EXTERNAL INDEPENDENT REVIEW

ACQUISITION PERFORMANCE BASELINE REVIEW (FOR CD-2)

OF THE

NATIONAL COMPACT STELLARATOR EXPERIMENT

AT

Princeton Plasma Physics Laboratory
Princeton, New Jersey

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EXTERNAL INDEPENDENT REVIEW OF THE NATIONAL COMPACT STELLARATOR EXPERIMENT PRINCETON PLASMA PHYSICS LABORATORY PRINCETON, NEW JERSEY

SECTION 1—EXECUTIVE SUMMARY

1.1 INTRODUCTION

At the direction of the Office of Engineering and Construction Management (OECM), LMI, an OECM contractor, conducted an External Independent Review (EIR) of the National Compact Stellarator Experiment (NCSX) project at the Princeton Plasma Physics Laboratory (PPPL). The purpose of the EIR was to support OECM's validation of the performance baseline. We conducted the EIR following the guidelines and procedures contained in DOE M 413-3.1.

After reviewing the required EIR project documentation, LMI conducted an on-site review during the week of November 17, 2003, and presented an outbriefing to the PPPL director and members of the project team following the on-site review. This EIR report details the scope of LMI's review and documents our findings, observations, and recommendations.

The PPPL project team cost estimate for the project is $80,940,000, with a completion date of September 2007.

1.2 PROJECT DESCRIPTION

NCSX is a major item of equipment (MIE) project that involves the design and fabrication of the stellarator and the necessary modifications to the facility that will house it. At the heart of the equipment is the plasma confinement device, or stellarator core, which will be an assembly of several magnet systems that surround a highly shaped plasma. Coils provide the magnetic field for plasma shape control, inductive current drive, and field error correction. The vacuum vessel produces a high vacuum plasma environment with access for heating, pumping, diagnostics, and maintenance. The entire system is surrounded by a cryostat to permit cooling of the magnets at cryogenic temperature.

The project scope includes all the equipment required at the start of operations (first plasma and initial field mapping), plus systems needed to support coil operation at cryogenic temperatures, and refurbishment of and installation of equipment for 1.5 MW of neutral beam heating power. The scope includes Title I through Title III engineering; physics analyses in support of the design; research and development for certain components; fabrication, assembly, and installation; integrated systems testing; and project management (PM) associated with producing an operational stellarator. The scope includes achievement of first plasma.

1.3 OVERALL EIR TEAM ASSESSMENT

1.3.1 Cost Assessment

The project can likely be completed for $81 million. Our rationale for this assessment is as follows:

- The cost estimate incorporates all activities necessary to successfully complete the project.
- Our review of various cost estimating assumptions verifies that they are reasonable and have been properly applied to the project.
- The majority of the cost estimate utilizes historical cost information from previous work at PPPL, vendor quotations for major equipment components, and catalog pricing based on detailed material takeoffs. The small percentage of the estimate that is classified as rough order of magnitude (ROM) provides additional credibility to the estimate.
- The cost estimates for six key focus areas of the project are well supported by vendor quotations, detailed material pricing, and activity-based cost techniques.
- The PM function is adequately staffed over the project duration with highly competent, motivated individuals.
- The relatively high project contingency reflects the risks associated with the highly complex nature of this first-of-a-kind project.

1.3.2 Schedule Baseline Assessment

The NCSX Critical Decision-4 (CD-4) can likely be achieved in September 2007. Our rationale for this assessment is as follows:

- Research and Development (R&D) and prototyping activities are ongoing and planned to address the unknowns related to high-risk activities, such as modular coil winding and modular coil casting and potting.
- The critical path is well understood and includes 5½ months of contingency.
- The 230 activities within 30 days of the critical path are well understood, have reasonable durations, and have risk mitigation plans to gain float.
- The definition of CD-4 is such that start-up under warm conditions is required, with cryogenic testing occurring after CD-4.
- Acquisition planning is flexible enough to allow procurement awards to more than one vendor for critical components if necessary.
- No new technology is included in this project. Key activities include prototyping.

The EIR team developed numerous findings and observations, with accompanying recommended actions, supporting the above assessments. We detail these findings, observations, and recommendations in this report.

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SECTION 2—EIR FINDINGS, OBSERVATIONS, AND RECOMMENDATIONS

In this section, we discuss the project's status in the context of each issue reviewed. These discussions set the stage for our findings, observations, and recommendations.

We limit our comments, prepared as findings and observations, to specific concerns and issues associated with the key review elements. If a finding states that a deficiency exists, we recommend a way to resolve it. Our recommendations are intended to assist the project team in addressing programmatic, operating, and statutory requirements; developing accurate cost, schedule, and technical scope baselines; and managing and controlling successful execution of the project.

Observations typically indicate that certain areas were in fact reviewed but do not warrant specific action by the project team. However, for some observations, we recommend ways to improve PM and to increase the chances of achieving project objectives.

We focused our review on the following 13 key elements:

- Resource-loaded schedule
- Total project cost (TPC) and project schedule
- Work breakdown structure (WBS)
- Risk management
- Preliminary design and design review
- System functions and requirements
- Hazard analysis
- Value management and engineering
- Project controls and earned value management system (EVMS)
- Project execution plan (PEP)
- Start-up test plan
- Acquisition strategy
- Integrated project team (IPT).

Within each element, we address three subsections:

- Key review element background
- Element scope of review

- Findings, observations, and recommendations.

In addition, the appendixes at the end of this report contain the following:

- Appendix A lists the abbreviations used in the report.
- Appendix B contains a brief resume of each review team member.
- Appendix C lists the project team members interviewed.
- Appendix D lists the documents reviewed.
- Appendix E presents all recommendations in a corrective action plan.

2.1 RESOURCE-LOADED SCHEDULE

2.1.1 Key Review Element Background

Three elements are necessary for an acceptable resource-loaded schedule activity—a reasonable duration, an accurate cost, and an accurate loading profile over the duration. Each element must also be considered in the context of the level of completion of the project documents. For the NCSX project, we assessed the reasonableness of the specific model the project team used to resource load the schedule. We also assessed the reasonableness of the estimates with regard to funding, manpower, and site considerations.

The project team developed the schedule for the NCSX project in Primavera P3 and resource-loaded it consistent with the current design status.

2.1.2 Element Scope of Review

For selected WBS elements, we

- summarized the detailed basis for the cost estimate and schedule duration,
- assessed the method of estimation and the strengths and weaknesses of the cost and schedule estimates,
- identified and analyzed key cost and schedule assumptions, and
- evaluated the reasonableness of these assumptions in relation to the quality of the cost and schedule estimates.

We augment our assessment by reviewing project cost estimating assumptions, the basis of the estimate, and corresponding scope of work; interviewing project managers and cost estimators; and referencing DOE guidance documentation. We accept the project team's technical basis and work scope as defined by the project baseline and base our review on the cost information provided to us. We focus on ensuring that all components are adequately addressed in the baseline cost estimate, assumptions are clearly identified and reasonable, and backup documentation clearly supports the costs.

The targeted WBS elements are as follows:

- 121 (Activity ID 121-038) Vacuum Vessel Vendor Fabricate, Test & Deliver
- 131 (Activity ID 131-037) TF Coil Procurement
- 141 (Activity ID 172-037) Modular Coil Winding Form—Procurement Vendor Cost
- 142 (Activity ID 171-041) Modular Coil Windings and Assembly—Modular Coil Winding (18 coils)
- 62 Cryogenic Systems
- 85 Integrated Systems Testing.

2.1.3 Findings, Observations, and Recommendations

2.1.3.1 Vacuum Vessel Vendor Fabricate, Test & Deliver (WBS 121, Activity ID 121-038)

2.1.3.1.1 Cost Analysis

The baseline cost estimate for the vacuum vessel fabrication is $2,948,437, according to the resource-loaded schedule. This includes site general and administrative (G&A) markups and escalation, but no contingency. Excluding the G&A and escalation, the baseline estimate is $2,873,715, comprising the following two components:

- Vacuum Vessel Assembly $2,729,355
- NBI Port Duct Extensions $144,360

Vacuum Vessel Assembly. Development of the cost estimate for the vacuum vessel assembly has followed a step-wise progression using information from a variety of vendors and fabricators. This was done, in part, because of the extremely difficult fabrication of this stellarator component. The project team told us that technological limits are being pushed, which justifies, in part, the 40 percent contingency assigned to this procurement.

Initially, five vendors were selected to provide preliminary price quotations for the fabrication. The project team examined the capabilities of each vendor, using such criteria as previous vacuum work, management organization, company depth, and financial soundness. The preliminary estimates provided a benchmark.

The project team selected two vendors to continue with R&D and prototype development of the vacuum vessel. Each vendor received design drawings, computer-aided design (CAD) models, specifications, and a statement of work from the project team. The project team has often met with and is working very closely with the vendors. Both vendors submitted budgetary cost estimates (in 2002) for the vacuum vessel fabrication on the basis of documentation provided to them and their in-house prototype development. The project team showed us the cost estimates—which include shipping and all testing—for verification. In addition, manufacturing, inspection, and test plans that accompanied each vendor's bid support the estimates. These plans cover the entire gamut of test and quality assurance procedures to be performed by the vendor before delivery of the production-unit vacuum vessel to PPPL, giving the quality and thoroughness of the two firms additional credibility.

For confidentiality reasons, this report does not identify the vendors or give the actual estimates. To estimate the cost of the vacuum vessel fabrication, the project team used a composite of the two bids. Because each vendor's bid is within a very reasonable range of the composite, the composite approach is valid.

The project team reports that neither vendor has discovered anything new as a result of their ongoing work that would change their estimates at this point. Both vendors will be asked to submit fixed-price bids for the final production unit.

Observation: The cost estimate for vacuum vessel fabrication is based on budgetary estimates from two reputable fabricators, using design specifications, drawings, and CAD models provided by the project team, complemented by ongoing research and prototype development. The approach is sound, and the assumptions are reasonable. The comparatively narrow range of the two budgetary estimates supports the credibility of the estimate. The comprehensive testing and quality control procedures submitted by the vendors also lend credence that all necessary work scope has been considered and included.

NBI Port Duct Extensions. The cost estimate for the port duct extensions is a bottom-up estimate based on the design configuration of the vacuum vessel. Three duct extensions are required, each estimated at $48,000. The estimate consists of the shell assembly, cover flanges, and seals. The shell assembly cost—the largest, at $35,000—is based on the design weight of 1,400 pounds per shell and a corresponding fabrication cost of $25 per pound. Pricing is based on historical steel structure work at PPPL as well as quotes from steel fabricators. Eleven separate flanges and flange covers are required for each port extension, ranging in size from 8 to 16.5 inches. These parts are individually priced in the estimate, and the prices are reasonable. Finally, a single large square flange cover, priced at $2,000, is required for each port extension.

Observation: The cost assumptions for the port duct extensions are well documented and reasonable. The strength of the cost estimate lies in the bottom-up approach, which uses detailed material lists.

2.1.3.1.2 Schedule Analysis

Observation: The 303-day duration (August 3, 2004–October 10, 2005), based on a vendor quote adjusted by PPPL, is reasonable at this stage of the project. PPPL lengthened the vendor quote because of the critical nature and technical risk of the vacuum vessel in the machine. The vendor will deliver a firm fixed-price proposal, including cost and detailed schedule, around June 2004. The project team will then adjust the master schedule. This activity is not on the critical path.

Observation: The costs are resource-loaded on the basis of a level distribution. The procurement will be funded in phases because it extends over FY04 and FY05.

Observation: The schedule logic as portrayed in the predecessor/successor report is valid. Both tasks for the receipt of firm fixed-price proposals are on the schedule.

2.1.3.2 TF Coil Procurement (WBS 131, Activity ID 131-037)

2.1.3.2.1 Cost Analysis

The baseline cost estimate for toroidal field (TF) coil procurement is $1,223,543, including G&A and escalation. The cost documentation backup (August 27, 2003) provided to us reports a base cost for the 18 TF coils of $956,000, distributed among tooling, materials, and labor. The estimate is bottom-up, based on calculated material quantities as well as previous winding experience at PPPL. The winding geometry material takeoff is comprehensive and is the basis for determining the total weight of copper required for the 18 coils. Likewise, the project team estimated the quantities for other materials, like insulation and epoxy, on the basis of coil geometry. It derived tooling costs using professional judgment and broke them down by engineering hours, design hours, and tooling fabrication. Labor hours for coil fabrication are based on assumed crew sizes, number of shifts per day, and the hours needed for activities such as prepping and winding each coil and performing vacuum pressure impregnation.

We have minor concerns with the consistency and accuracy of information in the cost backup. First, the estimates for tooling, material and subcontracts (M&S), and labor do not add to the $956,000 reported as total manufacturing costs. The correct figure is:

- Tooling $116,947
- M&S 278,925
- Labor 640,490
- Total $1,036,362

In discussions with the project team, we learned that the labor estimate may be high by $200,000, but conversely does not include labor costs for “nose machining.” The project team gave us an updated estimate worksheet, which purportedly corrected the previous errors and omissions. For the three categories above, the total estimate in the updated worksheet is $1,028,287, not much different from what we calculated.

The project team informed us that only a few conventional coil-winding companies are located in this country; thus, it is concerned about finding a U.S. company that can, and will, fabricate the TF coils. Oversight would be considerably less if a U.S. firm is chosen, and currency fluctuations would not be an issue; however, the project team is prepared to use a foreign source if necessary.

Finding: The backup cost documentation is somewhat inaccurate and inconsistent in places, contains some omissions, and may be outdated.

> **Recommendation 1:** Clean up the cost documentation for TF coil procurement, make the numbers consistent, and ensure that the cost basis is clear and defensible.

2.1.3.2.2 Schedule Analysis

Observation: The 415-day duration (October 1, 2004–June 16, 2006) is based on a detailed PPPL analysis of the process and the development of similar coils for the National Spherical Torus Experiment (NSTX) and Tokomak Fusion Test Reactor (TFTR) at PPPL. The duration is reasonable at this stage for these coils, which do not involve new technology. This activity is not on the critical path.

Observation: The costs are resource-loaded on the basis of a level distribution over the activity duration, which is reasonable at this stage for the fabrication of the 18 coils.

Observation: The schedule logic as portrayed in the predecessor/successor report is valid.

2.1.3.3 Modular Coil Winding Forms—Procurement Vendor Cost (WBS 141, Activity ID 172-037)

2.1.3.3.1 Cost Analysis

The baseline cost estimate for Modular Coil Winding Forms is $5,213,477, including G&A and escalation. The cost backup for the modular coil winding forms shows an estimate of $4.8 million (no G&A or escalation). The development method for the baseline cost is similar to that used for the vacuum vessel. The project initially contracted with five different companies to provide independent cost estimates for the winding forms. These international firms—which have a broad spectrum of experience in magnets, fusion, and winding forms—were provided preliminary specifications. On the basis of the responses from the five firms, the project team made an initial benchmark estimate of $4.2 million for this procurement.

Using the $4.2 million benchmark, the project team provided a detailed statement of work, specifications, a drawing package, and CAD models to additional companies and received proposals. (Several bidders declined to bid because they did not believe they could meet the $4.2 million constraint.) Two vendors were ultimately selected to work on a prototype and to provide firm fixed-price proposals (due June 2004) for the final winding forms. Additional scope (a poloidal break) has been added to the procurement. The two vendors have submitted budgetary price quotations for the current scope of work. Because of confidentiality, we do not identify the vendors or their quotations, which were within 20 percent of each other. The project team formed a composite cost estimate from the two vendor quotations for purposes of the baseline.

Similar to the vacuum vessel, the project team assigned the modular coil winding forms a 40 percent contingency because of the technological challenges and because it still awaits a prototype winding form.

2.1.3.3.2 Schedule Analysis

Observation: The 371-day duration (July 28, 2004–January 26, 2006), based on vendor quotes from the prototyping phase of this procurement, is reasonable at this stage. The activity includes the prototyping, fabrication, and delivery of the winding forms (patterns) on which PPPL will wind the modular coils. These forms are unique, and the procurement has included prototyping and development by two separate, independent vendors. Following receipt of firm fixed-price proposals around June 2004, the project team will adjust the master schedule. The delivery of the Type A and Type B casting forms are not on the critical path, but delivery of the first modular coil casting form (Type C) is. The Type C form is scheduled for delivery November 2004.

Observation: The costs are resource-loaded on the basis of a level distribution, which is reasonable with delivery of a casting scheduled about every 3½ weeks.

Observation: The schedule logic as portrayed in the predecessor/successor report is valid. Each of the three casting types is included.

2.1.3.4 Modular Coil Windings and Assembly—Modular Coil Winding (18 Coils) (WBS 142, Activity ID 171-041)

2.1.3.4.1 Cost Analysis

The baseline cost estimate for winding and assembly of the modular coils is $3,134,614. Excluding G&A and escalation, the baseline is $2,914,064. This estimate is entirely made up of labor and is based on years of actual winding experience at PPPL. An activity-based approach is used to develop a bottom-up estimate.

The project team developed the cost estimate by assigning manhours to each of the anticipated activities associated with six separate workstations. From his winding experience, the WBS manager assumed the number of working days for each activity, shifts per day, and technicians per shift. The work effort is based on one coil. Therefore, the total labor requirement per activity is derived by multiplying the labor for each coil times 18 coils. Table 2-1 shows the total estimate for Modular Coil Windings and Assembly.

Table 2-1
Modular Coil Windings and Assembly

Description	Total Manhours	Total Cost ($)	Basis
Station 1—Casting preparation	5,184	383,616	SME
Station 2—Conductor insulating	64	4,736	SME
Station 3—Coil winding	14,520	1,074,480	SME
Station 4—Final coil prep and mold application	8,640	639,360	SME
Station 5—VPI coil	8,064	596,736	SME
Complete coil preps following VPI activities	1,728	127,872	SME
Station 6—Electrical test station	864	87,264	SME
Total	39,064	2,914,064	

Note: SME = subject matter expert.

The average wage rate works out to about $74 per hour, which corresponds to the fully loaded technician wage rate at PPPL.

The backup documentation further breaks each of these workstations down into two additional levels of activity descriptions, at which estimates of technician labor are defined. This is an excellent approach. We reviewed the various activities with the WBS manager to understand the sequence of operations, as well as the actual work that needs to be performed on each coil. We checked that all sub-level activities consistently had manhour estimates, spot-checked the math, and found no errors.

2.1.3.4.2 Schedule Analysis

Observation: PPPL based the 384-day duration (December 1, 2004–June 16, 2006) on a bottom-up process analysis, which was used to develop the cost estimate for this activity. PPPL has no recent experience in winding these types of coils, but similar coils have been wound elsewhere. A prototype winding form will be used to test the winding process. The project team has accounted for the schedule risk in this process through development of contingency. Much of this activity is on or near the critical path.

Observation: The costs are resource-loaded on the basis of a level distribution, which is consistent with the planned uniform completion of the coils.

Observation: The schedule logic as portrayed on the schedule and in the predecessor/successor report is valid and reasonable. It includes the acquisition of the required materials, such as the copper conductor and epoxy, as well as the preparation of the casting and the actual winding of the coils.

2.1.3.5 Cryogenic Systems (WBS 62)

2.1.3.5.1 Cost Analysis

The baseline cost estimate for Cryogenic Systems is $787,000. The basis of estimate and assumptions for the cryogenic systems are clear and appear reasonable. The estimate is based on

- catalog research for purchased components,
- historic cost performance of past cryogenic work at PPPL,
- material takeoffs based on walkdowns of the system, and
- vendor quotations based on preliminary design criteria.

The estimate is also premised on a number of assumptions:

- The cryogenic systems will be installed but not used for first plasma. (First plasma will be attained at warm conditions for CD-4.)
- Integrated testing of the cryogenic systems is not included in the project scope.
- Certain existing equipment components are available to the project and in workable condition, such as the liquid nitrogen tank.
- Liquid helium will be supplied via 500-liter dewars.

- PPPL and temporary labor will fabricate most cryogenic systems (such as vacuum pipe) in the field because experience has demonstrated that it is more efficient than having vendors fabricate it.

Table 2-2 shows the detailed estimate from the resource-loaded schedule.

Table 2-2
Cryogenic Systems—Estimated Costs

Description	Cost ($)	Basis
Liquid N2-Liquid He Supply System		
Preliminary Design	15,032	SME
Final Design	21,267	SME
Fab/Assembly/Installation	79,528	Historical costs
Procurement	61,380	Vendor and catalog quotes
Subtotal	177,207	
Liquid N2 Coil Cooling Supply		
Preliminary Design	15,032	SME
Final Design	28,332	SME
Fab/Assembly/Installation	114,018	Historical costs
Procurement	116,001	Vendor and catalog quotes
Subtotal	273,383	
Gaseous N2 Cryostat Cooling System		
Preliminary Design	15,032	SME
Final Design	23,917	SME
Fab/Assembly/Installation	189,189	Historical costs
Procurement	108,092	Vendor and catalog quotes
Subtotal	336,230	
Total	786,820	

Note: SME = subject matter expert.

The project team told us they estimated 800 manhours for engineering and design (Title I, II, and III), at a total cost of about $120,000. This is based on expert judgment, considering the types of final design drawings needed. This represents 15 percent of the total construction cost for Cryogenic Systems, which is a reasonable benchmark.

We reviewed most components of the construction estimate. The costs for the liquid nitrogen supply line are based on a similar 1999 fabrication job at PPPL that cost $527 per lineal foot. The two pumps are vendor-priced based on design flow and discharge pressure. The costs for pump starters and disconnects are based on installing 200 feet of unistrut conduit from the pumps to the motor control center; the electrical estimate of 60 manhours per pump is reasonable. The piping, valves, expansion tank, and miscellaneous equipment needed for the cooling supply system are based on a schematic drawing of a skid-mounted system, and associated costs are largely engineering judgment at this point. Assumptions were made about materials of construction and type of assembly. Costs for oxygen monitors and controllers appear good.

Our major observation concerns what appears to be a mathematical error in the manhours estimated for duct and insulation labor. On the basis of 14 duct sections, each 10 feet long, and stated labor requirements of 1.5 man-days per 10-foot section, we estimate a total of 168 manhours. This contrasts with the project estimate of 1,680 manhours. If our observation is correct, this means the labor has been overstated by roughly $100,000.

Finding: The baseline estimate for cryogenic systems may be high by $100,000 due to a mathematical error in the labor estimate for ducting and insulation.

> **Recommendation 2:** Review the labor estimate for ducting and insulation, and revise as appropriate if an error is found.

2.1.3.5.2 Schedule Analysis

Observation: The 380-day duration for this activity (April 3, 2006–March 12, 2007), based on PPPL analysis of what is required to procure, fabricate, and install the systems, is reasonable. The project team developed the schedule duration in concert with the cost estimate for this activity, which will be completed by PPPL. The activity duration is based on PPPL workforces accomplishing the work following external procurements of materials and equipment.

Observation: The costs are appropriately loaded for each of the phases of this activity.

Observation: The logic ties to assembly of the systems is valid as portrayed in the predecessor/successor reports

2.1.3.6 Integrated Systems Testing (WBS 85)

2.1.3.6.1 Cost Analysis

Table 2-3 shows the baseline cost estimate for Integrated Systems Testing, which is $770,000.

Table 2-3
Integrated Systems Testing—Estimated Costs

Description	Cost ($)	Basis
Procedure and document preparation	437,179	Subject matter expert
Integrated system testing	332,580	Historical costs
Total	769,759	

Integrated Systems Testing for NCSX has a legacy in the TFTR and NSTX at PPPL. In particular, NSTX was similar in complexity to NCSX and had a similar technical platform. The NSTX was started up in 3 months and provides a basis for both the cost and schedule for NCSX. Thus, the cost estimate for Integrated Systems Testing is based on both previous experience and subject matter expertise. With regard to the latter, the WBS manager for the NCSX startup was intimately involved in the startup of NSTX, thereby providing good continuity.

Procedure and Document Preparation. The Test and Evaluation Plan (NCSX-PLAN-TEP-00) provides the backbone for Integrated Systems Testing for NCSX. It identifies the tasks, documents, actions, reviews, and staff required to start up NCSX in a safe, efficient, and compliant manner. In particular, it identifies 52 separate and discrete procedures and documents that must be completed prior to start-up. These documents include development of preoperational test procedures as well as configuration of existing subsystems to support experimental operations. Because of past and present projects and devices at PPPL, many of these documents already exist and can be used as they are or may only need modification for application to NCSX. Other documents will need to be prepared from scratch. The Test and Evaluation Plan clearly identifies all 52 needed documents and procedures, the status of each document (that is, whether it is satisfactory, needs minor revision, needs major revision, needs to be developed, etc.), and the estimated man-weeks of effort needed to complete each document. Therefore, documents that are currently satisfactory are shown as needing no time, whereas documents needing to be developed from scratch may show 4 to 5 man-weeks of effort.

The project team estimates 80 man-weeks total to prepare the necessary start-up documents, on the basis of a careful review of existing and proposed documents and deciding what needs to be done to each. The estimate uses a blended wage rate of management, engineering, and senior shop personnel—the people who will be working on the documents. From the information provided to us, this blended rate works out to about $5,300 per man-week. On the basis of 80 man weeks, we estimate the cost for Procedure and Document Preparation at $425,000, which is very close to the baseline estimate.

One of the key documents prepared will be a facility start-up integrated systems test procedure (ISTP), which establishes the readiness of the NCSX for first plasma and subsequent experimental operations. The ISTP will include the following stepwise and checkoff procedures:

- Facility preparations (such as work permits, interlock testing, and safety lockout devices)
- Vacuum vessel pumpdown and testing
- Water systems testing
- Energy conversion systems testing
- Preparations for coil energization
- Coil energization testing
- Bakeout in preparation for first plasma.

Integrated System Testing. The project team estimates 3 months from end of construction through first plasma from experience with similar devices at PPPL, such as the NSTX. It premises the baseline cost estimate of $332,000 on the following anticipated start-up and subsystem staffing requirements:

Start-Up Staff	**Full-Time Equivalent (FTE) Requirement**
Test Director	0.75
Chief Operations Engineer	0.5
Project Engineer	0.5
Machine Technician	0.5
Physicist	0.5
Subsystem Staff	
Water Systems Technician	0.5
AC Power Engineer	0.5
Computer Engineer	0.5
FCPC Technician	0.5
MG Operator	0.5.

On the basis of 1,700 manhours per year per FTE (estimating assumption used at PPPL), 3 months of a full-time equivalent are 425 hours. Using the above requirements, 5.25 FTEs are needed over 3 months. At a blended average hourly rate of about $140, we estimate a total cost of $312,000, which is very close to the project estimate.

2.1.3.6.2 Schedule Analysis

Observation: The 574-day duration for this activity (October 1, 2004–April 17, 2007) is broken into two subactivities. Our assessment of each subactivity indicates they are reasonable to reach CD-4 as defined for the project. The procedure and document preparation subactivity starts in October 2004 and requires 509 days of the 574-day duration, and $437,200 (57 percent of the $769,800 activity cost). The duration is based on development of detailed procedures as described further in the Cost portion of this section.

The integrated system testing subactivity takes 65 days, costs $332,600, begins in January 2007, and concludes in April 2007 at CD-4. The test plan is based on previous experience with NSTX at PPPL.

Finding: Work is required in other WBSs to support the procedure and document preparation, and these logic ties are not defined in the predecessor/successor reports. The project indicates that these activities are included within other activities in the related WBSs, but are not broken out.

> **Recommendation 3:** Develop activities in the WBSs that support the integrated system testing WBS, resource-load them, and provide logic ties to WBS 85.

Observation: Integrated system testing is adequately resource-loaded for this stage of the project. The project team is preparing more detailed loading in the Work Authorization Form (WAF) schedules and will complete it as the project moves into the FY04 forecast start of the activity.

Finding: The integrated system testing subactivity portion of this WBS is not on the critical path, but by some scheduling quirk is within 1 day of it. It clearly eclipses an activity on the critical path, which occurs at the same time—Activity 730-130, Power Tests. All logic indicates the integrated system testing should be on the critical path, and the schedule can easily be adjusted.

> **Recommendation 4**: Adjust the schedule to eliminate the float of 1 day and place Activity 920.005, Integrated System Testing, on the critical path.

2.2 TPC AND PROJECT SCHEDULE

The proposed baseline project cost is $80,940,000, with a mission need completion date of September 2007.

The project scope includes all the equipment required at the start of operations (first plasma and initial field mapping), plus systems needed to support coil operation at cryogenic temperatures and refurbishment and installation of equipment for 1.5 MW of neutral beam heating power. The scope includes Title I through Title III engineering, physics analyses in support of the design, manufacturing development for certain components, fabrication, assembly and installation, integrated systems testing, and PM associated with producing the in-scope equipment. It includes achievement of first plasma.

PPPL will design the NCSX machine so that anticipated equipment upgrades can be accommodated when needed. The project scope does not include the actual implementation of these upgrades, which will be funded from research program budgets, depending on program needs.

Activities to support NCSX research planning and preparation that will proceed in parallel with NCSX fabrication are not included in the NCSX project scope.

The project can be completed within the baseline budget of $81 million.

2.2.1 Key Review Element Background

The cost parameter is the total cost of the project, which includes the cost identified in the budget submission and appropriated by Congress directly for the project and other costs included in the program's operating budget. DOE has identified the NCSX project as an MIE project rather than a line item construction project. As such, the overall cost objective that encompasses all project work scope is measured in terms of the total estimated cost (TEC). Thus, the terms TEC and TPC are synonymous for the NCSX project.

Schedule is a key parameter because not meeting the required completion date has an impact. Ultimately, a delay in schedule must affect the programmatic mission and its ability to meet strategic goals; if it does not, then the mission need can be called into question. Schedule parameters should include all phases of the project, major decision points, initial operation, and other critical system events. The objective for schedule parameters is the minimum reasonably achievable date.

Table 2-4 summarizes the main components of the $80,940,000 TPC.

Table 2-4
NCSX Total Estimated Cost ($000)

WBS	Description	MIE Estimate	Contingency	Total Estimate
1	Stellarator core systems	39,058	12,255	51,312
2	Plasma heating, fueling, and vacuum system	1,608	213	1,820
3	Diagnostics	1,506	454	1,960
4	Electrical power systems	5,029	1,009	6,038
5	Central I&C systems	2,548	249	2,797
6	Facility systems	2,063	411	2,474
7	Test cell prep and machine assembly	3,559	696	4,255
8	Project oversight and support	8,076	1,156	9,232
TEC		64,402	16,538	80,940

2.2.2 Element Scope of Review

The EIR team

- independently evaluated the project cost and overall project schedule;
- assessed cost and schedule contingency and other cost and schedule factors related to the project cost and project completion schedule;
- reviewed the critical path schedule and assessed whether the critical path is accurate and whether the schedule is integrated and reflects reasonable durations;

- ensured that the project cost and completion date incorporate all activities necessary to successfully complete the project;
- reviewed all start-up activities, readiness reviews, and appropriate contingencies; and
- assessed whether the project funding profile is consistent with the resource-loaded schedule.

We augment our assessment by reviewing project cost estimating assumptions, basis of estimate, and corresponding scope of work; interviewing project managers and cost estimators; and referencing DOE guidance documentation. We accept the project team's technical basis and work scope as defined by the project baseline and base our review on the cost information provided to us. We focus on ensuring that the baseline cost estimate adequately addresses all components, assumptions are clearly identified and reasonable, and backup documentation clearly supports the costs.

Our review of the NCSX TEC focused on two components:

- *The six target WBS elements addressed and analyzed in Section 2.1.3*. At OECM direction, we assessed the six WBS elements to draw conclusions about the quality, completeness, and accuracy of the overall estimate on the premise that the six elements represent the overall quality of the TEC. Table 2-5 lists the six target WBS elements.
- *The reasonableness of the TEC.*

Table 2-5
Target WBS Cost Elements ($)

WBS Number	Title	Estimate[a]
121 (Activity ID 121-038)	Vacuum Vessel Vendor Fab, Test & Deliver	2,948,437
131 (Activity ID 131-037)	TF Coil Procurement	1,223,543
141 (Activity ID 172-037)	Modular Coil Winding Form—Procurement Vendor Cost	5,213,477
142 (Activity ID 171-041)	Modular Coil Windings and Assembly—Modular Coil Winding (18 coils)	3,134,614
62	Cryogenic Systems	787,000
85	Integrated Systems Testing	770,000

[a] Excludes contingency.

2.2.3 Findings, Observations, and Recommendations

This section is divided into two subsections that summarize our evaluation—the TEC and the project schedule.

2.2.3.1 TEC Findings, Observations, and Recommendations

This subsection contains our findings, observations, and recommendations regarding the TEC. Our review consists of the following activities:

- A detailed evaluation of six target WBS elements (Section 2.1.3)
- An evaluation of the appropriateness of the general estimating assumptions
- An evaluation of certain components of the NCSX
- An evaluation of escalation and contingency.

The following subsections summarize the results of our review.

2.2.3.1.1 General Cost-Estimating Assumptions and Method

Under the cost-estimating method for the project, each WBS manager prepares input data for his particular area of focus. This input data consists of items such as labor manhours, vendor quotations, cost data book information, and historical costs. Guidance documents describe the type of information the project control manager needs from each WBS manager (such as manhours, activity descriptions, and specific resource requirements). The project control manager then collects and inputs the data into the resource-loaded schedule program, which has built-in labor rates, markups, escalation, etc.

This general approach is widely used among DOE projects, but in the case of the NCSX project, we are somewhat concerned about the traceability of the estimates from the WBS manager worksheets to the cost figures in the resource-loaded schedule. We found inconsistencies (for example, in PM), which may ultimately affect cost tracking and updating. In addition, the linkage between the cost backup documentation prepared by the WBS managers and the specific activity IDs in the resource-loaded schedule is not apparent. These shortcomings may be mitigated by using (1) standardized cost-estimating input forms, and (2) an expanded WBS dictionary that clearly identifies cost-estimating assumptions and resource requirements for each WBS.

Finding: Tracing the cost estimates in the resource-loaded schedule to the cost backup documentation is difficult in some instances. The cost backup is not linked to specific activity IDs, and we found some inconsistencies.

> **Recommendation 5:** Tie the cost-estimating backup to the resource-loaded schedule using standardized cost-estimating input forms and an expanded WBS dictionary.

We would expect to see a “basis of estimate” or similar document that captures, in one place, such criteria as

- overhead and site markups,
- subcontractor markups,
- escalation assumptions,

- standard labor rates,
- definitions of specific terminology and abbreviations used in the estimate,
- specific personnel covered within the PM and project engineering functions,
- specific project personnel covered through site overhead accounts,
- basis for allocation expenses,
- workweek assumptions,
- number of shifts,
- sales tax,
- overtime assumptions,
- productivity factors or unproductive time,
- applicable fees,
- contingency assumptions and methods,
- scope of work and associated project battery limits,
- estimate exclusions,
- date of the estimate (estimate reflects prices "as of"), and
- start and finish date that the estimate covers.

Finding: A centralized, written compilation of general cost estimating assumptions does not appear to exist.

> **Recommendation 6:** Create a basis of estimate or estimate assumptions document that clearly presents the key estimating criteria and assumptions for the project.

We examined and reviewed several cost estimating criteria, such as baseline labor rates and various burdens, overheads, and G&A markups. These appear reasonable and have been correctly applied within the cost estimate. In addition, some of the WBS managers provided assumptions of the number of shifts required and the manpower per shift when preparing cost estimates for their area of responsibility. These assumptions help to clarify the estimate and provide credibility.

PM and project engineering are largely level of effort.

The project team provided us the escalation rate assumptions, as well as the rationale for using the particular rates, in a separate document. The escalation rates assumed by the project team do not appear radically different from the DOE published rates.

The contingency determination (detailed in subsection 2.2.3.1.4) is based on various technical, schedule, and cost risk and weighting factors assigned by the WBS managers. The approach differs from traditional probabilistic techniques.

Finally, spare equipment is assumed not critical to the project, and money has not been allocated for spares. The rationale for this position is that

- critical components of the stellarator core are robust and have been designed with conservative margins to minimize the likelihood of failure,
- facilities are available on-site for replacement coil windings, if required,
- legacy systems are already operational and have ample excess capacity,
- common equipment items have spare parts already stocked, and
- redundant equipment is already available for some items.

Observation: Our review of various cost-estimating assumptions verifies that they are reasonable and have been properly applied.

2.2.3.1.2 Additional Evaluations

As part of our review, we evaluated the reasonableness of the PM cost estimate and project cost growth.

Project Management. The personnel typically captured within the PM category are actually distributed between two WBS elements in the project (Table 2-6).

Table 2-6
NCSX PM ($000)

WBS	Description	Estimate	Contingency	Total
81	Project Management	2,849	408	3,257
82	Project Engineering	3,986	587	4,573
Total		6,835	995	7,830

WBS 81, Project Management, consists of the project manager, deputy project manager, project controls, and clerical support. WBS 82, Project Engineering, consists of the engineering manager, systems and configuration management, design integration, and technical assurance functions. Personnel associated with procurement; environment, safety, and health (ES&H); and quality assurance are not billed directly to the project, but are instead captured in the site overhead.

About 67 percent of the aforementioned personnel, such as the project manager and engineering manager, are dedicated full-time to the project. The remaining personnel provide part-time support. The cost estimate is largely level of effort based on projected FTEs required over the project life. Our review shows about six FTEs allocated to the combined WBS 81 and 82 during FY03 and FY04, and then gradually ramping down to about five FTEs in FY06 as the project nears completion. This level of support appears reasonable.

The total PM function constitutes 9.6 percent (including contingency) of the TEC. Typical PM costs for DOE projects are in the 4–10 percent range, so the PM costs for the project are on the high end. When coupled with the site markups, fully loaded rates for many of the PM staff are between $150 and $250 per hour, which is probably 50 percent higher than at many other DOE sites. So even though the 5- to 6-FTE level is fairly modest, the actual cost for PM is on the high side because of these high hourly rates. However, the costs are not unreasonable, particularly given the extremely complex nature of this project. A mitigating factor is the relatively high base wage rates paid at PPPL compared with other parts of the country.

Observation: The PM costs constitute 9.6 percent of TEC, which is on the high end of the range for DOE projects, but not unreasonable given the nature of the project. Although the FTE distribution looks reasonable over the project life, the high costs are partly attributed to high base wage rates at PPPL compared with other DOE sites, which translate into full-loaded billable rates between $150 and $250 per hour.

The contingency for PM is 17 percent. We questioned the project team about the contingency, which is somewhat high for a level-of-effort activity at the CD-2 stage. We typically expect to see a contingency of 10–15 percent at this stage of the project. The project team said that some activities included in the work packages might need to be augmented sporadically to respond to unexpected project or system-level issues, such as extra cost or schedule rebaselining exercises by the project controls staff.

Finding: The contingency for PM appears somewhat high given that specific resources are defined and assigned using a level-of-effort approach.

> **Recommendation 7:** Reevaluate the contingency for PM.

We find some inconsistency in PM costs among the project documentation. Specifically, the resource-loaded schedule, cost backup, and PM briefing materials are inconsistent with fiscal year funding, FTEs, and overall costs.

Finding: Various project documentation is inconsistent with PM fiscal year funding, FTEs, and overall costs.

> **Recommendation 8:** Rework the various project documentation so that PM costs are consistent throughout.

Project Cost Growth. We questioned the project team about the cost growth in the project. The TPC was $72 million at CD-1 and is $81 million today. The project team explained that costs actually increased from $72 million to $73.5 million between the conceptual design report (CDR) and CD-1, largely due to a 3-month schedule extension caused by Office of Fusion Energy Sciences (OFES) funding constraints. Concerning the remainder of the cost growth, the project team explained that though physics requirements have not changed, their cost implications have become better understood through design and R&D. As a result, it revised estimates for stellarator core fabrication upward in all phases: engineering, design, R&D, manufacture, and assembly. It increased budgets for system engineering and construction support to reduce the risk of greater cost growth downstream due to poor integration or coordination. The increases were partially offset by cost savings due to value engineering (VE) improvements and deferral of some ancillary system scope not needed for first plasma. The project team points out that the current TPC is within the pre-conceptual forecasted range of $69–83 million.

Observation: The project cost growth stems from two key items:

- Schedule extension resulting from funding constraints
- Better understanding of the technological challenges and risks, which have a ripple effect on costs throughout engineering, design, R&D, manufacture, and assembly.

2.2.3.1.3 Escalation

Although not specifically indicated on the resource-loaded schedule or other cost estimates, we learned that total escalation for the project is $5.5 million. PPPL uses different escalation rates than those suggested by DOE guidance documents—a non-labor escalation factor and a labor escalation factor:

- *Non-labor factor*. PPPL examined three economic statistics to establish a default non-labor inflation rate: the Gross Domestic Product (GDP) Deflator, Consumer Price Index, and Producer Price Index. All three project escalation of 1.7 to 2.2 percent per year for FY04 through FY07. The GDP Deflator is the broadest of the three measures, and because it is very close to the average of the three indexes, PPPL chose to use it as its default non-labor escalation rate. The GDP Deflator index is 2.0 percent per year.
- *Labor factor*. The determination of labor escalation is more subjective and is based on PPPL's salary increases as determined by Princeton University, which establishes a merit pool. For the FY01 through FY04, the merit pool is 4.4 percent per year. Using a combination of breakage factors, trend analysis, and economic activity, PPPL selected an average labor escalation rate of 3.9 percent per year for FY04 through FY07.

The project team told us that DOE agreed to these escalation rates.

As a comparison, we calculated total project escalation for NCSX using the DOE published rates (January 2003 update for R&D projects) and applied the appropriate yearly index across the expected constant dollar funding profile. Our calculation shows total escalation of $4.6 million, or $900,000 less than predicted using PPPL's method.

Finding: The project escalation is not shown on the resource-loaded schedule or other cost documents.

> **Recommendation 9:** Revise project cost documentation to clearly show escalation dollars.

2.2.3.1.4 Contingency

The total contingency in the preliminary design estimate is $16.5 million—20 percent of the TEC ($81 million) and 28 percent of the estimated "to-go" costs ($59 million).

The WBS managers estimate contingency at the subsystem level, evaluating cost, schedule, and technical risks on a numerical scale; weighting these factors; and computing the percentage contingency from these assessments using an algorithm. To ensure a uniform method, the project team provides the algorithm and an assessment criterion, but the WBS manager does the evaluation on the basis of his understanding of the risks. The project team said that this method provides simplicity while enabling risks to be quantified by those most familiar with them.

The project team's method differs from the traditional probabilistic techniques used by most DOE project teams. While we cannot conclude that it is inappropriate, the project team should critically review its applicability and usefulness. It appears to have pros and cons. The advantages are as follows:

- It is a simple technique.
- It considers cost, schedule, and technical risks.
- It quantifies risks and weighting factors.
- It may be amenable to a first-of-its-kind project like NCSX, because no comparable industry benchmarks exist.
- It draws on the knowledge base of the person (or people) most familiar with a particular WBS.

The inherent drawbacks are as follows:

- The probability, or likelihood, of an event happening is not factored in.
- The numerical risk and weighting factors are subjective.
- The Contingency Estimating Procedure states, "each WBS manager has the option to modify it (the procedure) to reach a more appropriate level of contingency for his subsystem." This statement tends to invalidate the method because it suggests that if the WBS manager doesn't like the results, he or she can change them to fit his or her perception of the needed contingency.
- The results may be biased if only one individual is involved in the assignment of risk and weighting factors.

Finding: The contingency determination method has a number of suspect considerations that lead to questions about its applicability and usefulness for the project.

> **Recommendation 10:** Review the current contingency method and approach, and determine whether it is the best method to use for determination of contingency dollars.

Observation: The contingency percentage is unchanged from a year ago. It was 28 percent at CD-1, and it is still at 28 percent. Because the project cost has grown from about $73 million at CD-1 to $81 million today, more contingency dollars reside in the project now than a year ago. The project team acknowledges that design and R&D progress over the past 18 months have increased its understanding of the project issues and have reduced some uncertainties. However, as the understanding of the project improves, an understanding of the risks improves. Computer design and modeling are being pushed to the technological limits, and this directly translates into manufacturing problems in such areas as tooling, prototype development, and assembly. The project team said that the risks have not decreased. Quite frankly, the project team admits that the risks were underestimated at the CDR stage.

Because the stellarator is a first-of-its-kind, very complex piece of equipment, we had difficulty assessing the validity and reasonableness of the 28 percent contingency. From a project complexity standpoint, experimental projects may carry up to 50 percent contingency.

Observation: In our opinion, the 28 percent contingency is not out of line for an experimental project at the preliminary design stage. However, for a complex, experimental project like NCSX—without industry benchmarks and without a probabilistic analysis that incorporates all the known risks and utilizes confidence levels—we had difficulty validating the stated contingency.

2.2.3.1.5 TEC Summary

The NCSX MIE project can likely be completed within the $81 million baseline budget. The rationale for this assessment is as follows:

- The TEC incorporates all activities necessary to successfully complete the project. The project team has adequately identified the project scope and project exclusions. Future system upgrades that are not part of the project are identified, and costs are not included in the TPC. Systems that will be installed but not connected or utilized for achievement of first plasma have been identified, and the costs have been appropriately captured. The criteria for CD-4 are clearly defined, and all activities necessary to achieve CD-4 are properly included and estimated.
- The majority of the cost estimates utilize historical cost information from previous work at PPPL, vendor quotations for major equipment components, and catalog pricing based on detailed material takeoffs. The small percentage of the estimate that is classified as ROM provides additional credibility to the soundness of the TPC (Table 2-7).

Table 2-7
Target WBS Cost Elements

WBS Number	Title	% ROM
121 (Activity ID 121-038)	Vacuum Vessel Vendor Fabricate, Test & Deliver	0
131 (Activity ID 131-037)	TF Coil Procurement	0
141 (Activity ID 172-037)	Modular Coil Winding Form—Procurement Vendor Cost	0
142 (Activity ID 171-041)	Modular Coil Windings and Assembly—Modular Coil Winding (18 coils)	0
62	Cryogenic Systems	20
85	Integrated Systems Testing	20

- The cost estimate for vacuum vessel fabrication is based on budgetary estimates from two reputable fabricators, using design specifications, drawings, and CAD models provided by the project team and complemented by ongoing research and prototype development. The approach is sound, and the assumptions are reasonable. The comparatively narrow range of the two budgetary estimates supports the credibility of the estimate. The comprehensive testing and quality control procedures submitted by both vendors also lend credence that all necessary work scope is considered and included.
- The cost assumptions for the port duct extensions are well documented and reasonable. The strength of the cost estimate lies in the bottom-up approach using detailed material lists.
- The basis for the TF coil procurement is bottom-up, based on calculated material quantities as well as previous winding experience at PPPL. Total baseline manufacturing cost (less vendor profit, contingency, and site markups) for the 18 coils is about $1.05 million.
- The baseline estimate of $4.8 million for the modular coil winding forms is supported by (1) initial independent cost estimates received from multiple industrial groups with expertise in magnets, fusion, and winding forms, and based on preliminary specifications, and (2) a composite cost estimate derived from two separate budgetary quotations provided by firms currently working on the winding form prototype. The two budgetary quotations are credible because they are within 20 percent.
- The baseline cost estimate for modular coil windings and assembly is based on previous winding operations at PPPL. The estimate is activity based to an acceptable level of detail, with corresponding manhours estimated for each activity based on expected workdays per coil, number of shifts per day, and number of technicians per shift. The documentation is excellent.
- The basis of estimate and assumptions for the cryogenic systems are clear and appear reasonable. The baseline estimate for cryogenic systems may be high by $100,000 due to a mathematical error in the labor estimate for ducting and insulation. With the exception of the aforementioned math error, the baseline estimate for cryogenic systems appears well documented and sound. The strength of the estimate lies in the utilization of costs from previous cryogenic work at PPPL, material takeoffs, vendor quotations, and current catalog pricing for various equipment components.
- The baseline estimate of $437,000 for procedure and document preparation is well documented and based on the completion of 52 necessary documents and procedures that collectively are estimated at 80 man-weeks.
- The baseline estimate of $332,000 for the 3-month integrated system testing phase is supported by start-up experience with similar devices at PPPL, as well as identification of specific resource requirements over the start-up duration.
- Our review of various cost estimating assumptions verifies their reasonableness and proper application to the project. Tracing the cost estimates in the resource-loaded schedule to the cost backup documentation is difficult in some instances. In addition, a centralized written compilation of general cost estimating assumptions does not appear to exist.

- The PM costs represent 9.6 percent of the TEC, on the high end of the range for DOE projects, but not unreasonable given the nature of the project. The FTE distribution looks reasonable over the project life, and the high costs are partly attributed to high base wage rates at PPPL compared with other DOE sites, which translate into high project billable hourly rates.
- PPPL uses different escalation rates than the DOE published rates, and its escalation rates are divided into labor and non-labor components. PPPL states that DOE has agreed to use these rates for this project. Using the DOE published escalation rates would lower the overall project escalation by about $900,000.
- The 28 percent contingency is not out of line for an experimental project at the preliminary design phase, but we had difficulty validating this percentage because of the unique and complex nature of the project. Because the contingency percentage remains unchanged from the CDR stage, actual contingency dollars have increased because of cost growth. The contingency determination method has a number of pros and cons that should be evaluated to determine whether it should continue to be used in future contingency evaluations.

2.2.3.2 Project Schedule Findings, Observations, and Recommendations

CD-4 can likely be achieved in September 2007. The rationale for this assessment is as follows:

- R&D and prototyping activities are ongoing and planned to address the unknowns related to high-risk activities such as modular coil winding and modular coil casting and potting.
- The critical path is well understood and has 5.5 months of contingency included.
- The 230 activities within 30 days of the critical path are well understood, have reasonable durations, and have risk mitigation plans to gain float.
- The definition of CD-4 is such that start-up under warm conditions is required, with cryogenic testing occurring after CD-4.
- Acquisition planning is flexible enough to allow procurement awards to more than one vendor for critical components if necessary.
- No new technology is included in this project. Key activities include prototyping.

Observation: The project schedule is included as approximately 600 activities in a Primavera P3 software with appropriate milestones, logic, and resource loading. The project schedule is at Level II, with a project summary schedule available. WBS managers prepare the schedule for their areas, and the project controls manager compiles it in an integrated form.

Observation: Resource-loading of costs on the schedule is consistent with the appropriations and obligations profile. We reviewed the funding profile and found it consistent with the associated obligations and costs. We assessed the resource-loading for the target elements in Section 2.1 and found it consistent with the method by which the activities were to be accomplished. In a very good scheduling technique, which we found unique to this project, the project team includes labor codes and associated hours for each activity on the schedule to identify resources included.

Observation: The project team uses a "rolling wave" scheduling plan, in which a WAF is continuously developed for the next 2 fiscal years. This WAF includes a more detailed schedule for the period and currently includes approximately 1,000 activities.

Finding: The P3 schedule contains floats of unreasonable duration. They appear to result from not having certain activities tied to specific successors. Floats from 1,500 to more than 2,300 days are included. These float values are obviously not valid, have no meaning, and are distracting to those using the schedule.

> **Recommendation 11**: Correct the unreasonable floats included in the schedule.

Finding: Schedule assumptions are not clearly defined in a single location. The WBS managers guidance for preparation of the schedules includes some of the assumptions, but not in a form that can be included under the document control of the project schedule. These assumptions are vital to documenting and defending the schedule basis for change control and outside review purposes. Assumptions, such as inclusion of workdays on the schedule, shifts planned, and key duration basis, should be documented.

> **Recommendation 12**: Develop a set of schedule assumptions and place them under document control.

Observation: The budget authority (BA) and budget obligation (BO), or spending curves, are consistent with the schedule.

Finding: Milestones are included on the project summary schedule and spread appropriately over the entire duration of the project in the Level II schedule. DOE "Joule" milestones are also included for measurement purposes. The PEP (Section 2.2.5) includes a table of DOE milestones at Level I and Level II. However, we had difficulty determining from the milestone titles—for example, "Authorize Prototype Fabrication of MCC and Vacuum Vessel," "Complete Prerequisites for the CD-3 Milestone for Procurement and Fabrication of Components," and "Initiate Winding Process on a 3D Surface"—the criteria for successful completion

> **Recommendation 13:** Develop a milestone dictionary for key project milestones that clearly defines successful milestone completion.

Finding: The schedule does not include adequate milestones at Level II for certain WBSs. Our review of the Level II schedule found no milestones for the important activities, such as WBS 14 Job 1408 Modular Coil Prototype Winding (June 14–October 25, 2004), Job 1421 Type 1 Winding, Job 1422 Type 2 Winding, and Job 1423 Type 3 Winding. In our review, we could find no milestones for WBS 15 Structures ($1.783 million), WBS 17 Cryostat and Base Support Structure ($2.298 million), or WBS 18 Field Period Assembly ($5.036 million). The milestone table does include a single milestone for several of these activities. Additional milestones are another tool for measuring performance.

Recommendation 14: Include additional milestones at Level II, as appropriate, for WBS elements that do not have well spaced milestones.

Observation: The CD-4 milestone is the focal end point of this MIE project—the conclusion of the project. The project team has a detailed description of what constitutes successful completion of CD-4. It clearly defines the conditions associated with first plasma in September 2007and the activities that continue after CD-4(such as cryogenic systems and integrated systems testing).

Observation: A schedule contingency of 116 days is included on the critical path, and "hotel load" resources are included to fund this time, should it be required. The contingency is based on the project's "expert analysis" of schedule risk. Contingency is spread across the project duration to be available when required.

Finding: The schedule baseline, as defined in the PEP, is not clear. Section 2.2.1, Performance Baseline Parameters, states that the performance baseline for schedule is the estimated project completion date; PEP Section 7 states the schedule baseline is "documented in the NCSX project resource loaded schedule." In addition, the baseline change control thresholds in PEP Section 8.3 (Tables 8-1 through 8-4) give the completion date, level 2 milestones, and performance measurement baseline schedules all as a basis for "Performance Baseline Change Authority." The milestones in Figure 0-1, "NCSX DOE Milestones," form an excellent basis for the NCSX schedule baseline, and Sections 2.2.1 and 7 of the PEP should be revised to state this, validating the change thresholds in Section 8.3 as written.

Recommendation 15: Develop and use a consistent definition for the schedule baseline in the PEP.

2.3 WORK BREAKDOWN STRUCTURE

2.3.1 Key Review Element Background

A WBS is a product-oriented grouping of project elements that organizes and defines the total scope of a project. Each descending level represents an increasingly detailed definition of a project component. This structure integrates and relates all project work (technical, schedule, and cost) and is used throughout a project's life cycle to identify and track specific work scope elements. The WBS dictionary is a listing of individual work breakdown structure elements that describes the work scope content of each element, deliverables, basis of estimate, assumptions, milestones, and resource requirements.

2.3.2 Element Scope of Review

The EIR team assessed whether

- the WBS incorporates all project work,
- it represents a reasonable breakdown of the project work scope, and
- the resource-loaded schedule is consistent with the WBS for the project work scope.

2.3.3 Findings, Observations, and Recommendations

Table 2-8 shows the summary-level WBS for the project.

Table 2-8
NCSX Project WBS Structure

WBS	Description	WBS	Description
1	**Stellarator Core Systems**	**6**	**Facility Systems**
11	In-vessel Components	61	Water Cooling System
12	Vacuum Vessel Systems	62	Cryogenic Systems
13	Conventional Coils	63	Utility Systems
14	Modular Coils	64	Helium Breakout System
15	Coil Support Structure	**7**	**Test Cell Prep and Machine Assembly**
16	Coil Services	71	Shield Wall Reconfiguration
17	Cryostat and Base Support Structure	72	Control Room Refurbishment
18	Field Period Assembly	73	Platform Design and Fabrication
19	Stellarator Core Management and Integration	74	Machine Assembly Planning and Oversight
2	**Auxiliary Systems**	75	Test Cell and Basement Assembly Operations
21	Fueling Systems	76	Tooling Design and Fabrication
22	Torus Vacuum Pumping System	**8**	**Project Management and Integration**
23	Neutral Beam Injection System	81	Project Management and Control
3	**Diagnostics**	82	Project Engineering
4	**Electrical Power Systems**	83	ES&H and QA
5	**Central I&C and Data Acquisition System**	84	Project Physics
		85	Integrated Systems Testing

Observation: The project has a WBS and WBS dictionary, as required by DOE M 413.3-1. A dictionary is critical to defining work and responsibilities in each WBS element.

Finding: We found inconsistencies in the WBS related to the work scope included or not included in the project. The project team corrected these inconsistencies during our on-site review.

> **Recommendation16:** Check the consistency of the WBS, WBS dictionary, cost estimate, and schedule.

Observation: The resource-loaded schedule and cost estimate are consistent with the WBS for the project work scope.

Observation: The WBS dictionary for the project consists only of brief scope descriptions for work elements down to the third level, which limits its usefulness. From our examinations of other DOE projects, we find that WBS dictionaries are comprehensive working tools, which include not only general scope descriptions, but activity descriptions and IDs linked to the resource-loaded schedule, basis of estimate and estimating assumptions, resource requirements by fiscal year, legal drivers, reference documents, milestones, and clarifying notes. Ideally, the dictionaries link the WBS managers' estimating worksheets to the resource-loaded schedule.

> **Recommendation 17:** Consider expanding the WBS dictionary to provide greater detail and usefulness to the project and greater continuity and traceability between the WBS managers' estimates and resource-loaded schedule.

Finding: An essential component of the project work scope is to prepare an integrated start-up test plan to ensure a smooth, delay-free transition from the equipment installation phase to operations, or commencement of experimental work. However, the WBS dictionary does not identify development of the integrated start-up test plan as a project activity.

> **Recommendation 18:** Add an activity, "Develop Integrated Startup Test Plan," to the WBS dictionary for WBS element 85, "Preoperational and Integrated Systems Testing."

2.4 RISK MANAGEMENT

2.4.1 Key Review Element Background

DOE Order 413.3 states: "Project technical, cost, and schedule risks must be identified, quantified, and mitigated (as appropriate). Risk mitigation strategies must be developed and implemented." Risk management must be analytical, forward-looking, structured, informative, and continuous. Risk assessments should be performed early and should identify critical technical, performance, schedule, and cost risks. Risk mitigation plans should not use contingency as the only mitigation strategy. The entire project team performs effective risk management throughout the project life cycle. All stakeholders should participate in the assessment process so that an acceptable balance between cost, schedule, performance, and risk is maintained. Risks mitigation actions should be tracked using a project action-tracking process.

2.4.2 Element Scope of Review

The EIR team

- reviewed the risk management process;
- identified the approaches used to determine project and program risks;
- assessed the adequacy of the risk analysis method;
- determined whether risks had been identified and properly classified as high, medium, or low;
- assessed whether appropriate risk mitigation actions had been incorporated into the baseline; and
- assessed whether adequate contingency had been included in the TEC and schedule.

2.4.3 Findings, Observations, and Recommendations

The project team has prepared a document, *NSCX Risk Management Plan, October 2003,* which identifies a total of 12 significant, anticipated risks. It further describes the consequences of each risk and the mitigating actions proposed to minimize and manage them.

Finding: Specific responsibilities and actions required from individuals are not defined in the risk management plan.

> **Recommendation 19:** Consider expanding the risk management plan, as appropriate, to include actions required from identified individuals to enact mitigation strategies.

Finding: The *NSCX Risk Management Plan* provided to us does not appear to be a controlled document. It has no cover sheet and no approval or signature page, the pages are unnumbered, and the document has not been assigned a project identifier. This document should be dynamic, subject to strict configuration control, and periodically revised as required.

> **Recommendation 20:** Manage the risk management plan as an official, controlled project document, with appropriate endorsements included.

Finding: The schedule includes a contingency of 116 days based on "expert opinion" assessment of the schedule risk. This assessment broke the project into three major intervals (from April 1, 2003, to September 30, 2007, as follows:

- "Preliminary Design" to "Award Mod Coil Production Contract" (14 months)
- "Coil and VV Fabrication" to "Start Field Period Assembly" (20 months)
- "Field Period Assembly/Machine Assembly" to "First Plasma" (14 months).

The project team assessed the risk associated with each of these periods and applied an appropriate contingency: for interval 1, 4.2 months; for interval 2, 0.6 month; and for interval 3, 0.7 month—a total of 5.5 months (116 days).

We accept this method of risk assessment and contingency derivation; it is adequate in total for the project, with the risks presently defined and the prototyping and ongoing parallel procurement actions. However, the 0.7 month of contingency (about 2 weeks) for the third interval could prove to be inadequate if the extensive work planned to address the unique aspects of the machine assembly is done and additional problems are encountered. The complicated assembly process could require more time if the planned activities prove more difficult than anticipated (such as welding of the field spool pieces).

> **Recommendation 21:** Conserve schedule contingency to allow as much as possible to be available during the "Field Period Assembly" to "First Plasma" portion of the project.

Observation: Approximately 230 activities of varying technical importance lie within 30 days of the critical path. These activities are well understood and are being managed by the project team to ensure they do not become critical.

Observation: Tracking of risks and of mitigation strategies is a component of ongoing project dialogue as embodied in regular meeting exchanges and progress report notes. Periodic conferences are not held, nor are risk mitigation reports written to specifically address risk mitigation issues.

Observation: No cost contingency is added to the project cost estimate to address the 12 identified significant risks. Rather, the cost estimate includes the costs of any risk mitigation strategies devised to moderate the risks.

Observation: Each WBS manager determined the appropriate amount of cost contingency to add at WBS level 4 through application of the NCSX "Contingency Estimating Procedure." This procedure is a deterministic process; probabilistic evaluations of contingency are not used for the project, nor are they used in general at PPPL. Although this is acceptable method for determining contingency, elimination of probabilistic techniques means the project cannot express the mathematical "level of confidence" in the project estimate.

2.5 PRELIMINARY DESIGN AND DESIGN REVIEW

2.5.1 Key Review Element Background

DOE O 413.3 and DOE M 413.3-1 provide requirements and guidance for establishing the technical baseline necessary for CD-2. A configuration management process must be established that controls changes to the physical configuration of project facilities, structures, systems, and components. The technical baseline consists of the preliminary design package—including controlled design drawings, schematic diagrams, specifications, design reports, design lists, and system design documents or reports—and also may include status drawings, calculations, design studies, and similar documents, at various stages of completion. The controlled design drawings should be those that form the basis for the detailed design. The preliminary design should be consistent with system functions and requirements and should identify any safety structures, systems, and components (SSCs) incorporated into the preliminary design. The preliminary design package should have been subject to a design review and had corrective actions identified. Any additional work identified by the review should be incorporated into the baseline design documents. Comments on other documents should be included in the final design package, prepared for CD-3.

2.5.2 Element Scope of Review

The EIR team assessed

- whether the design is consistent with system functions and requirements;
- whether all safety SSCs are incorporated into the preliminary design;
- results of the preliminary design review;
- the processes implemented to control the design baseline; and
- whether additional work identified in the design review has been incorporated into the performance baseline;

2.5.3 Findings, Observations, and Recommendations

Observation: Preliminary design has not been completed for the ancillary systems; however, due to the project team's reliance on existing technologies and designs, legacy equipment, and PPPL experience, the cost and schedule estimates have a sound basis.

Observation: Preliminary design, which reflects system and subsystem requirements spelled out in the general requirements document, forms the technical scope (performance baseline) of the project.

Observation: A panel of 13 experts from fusion and other SC programs has completed a preliminary design review; the project team is addressing 24 recommendations from that review.

> **Recommendation 22:** Adjust the performance baseline, as appropriate, once all preliminary design review recommendations have been addressed and the cost and schedule impacts have been assessed.

Observation: A preliminary design analysis has been completed for

- coil and lead field errors,
- eddy currents in modular coil structure,
- thermal and thermo-hydraulic response,
- electromagnetic field and forces, and
- stress due to thermal and electromagnetic loads.

Observation: Structural analysis involves several models, which focus on

- global deflection and stress in the winding forms,
- nonlinear behavior of the windings due to thermal and electromagnetic loads, and
- deflection and stress in the clamps and other local supports.

A detailed deflection and stress analysis of the assembly is in progress at this time.

Observation: Analysis of the stellarator core shows components have margin for the operating scenarios and load cases being considered; however, the project team plans additional analysis during final design. Additional R&D is in progress to verify both component performance as well as manufacturing procedures.

Observation: Considerable risk appears to be associated with the 350 °C bake-out.

Observation: The project team does not expect the NCSX to have any "safety class" or "safety significant" SSCs.

Observation: The project team does not appear to have a plan for simulating the procedure for welding the spool pieces. Since no spares are being procured, improper spool welding or causing damage to the periods during welding could significantly impact the project cost and schedule.

> **Recommendation 23:** Consider developing and implementing a plan to simulate the welding of the spool pieces.

2.6 SYSTEM FUNCTIONS AND REQUIREMENTS

2.6.1 Key Review Element Background

Requirements for a project usually start with a mission need statement and site or program planning documents. Program functional requirements identify specific features or capabilities that the project or process must meet, including acceptance criteria. Projects must also meet applicable DOE requirements and other federal, state, and local laws, rules, and regulations, including safety and environmental protection regulations. The project team should prepare detailed design requirements or criteria to guide the project design. The project may require external approvals by regulatory, licensing, or permitting agencies. These requirements should be reflected in the design features of the project.

2.6.2 Element Scope of Review

The EIR team

- reviewed the program functional requirements and design criteria documents;
- performed an assessment whether "design to" functions and requirements are reflected in the baseline, including safety and external requirements such as permits, licenses, and regulatory approvals; and
- evaluated whether system requirements are derived from and consistent with the mission need.

2.6.3 Findings, Observations, and Recommendations

The PPPL has been involved in the development of plasma systems with the goal of advancing fusion research for over half a century. This work has involved the construction of a variety of devices that use magnet fields to confine the heated plasmas so that nuclei, such as deuterium and tritium, will reach temperatures where they can fuse together, thereby releasing energy. PPPL has been the major U.S. center of this research and the site of most of the large plasma physics devices constructed in this country. In the process, PPPL has developed the facility and engineering infrastructure needed to build and operate devices such as the NCSX. The largest magnetic confinement device built at PPPL was the TFTR. In terms of sheer scale, it was about 10 times heavier and was twice as large in each dimension as the NCSX. The TFTR operated for over a decade, beginning in the mid 1980s. Full operation of the TFTR required more than five times as much electrical power as the NCSX.

After the TFTR was decommissioned, the power supplies, cooling systems, etc., remained and have been available for use on other projects. Parts of this legacy equipment will be integrated into the facility support for the NCSX. The operational and safety procedures for the NCSX are based on the use of this equipment and the larger predecessors. The PPPL staff is familiar with this equipment.

The major changes in operations over the past 20 years have been in the improvement in controls and operation that are based on advanced computer architecture. Perhaps the major change in operation of the NCSX from that of the TFTR will be that operators will interface with the system via state-of-the-art monitoring and control systems. This will provide users with better physics information, and it will allow safer operation because of the more rapid response times of today's electronics and the ability to use more sophisticated logic systems to separate potential hazards and safety related issues from normal operational conditions.

Observation: The NCSX machine will have 18 modular coils, and the plan is to have 18 separate winding forms, one for each coil. The modular coils come in 3 different shapes, and there are 6 coils of each shape. The modular coils greatly differ from the other coils in the NCSX system; furthermore, they differ from those used in any other fusion device (past or present) at PPPL. Recognizing these differences, PPPL is carrying out a thorough industrial development of the winding forms for these coils. The effort to date in this area has succeeded and has reduced the cost and schedule risk associated with these coils. It has also reduced the anticipated fabrication period. Nevertheless, the modular coils are on the critical path.

Observation: The modular coil winding forms will be fabricated in series, and the coils will then be wound in series. Any delay in one of the steps, rework, or redesign could significantly delay project completion. Modifying the design and fabrication of the winding forms so that 2 of the 3 coils are on a single form would reduce the number of different types of winding forms from 3 to 2, the number of vacuum interconnections from 18 to 12, and the number of flanges from 36 to 24, decreasing the total weight of the modular coil system. This approach might simplify or complicate coil winding, but it would also reduce the number of coil curing procedures from 18 to 12. It would also eliminate one form of assembly error, thus eliminating the need for field correction of the system and reducing metrology procedures for the modular coils.

> **Recommendation 24:** Evaluate the potential benefits of modifying the design and fabrication of the winding forms so that two of the three coils are on a single form.

Observation: The preliminary design includes the system and subsystem functions and requirements described in Draft D of the General Requirements Document, September 20, 2003.

Observation: An environmental assessment has been completed and a FONSI approved.

2.7 HAZARD ANALYSIS

2.7.1 Key Review Element Background

A project analyzes potential hazards, including internal and external hazards, environmental releases, electrical surges, explosions, fires, earthquakes, tornados, flooding, loss of power, and transportation accidents. For the preliminary design phase, a preliminary hazard analysis and a companion preliminary fire hazard analysis are typically performed. These analyses are refined into final reports at the end of the design phase. A safety analysis report is also usually prepared for the project or as an update to the site safety analysis report. Outside agencies or regulatory agencies, as appropriate, may conduct safety reviews. The project team should consider the results of the hazard analyses in determining structures, systems, and components that are important to safety and any specific design features needed to mitigate potential hazards.

2.7.2 Element Scope of Review

The EIR team

- reviewed the preliminary hazard analysis, the preliminary safety analysis report, and the site wide safety analysis report;
- evaluated the quality of the hazard analyses;
- assessed whether all scope, schedule, and costs necessary for safety are incorporated into the baseline;
- reviewed whether the classification of SSCs as safety class or safety significant was done; and
- assessed the hazard analysis process utilized, including the use of internal and external safety reviews.

2.7.3 Findings, Observations, and Recommendations

The NCSX will become one of a series of fusion experiments built and operated at PPPL. PPPL has adapted existing site-wide procedures and analyses as appropriate for the NCSX project. It has a thorough hazard analysis process that has resulted in an NCSX preliminary hazard analysis (PHA), integrated safety management procedure (ISMP), and job hazard analysis. The project team's implementation of the hazard analysis process appears appropriate to date, with additional, project-specific hazard analysis activities scheduled for completion as the design progresses. Cost and manpower estimates are included for this activity. Hazard analysis documents appear to be appropriate for this project stage. The ISMP will require updating to include this facility, as discussed below.

Finding: The project team does not expect the NCSX to have any safety class or safety significant SSCs. Considerable quantities of inert nitrogen liquid and gas will be used during operation of the stellarator; a large loss of nitrogen from the cryostat is a potential threat to workers.

> **Recommendation 25:** As design progresses, assess the potential of a significant release of nitrogen during operation of the stellarator and evaluate the need to add monitors or alarms, for example, for low oxygen conditions.

The PHA identifies 10 groupings or events that may affect the project. These have been or will be analyzed and included in the PHA:

- Radiation
- Electrical
- Fire in the facility
- Earthquakes
- Vacuum windows
- Magnetic fields
- Radio frequency (RF) fields
- Mechanical
- Hot fluids
- Gases and cryogenics.

Finding: The project team is relying on safety analysis for many of the identified hazards to be included in the NCSX safety assessment document (SAD). The PHA will be updated as the design progresses and will be incorporated into the SAD.

> **Recommendation 26:** As the project continues, analyze potential hazards in detail on the basis of final design and incorporate them into the NCSX PHA and SAD.

Observation: The hazard analysis process has included reviews of the PHA as part of the CDR and reviews of the environmental assessment by DOE and the New Jersey Department of Environmental Protection. Hazard analysis was part of the preliminary design review and will be part of the final design review. PPPL intends to follow procedures used for similar projects and will establish an activity certification committee to review an NCSX SAD and safety aspects of planned operations. The SAD, which will be approved prior to first plasma, will address the relevant NCSX structures, systems, and components; identify hazards associated with operation, and explore design features and administrative controls to mitigate these hazards.

Observation: DOE will conduct an operational readiness assessment prior to CD-4.

2.8 VALUE MANAGEMENT/ENGINEERING

2.8.1 Key Review Element Background

In accordance with the requirements of DOE M 413.3-1, "All projects shall include a value management assessment. The assessment shall be conducted as part of the conceptual design process to include making a determination of whether a formal value engineering study is required. Any decision to not perform a formal value engineering study shall be documented in the Project Execution Plan."

In addition, DOE M 413.3-1 states that "Value management should be employed as early as possible in the project development and design process so recommendations can be included in the planning and implemented without delaying the progress of the project or causing significant re-work of completed designs."

Lastly, DOE M 413.3-1 also provides guidance for using a two-tiered approach to applying value management that includes both a "mandatory program" (the formal VE study) and an "incentive" (also known as voluntary) program. The value management incentive program consists of incorporating cost-saving incentive clauses ("shared savings" clauses) in all contracts awarded on facility construction projects after CD-2, where certain contract conditions exist.

2.8.2 Element Scope of Review

The EIR team

- ensured that a formal VE study had been performed (or specifically excluded and so documented in the PEP),
- resolved whether a trained, qualified VE leader directed any formal VE study,
- determined that a formal VE study had been conducted during the early phases of the project to yield the greatest cost reductions,
- ascertained whether recommendations from a formal VE study have actually been incorporated into the design concept,
- decided if appropriate conditions exist within the project for implementing cost-saving incentive clauses in contracts awarded post CD-2, and
- determined whether the project proposes to use cost-saving incentive clauses in contracts awarded post CD-2 at this time.

We were able to reach firm conclusions on these six issues after reviewing documentation provided by the project team before and during our site visit and through discussions with the project manager and other NCSX project staff members.

2.8.3 Findings, Observations, and Recommendations

The project team conducted a formal VE study, led by the project experimental physics director. Although not a certified VE practitioner, this individual knows the requirements of the stellarator, in terms of utilities and support system requirements as well as the performance envelope that the machine must ultimately embrace. The results of the study are embodied in the document, *NCSX Value Engineering Taskforce*.

Finding: Like the risk management plan, the *NSCX Value Engineering Taskforce* provided us does not appear to be a controlled document. It has no cover sheet or approval or signature page, the pages are unnumbered, and the document has not been assigned a project identifier. The *NCSX Value Engineering Taskforce* should be dynamic, subject to strict configuration control, and periodically revised as required.

Recommendation 27: Ensure that the *Value Engineering Task Force* document is managed as an official, controlled project document, with appropriate endorsements included.

Observation: The VE study has identified nine cost-savings concepts. To date, five have been accepted and incorporated into the technical baseline, with a resulting cost savings of about $3.4 million. One was rejected as impractical, and three continue to be studied and ultimately may be incorporated.

Observation: The *NSCX Value Engineering Taskforce* document does not mention that cost savings incentive clauses will be considered for contracts or procurements awarded after CD-2.

Recommendation 28: Add wording to the *NSCX Value Engineering Taskforce* document indicating that "shared savings" clauses (the "voluntary" component of value management) will be considered in all procurements awarded after CD-2, when appropriate.

2.9 PROJECT CONTROLS AND EARNED VALUE MANAGEMENT SYSTEM

2.9.1 Key Review Element Background

In accordance with requirements of DOE M 413.3-1, "For projects with a total projected cost greater than $20 million, the performance management system shall be an Earned Value Management System that is certified as compliant with ANSI/EIA-748." In addition, DOE M 413.3-1 states, "Starting at Critical Decision-2, project performance shall be reported monthly using PARS." Finally, DOE M 413.3-1 states that "Every project shall have a functioning performance management system, no later than final Performance Baseline approval."

2.9.2 Element Scope of Review

The EIR team

- determined whether the project is using an earned value management process to evaluate project status,
- assessed whether the earned value management process complies with ANSI/EIA-748,
- assessed whether the project earned value management process is in accordance with PPPL site procedures and guidelines,
- ensured that the EVMS and reports produced by the system are in-place and functioning by CD-2,
- assessed the adequacy (size, functions, and relationships) of the project controls organization,
- evaluated the qualifications and experience level of the project controls staff,
- determined that project performance will be reported monthly using PARS by CD-2, and
- deduced whether the EVMS is adequate for monitoring and controlling project costs and schedules.

We were able to reach firm conclusions on these eight issues after reviewing documentation provided by the project team before and during our site visit and through discussions with the project team members.

2.9.3 Findings, Observations, and Recommendations

A single person—the PPPL NCSX project control manager—performs the current project controls function for the NCSX project on a part-time basis. A counterpart project control manager function resides at Oak Ridge National Laboratory (ORNL), but the requirement of this position is to collect ORNL costs monthly and provide them to the PPPL NCSX project control manager for overall earned value reporting.

We did not interview the ORNL project control manager, who did not attend our site visit. We interviewed the PPPL NCSX project control manager at length. He is very experienced and well versed—in the theory of EVMS and in the practical project application. He compiles P3 project schedules (with the assistance of the WBS managers) and cost-loads the schedule activities using the P3 software. He also performs a chief estimator and project scheduler function, although his role is more akin to integrating cost and schedule estimate information provided by the WBS managers than creating original estimates. The cost assembly process he performs includes applying appropriate overheads and burdens, escalation, and contingency to the "raw costs" provided by the WBS managers.

The WBS managers typically provide "percent complete" information used in the monthly EVMS reporting. The PPPL NCSX project control manager produces the monthly reports. Cost and schedule performance indices, CPI and SPI, and estimate at completion (EAC) are reflected in the reports.

A department-designated committee reviewed the NCSX project controls system on February 27 and 28, 2003, in response to a request from the NCSX federal project director, to ensure appropriate EVMS processes were being applied. The committee found, in essence, that

- the reporting format and frequency is adequate considering the project size, complexity, and risk;
- the project EVMS system produces timely and accurate reports in a readable and meaningful format;
- the system is flexible enough for changes without extensive modification;
- the management structure is adequate for guiding the project to completion considering the joint responsibilities of ORNL and PPPL; and
- the system is "consistent with the fundamentals of" ANSI/EIA-748.

Finding: We noted document control shortcomings in the cost estimate and schedule sections of this report. The project team gave us cost estimates and schedules during the EIR, which were not the latest available (such as cryogenic systems schedules and cost estimates), and we had no way to determine from the documents whether they were current. For example, the schedules had no approval block and no revision history.

> **Recommendation 29:** Institute a system for document control of the cost estimates and schedules that includes a formal issuance system for revisions and updates.

Observation: We are concerned that this relatively large and complex project has a project control staff of less than one full-time person. Although we encountered no glaring deficiencies resulting from this practice, we did note some subtle differences compared with other projects we have reviewed recently within the DOE complex. For example, no one person can take "ownership" for the entire cost estimate. The project control manager can explain how burdens and overhead costs were applied, but only the WBS manager can explain the underlying cost estimate manhours and equipment costs. Also, no conventional cost estimate spreadsheet exists, explaining all estimate bases in one document. We expressed our concerns to the project team, but were assured that the practice (of limited staffing for project controls) is site-wide, has been successfully used for equally complex projects in the past, and no problems are expected. We are reluctant to recommend adding project control staff since we did not discern any actual performance shortcomings at this time.

> **Recommendation 30:** Consider adding project control support staff to bolster the project EVMS capabilities in the event project performance data begin to degrade in accuracy and timeliness.

Observation: Monthly reports currently produced by the EVMS are adequate—well laid out and informative.

Observation: We concur with the review committee finding of February 2003 that the NCSX project complies with ANSI/EIA 748-A-1998 (Earned Value Management Systems) in implementing EVMS.

Observation: The project earned value management process is in accordance with PPPL site procedures and guidelines, based on our review of *PPPL Project Control System Description, Revision 0, July 1996*.

Observation: The EVMS and reports produced by the system are in-place at this time, and have been for some time, well in advance of CD-2.

Observation: Design phase project performance is currently reported monthly using PARS and will continue after CD-2.

Observation: As noted earlier, project controls at PPPL are instituted in accordance with *PPPL Project Control System Description, Revision 0, July 1996*. It is unusual to find a management process description unchanged after more than 7 years.

> **Recommendation 31:** Evaluate the *PPPL Project Control System Description, Revision 0, July 1996*, to ensure it remains viable and consistent with current practice at the laboratory.

2.10 PROJECT EXECUTION PLAN

2.10.1 Key Review Element Background

In accordance with DOE M 413.3-1, each project must have a PEP that includes an accurate description of how the project is to be accomplished and defines resource requirements, technical considerations, risk management, and roles and responsibilities. Also, project changes must be identified, controlled, and managed through a traceable, documented change control process defined in the PEP. As a condition of CD-2 approval, an approved, formal, final PEP embodying these requirements should be in place.

2.10.2 Element Scope of Review

The EIR team

- concluded whether the integrated project team, under the leadership of the federal project director, developed the PEP;
- determined whether the PEP had been formally approved;
- identified project participants' responsibilities, authorities, and accountabilities, including the integrated project team;
- determined that the WBS and dictionary are defined;
- identified the overall performance baseline, and the individual technical, schedule, and cost baselines, against which changes are monitored and controlled;
- decided whether the PEP adequately addresses Integrated Safety Management (ISM) implementation within the project;
- determined the extent to which Safeguards and Security are included as part of the PEP and reflected in other components of the PEP, such as emergency preparedness planning, communications, and procurement planning;
- concluded that a realistic and workable change control process is defined; and
- identified that the acquisition strategy envisioned for the project is referenced in the PEP.

We were able to reach firm conclusions on these nine issues after reviewing documentation provided by the project team before and during our site visit and through discussions with the project team members.

2.10.3 Findings, Observations, and Recommendations

The PEP reflects the actual management process in place for the project and provides a good summary of the processes and events that drive and control the work.

The PEP was unsigned at the time of our site visit. The project team indicated that the documentation appropriate for the CD-2 package would be locally signed just prior to submittal to headquarters for approval. Headquarters approval of the final PEP (and other CD-2 documentation) will then be requested as part of an overall CD-2 approval process. From our EIRs performed in recent months, we find that this practice has become the norm for most projects and is compatible with the intent of DOE M 413.3-1 requirements.

Observation: The November 18, 2003, version of the PEP contains several inconsequential but annoying inconsistencies, typographical errors, incorrect references, etc. We discussed these with the project team, and it committed to correcting the text before submitting the PEP to HQ for approval.

> **Recommendation 32:** Ensure that the PEP is given a general "housekeeping" revision prior to submittal.

Observation: The PEP does a good job of identifying project participants and their responsibilities, authorities, and accountabilities. The identity and role of the integrated project team is well defined.

Observation: The PEP includes a summary of the WBS (page 18) and refers to the WBS dictionary. However, no reference is given as to where the complete WBS or the WBS dictionary can be found.

> **Recommendation 33**: Provide a reference to the document identifiers for the complete WBS and WBS dictionary.

Observation: The overall performance baseline, and the individual technical, schedule, and cost baselines, against which changes are monitored and controlled are adequately defined in the PEP.

Observation: Section 15 of the PEP addresses ISM implementation within the project.

Observation: A realistic and workable baseline change control process is defined in the PEP (page 24). The approval thresholds defined for the project are appropriate for the work.

Observation: The PEP acknowledges the value management process employed by the project and discusses the formal value management study performed. It cites examples of the viable recommendations from the study and indicates they have been incorporated into the project performance baselines.

2.11 START-UP TEST PLAN

2.11.1 Key Review Element Background

DOE Order 413.3 and Manual 413.3-1 contain requirements and guidance for start-up testing to ensure the production facility meets acceptance criteria. To establish the technical, cost, and schedule performance baseline (CD-2), provisions for start-up testing should be provided with sufficient basis to evaluate the baseline. Key tests should be determined to that ensure the facility and systems meet operational and safety requirements. Any permanent plan equipment necessary for testing or validation should be included in the plant design.

2.11.2 Element Scope of Review

The EIR team

- reviewed the cost and schedule basis for start-up testing;
- reviewed the facility test and evaluation plan;
- assessed whether all scope, schedule, and costs necessary for start-up testing are incorporated into the baseline;
- reviewed the facility design for potential features necessary for testing and evaluation.

2.11.3 Findings, Observations, and Recommendations

The cost and schedule baseline includes appropriate start-up and testing activities. The facility test and evaluation plan (TEP) addresses the procedures required to meet the scope of the construction project, which includes a minimal set of initial tests of the stellarator. We consider the quality of the work completed to date to be satisfactory. The test plan is thorough and comprehensive.

Observation: The procedures required in the NCSX start-up are similar to those used for the start-up and operation of existing facilities at PPPL. Thus, the development of a start-up plan has been a straightforward effort, and the existing staff is familiar with the procedures.

Observation: The definition of project completion includes first plasma and a measurement of magnetic fields produced by the various sets of coils. Start-up is thus limited to this scope.

Observation: The total cost for system start-up is uncertain. Though all costs and effort required for start-up are included in the individual WBS sections, no single compilation of the effort for this item exists.

> **Recommendation 34:** Consider establishing a single and separate document that includes all items required for start-up. Details in the document should come from the various WBS sections and include cost of labor, materials, etc.

2.12 ACQUISITION STRATEGY

2.12.1 Key Review Element Background

DOE O 413.3 and DOE M 413.3-1 address the timing and requirements for developing an acquisition strategy that sets forth management's approach to ensuring the project contract satisfies the mission need. The acquisition strategy can be part of the mission need document, a separate document, or a part of the acquisition plan. The OECM reviews the acquisition strategy, which accounts for project risks and mitigation strategies, before the acquisition executive approves it at CD-1. The acquisition plan, developed by the maintenance and operations (M&O) contractor, describes the contractual means by which the project's acquisition strategy will be executed; it is also a prerequisite for CD-1 approval.

2.12.2 Element Scope of Review

The EIR team determined whether

- the acquisition strategy is consistent with the way the project is being executed, and
- any changes from CD-1 were made that might affect whether the current strategy continues to represent best value to the government.

2.12.3 Findings, Observations, and Recommendations

The acquisition strategy is consistent with the current execution process and is unchanged from CD-1. References to the acquisition strategy in the PEP are consistent with this strategy, and the acquisition execution plan (AEP) and PEP are otherwise consistent.

Observation: From our review of the project documentation—particularly the PEP and AEP—it appears that appropriate conditions exist within the project for implementing cost-saving incentive clauses in contracts awarded after CD-2. Although the federal project director and NCSX project manager said that the project is open to including such incentives, the project documentation currently does not mention them.

> **Recommendation 35:** Include wording in the AEP that cost-saving incentive clauses will be considered and incorporated where practical in contracts awarded post CD-2.

Observation: The procurement of coils is planned in several procurements (TF, PF, and external trim coils). The project staff said that the relatively small cost of several of these procurements could affect the final cost and possibly the delivery schedule. Combining several or all of the coil procurements could possibly result in a more favorable bid. Other factors may make this option unfavorable, but they were not mentioned during our EIR discussion.

> **Recommendation 36:** Consider combining coil procurements to attempt to obtain more favorable bids.

Observation: We noted some minor deficiencies in the AEP (outdated information, for example); however, no substantive changes to the procurement plans have taken place. The project team does not plan to revise the AEP at this time.

> **Recommendation 37:** Ensure that all outdated references in the AEP are noted and corrections readied to include in the next general revision.

Observation: The program in use by the project team to qualify vendors of critical components appears to be successful and beneficial to the project schedule and cost.

2.13 INTEGRATED PROJECT TEAM

2.13.1 Key Review Element Background

According to DOE M 413.3-1, an IPT is an essential element of the acquisition process and should be used during all phases of a project's life cycle. The IPT is a team of professionals representing diverse disciplines with the specific knowledge, skills, and abilities necessary to support the successful execution of a project. Project directors, project managers, contracting officers, safety and quality assurance personnel, legal specialists, and technicians typically constitute IPT membership. Members of an IPT can be DOE federal staff and contractor employees. Membership, which can be full or part time, should change as the project progresses through various stages. The federal project director charters and leads the IPT.

2.13.2 Element Scope of Review

The EIR team

- assessed whether the PM staffing level is appropriate;
- determined whether appropriate disciplines are included on the IPT—considering qualifications, experience, and training;
- identified any deficiencies in the IPT that could hinder successful execution of the project; and
- clarified differences between the IPT and the core project team.

2.13.3 Findings, Observations, and Recommendations

Observation: The federal project director appointed the IPT, with extensive input from the NCSX project manager. It has appropriate representation from suitable organizations.

Observation: Members of the IPT appear highly qualified for their positions, both in terms of formal education and prior project experience.

Observation: The IPT holds regular meetings attended by all members. Objectives of the meetings include reviewing documents and issues and making recommendations to guide project decisions. The IPT is not just a figurehead organization: its recommendations genuinely influence project events.

Observation: In addition to the IPT, there is a program advisory committee (PAC), which meets periodically to provide technical advice to the project team. PAC minutes are kept in the project files.

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APPENDIX A—ABBREVIATIONS

AEP	acquisition execution plan
BA	budget authority
BO	budget obligation
CAD	computer aided design
CD	critical decision
CDR	conceptual design report
CPI	cost performance index
DOE	Department of Energy
EAC	estimate at completion
EIR	external independent review
ES&H	environment, safety, and health
EVMS	earned value management system
FONSI	finding of no significant impact
FTE	full-time equivalent
G&A	general and administrative
IPT	integrated project team
ISMP	integrated safety management procedure
ISTP	integrated systems test procedure
MCC	modular coil configuration
M&S	material and subcontracts
MIE	major item of equipment
MW	megawatt
NBI	neutral beam injection
NCSX	National Compact Stellarator Experiment
NSTX	National Spherical Torus Experiment
OECM	Office of Engineering and Construction Management
OFES	Office of Fusion Energy Sciences

ORNL	Oak Ridge National Laboratory
PAC	program advisory committee
PARS	project assessment reporting system
PDR	preliminary design review
PEP	project execution plan
PF	poloidal field
PM	project management
PPPL	Princeton Plasma Physics Laboratory
R&D	research and development
ROM	rough order of magnitude
SAD	safety assessment document
SPI	schedule performance index
TF	toroidal field
TEC	total estimated cost
TEP	test and evaluation plan
TFTR	Tokomak Fusion Test Reactor
TPC	total project cost
VE	value engineering
VV	vacuum vessel
WAF	work authorization form
WBS	work breakdown structure

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APPENDIX B—REVIEW TEAM BACKGROUND

DOUGLAS GRAY, P.E.
LMI Consultant
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EDUCATION

B.S., Chemical Engineering, Iowa State University, 1975

EXPERIENCE SUMMARY

Mr. Gray has more than 26 years of experience in engineering, independent cost estimating, validations, and external assessments. He was past program manager for an independent cost estimating contract with DOE/FM-20. He has more than 13 years' experience as a project and program manager, and has managed DOE projects since 1990 at such locations as Rocky Flats, Oak Ridge, and DOE Headquarters. Mr. Gray's cost estimating, cost analysis, economic analysis, and scheduling expertise is derived from a number of engineering and project management assignments in the private sector, as well as from management of over 40 independent cost estimates and validations for DOE, including such projects as the Accelerator Production of Tritium and the Tritium Extraction Facility. Mr. Gray was the task manager for the external assessment of the Stockpile Management Restructuring Initiative at DOE's Kansas City Plant. He also has prepared independent cost reviews for the Distributed Information Systems Laboratory, the Terascale Simulation Facility, and the Weapons Evaluation Test Laboratory. As a result of the work performed by Mr. Gray's teams, numerous recommendations have been submitted to DOE for improved project/program management, project controls, and cost estimating. Many of the recommendations have been accepted and implemented by DOE, leading to significantly improved project performance.

CERTIFICATION/PROFESSIONAL AFFILIATIONS

Professional Engineer, Colorado, No. 25722
Professional Engineer, Ohio, No. E-55299
American Institute of Chemical Engineers
Society of Mining Engineers
Colorado Hazardous Waste Management Society

STEPHEN A. FLANNERY, CCE
LMI Consultant
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McLean, VA 22102
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EDUCATION

B.S., Civil Engineering, The University of Michigan
M.S., Civil Engineering, The University of Michigan

EXPERIENCE SUMMARY

Mr. Flannery has more than 35 years' experience in all phases of management and control of projects as an employee of owner, A-E, and consulting firms. He possesses extensive experience in cost engineering involving estimation, control, and analysis of capital expenditures for varied industrial applications. He is experienced in conceptual and detailed estimating, cost monitoring, trending, value engineering, performance measurement and cost control; bid analysis and contract development; cost management system development and evaluation; planning and scheduling; and procedures development.

Mr. Flannery has 16 years' experience in directing up to 70 professional and support personnel. He has extensive experience performing independent cost estimates and validations of projects for the U.S. Department of Energy's Environmental Restoration, Waste Management, and Civilian Radioactive Waste Management programs.

He has provided successful management and execution of cost engineering projects including independent cost estimate and schedule reviews, system and procedure evaluation and development, estimate and schedule development, and economic and financial feasibility analyses.

His experience also includes extensive work in environmental restoration, hazardous waste management facilities and operations, utility (power plant) engineering and construction, oil field facilities design and construction, petroleum refinery construction, and U.S. Department of Energy reviews of high technology projects and programs.

CERTIFICATION/PROFESSIONAL AFFILIATIONS

Certified as Cost Engineer No. 1473, current registration expires March 1, 2004
Member, Project Management Institute (PMI)

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EDUCATION

B.S., Mechanical Engineering, Carnegie Mellon University

EXPERIENCE SUMMARY

Mr. Scango has 37 years of program/project management experience in both private industry and government with a comprehensive hands-on background in project management, design, construction, and operation of large programs and complex projects. Mr. Scango has a comprehensive knowledge of the DOE baselining process, including establishing/assessing baselines. He is experienced in independent cost estimates, development and assessment of resource loaded schedules, and contingency and risk analysis. As a DOE employee, he served in the Office of Civilian Radioactive Waste, Office of Field Management, and Superconducting Super Collider program. Mr. Scango participated in an independent review of the Tank Waste Remediation System at the Hanford Site and managed independent cost estimates on more than 40 programs, including the Nuclear Waste Stockpile Program and the $5.3 billion Environmental Cleanup Program.

As an independent consultant, Mr. Scango has completed such tasks as the Strategic Petroleum Reserve Readiness Review, numerous DOE waste management project reviews, Brookhaven Graphite Reactor deactivation, and a Spallation Neutron Source Independent Review. In private industry, he served as the Director of Cost for the U.S. Synthetic Fuels Corporation. He has extensive experience performing independent cost estimates and validations of projects for the U.S. Department of Energy's Environmental Restoration, Waste Management, and Civilian Radioactive Waste Management programs. He has provided successful management and execution of cost engineering projects including independent cost estimate and schedule reviews, system and procedure evaluation and development, estimate and schedule development, and economic and financial feasibility analyses.

CERTIFICATION/PROFESSIONAL AFFILIATIONS

Professional Engineer, District of Columbia, No. 1474
American Society of Professional Engineers
Association for the Advancement of Cost Engineering

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EDUCATION

B.S., Physics, California Institute of Technology
M.S., Physics, University of Illinois
Ph.D., Physics, University of Illinois

EXPERIENCE SUMMARY

Dr. Hassenzahl has over 35 years experience in the development of magnetic and superconducting systems from both an industry and government perspective. He is the founder of Advanced Energy Analysis, which specializes in analysis and development of technology for electrical power and other energy intensive systems, including a variety of applications using electric and magnetic systems for energy storage, motion, detection, and analysis. His technical and management experience spans areas of energy storage, electrical power system stability, magnetic systems, superconductivity, accelerator design and operation, and other areas related to electrical systems ranging from large electric power grids to advanced medical devices. He is Chairman of the Electricity Storage Association and has authored of over 200 technical articles. Dr. Hassenzahl spent 27 years with the University of California as a research scientist and program manager for a variety of energy and advanced technology programs at Lawrence Livermore National Laboratory (LLNL), Lawrence Berkeley National Laboratory (LBNL), and the Los Alamos National Laboratory (LANL). He has carried out independent estimates/evaluations of system costs, development efforts, resource loaded schedules, and contingency and risk analysis. As a University of California detailee to DOE, he served in the initial phases of program development and cost estimating for the Superconducting Super Collider. Prior to his retirement from the University of California in 1993, Dr. Hassenzahl was the leader of the Applied Superconductivity Group (ASG) at LLNL. The group, which included physicists, engineers, designers, and technicians, operated LLNL facilities for testing high-field, high-current superconductors, including the FENIX facility. The ASG was responsible for the development of superconducting magnets for the plasma fusion program at LLNL and included work on the International Tokomak Experimental Reactor (ITER) and the Tokamak Physics Experiment (TPX). Dr. Hassenzahl was the leader of the design team for the TPX superconducting magnets. He was responsible for coordinating work within LLNL and at other institutions—mainly at PPPL and at MIT.

CERTIFICATION/PROFESSIONAL AFFILIATIONS

Member, IEEE, and Power Engineering Society Rep to the IEEE Council on Superconductivity
Chairman, Electricity Storage Association

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EDUCATION

Graduate of Industrial College of the Armed Forces; Air Command and Staff College, and Squadron Officers School
M.B.A., Wright State University
M.S., Electrical Engineering, University of Pittsburgh
B.S., Engineering Science, U.S. Air Force Academy

EXPERIENCE SUMMARY

Mr. Westerbeck is the LMI Program Manager for the DOE program. He has 40 years of experience in the public sector as an engineer, program and project manager, and consultant, including 32 years in facilities engineering and environmental management at both the federal installation and headquarters levels. Mr. Westerbeck has served as a construction project planner, programmer, designer, and construction manager for major construction, alteration, and repair projects at U.S. Air Force bases in the United States, Okinawa, and Vietnam. He also served as the deputy manager of a U.S. Air Force office coordinating the efforts of the other military services and the Office of the Secretary of Defense to improve the productivity of the U.S. industrial base and its preparedness for increased wartime production, and to reduce U.S. dependency on foreign critical and strategic materials.

In 1987, Mr. Westerbeck was selected to establish an environmental restoration and compliance program at Wright-Patterson Air Force Base; that program quickly became a model for other federal facilities. As a DOE site manager in the field and at DOE Headquarters, he gained extensive experience in the management and technical aspects of environmental restoration, the management and disposition of hazardous and radioactive waste materials, and decontamination and decommissioning of excess facilities and equipment.

At LMI, he has managed studies and analyses for numerous federal agencies, including more than 40 External Independent Reviews or Independent Cost Reviews of DOE and NNSA line item projects. Mr. Westerbeck is a retired member of the Senior Executive Service and a retired Colonel from the U.S. Air Force. His decorations and awards include the Legion of Merit, the Bronze Star, the Meritorious Service Medal, and the Distinguished Career Service Award.

CERTIFICATION/PROFESSIONAL AFFILIATIONS

The Military Officers Association
The Reserve Officer Association

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APPENDIX C—PERSONS INTERVIEWED

- B. Stratton
- Bill Lyon
- Brad Nelson
- Charles Gentile
- E. Perry
- G. Oliaro
- Geoffrey Gettelfinger
- Greg Pitonak
- Hutch Nielson
- J. F. Lyon
- Jerry Levine
- Jim Chrzanowski
- Larry Dudek
- M. Cole
- M. Zarnsdorff
- Michael Kalish
- Mike Viola
- Paul Goranson
- Phil Heitzenroeder
- Rod Templon
- Ron Strykowski
- S. Ramakrishman
- T. Stevenson
- W. Blanchard
- Wayne Reiersen

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APPENDIX D—DOCUMENTS REVIEWED

- Project Execution Plan for National Compact Stellarator Experiment, Revision 1, Draft K, October 24, 2003.
- NCSX Acquisition Execution Plan, Revision 0, June 28, 2002.
- NCSX Risk Management Plan, October 2003.
- Resource Loaded Schedule, September 23, 2003.
- General Requirements Document, Draft D, September 20, 2003.
- NCSX Cost Summary, September 19, 2003.
- NCSX Preliminary Design Review, Cost and Schedule Document, October 2003.
- NCSX Summary Schedule
- NCSX Work Breakdown Structure, September 8, 2003.
- WBS Dictionary, Revision 0, August–September 2003.
- BA & BO Profiles.
- NCSX Project Milestones.
- Systems Design Descriptions.
- NCSX Preliminary Hazards Analysis, Revision 1, May 7, 2003.
- Department of Energy Review Committee Report on the Technical, Cost, Schedule, ES&H, and Management Review of the NCSX Project, May 2002.
- Project Briefing Charts, November 18, 2003.
- Test and Evaluation Plan, National Compact Stellarator Experiment, NCSX-PLAN-TEP-00, Draft D, November 10, 2003.
- Response to the EIR-Team Initial Questions for the External Independent Review, National Compact Stellarator Experiment, Princeton Plasma Physics laboratory, Oak Ridge National Laboratory, November 14, 2003.

- Master Schedule
- Procurement documents for Vacuum Vessel and Modular Coils (Procurement sensitive)
- Predecessor/Successor Report, dated November 10, 2003, data date August 18, 2003.
- Critical Path Schedule activities, dated October 18, 2003
- NCSX Level II Schedule, dated 9/23/2003
- Preliminary Design
- Preliminary Design Review Comments
- NCSX Facility Start Up and Integrated Systems Test Procedure
- NCSX Systems Engineering Management Plan NCSX-PLAN-SEMP
- PPPL Integrated Safety Management Procedure, Revision 4, September 2002
- PPPL Job Hazards Analysis, ESH-004 Rev.1, Revision 1, September 6, 2002
- Environmental Assessment "The National Compact Stellarator Experiment at the Princeton Plasma Physics Laboratory," DOE/EA 1437 September, 2002
- PPPL Work Planning Procedure ENG-032, Revision 2, May 30, 2003
- Document, NCSX Value Engineering Taskforce
- NCSX Project Control System Review, February 2003
- NCSX PCS Reports, Performance through August 1, 2003
- PPPL Project Control System Description, Revision 0, July 1996

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APPENDIX E—CORRECTIVE ACTION PLAN

Table E-1
EIR Corrective Action Plan

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
1	2.1	7	Clean up the cost documentation for TF coil procurement, make the numbers consistent, and ensure that the cost basis is clear and defensible.						
2	2.1	12	Review the labor estimate for ducting and insulation, and revise as appropriate if an error is found.						
3	2.1	15	Develop activities in the WBSs that support the integrated system testing WBS, resource-load them, and provide logic ties to WBS 85.						
4	2.1	15	Adjust the schedule to eliminate the one day of float and place Activity 920.005, Integrated System Testing, on the critical path.						

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
5	2.2	18	Tie the cost-estimating backup to the resource-loaded schedule using standardized cost estimating input forms and an expanded WBS dictionary.						
6	2.2	19	Create a Basis of Estimate or Estimate Assumptions document that clearly presents the key estimating criteria and assumptions for the project.						
7	2.2	21	Re-evaluate the contingency for Project Management.						
8	2.2	21	Re-work the various project documentation so that PM costs are consistent throughout.						
9	2.2	22	Revise project cost documentation to clearly show escalation dollars.						
10	2.2	23	Review the current contingency methodology and approach, and determine whether it is the best method to use for determination of contingency dollars.						
11	2.2	27	Correct the unreasonable floats included in the schedule.						

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
12	2.2	27	Develop a set of Schedule Assumptions and place them under document control.						
13	2.2	27	Develop a milestone dictionary for key project milestones that clearly defines successful milestone completion.						
14	2.2	28	Include additional milestones at Level II, as appropriate, for WBS elements that do not have well spaced milestones						
15	2.2	28	Develop and use a consistent definition for the schedule baseline in the PEP.						
16	2.3	29	Check the consistency of the WBS, WBS dictionary, cost estimate, and schedule.						
17	2.3	30	Consider expanding the WBS dictionary to provide greater detail and usefulness to the NCSX Project, and greater continuity and traceability between the WBS Manager's estimate and resource-loaded schedule.						

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
18	2.3	30	Add an activity "Develop integrated Startup Test Plan" to the WBS dictionary for WBS element 85, "Pre-operational and Integrated Systems Testing."						
19	2.4	31	Consider expanding the Risk Management Plan, as appropriate, to include actions required from identified individuals to enact mitigation strategies.						
20	2.4	31	Ensure that the Risk Management Plan is managed as an official, controlled project document, with appropriate endorsements included.						
21	2.4	31	Conserve schedule contingency in order to allow as much as possible to be available during the "Field Period Assembly" to "First Plasma" portion of the project.						
22	2.5	33	Adjust the Performance Baseline, as appropriate, once all Preliminary Design Review recommendations have been addressed and the cost and schedule impacts have been assessed.						

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
23	2.5	34	Consider developing and implementing a plan to simulate the welding of the spool pieces.						
24	2.6	35	Evaluate the potential benefits of modifying the design and fabrication of the winding forms so that two of the three coils are on a single form.						
25	2.7	36	As design progresses, assess the potential of a significant release of nitrogen during operation of the stellarator and evaluate the need to add monitors or alarms, for example, for low oxygen conditions.						
26	2.7	37	As the project continues, analyze potential hazards in detail on the basis of final design and incorporate them into the NCSX PHA and SAD.						
27	2.8	39	Ensure that the Value Engineering Task Force document is managed as an official, controlled project document, with appropriate endorsements included.						

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
28	2.8	39	Add wording to the "NSCX Value Engineering Task-force" document indicating that "shared savings" clauses (the "voluntary" component of value management) will be considered in all procurements awarded after CD-2, when appropriate.						
29	2.9	41	Institute a system for document control of the cost estimates and schedules that includes a formal issuance system for revisions/updates.						
30	2.9	41	Consider adding project controls support staff to bolster the project EVMS capabilities in the event project performance data begins to degrade in accuracy and timeliness.						
31	2.9	41	Evaluate the *PPPL Project Control System Description, Revision 0, July 1996* to ensure that it remains viable and consistent with current practice at the laboratory.						

ID No.	Section Ref	Page Ref	Recommendation	Required Action (Discussion)	Action Office	Start/Compliance	Current Status	Site Use	Review Team Perspective
32	2.10	43	Ensure that the PEP is given a general "house-keeping" revision prior to submittal.						
33	2.10	43	Provide a reference to the document identifiers for the complete WBS and WBS dictionary.						
34	2.11	44	Consider establishing a single and separate document that includes all items required for startup. Details in the document should feed from the various WBS sections and include cost of labor, materials, etc.						
35	2.12	45	Include wording in the Acquisition Execution Plan to the effect that cost savings incentive clauses in contracts awarded post CD-2 will be considered and incorporated where practical.						
36	2.12	45	Consider combining coil procurements to attempt to obtain more favorable bids.						
37	2.12	45	Ensure that all outdated references in the Acquisition Execution Plan are noted and corrections made ready to include in the next general revision.						