Department of Energy
Review Committee

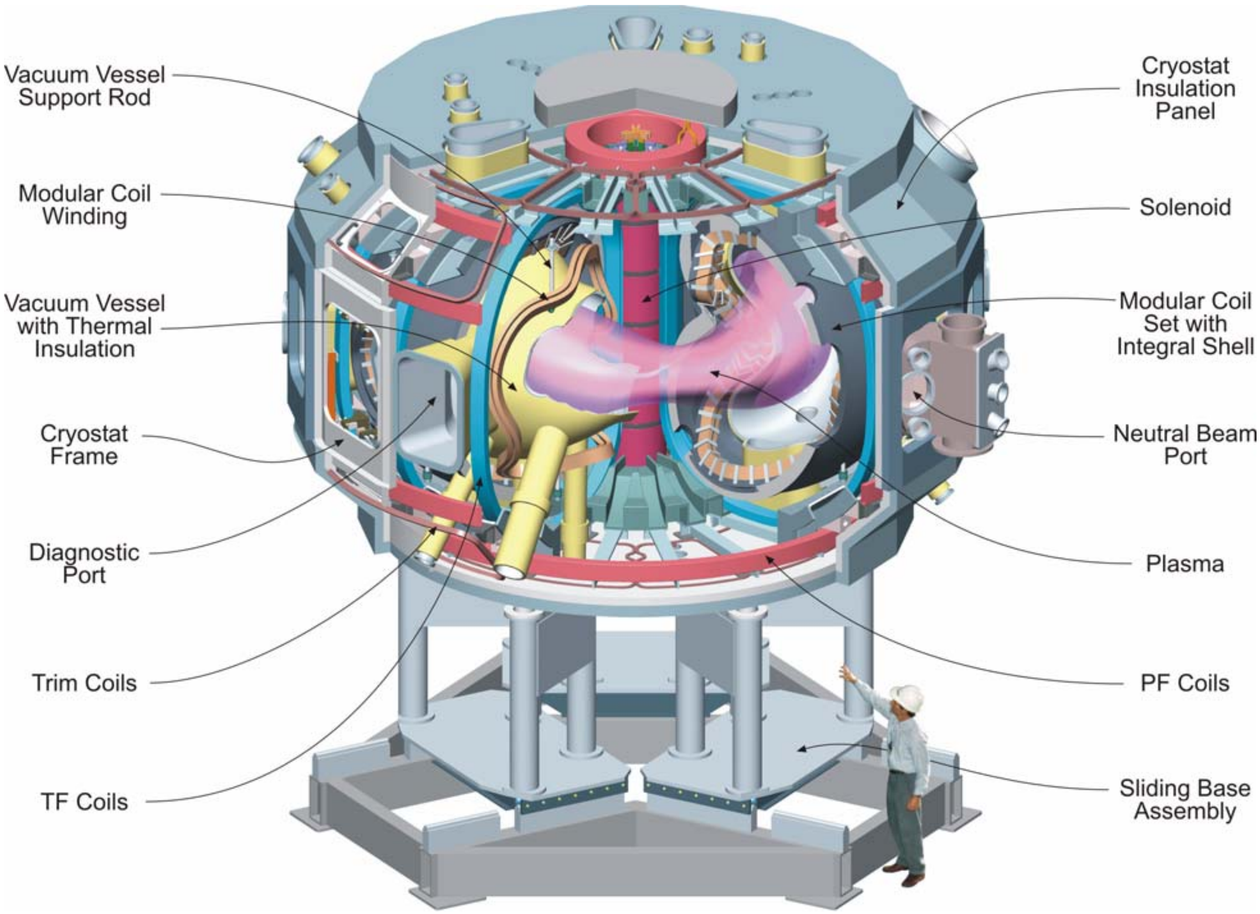
for the

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

of the

NATIONAL COMPACT STELLARATOR EXPERIMENT (NCSX) PROJECT

November 2005



NATIONAL COMPACT STELLARATOR EXPERIMENT (NCSX) PROJECT

EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science review of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment was performed at the Princeton Plasma Physics Laboratory on November 2-3, 2005, at the request of Dr. N. Anne Davies, Associate Director for the Office of Fusion Energy Sciences. The purpose of the review was to assess the project's overall cost, schedule, performance to date, and future plans. Specifically, the Committee was asked to determine if the procurements for the modular coil winding forms (MCWF) and Vacuum Vessel Sub-Assemblies were proceeding according to the August 2005 baseline; if the project has credible risk management system in place; if the cost and schedule (including contingencies) are adequate; if "in-house" work at PPPL is the best value for the government; and if the management and labor staff are adequate and appropriate.

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 (TF), poloidal field (PF), and trim coils. Diagnostic systems provide the detailed measurement of the plasma parameters that are critical to the research goals of NCSX.

The Total Estimated Cost for the NCSX project is $92.4 million including escalation and contingency. The project has expended approximately $38.3 million for activities leading up to the end of September 2005. Contingency remaining is $9.6 million, which is approximately 21.7 percent of remaining project costs. The project is scheduled for completion in July 2009 and includes five months of schedule contingency.

Overall, the Committee found that the project is progressing and the Committee was very impressed to see the amount of work accomplished. Examples of technical accomplishments include completion of all MCWF patterns and casting of eight of eighteen MCWF; two winding stations have been erected and the project has initiated winding of the first MC; and two of the three Vacuum Vessel (VV) shell sectors have been welded; completion of twisted racetrack research and development; and other tasks. Although several key risks have been reduced or retired, only one MCWF has been delivered (approximately three months delayed) to date and major on-site fabrication and assembly is just beginning.

Currently, the project's cost and schedule are performing satisfactorily. Much of the critical work remains in the early stages and the current assumptions on fabrication and winding learning curves are likely, but not proven—the next six months are a critical period that will or will not validate the project cost and schedule assumptions. The Committee was also concerned with the overall pattern of cost savings initiatives (i.e., use of poloidal field coils from the National Spherical Torus Experiment, simplified Trim Coil design, etc.) that may have implication for long term machine performance. Finally, the Committee saw a staffing plan detailed with appropriate resources. However, there are concerns of potential challenges resulting from the lengthy duration of planned multiple shifts, multiple winding lines, and external project influences (i.e., ITER work) that could impact the availability and productivity of project staff.

The Committee's major recommendations to the project included the following:

- Continue to place high priority on Modular Coil (MC) winding activities with the goal to minimizing fabrication time while maintaining high quality.

- Continue to work with Energy Industries of Ohio to maintain the MCWF delivery schedule.

- Because of uncertainty with the winding time required for the MCs, the Committee did not recommend the alternative of performing additional PF winding as an in-house activity. Pursue the option of having all TF and PF coils fabricated in industry and especially the option for fabrication in China leading to a decision by second quarter 2006.

- Apply further effort to reducing the cost of the TF wedge castings, so that procurement can proceed without schedule impact.

- Pursue further the development and refinement of the assembly procedures using the crane method to install the MC over the VV sectors. Pay particular attention to safety due to the heavy lifts and critical nature of the procedure.

- Closely re-examine the schedule and cost of the MC systems after the fabrication of the first three coils. Report to DOE on the results and progress with all aspects of the MC fabrication by the next DOE review.

- Analyze and report on the status of the contingency risks and opportunities identified in this review at the next DOE review.

- Assure continuity of engineering leadership, and effective oversight in the face of internal project demands (multi-shift strategies, plan to wind conventional coils in-house) and external project influences (ITER).

There was only one an action item: to conduct the next DOE 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. Earlier in 2002, a panel of plasma physicists and engineers conducted a Physics Validation Review (PVR) 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, by OFES occurred 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 will be led by PPPL with Oak Ridge National Laboratory (ORNL) 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 (MIE) and included it as such in the FY 2003 budget. The cost initial 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 (which was approved in February 2004 with a baseline TEC of $86.3M 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, Start of Construction, was approved 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

2.1 Modular Coil Winding Forms, the Twisted Racetrack Coil R&D, and Modular Coil Winding Process

The modular coils (MC) are formed by winding and potting flexible cable into cast and machined modular coil winding forms (MCWF). These are being fabricated by the Energy Industries of Ohio (EIO) under a fixed price contract. The first of these forms has been delivered to PPPL and is in the winding process.

The NCSX winding team has moved expeditiously on the R&D of the twisted racetrack coil (TRC) to resolve outstanding issues with conductor placement, clamping, potting, and cooling raised in previous reviews. This had many positive impacts on the winding process, which has just begun on the MCWF, and confidence in the performance of the completed MCs.

2.1.1 Findings

The first MC winding form has arrived and with some modest in-house work is now ready for winding. The patterns for all three MCWF's are complete. The foundry has cast six of the type "C" castings (the most complicated) and two type "A" castings. The material for the castings, "Stellalloy" has been fully characterized and exceeds all needed requirements.

The critical path for the MCWF production is the machining required to clean up the casting and produce the winding surfaces for the flexible conductor. The first MCFW took 26 weeks to machine and arrived three months late, due to a large number of required setups on the machine tool and significant programming changes needed to avoid tool/form interferences and generate the complicated needed shape. The second and third forms are in process with expected delivery by the end of November and December 29, 2005, respectively. Some improvement in the machining rate is being achieved on the second and third castings, but remains far below that projected in the contract schedule. Good relations appear to be maintained between PPPL and the vendors and every effort is being made to speed up the MCWF machining. With the delivery of the next two forms, coil winding can continue at PPPL on those articles without impact from the MCWF delivery.

Costs have been held to date at contract levels, with only a minor revision (approximately two percent) due to NCSX initiated changes for stress relieving of the casting and some winding details such as penetrations. The biggest risk appears to be schedule due to the excessive machining time required. Even so, the project has assessed delivery with estimates more conservative than those now provided by EIO and determined that the critical path now includes the coil winding process.

Methods have been developed to accurately place and hold the flexible cable conductor against the winding form. As a result of this experience, and in accordance with a previous review, a decision to eliminate the shimming from turn-to-turn (as previously considered) was made and a "go/no-go" gauging type system for turn placement within a prescribed winding envelope was chosen. This has the benefit of faster winding, but more importantly, the ability to add an additional layer into the winding pack resulting in reduced current densities and a 20 percent reduction in the heat deposited in a discharge.

Concerns about the coil cooling method have been addressed and the design simplified from that presented at the Final Design Review (FDR) resulting in a more workable design with easier installation at winding time and impact on clamping. The cooling has been tested on the TRC with equivalent I**2t pulses for similar heat deposition. Tests showed sufficient thermal conductivity to remove the heat in the envisaged 15-minute cycle time with only a small amount of ratcheting (approximately 20C). No extensive thermal cycling tests were performed. This modified design is projected to add roughly 300 person-hours/coil to fabrication time.

A problem encountered with conductor motion in the outer turns when clamps are removed for installation of the ground wrap has been resolved by a technique of "lacing" (or fixing of the winding locations with strips of glass/epoxy at critical spots).

A revised method of cocooning (or bagging) of the coil for epoxy impregnation has been developed that substantially reduces the time needed for this step in the fabrication. The impregnation has been tested on the TRC and subsequent examination through cuts in the TRC show complete impregnation and that there are no dry spots. A resin-rich area was identified and a method to prevent this has been developed.

Increased costs have been identified for groundwrap and metrology from experience on the TRC, also resulting in increased fabrication time/coil. The schedule planning, as it stands, has allowed an adequate time for the fabrication of first articles of a given type, with a modest credit in subsequent articles for the learning process. It is possible that more significant improvements in the speed of fabrication will be achieved as the crews develop experience, potentially offsetting the envisioned increased costs.

Torsion and bending tests of material properties of the copper/glass/epoxy matrix was completed on beam samples showing values sufficient for structural modeling of the coil/support system for over 600,000 cycles. Tensile tests in the TRC also showed sufficient properties.

A workable fixture has been developed for positioning the coil during the winding process, which permits access to both sides of the coil, speeds the winding process, and minimizes the lifts/moves needed of the coil/form.

Two winding stations in the clean rooms have been established so that winding can proceed on two coil modules concurrently. The first MC, using the single-delivered MC winding form, was in the fabrication process. The project plans to run both lines for two shifts per day to speed up the MC winding process.

2.1.2 Comments

The Committee found that NCSX has made significant progress in identifying and resolving many of the complex fabrication steps required to wind and use the VACUUM PRESSURE IMPREGNATION (VPI) on the MCs—this achievement is to be commended. The outstanding issue is the total amount of time required to fabricate each MC, since the project critical path is now determined by this activity. The Committee judged that the project has made a realistic and probably conservative estimate for MC fabrication and agrees that the two winding lines and double shifts are necessary to maintain the five-month schedule contingency. The project is developing contingency plans to maintain or accelerate MC winding production should these activities take longer than presently scheduled. This schedule contingency includes adding a third winding line first, followed by weekend shifts if necessary. The Committee stated that experienced engineering oversight of these MC fabrication activities is critical to achieving the schedule milestones while preserving the critical important fabrication quality. Presently, planned engineering staffing is adequate but not excessive. Project management should continue to ensure that qualified engineering personnel are available to maintain high quality oversight for the extended MC manufacturing period without excessive stress of personnel (especially if a third winding line becomes necessary to maintain the schedule).

There is particular concern with the actual manufacturing time for machining and delivery of the remaining MCWF. Project personnel have worked very well with EIO to ensure achieving the tight tolerances required on the machined MCWFs. The Committee is concerned that the overall acceleration of delivered pieces may not materialize because of the highly complex nature of the machining operations. It is possible that the critical path may alternate between MCWF delivery and coil winding, although at this point it is clearly on the winding line.

2.1.3 Recommendations

1. Continue to place high priority on MC winding activities with the goal to minimizing fabrication time while maintaining high quality.

2. Continue to work proactively with EIO for delivery of the MCWFs to the most recently developed schedule.

3. Closely re-examine the schedule and costing for the MC systems after the fabrication of the first three articles and provide an interim report to DOE on these results and progress with all aspects of the MC fabrication.

2.2 Vacuum Vessel Sub-Assembly

2.2.1 Findings and Comments

Substantial progress has been made in the Vacuum Vessel Sub-Assembly (VVSA) including completing the R&D and completion of all production processes for the panel stampings, including development of production welding procedures and port boring steps. To date, panels for two of the three 120 segment shells have been welded into their final shell configuration. Ports are being fabricated and port holes remain to be bored. NCSX staff will assist Major Tools and Machines (MTM) with developing leak checking procedures. On site quality assurance support is given by the Defense Contractor Management Agency (DCMA). Excellent geometric results have been confirmed using Verisurf® software, with only a few, non-critical areas outside the tolerance specification. This will not be an interference problem for assembly.

The schedule has slipped about one month from the baseline but it is well within schedule contingency allowance. The subcontract cost increased about ten percent from the original price due to the need for new forming dies and new flanges made from material with lower permeability. Since most of the process development has been completed there appears to be little risk of cost growth.

Excellent communications and working relationships have been established between NCSX project staff and MTM, and it appears that this task should proceed as scheduled and budgeted, pending confirmation of port welding and leak checking process finalization.

The Committee supported the project's decision to provide leak checking equipment and personnel to establish and supervise MTM leak checking of the vacuum vessel (VV) segments with ports installed.

2.2.2 Recommendations

None.

2.3 Conventional Coils

2.3.1 Findings

The current baseline plan is to have all conventional coils (toroidal field (TF) and poroidal field (PF)) manufactured by industrial vendors. Based on this prior experience and perceived lack of attention to production quality, NCSX performed a "Make vs. Buy" study for the TF coils. It was concluded that there was no cost difference when oversight costs, estimates of general administration, and vendor profit were taken into account. One of the main concerns was potential risk associated with manufacturing quality, because, if a TF coil fails in service it would cause severe disruption to machine operations if it needed to be replaced. The alternative, at this time, is for PPPL to wind the TF coils, but some other options are being investigated, including the possibility of having the TF (and possibly the PF) coils fabricated in China by the IPP-Hefei.

The project has established a TF coil winding line and begun setting up the clean room and winding table. All tooling has been designed except for about 50 percent of the VPI molds. Much of the tooling has started fabrication in PPPL facilities. The estimate for the TF coil fabrication was increased by $880K. The project has offset some of these increases through use of the NSTX PF1a coils and simplified trim coils.

A single bid was received from industry for the TF wedge castings. The quotation was significantly above the budget estimate. The project is reconsidering the tolerance and materials specification. Castings are not required until late FY 2006 so the schedule is not yet impacted.

The project is also planning on using poloidal field coils from the National Spherical Torus Experiment or simplified the design of Trim Coil that will lead to cost savings.

2.3.2 Comments

The Committee agreed with the project's concern about coil quality is legitimate, especially based on prior experience with the few U.S. vendors still active in this area of coil fabrication. The Committee's main concern was whether the additional effort required to wind all 18 coils in-house will overload the qualified personnel resources available to the project. The project has established the TF winding next to the MC winding lines and this should result in efficient use of shared oversight engineering personnel. The availability of adequate oversight engineering personnel should be a factor in future decisions about additional winding lines, weekend shifts, or possibly winding the PF coils in-house. The issue of where the PF coils will be fabricated should soon be determined so that provisions can be made in the schedule, especially if it is determined that coils need to be wound in-house.

Fabrication of the TF and PF coils in China at IPP-Hefei may be a credible and even preferred option, if a suitable collaboration could be established. The IPP-Hefei has developed a significant in-house capability in coil fabrication and has just completed manufacturing of the entire superconducting magnet system for the EAST tokamak. This could lead to a significant cost reduction in conventional coil fabrication.

The high-quoted cost from a single vendor for the TF wedge castings is also a significant concern—further effort should be given to understanding the reasons for this situation. The project should also continue efforts to modify the choice of alloy and manufacturing tolerances to bring the cost lower.

The Committee is concerned with the overall pattern of cost savings initiatives (i.e., use of poloidal field coils from the National Spherical Torus Experiment (NSTX), simplified Trim Coil design, etc.). Although the changes should not impact the initial operation of the NCSX as required to meet the CD-4 scope, however, these changes may have implication for future machine performance. A credit for $466K and $154K has been taken for use of NSTX solenoid coils and simplifying the design of the trim coils, although no further design details were presented during this review.

2.3.3 Recommendations

1. Pursue the option of having all TF and PF coils fabricated in China leading to a decision by second quarter 2006. Based on the uncertainty with the winding time required for the MCs, the Committee did not recommend that additional PF winding be undertaken as an in-house activity.

2. Investigate further the feasibility of having the TF and PF coils fabricated in industry with high quality if sufficient oversight personnel can be provided at the necessary level.

3. Apply further effort to reducing the cost of the TF wedge castings, so procurement can proceed without schedule impact.

4. Analyze the modified design of the correction coils to ensure adequate performance for plasma quality and confirm the cost reduction credit.

2.4 Field Period Assembly

2.4.1 Findings and Comments

Significant progress is reported in Field Period Assembly (FPA) including design work on VV prep stations, half-period assembly tooling, and spherical seat locators. R&D activities include a demonstration for testing the alignment of the spherical seat assemblies and measurement of their position using the Leica laser metrology system. There was a cost increase of $655K identified through required assembly hardware not in the rebaselined budget.

A rather complex and relatively expensive mechanical assembly tool was designed to install the MC over the VV. But a clever suggestion was made to try to use the overhead crane as the primary tool to perform this assembly process. A demonstration of this technique was performed using the overhead crane and hand assisted assembly. It was concluded that this could be a viable and very cost effective solution for performing this critical assembly step.

The Committee commends the project on their ingenuity in developing the crane plus hand assist method for FPA. This could result in significant cost savings to the project.

2.4.2 Recommendation

1. Pursue further the development and refinement of the assembly procedures using the crane method for installation of the MC over the VV sectors. Pay particular attention to safety in developing these procedures due to the heavy lifts and critical nature of the procedure.

3. COST ESTIMATE

3.1 Findings

The TEC for the NCSX is $92.4 million. The project has expended approximately $38.3 million for activities to the end of September 2005. There is approximately $12 million in contingency, which as a percentage of remaining project cost is approximately 25 percent. The project submitted a comprehensive plan that meets the CD-4, Approve Start of Operation, deliverable with five months of schedule contingency (consistent with the budget authority funding profile). This plan requested the use of $2.4 million in additional contingency to cover planned work through the end of third quarter 2006. This would lower the contingency as a percentage of remaining cost to approximately 22 percent.

The largest cost risks identified by the project are related to the MC winding and TF coil winding operations.

3.2 Comments

Contingency at this stage of the project appears to be very tight, but reasonable. The project has identified the possible need for contingency use in winding of the modular and TF coils. The assigned contingency for the fixed-price contracts for the VVSA and MCWF appear to be low.

The risk analysis presented appeared to be well planned and reasonable, with both risks and opportunities identified.

The project's cost performance, as represented by the Cost Performance Index, remains good. There does, however, appear to be a downward trend in the index.

3.3 Recommendation

1. The project should analyze and report on the status of the contingency risks and opportunities identified in this review at the next review.

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4. SCHEDULE and FUNDING

4.1 Findings

The NCSX baseline schedule remains credible. Fabrication of the MCWF and winding of the MCs remain as major activities on the project's critical path. Five months of schedule contingency remains in the project baseline schedule. Additionally, the project has identified means to recover another two months of critical path schedule, by using multiple shifts and multiple coil winding lines, if needed.

There remains a significant degree of uncertainty in the critical path schedule due to the performance of the MCWF vendor. Additionally, uncertainty remains in the MC winding schedule.

Table 4-1. NCSX Funding ($M)

	FY03	FY04	FY05	FY06	FY07	FY08	FY09	Total
BA	7.9	15.9	17.5	15.9	15.9	15.9	3.4	92.4
Contingency				1.3	2.5	4.8	1.0	9.6
Performance Measurement Baseline (PMB)	5.9	14.2	18.2	17.5	13.4	11.1	2.4	82.7
BO (PMB+Cont)	**5.9**	**14.2**	**18.2**	**18.8**	**15.9**	**15.9**	**3.4**	**92.3***

***There is $75K for DCMA services not included in BO, but included with BA**

4.2 Comments

Given the nature of the critical path schedule that requires serial activities of producing the Winding Forms, winding the MCs, and then assembling them with the VVSA into the Stellarator Core, the project's five months of schedule contingency is appropriate.

Performance of the MCWF vendor appears to be a major schedule uncertainty; however, the project has identified additional ways of recouping schedule by increasing shifts and additional winding lines. The schedule performance, as indicated by the Schedule Performance Index, remains good. There is, however, a downward trend in the index.

The project is 44.4 percent complete, verses plans to be 46.6 percent complete.

4.3 Recommendation

1. The project should re-evaluate the schedule uncertainties after more performance history is gained with the MCWF vendor and the MC winding operation and present results at the next scheduled DOE review.

5. MANAGEMENT

5.1 Findings

The NCSX project is approximately 44 percent complete and is generally tracking the baseline plan. Manufacturing R&D is complete. Since the April 2005 DOE review, the TRC fabrication has been completed. Testing and analysis of the TRC is providing lessons that will be directly applicable and useful in the full-scale MC development and assembly.

MCWF and VVSA fabrication is well underway. Work on the infrastructure to support MC fabrication and field period assembly is impressive, well done, and well managed.

A strong Integrated Project Team is in place, both management and technical, which has a clear understanding of the scope and challenges of the project. Tools and processes to manage project activities are in place and appear to be functioning effectively.

The NCSX management team presented the status of NCSX management, cost and schedule, risk management, and contingency management in a very clear and concise manner. The presentation material was very well organized and presented a picture of a project that is "well managed" by a very competent team. The team has maintained excellent communications internally among all PPPL/ORNL groups, DOE, and also with the key industrial vendors.

PPPL and ORNL management continue to place a very high priority on NCSX and provide regular oversight of the project. The NCSX project organization has been recently updated to formally designate On-Site Fabrication Organizations, which makes the transition of project activities from R&D and design to manufacturing and assembly visible.

A process is in place to identify and address critical issues (technical, cost, schedule) that could potentially impact the project. Risks are monitored and mitigated.

5.2 Comments

The integration between ORNL and PPPL seems to be working seamlessly. The NCSX project schedule was a focus for the Committee due to the critical nature of the work to produce the MCs. The key vendor has made progress in turning on the production line and the first MCWF has been delivered and is in the winding clean room at PPPL. This vendor has not yet "reached its stride" as the second MCWF is taking considerably longer than the projections and it is too early to tell if the third MCWF is gaining ground.

While progress is visible and impressive, major on-site fabrication and assembly is just beginning. The NCSX management has recognized the production of MCs as the critical path/critical technical element and has taken appropriate steps to maintain forward momentum. The team implementation of parallel winding lines with multiple-shift operation is an effective management response to the schedule for MCWF production with the expectation that the critical path will shift from MCWF production to MC winding in very few months even if the production goals of the MCWF contractor are not met. NCSX management has contingency plans for a third winding line, if necessary, to keep the project on schedule.

The next six months will provide the critical MCWF and MC production time data and confirmation of the reality of anticipated MC learning curves will be apparent. Additional schedule contingency planning is underway to apply a multiple-line, multiple-shift strategy to the production of FPA and Final Machine Assembly (FMA). This forward thinking is evidence of a culture of proactive management.

The various employee incentive plans in place at PPPL will be an essential part of encouraging the innovation necessary by the production staff to find the efficiencies necessary to meet the MC production goals. The Committee applauded and encouraged this system of recognitions and rewards.

In general, staffing is well planned, but the Committee is concerned about the potential impacts of overbooking of key staff, the lengthy duration of planned multiple fabrication and assembly shifts, and future schedule uncertainties.

Make or buy considerations appear to appropriately balance cost and quality, and to provide best value. However, the Committee is concerned that key staff attention may be diluted if NCSX proceeds with their plans to fabricate the TF coils (and possibly PF) in-house. The Committee encouraged further efforts to outsource these components either in industry or through the potential arrangement with the laboratory in China as described during the plenary session. The reduced stress on critical staff and the potential for savings in cost and contingency are very attractive if these items (TF, PF, TF wedges) can be outsourced.

5.3 Recommendations

1. Continue ongoing efforts to outsource TF and PF coils (decision by second quarter 2006).

2. Assure continuity of engineering leadership and effective oversight in the face of internal project demands (multi-shift strategies) and external project influences (ITER).

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APPENDIX A

CHARGE MEMORANDUM

Department of Energy
Washington, D.C. 20585

August 4, 2005

MEMORANDUM FOR Daniel R. Lehman, Director
Construction Management Support Division

FROM: N. Anne Davies (signed)
Associate Director for Fusion Energy Sciences

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 cost, scope, and schedule performance to date and its future plans. This information will help SC determine that the NCSX Project is meeting the SC project performance goals, and provide recommendations to address any issues you may discover.

The review shall be conducted on November 2 and 3rd, 2006, at PPPL. In carrying out its charge, the review committee should respond to the following questions:

1. Does the project performance information provided to date support the conclusion that the procurements for the modular coil winding forms and vacuum vessel assemblies are proceeding according to the August 2005 approved baseline cost and schedule?

2. Are there credible mechanisms in place for evaluating and resolving past and future project risks, including technical issues and changes, which have or may arise?

3. Are the project's cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate cost and schedule contingency? Is the contingency based on a thorough risk-based analysis?

4. Is the work that PPPL has decided to do "in-house" the best value for the government?

5. Is the Integrated Project Team appropriately staffed and functioning as defined in DOE Order 413.3 and the Project Execution Plan? Is the plan for augmenting the labor staff adequate to meet the project's objectives?

Barry Sullivan, 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 on cost and schedule. Thank you for your help in this matter. If you have any questions or need additional information, please contact Barry at 3-8438.

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APPENDIX B

REVIEW PARTICIPANTS

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

REVIEW COMMITTEE PARTICIPANTS

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Consultants

Dave Anderson, U. of Wisconsin
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APPENDIX C

REVIEW
AGENDA

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

AGENDA

Wednesday, November 2, 2005—Lyman Spitzer Building, Room 318

8:00 am	DOE Executive Session	K. Chao
8:30 am	PPPL Welcome	R. Goldston
8:35 am	Project Overview and Management	H. Neilson
9:15 am	MCWF Procurement	P. Heitzenroeder
10:00 am	BREAK	
10:15 am	VVSA Procurement	M. Viola
10:45 am	Stellarator Core Design	B. Nelson
11:25 am	On-Site Fabrication Overview	L. Dudek
11:45 am	Tour of Coil Winding Facilities	
12:45 pm	LUNCH	
1:30 pm	Coil Winding	J. Chrzanowski
1:55 pm	Field Period Assembly	M. Viola
2:15 pm	BREAK	
2:30 pm	Risk Assessment Summary	W. Reiersen
3:00 pm	Cost and Schedule Summary	R. Strykowsky
3:30 pm	DOE Executive Session	
5:00 pm	Adjourn	

Thursday, November 3, 2005

8:00 am	DOE Executive Session/Dry Run of Closeout
12:00 pm	LUNCH
1:00 pm	Closeout Presentation with NCSX Management
2:00 pm	Adjourn

APPENDIX D

COST
TABLE

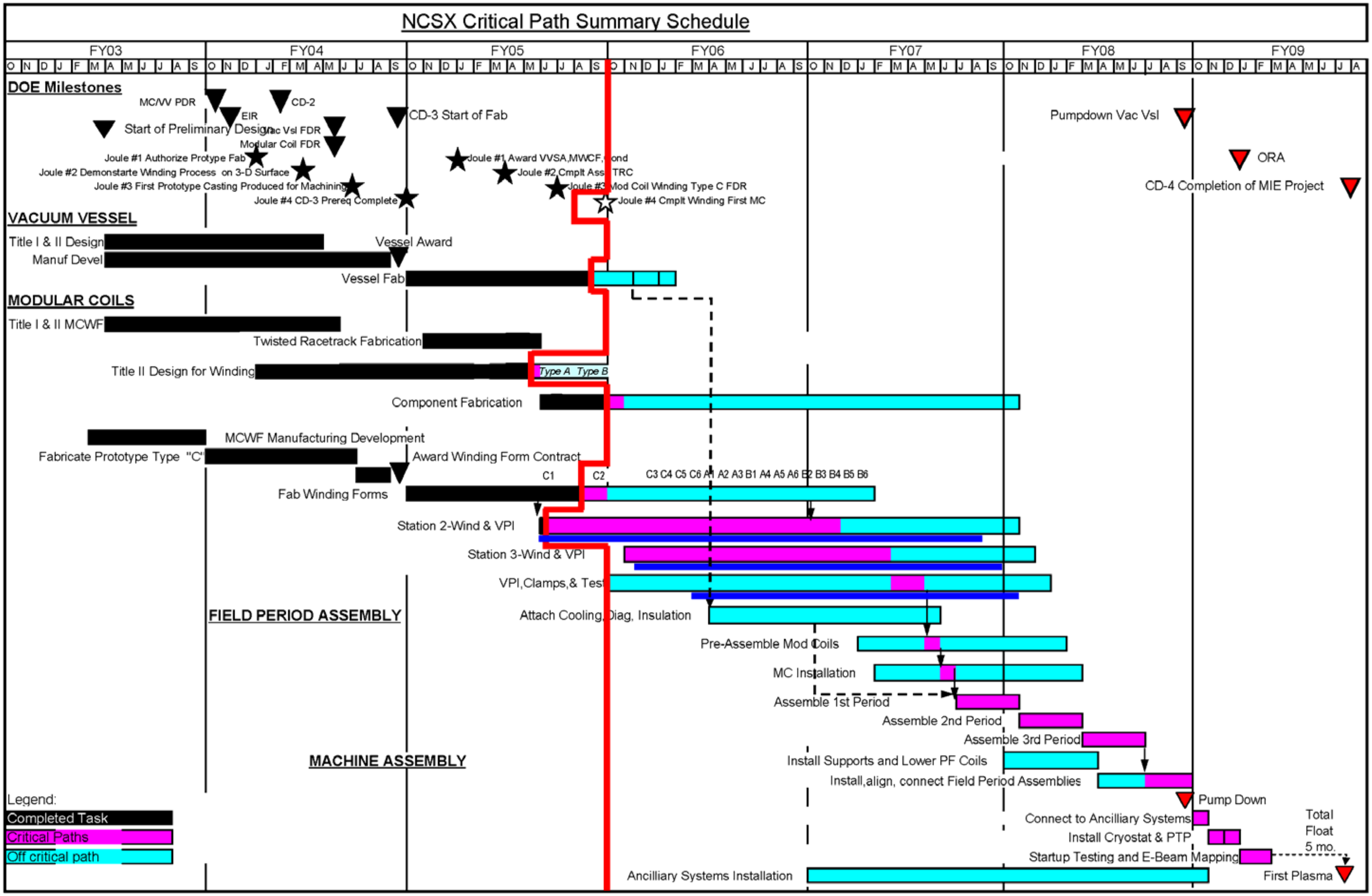
NCSX Cost Baseline

WBS	WBS Title	Project Estimate					
			Base To Date	Base To Go	Contingency		Total ($K)
		Base Cost ($K)	Cost	Cost	%	$	
1	**Stellarator Core Systems**	**57,728,100**	**29,727,000**	**28,001,100**	**24.6%**	**6,878,349**	**64,606,449**
11	In Vessel Components		0	0			0
12	Vacuum Vessel Systems	9,439,300	6,191,000	3,248,300	14%	451,892	9,891,192
13	Conventional Coils	4,831,000	1,515,000	3,316,000	38%	1,267,951	6,098,951
14	Mod Coils	31,355,900	18,753,000	12,602,900	22%	2,773,324	34,129,224
15	Coil Support Structures	1,386,200	75,000	1,311,200	30%	391,108	1,777,308
16	Coil Services	1,135,000	0	1,135,000	30%	340,504	1,475,504
17	Cryostat & Base Support Structure	1,532,900	372,000	1,160,900	30%	346,769	1,879,669
18	Field Period Assembly	5,280,800	1,336,000	3,944,800	30%	1,178,591	6,459,391
19	Stellarator Core Mgmt. & Integration	2,767,000	1,485,000	1,282,000	10%	128,210	2,895,210
2	**Plasma Heating Fueling & Vac Sys**	**791,300**	**347,400**	**443,900**	**14%**	**62,055**	**853,355**
21	Fueling Systems	88,100		88,100	14%	12,333	100,433
22	Torus Vacuum Pump	418,800	63,000	355,800	14%	49,722	468,522
23	Wall Conditioning System			0			0
25	Neutral Beam Injection System	284,400	284,400	0			284,400
3	**Diagnostics**	**1,148,700**	**405,000**	**743,700**	**24%**	**175,717**	**1,324,417**
31	Magnetic Diagnostics	551,600	131,000	420,600	21%	89,442	641,042
35	Profile Diagnostics			0			0
36	Edge & Divertor Diagnostics	45,600		45,600	20%	9,116	54,716
38	Electron Beam (EB) Mapping	206,200		206,200	34%	70,107	276,307
39	Diagnostics Integration	345,300	274,000	71,300	10%	7,052	352,352
4	**Electrical Power Systems**	**3,305,100**	**527,000**	**2,778,100**	**20%**	**548,806**	**3,853,906**
41	AC Power	423,900	107,000	316,900	18%	56,691	480,591
42	AC/DC Converter			0			0
43	DC Systems	478,800	226,000	252,800	21%	53,641	532,441
44	Control & protection system	1,346,000	55,000	1,291,000	20%	252,770	1,598,770
45	Power System Design & Integration	1,055,100	138,000	917,100	20%	185,704	1,240,804
46	FCPC Building Modification	1,300	1,000	300	0%		1,300
5	**Central I&C Systems**	**1,873,585**	**33,400**	**1,840,185**	**10%**	**187,484**	**2,061,069**
51	TCP/IP Infrastructure System	280,385		280,385	5%	14,019	294,404
52	Central Instrum. & Controls System	530,100		530,100	10%	53,011	583,111
53	DAQ & Facility Computing	329,100		329,100	16%	52,652	381,752
54	Facility Timing & Synch. System	195,800		195,800	14%	27,415	223,215
55	Real Time Plasma/Power Cont Sys	179,300		179,300	8%	14,347	193,647

56	Central Safety Interlock System	325,500		325,500	8%	26,040	351,540
57	Control Room Facility			0			0
58	Central I&C Mgmt and Integration	33,400	33,400	0			33,400
6	**Facility Systems**	**678,200**	**24,000**	**654,200**	**20%**	**130,842**	**809,042**
61	Water Cooling Systems	92,300	15,000	77,300	24%	18,454	110,754
62	Cryogenic System	455,000		455,000	20%	91,007	546,007
63	Utility Systems	106,900	9,000	97,900	22%	21,381	128,281
64	Bakeout System			0			0
65	Facility System	24,000		24,000	0%		24,000
7	**Test Cell Prep & Machine Assembly**	**4,555,200**	**900,200**	**3,655,000**	**22%**	**793,147**	**5,348,347**
71	Shield Wall Reconfiguration	32,200	32,200	0		-	32,200
72	Control Room Refurbishment	9,100	0	9,100	10%	910	10,010
73	Platform Design	109,100	73,000	36,100	10%	3,644	112,744
74	Planning/Oversight	1,753,200	795,000	958,200	15%	145,873	1,899,073
75	Machine Assembly Planning & Oversight	2,413,800		2,413,800	24%	585,653	2,999,453
76	Tooling Design & Fabrication	237,800		237,800	24%	57,067	294,867
8	**Project Oversight & Support**	**12,633,000**	**6,349,900**	**6,283,100**	**13%**	**836,075**	**13,469,075**
81	Project Management & Control	4,452,900	2,209,000	2,243,900	11%	248,820	4,701,720
82	Project Engineering	4,904,100	2,891,000	2,013,100	10%	193,367	5,097,467
83	E&Safety/QA/QC in overhead			0			0
84	Project Physics	469,900	469,900	0			469,900
85	Integrated System Testing	1,197,700	0	1,197,700	26%	310,999	1,508,699
A	Allocations	1,608,400	780,000	828,400	10%	82,889	1,691,289
	TOTAL	**82,713,185**	**38,313,900**	**44,399,285**	**21.65%**	**9,612,474**	**92,325,659**
	DCMA	75,000					75,000
		82,788,185					**92,400,659**

APPENDIX E

SCHEDULE CHART



NCSX Critical Path Summary Schedule
FY03
FY04
FY05
FY06
FY07
FY08
FY09
DOE Milestones
MC/VV PDR
CD-2
EIR
Start of Preliminary Design
Vac Vsl FDR
Modular Coil FDR
CD-3 Start of Fab
Pumpdown Vac Vsl
ORA
CD-4 Completion of MIE Project
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 Ass TRC
Joule #3 Mod Coil Winding Type C FDR
Joule #4 Cmplt Winding First MC
VACUUM VESSEL
Title I & II Design
Manuf Devel
Vessel Award
Vessel Fab
MODULAR COILS
Title I & II MCWF
Twisted Racetrack Fabrication
Title II Design for Winding
Type A Type B
Component Fabrication
MCWF Manufacturing Development
Fabricate Prototype Type "C"
Award Winding Form Contract
C1
C2
C3 C4 C5 C6 A1 A2 A3 B1 A4 A5 A6 B2 B3 B4 B5 B6
Fab Winding Forms
Station 2-Wind & VPI
Station 3-Wind & VPI
VPI,Clamps,& Test
FIELD PERIOD ASSEMBLY
Attach Cooling,Diag, Insulation
Pre-Assemble Mod Coils
MC Installation
Assemble 1st Period
Assemble 2nd Period
Assemble 3rd Period
MACHINE ASSEMBLY
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
Total Float 5 mo.
First Plasma
Ancilliary Systems Installation
Legend:
Completed Task
Critical Paths
Off critical path

APPENDIX F

ACTION ITEMS

Action Items

Resulting from the November 2-3, 2005

Department of Energy Review of the

NCSX Project

Action	Responsibility	Due Date
1. Schedule an interim review	SC/NCSX	within 3 months
2. Conduct a DOE review	SC/NCSX	within 6 months