement	M. Kalish
11:35 am	On-Site Fabrication Overview	L. Dudek
12:00 pm	Lunch	
12:45 pm	Tour of NCSX Manufacturing Facility	
1:30 pm	Coil Winding	J. Chrzanowski
2:00 pm	Field Period Assembly Operations	M. Viola
2:30 pm	Break	
2:45 pm	Summary Risk and Contingency Assessment	W. Reiersen
3:15 pm	Cost and Schedule Summary	R. Strykowsky
3:45 pm	DOE Executive Session	
5:00 pm	Feedback/Questions to Project Team	
6:00 pm	Adjourn	

<u>Wednesday, December 20, 2006</u>

8:00 am	DOE Executive Session
8:30 am	Discussion/Responses from Project Team
10:00 am	Report Writing
12:00 pm	Lunch
12:45 pm	Closeout Dry-run
2:00 pm	Closeout (video conference with OFES)
3:00 pm	Adjourn

APPENDIX D

COST TABLE

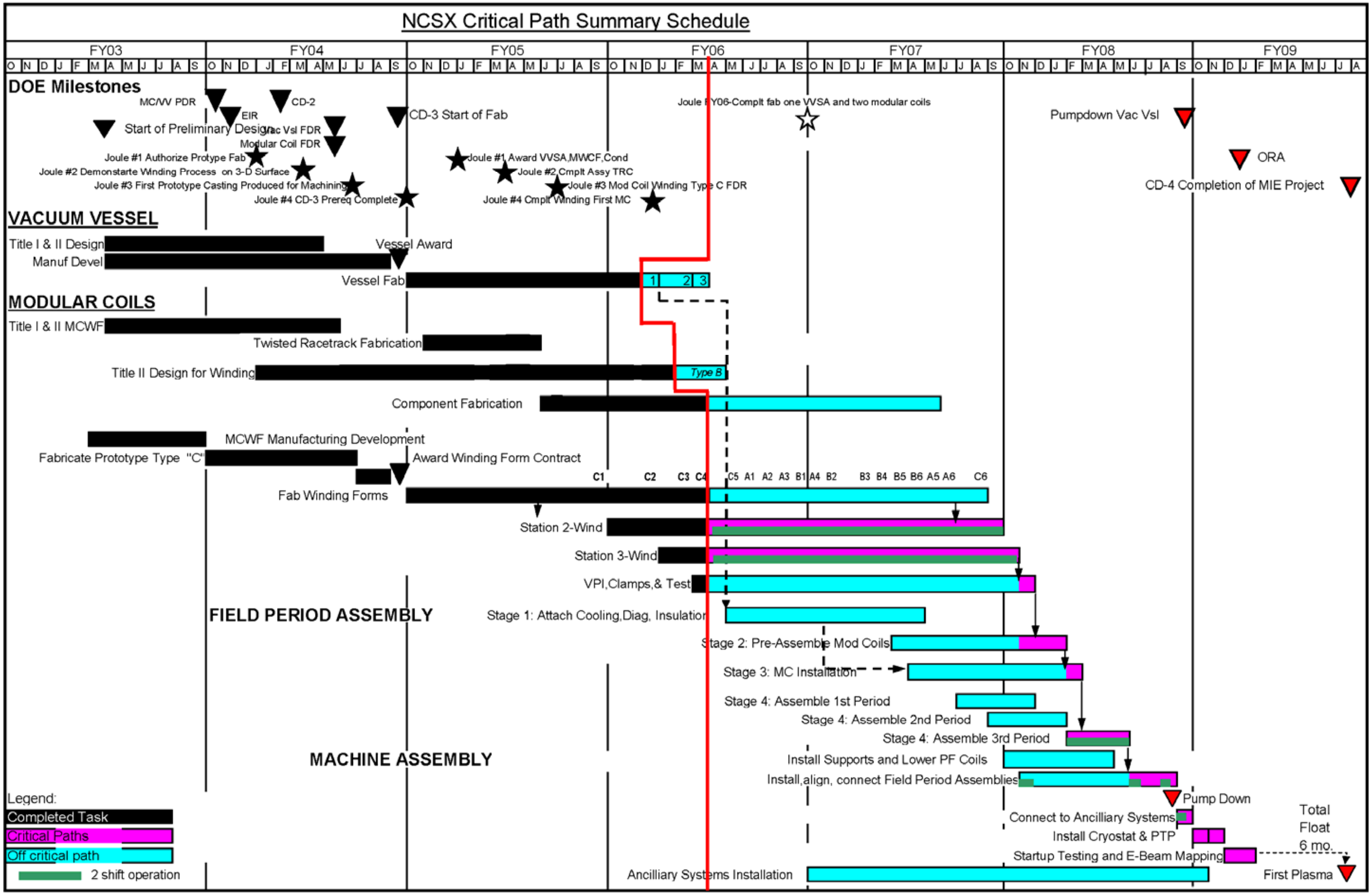
Contingency Analysis

WBS Le	Job Level	Base (BCWS)	Base To Date (11/30/06)	Base To Go	Budgeted Contingency		Total
		$k	$k	$k	$k	%	$k
dcma	dcma	75	75	-	-		75
12	Job: 1201 - Vacuum Vessel Prelim Dsn-**CLOSED**	424	424	-	-		424
12	Job: 1202 - Vacuum Vessel R&D	1,770	1,771	-	-		1,771
12	Job: 1203 - Vacuum Vessel Final Dsn-**CLOSED**	1,218	1,220	-	-		1,220
12	Job: 1204-VV Sys Procurements (non VVSA)-DUDEK	685	378	361	53	15%	791
12	Job: 1206 - VV Field Weld Joint R&D-**CLOSED**	16	16	-	-		16
12	Job: 1250 - Vacuum Vessel Fabrication--**CLOSED**	5,809	5,815	-	-		5,815
13	Job: 1301 - TF Design-KALISH**CLOSED**	971	970	-	-		970
13	Job: 1302 - PF Design -KALISH	132	19	140	20	15%	179
13	Job: 1303 -Central Solenoid Support Dsn-DAHLGREN	106	138	-	-		138
13	Job: 1350 TF Coil Fab Prep-CHRZANOWSKI**CLOSED**	547	536	-	-		536
13	Job: 1351 - TF Coil Fabr Supplies-KALISH	470	453	7	0	6%	460
13	Job: 1352 - PF Coil Procurement-KALISH	788	-	787	138	18%	925
13	Job: 1353 - CS Structure Procurement-DAHLGREN	123	-	123	18	15%	140
13	Job: 1354 - Trim Coil Design &Procurement-KALISH	106	-	106	23	22%	129
13	Job: 1355 - WBS 13 I&C Proc &	93	-	93	8	9%	101
13	Job: 1361 - TF Fabrication-KALISH	2,045	841	1,121	33	3%	1,994
14	Job: 1401 - Mod Coil Prel.Dsn**CLOSED**	304	304	-	-		304
14	Job: 1402 - Mod.Coil Analyses**CLOSED**	239	239	-	-		239
14	Job: 1403 - Modular Coil Final Design-WILLIAMSON	3,310	3,310	-	-		3,310
14	Job: 1404-MCWF R&D & 1st Prod Casting**CLOSED**	2,544	2,554	-	-		2,554
14	Job: 1405-Mod Coil Winding R&D Prep-**CLOSED**	168	168	-	-		168
14	Job: 1406 - Mod. Coil Winding	2,263	2,263	-	-		2,263
14	Job: 1407 -Mod Coil Winding Facility-**CLOSED**	2,571	2,570	-	-		2,570
14	Job: 1408-Mod Coil Winding Supplies-CHRZANOWSKI	1,953	1,957	228	17	7%	2,201
14	Job: 1409 - Coil Test Stand-GETTELFINGER*CLOSED*	826	833	-	-		833
14	Job: 1410 MC Twisted Racetrack Fabr-**CLOSED**	1,050	1,050	-	-		1,050
14	Job: 1411-MCWF Fabrication S005242-HEITZENROEDER	9,844	8,720	1,175	34	3%	9,929
14	Job: 1412 - Complete Winding Facilities-*CLOSED*	541	541	-	-		541
14	Job: 1413 -MCWF Fracture Analysis-**CLOSED**	28	28	-	-		28
14	Job: 1414 Coil Testing-Gettelfinger**CLOSED**	675	639	-	-		639
14	Job: 1415 Dim Cntrl Testing-RAFTOPOLOUS*CLOSED**	24	24	-	-		24
14	Job: 1416-Mod Coil Type A&B Final Dsn-WILLIAMSON	686	642	227	17	7%	886
14	Job: 1419-Winding Fac. Mods-CHRZANOWSKI*CLOSED*	55	46	-	-		46
14	Job: 1421-Mod Coil Interface Design-WILLIAMSON	380	120	488	71	15%	679
14	Job: 1431 - Mod. Coil Interface Hardware-DUDEK	699		699	204	29%	903
14	Job: 1451 - Mod Coil Winding-CHRZANOWSKI	5,994	4,045	3,811	223	6%	8,079
	Job: 1459 - Mod Coil Fabr.Punch List-CHRZANOWSKI	423	45	344	101	29%	490
14	Job: 1460 3rd Winding Fixture-CHRZANOWSKI	63	37	10	1	7%	48
15	Job: 1501 - Coil Structures Design- DAHLGREN	218	143	93	41	44%	277
15	Job: 1550 - Coil Structures Procurement -DAHLGREN	1,132		1,141	250	22%	1,392
16	Job: 1601 - Coil Services Design-WILLIAMSON	1,148	3	1,144	167	15%	1,314
17	Job: 1701-Cryost&Base Sprt Strct Dsn-GETTLEFINGER	606	417	180	53	29%	650
17	Job: 1751 - Cryostat Procurement	377		377	55	15%	432
17	Job: 1752 - Base Support Structure Procurement	231		231	34	15%	264
18	Job: 1801-Field Period Assly -CHRZANOWSKI (ORNL)	65	64	-	-		64
18	Job: 1802 - FP Assy Oversight&Support-VIOLA	1,614	754	826	97	12%	1,677
18	Job: 1803- FP Assy Toolg/Constructability-BROWN	1,170	1,007	299	44	15%	1,349
18	Job: 1804-Metrology Hardware-RAFTOPOULOS	587	559	13	-	0%	572
18	Job: 1805 -FP Assy H/W&Fixture	315	7	313	69	22%	389
18	Job: 1806 - FP Assembly specs & dwgs	210	4	178	21	12%	203
18	Job: 1810 - Field Period Assembly-VIOLA	2,618	304	2,372	1,246	53%	3,922
19	Job: 1901 - Stellarator Core Mngtt&Integr-NELSON	2,621	2,008	577	34	6%	2,618
2	Job: 2001-VPS Gas& Cond Sys Oversight-BLANCHARD	63	63	-	-		63
2	Job: 2101 - Fueling Systems	61		61	5	9%	67
2	Job: 2201 - Vacuum Pumping Systems	77		77	7	9%	84
2	Job: 2501 - Neutral Beam Refurbishment-STEVENSON	285	285	-	-		285
3	Job: 3101 Magnetic Diagnostics	522	481	134	10	7%	625
3	Job: 3601 - Edge and Divertor	9		9	1	15%	10
3	Job: 3801 - Electron Beam Mapping	30		29	4	15%	33
3	Job: 3901 - Diagnostics sys Integration-JOHNSON	375	327	25	4	15%	356
4	Job: 4101 - AC Power-RAMAKRISHNAN	364	107	(123)	-	0%	(16)
4	Job: 4301 - DC Systems-RAMAKRISHNAN	729	370	347	25	7%	742
4	Job: 4401 - Control & Protection-RAMAKRISHNAN	1,013	81	855	62	7%	998
4	Job: 4501 - Power Sys Dsn & Integr-RAMAKRISHNAN	1,076	155	751	55	7%	961
4	Job: 4601 - FCPC Bldg Mods-RAMAKRISHNAN	1	1	-	-		1

5 Job: 5101 - TCP/IP Infrastructure Systems	151		150	13	9%	163
5 Job: 5201 - I&C Systems	139		137	12	9%	149
5 Job: 5301 - Data Acquisition	150		150	13	9%	163
5 Job: 5401 - Facility Timing &	82		82	7	9%	89
5 Job: 5501 - Real Time Control System	94		93	8	9%	101
5 Job: 5601 - Central Safety Interlock Systems	129		129	11	9%	140
5 Job: 5801 -Central I&C Integr	58	33	12	1	9%	46
6 Job: 6101 - Water Systems	14		13	2	12%	15
6 Job: 6163 - Facility Systems Support FY04	15	15	-	-		15
6 Job: 6201 - Cryogenic Systems	456		456	67	15%	523
6 Job: 6301 - Utility Systems	107		107	73	68%	180
6 Job: 6501 - Facility Systems Integration-DUDEK	9	9	-	-		9
7 Job: 7101 - Shield Wall Modif	33	33	-	-		33
7 Job: 7301 - Platform Design &	114	76	39	6	15%	121
7 Job: 7401 - TC Prep & Mach Assy Planning-PERRY	1,552	844	718	52	7%	1,614
7 Job: 7501 - Construction Support Crew	589		588	43	7%	631
7 Job: 7503 - Machine Assembly	1,306		1,294	378	29%	1,672
7 Job: 7601 - Tooling Design & Fabrication	238		236	34	15%	270
8 Job: 8101 - Project Management & Control-NEILSON	3,836	2,639	999	29	3%	3,667
8 Job: 8102 - NCSX MIE Management ORNL-LYON	532	466	89	3	3%	557
8 Job: 8202 - Engr Mgmt & Sys Eng Support-REIERSEN	3,091	2,382	873	51	6%	3,306
8 Job: 8203 - Design Integration-BROWN	1,037	889	153	789	517%	1,830
8 Job: 8204 - Systems Analysis-BROOKS	1,216	1,061	204	24	12%	1,289
8 Job: 8205 - Dimensional Control Coordination	301	242	57	7	12%	305
8 Job: 8401 - Project Physcis-ZARNSTORFF	325	324	-	-		324
8 Job: 8402 - Project Physics MIE ORNL-LYON	146	146	-	-		146
8 Job: 8501 - Integrated Systems Testing	814		812	119	15%	931
8 Job: 8998 - Allocations	1,704	1,257	52	4	7%	1,313
	85,774	60,344	27,068	4,989	18%	92,401
TEC=	92,401					

APPENDIX E

SCHEDULE
CHART


NCSX Critical Path Summary Schedule
FY03
FY04
FY05
FY06
FY07
FY08
FY09
DOE Milestones
MC/VV PDR
EIR
CD-2
CD-3 Start of Fab
Start of Preliminary Design
Vac Vsl FDR
Modular Coil FDR
Joule #1 Authorize Protype Fab
Joule #2 Demonstarte Winding Process on 3-D Surface
Joule #3 First Prototype Casting Produced for Machining
Joule #4 CD-3 Prereq Complete
Joule #1 Award VVSA,MWCF,Cond
Joule #2 Cmplt Assy TRC
Joule #3 Mod Coil Winding Type C FDR
Joule #4 Cmplt Winding First MC
Joule FY06-Complt fab one VVSA and two modular coils
Pumpdown Vac Vsl
ORA
CD-4 Completion of MIE Project
VACUUM VESSEL
Title I & II Design
Manuf Devel
Vessel Award
Vessel Fab
1
2
3
MODULAR COILS
Title I & II MCWF
Twisted Racetrack Fabrication
Title II Design for Winding
Type B
Component Fabrication
MCWF Manufacturing Development
Fabricate Prototype Type "C"
Award Winding Form Contract
C1
C2
C3
C4
C5
A1
A2
A3
B1
A4
B2
B3
B4
B5
B6
A5
A6
C6
Fab Winding Forms
Station 2-Wind
Station 3-Wind
VPI,Clamps,& Test
FIELD PERIOD ASSEMBLY
Stage 1: Attach Cooling,Diag, Insulation
Stage 2: Pre-Assemble Mod Coils
Stage 3: MC Installation
MACHINE ASSEMBLY
Stage 4: Assemble 1st Period
Stage 4: Assemble 2nd Period
Stage 4: Assemble 3rd Period
Install Supports and Lower PF Coils
Install,align, connect Field Period Assemblies
Pump Down
Connect to Ancilliary Systems
Install Cryostat & PTP
Startup Testing and E-Beam Mapping
Ancilliary Systems Installation
Total
Float
6 mo.
First Plasma
Legend:
Completed Task
Critical Paths
Off critical path
2 shift operation

APPENDIX F

ACTION ITEMS

Action Items
Resulting from the December 2006
Department of Energy Review of the
NCSX Project

Action	Responsibility	Due Date
1. Conduct a DOE review	SC/NCSX	within 6 months