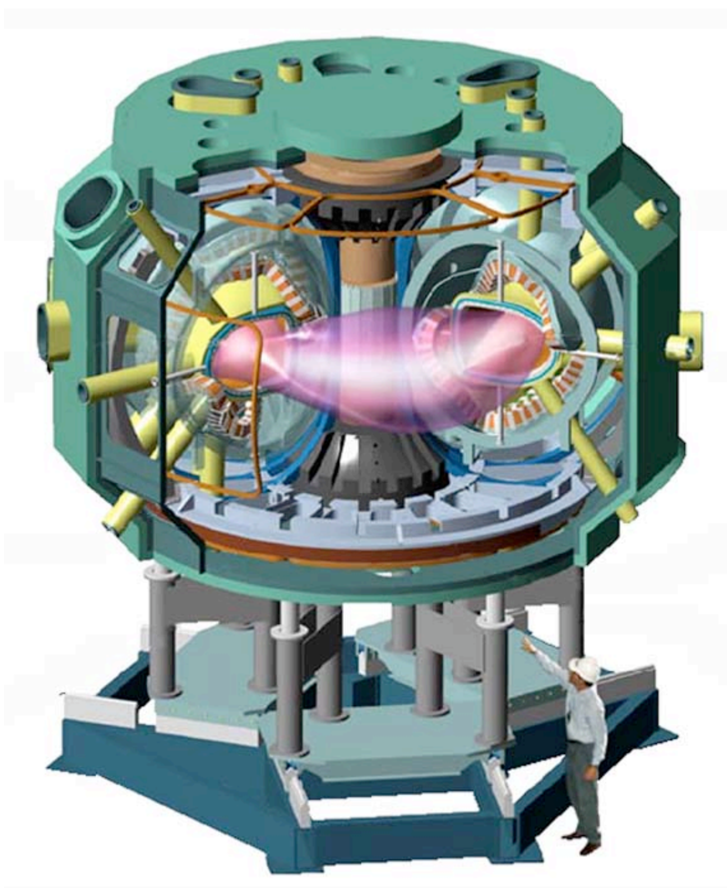
National Compact Stellarator Experiment (NCSX)
PROJECT EXECUTION PLAN (NCSX-PLAN-PEP-01)

Revision 1
February 2004



NCSX Project Execution Plan

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Revision	Date	Description of Changes
0	July, 2002	Initial Issue.
1	February, 2004	Issued for CD-2, Performance Baseline Approval

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1 INTRODUCTION AND SCOPE OF THIS DOCUMENT

The National Compact Stellarator Experiment (NCSX) is an experimental research facility that is to be designed and constructed at the Department of Energy's Princeton Plasma Physics Laboratory (PPPL). Its purpose is to develop the physics of compact stellarators, an innovative fusion confinement concept. The facility will include the stellarator device and ancillary support systems. The design and fabrication project will be led by PPPL, in partnership with the Oak Ridge National Laboratory (ORNL).

This Project Execution Plan (PEP) covers the NCSX Fabrication Project, from design and fabrication through integrated system testing and producing the first plasma. The Department of Energy has identified the NCSX Project as a Major Item of Equipment (MIE) Project vs. as a Line Item construction project. The differentiating factor between capital equipment and line item construction designation is that the equipment can be installed with little or no significant construction activities required. The device will be sited within existing experimental facilities at PPPL. No major building additions are required to accommodate the device; while there may be some minor interior changes in configuration, these changes will not affect the structural integrity of the existing facility. In addition, the existing facility is currently served by most of the utilities necessary to support the NCSX device, with only minor additional ancillary equipment needed. As a result, the overall cost objective that encompasses all project work scope is measured in terms of the Total Estimated Cost (TEC).

Although a MIE Project, the same overall management concepts applicable to line item projects will be applied to the degree appropriate for a project the size and cost of the NCSX. DOE Order 413.3 will provide the basis for the overall management of the Project.

Key documents and plans that describe the NCSX Project and how it will be managed are listed below.

<u>DOE-approved project documents</u>

- Acquisition Execution Plan (AEP)–□Approved November, 2002
  DOE document that delineates the process by which DOE and the performing organizations (PPPL and ORNL) will acquire components and systems critical to completing and achieving the NCSX Project goals and mission. For the NCSX Project, the Acquisition Executive Officer will be the Associate Director for Fusion Energy Sciences, Office of Science.

- Project Execution Plan (PEP)– Approved January, 2004
  Primary agreement on project planning and objectives between OFES, the Federal Project Director, and PPPL

<u>DOE certified institutional systems or plans</u>

- PPPL Project Control System Description (PCSD)– Approved 1996, Validated for NCSX, February, 2003.
  Describes PPPL's system for planning, authorizing, and tracking project work.

- PPPL Integrated Safety Management Plan (ISMP)– Latest revision approved Sept., 2002.

Describes the structure and implementation of Integrated Safety Management at PPPL, consistent with DOE policy, requirements, and guidance.

NCSX Project approved documents

- General Requirements Document (GRD)
  Top-level (i.e., system-level) specification for the NCSX project.
- Systems Engineering Management Plan (SEMP)
  Describes systems engineering processes and management practices to be utilized by the NCSX Project.
- Data Management Plan (DMP)
  Describes the processes to be utilized for document and drawing control.
- Document and Records Plan (DOC)
  Describes the purpose, content, format, approval level, records retention requirements, and file/document naming convention for each controlled document for the NCSX Project.
- Configuration Management Plan (CMP)
  Describes the processes for proposing, approving, and implementing changes to the configuration, cost, and schedule baselines and controlled documents.
- Interface Control Management Plan (ICMP)
  Describes the processes for generating and administering technical interface agreements between two or more technical activities.
- Test and Evaluation Plan (TEP)
  Describes the processes to transition from the design and fabrication activities to an operational experiment.
- Reliability, Availability, and Maintainability Plan (RAMP)
  Describes the processes for factoring reliability, availability, and maintainability considerations into the design. The General Requirements Document (GRD) provides the overall top level RAM requirements for the Project.
- NCSX Quality Assurance Plan (QAP)
  Integrates the PPPL and ORNL FED Quality Assurance Plans and implementing documents with project specific plans and procedures to assure that an appropriate quality assurance program exists for NCSX, consistent with DOE and PPPL policy, requirements, and guidance.

2 MISSION NEED JUSTIFICATION/PROJECT OBJECTIVES

2.1 Mission Need

The NCSX mission need (Critical Decision 0) was approved by the Office of Fusion Energy Sciences in May 2001. Its mission is to acquire the physics knowledge needed to evaluate the compact stellarator as a fusion concept, and to advance the understanding of 3D plasma physics for fusion and basic science. As indicated in the Mission Need document, NCSX is an integral part of the Department's Office of Fusion Energy Sciences program. The mission of the NCSX supports two of the program's goals (Report of the Integrated Program Planning Activity, December, 2000), namely:

- Goal 2: Resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations.
- Goal 1: Advance understanding of plasma, the fourth state of matter, and enhance predictive capabilities through comparison of well-diagnosed experiments, theory, and simulation.

2.1.1 NCSX Mission in Support of Program Goal 2

The compact stellarator (CS) is one of the innovative magnetic confinement configurations being investigated by the Fusion Energy Sciences Program. Within Goal 2, there is a ten-year objective for the CS, namely "Determine the attractiveness of a compact stellarator by assessing resistance to disruption at high beta without instability feedback control or significant current drive, assessing confinement at high temperature, and investigating 3-D divertor operation." The potential of the compact stellarator as an attractive concept lies in its possibility to eliminate disruptions and operate steady-state with minimal recirculating power. In order to assess it quantitatively, however, the physics of compact stellarators must be further developed. A stellarator proof-of-principle (PoP) program consisting of theory, experiment, international collaboration, and design has been established for this purpose. The NCSX, as the PoP program's lead element, has the primary responsibility to test the physics understanding and develop the physics knowledge base needed to determine the concept's attractiveness. Accordingly, the NCSX mission in support of Goal 2 is to:

- Demonstrate conditions for high-beta disruption-free operation, compatible with bootstrap current and external transform in a compact stellarator configuration.
- Understand beta limits and limiting mechanisms in a low-aspect-ratio current-carrying stellarator.
- Understand reduction of neoclassical transport by quasi-axisymmetric (QA) design.
- Understand confinement scaling and reduction of anomalous transport by flow-shear control.
- Understand equilibrium islands and stabilization of neoclassical tearing-modes by choice of magnetic shear.
- Understand compatibility between power and particle exhaust methods and good core performance in a compact stellarator.

2.1.2 NCSX Mission in Support of Program Goal 1

Within Goal 1, the Fusion Energy Science program aims to advance understanding and predictive capability in fusion plasma physics, including turbulence and transport, macroscopic stability, wave-particle interactions, plasma-wall interactions, and general plasma science. The NCSX mission in support of Goal□ is to understand three-dimensional plasma effects important to toroidal magnetic configurations generally. Critical questions to be answered using the NCSX facility include:

- Can pulse-length-limiting instabilities, such as external kinks and neoclassical tearing modes, be stabilized by external transform and 3D shaping?
- How do externally-generated transform and 3D shaping affect disruptions and their occurrence?
- Can the collisionless orbit losses typically associated with 3D fields be reduced by designing the magnetic field to be quasi-axisymmetric? Is flow damping reduced?
- Do anomalous transport control and reduction mechanisms that work in tokamaks transfer to quasi-axisymmetric stellarators? How does the transport scale in a compact stellarator?
- How do stellarator field characteristics such as islands and stochasticity affect the boundary plasma and plasma-material interactions? Are 3D methods for controlling particle and power exhaust compatible with good core confinement?

A program of experimental research will be carried out to accomplish this mission. The critical physics issues to be addressed– stability at high beta, confinement at high temperature, and divertor operation– set minimum plasma performance requirements. These considerations define the scale and scope of facility that is needed. They set the requirements on plasma size, magnetic field strength, plasma control, plasma heating, diagnostic access, and flexibility that the facility must satisfy. In the fusion program's concept development hierarchy, NCSX is in a class of facilities called proof-of-principle (PoP) experiments. The National Spherical Torus Experiment (NSTX) at PPPL, which is of a scale similar to NCSX, is another example. The NCSX design and fabrication project addressed by this plan will provide an operational facility that meets the physics requirements necessary to support the NCSX physics mission. The mission itself will be carried out in the Operations phase.

2.2 Project Objectives

The key technical objective of the NCSX project is the fabrication and assembly of the NCSX experimental facility. The facility will be capable of producing magnetized plasmas with a well-defined set of configuration properties, such as size, shape, magnetic field strength, and pressure, which in turn determine its physics properties. The NCSX will provide the flexibility to vary the configuration parameters over a range.

The plasmas to be studied are three-dimensional toroids, that is, doughnut-shaped plasmas whose cross sectional shape varies depending on where it is sliced. The magnetic field coils, which control the plasma shape, must be accurately constructed to precise shape specifications. The NCSX will provide the initial set of equipment necessary to achieve the CD-4 First Plasma milestone defined herein and to begin the research program. It will be able to accommodate later upgrades, to meet the needs of the research program.

2.2.1 <u>Performance Baseline Parameters</u>

The NCSX project's Performance Baseline is defined by key performance, scope, cost, and schedule parameters:

- Performance - The system performance levels to be demonstrated at project completion (First Plasma). These include quantitative metrics such as plasma parameters, coil and power supply currents, as well as certain subsystem functional tests.
- Scope - A quantitative description of the equipment to be provided.
- Cost - The total estimated cost of the project.
- Schedule - The estimated project completion date.

The project's cost and schedule baseline are supported by bottoms-up estimates of costs, task durations, and risk-based contingencies, whose technical basis is consistent with the performance and scope parameters. The implementation of any future changes in the baseline will be made in accordance with the change control procedures and approval thresholds specified in this Project Execution Plan.

2.2.2 Fabrication Project Performance at Project Completion

The NCSX facility will initially support First Plasma operation with a magnetic field strength of 0.5T and a plasma current of 25 kA, and field-line mapping operation with a magnetic field strength of 0.1 T and no plasma. Refurbishment and testing of equipment for 1.5 MW of Neutral Beam Injection (NBI) heating will be done as part of the NCSX MIE project.

The equipment will be designed to meet performance requirements and to accommodate a range of possible future upgrades for later phases of the research program, as documented in the General Requirements Document. The implementation plan will evolve as the needs of the research program as a function of time are defined in more detail.

The milestone marking the transition from a fabrication project to an operating facility is the DOE Critical Decision 4 (CD-4) milestone also known as "First Plasma". The operations phase will begin upon completion of the First Plasma milestone. The First Plasma milestone will demonstrate a level of system performance sufficient for the start of research operations. The performance criteria at Project Completion are tabulated at the end of this sub-section in Table 2-1. It is important to note that the system design targets a level of performance that exceeds these criteria (e.g., 2 T *vs.* 1.6 T magnetic field, 5×10^{-8} torr *vs.* 8×10^{-8} torr base pressure). This provides valuable additional physics capability if the target performance can be achieved as well as additional margin to ensure that the project completion criteria (Table 2-1) will be achieved.

As required by DOE, a Project Completion Report will be prepared and submitted to DOE/PAO within six months of completion of the Project. This report will provide the following information:

- The actual schedule on which the project will have been completed;
- The actual cost of the project;
- The technical performance of the systems at project completion; and
- Itemized changes in cost, schedule, and technical parameters as compared to the initial baseline.

Table 2-1 NCSX Performance Criteria at Project Completion

Parameter	Completion Objective at CD-4
First Plasma	An Ohmically heated stellarator discharge will be produced with: • major radius 1.4 m. • magnetic field of ≥ 0.5 T • plasma current of ≥25kA • at least 50% of the rotational transform provided by stellarator fields. The three-dimensional stellarator geometry will be confirmed by taking video images of the plasma.
Coils and Power Supply Performance.	The coils will be operated at cryogenic temperature and energized with the baseline power supplies (except as noted) to the following currents: • Modular coils: 12 kA • TF Coils: 2 kA • PF1 & PF2 Coils: 12 kA • PF3-4 Coils: 3 kA • PF5-6 Coils: 2 kA • External Trim Coils: 1 kA. (w/ temp. power supplies).
Magnet System Rating	It will be demonstrated on the basis of component design verification data that the stellarator magnet system of modular coils, TF coils, and PF coils is rated for operation at cryogenic temperatures to support plasma conditions with: • high beta (4%) • magnetic field up to 1.6 T (0.2 s) or 1.2 T (1 s) • Ohmic current drive up to 250 kA • flexibility per the General Requirements Document
Magnet System Accuracy	It will be demonstrated on the basis of design verification data, including electron-beam flux-surface mapping with the coils at room temperature, that the stellarator magnet system of modular coils, TF coils, and PF coils produces vacuum magnetic surfaces.
Vacuum Vessel System Rating	It will be demonstrated on the basis of component design verification data that the vacuum vessel system is rated for high-vacuum performance with: • base pressure less than or equal to 8×10^{-8} torr @293K • global leak rate less than or equal to 5×10^{-5} torr-l/s @293K • bakeable at 150°C.
Vacuum Pressure	A base pressure of $4\text{x}10^{-7}$ torr will be achieved.
Vacuum Pumping	A pumping speed of 1,300 l/s at the torus will be achieved.

Parameter	Completion Objective at CD-4
Controls	Integrated subsystem tests, to the level required for First Plasma, will be completed for the following systems: • Safety interlocks. • Timing and synchronization. • Power supply real time control. • Data acquisition.
Neutral beams	For one neutral beam injector: • Beamline operating vacuum shall have been achieved. • Beamline cryopanels shall be leak-checked. • A source shall be leak-checked

2.2.3 Fabrication Project Scope

The NCSX fabrication project scope includes all the equipment required at the start of operations (First Plasma and initial field mapping) with coil operation at cryogenic temperatures, and refurbishment and testing 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 project management associated with producing the in-scope equipment. It includes achievement of First Plasma. See Annex I for detailed scope by WBS.

The NCSX will be designed so that anticipated equipment upgrades can be accommodated when needed. Specifically, the system is designed to accommodate the following upgrades: a total of 6 MW of neutral beam injection (NBI) heating power, 6 MW of ion cyclotron radiofrequency (ICRF) heating power, 3 MW of electron cyclotron heating (ECH) power, a pellet injector, trim coils, power supplies for increased flexibility, additional plasma facing components and internal pumps for divertor operation, alternate first-wall materials, additional wall conditioning systems, and additional diagnostics) can be accommodated when needed. (See Annex II). The NCSX Project scope does not include the actual implementation of these upgrades, which will be funded out of 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 MIE Fabrication Project scope.

2.2.4 Fabrication Project Cost

As indicated in Section 1.0 of this PEP, the NCSX Project has been designated as a Major Item of Equipment (MIE) by the Department of Energy and will be built using Capital Equipment Funds. At CD-1 approval, a baseline total estimated cost (TEC) range of $69M - $83M for the MIE fabrication project was established. As part of the CD-2 approval process, a baseline TEC objective was established as $86.3M.

2.2.5 Fabrication Project Schedule

The project's schedule objective is to complete the project with the Achievement of First Plasma by May, 2008. The DOE level schedule milestone (Level 1 and 2) definitions and their criteria for completion are included in the NCSX Project Milestone Dictionary. These DOE level milestones are summarized in Table 2-2:

Table 2-2 NCSX DOE Milestones

Milestone	Schedule	DOE Acquisition Executive (Level 1)	DOE Federal Project Director (Level 2)
Complete Physics Validation Review	**March 2001A**		X
Complete CD-0 Milestone	**May 2001A**	X	
Select Conceptual Design Configuration	**December 2001A**		X
Submit NEPA Preliminary Hazards Analyses	**April 2002A**		X
Complete Conceptual Design Review	**May 2002A**		X
Receive FONSI	**October 2002 A**		X
Complete CD-1 Milestone	**November 2002A**	X	
Award Prototype Contracts for Modular Coils Winding (MCC) Forms	**March 2003 A**		X
Award Prototype Contracts for Vacuum Vessel	**April 2003 A**		X
Start Preliminary Design (Title I)	**April 2003 A**		X
Complete Project Preliminary Design Review	**October 2003 A**		X
Complete External Independent Review and DOE Performance Baseline Review	**November 2003 A**		X
Authorize Prototype Fabrication of MCC and Vacuum Vessel	**December 2003 A**		X
Complete CD-2 Milestones	**February 2004 A**	X	
Initiate Modular Coils Winding Process on a 3D Surface	March 2004		X
Produce First Prototype Modular Coil Winding Form Casting for Machining	June 2004		X
Complete Final Design Review for Modular Coils Winding Forms	July 2004		X
Complete Final Design Review for the Vacuum Vessel	July 2004		X
Complete Prerequisites for the CD-3 Milestone for Procurement and Fabrication of Components	September 2004		X

Milestone	Schedule	DOE Acquisition Executive (Level 1)	DOE Federal Project Director (Level 2)
Award Conductor Contract	September 2004		X
Complete CD-3 Milestone	October 2004	X	
Award Production Contract for Modular Coils Winding Forms	November 2004		X
Award Production Contract for Vacuum Vessel	December 2004		X
First Modular Coil Winding Forms Delivered	March 2005		X
Award Production Contract for TF Coils	April 2005		X
Complete First Modular Coil Fabrication	August 2005		X
Vacuum Vessel Delivered	February 2006		X
Award Production Contract for PF Coils	June 2006		X
Last Modular Coil Winding Form Delivered	August 2006		
Begin Assembly of First Field Period	September 2006		X
Complete Delivery of TF Coils	January 2007		X
Last Field Period Assembled	June 2007		X
Pump Down of Vacuum Vessel	September 2007		X
Complete Operational Readiness Assessment	November 2007		X
Begin Start-Up Testing	November 2007		
Begin Cryostat Installation	March 2008		
Complete CD-4 Milestone (First Plasma and Completion of MIE Project)	May 2008	X	

Note: **"A" => Achieved**

3 PROJECT DESCRIPTION

The NCSX project involves the design and fabrication of the NCSX facility. At the heart of the facility is the plasma confinement device, or stellarator core. This 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 and plasma facing components produce 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. Figure 3-1 shows a cutaway view of the stellarator core assembly.

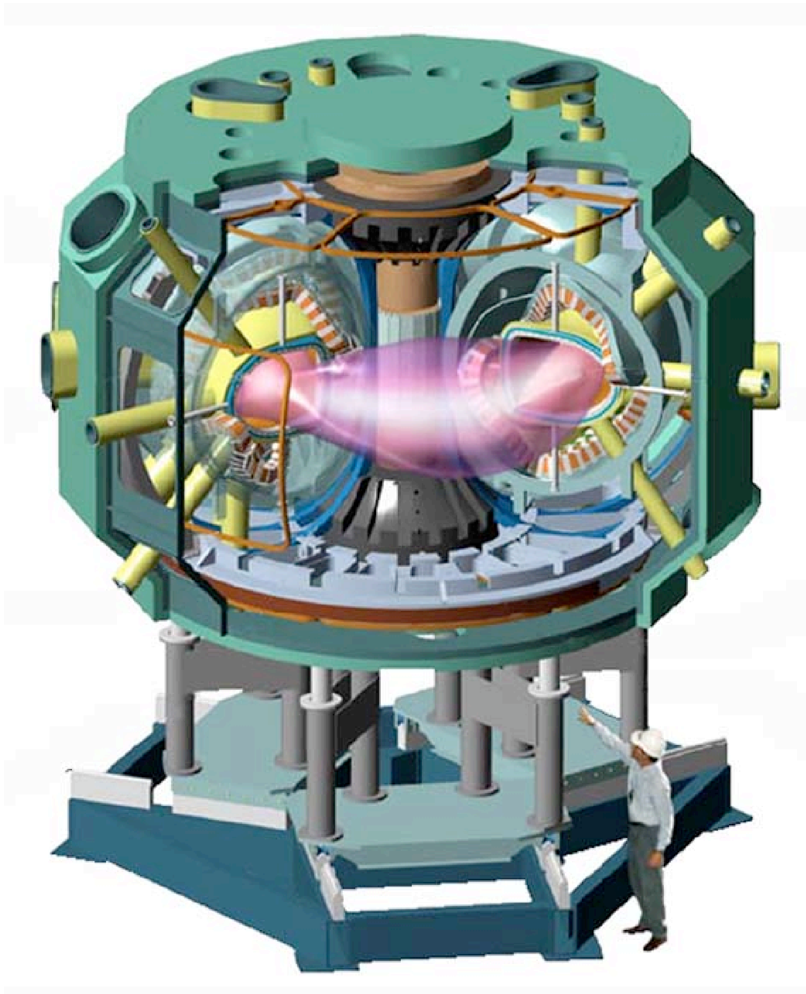

Figure 3-1 NCSX Stellarator Core

The NCSX core will be assembled in the combined Princeton Beta Experiment/Princeton Large Torus (PBX/PLT) test cell at the Princeton Plasma Physics Laboratory (PPPL). It will be equipped with neutral-beam heating systems, pumps, fueling systems, diagnostics, control systems, and data acquisition systems. Site infrastructure such as cryogenic systems and utility services will be provided. The PBX/PLT computer and control rooms, which are contiguous to the test cell, will be refurbished and utilized. Power supplies located at D-site will be used.

The design of the stellarator core and facility re-configuration will be accomplished by Laboratory (PPPL and ORNL) researchers and engineers. Development and manufacture of the major stellarator core components such as the coils and vacuum vessel will be done in industry, under contract to PPPL, or by a combination of industry and Laboratory efforts. Laboratory personnel will assemble the device. Ancillary systems will be assembled from a combination of new and existing equipment. Major site credits to be used are the PBX-M neutral beams, D-site magnet power supplies originally used on the Tokamak Fusion Test

Reactor (TFTR), some C-site power supplies, the PBX-M vacuum pumping and gas injection systems, the test cell and associated infrastructure, and the adjacent control and computer rooms. As part of the project, the facilities and equipment to be re-used will be reconfigured or refurbished as needed to meet NCSX requirements. In the final stage of the project, an integrated testing program will be carried out and a plasma ("first plasma") will be produced in the device to make it ready for experimental operations.

4 MANAGEMENT STRUCTURE AND RESPONSIBILITIES

4.1 NCSX Project Organization

The NCSX project will be led by the Princeton Plasma Physics Laboratory (PPPL) with the Oak Ridge National Laboratory (ORNL) providing major leadership and support as a partner. The partners have formed an integrated team to carry out the NCSX project, where engineers and scientists from PPPL and ORNL work together to bring the necessary expertise to the project. This means that PPPL engineers and scientists will support areas in which ORNL has the lead and similarly, ORNL engineers and scientists will support areas in which PPPL has the lead. Management responsibilities are clearly assigned to one partner or the other, and PPPL has overall responsibility for the project.

Figure 4-1 depicts the NCSX project organization structure and the key management responsibilities of the partner institutions.

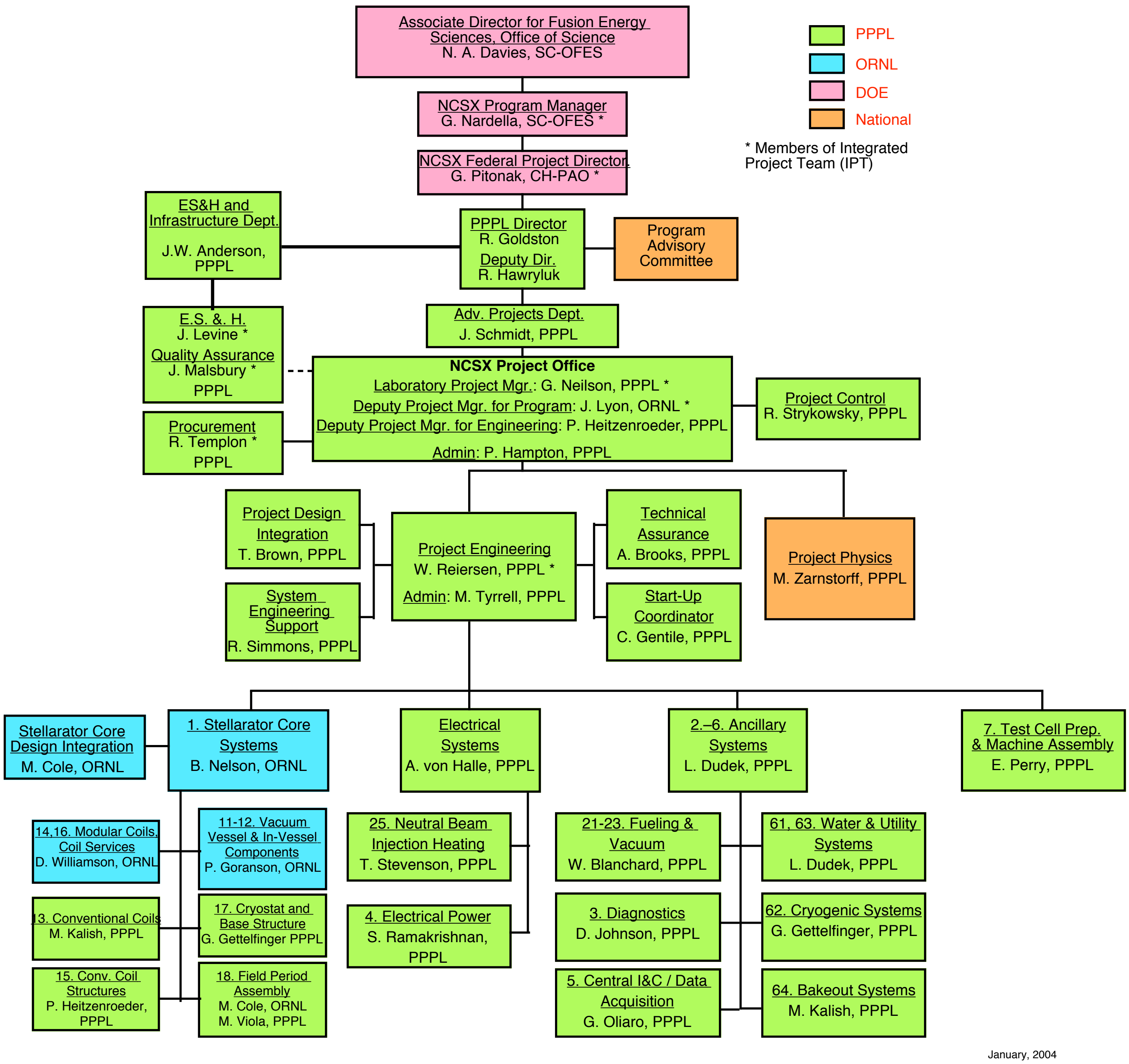

Figure 4-1 NCSX Project Organization Structure

The following subsections describe the relationships between the elements of the organization and their responsibilities.

4.1.1 U.S. Department of Energy (DOE)

Within the DOE, the responsibility for the NCSX Program resides in the Office of Fusion Energy Sciences (OFES). OFES will also maintain executive level awareness of project progress, and an OFES NCSX Program Manager has been assigned. The management responsibility, authority, and accountability for the day-to-day execution of the NCSX

Project within the DOE are the responsibility of the Manager of the Chicago Operations Office (CH). CH has delegated major authorities and responsibilities for the NCSX Project to the Manager of the Princeton Area Office (PAO), who has designated a NCSX Federal Project Director.

The Associate Director for Fusion Energy Sciences has been designated as the Acquisition Executive (AE) for the NCSX Project. However, approval of the AEP was not delegated, and this plan was approved by the Under Secretary of Energy, Science and Environment.

The OFES NCSX Program Manager (DOE-OFES) is:

- Responsible for programmatic guidance, including defining project objectives, scope, schedule and cost.
- Responsible for allocating project funding.
- Responsible for coordinating the organization and implementation of major project reviews (e.g. Physics Validation Review, Conceptual Design Review, etc.)
- Responsible for project oversight at an executive level.

The NCSX Federal Project Director (DOE-PAO) is equivalent to an investor, strategist, developer, and contract manager in the private sector. He is:

- Responsible and accountable for planning and implementing, and completing the project using a systems approach.
- Organizing and directing the Integrated Project Team (IPT) that is comprised of both DOE and NCSX Project team personnel to implement and achieve the overall project objectives and goals.
- Responsible for overseeing implementation of the project objectives, scope, schedule and cost, including:
    - Overseeing the design, fabrication, environmental, safety, and health efforts, including risk management, performed by the PPPL and ORNL team and their subcontractors, and other functions enumerated in the Project Execution Plan, in accordance with public law, regulations, and Executive orders.
    - Serving as the point of contact between federal and contractor staff for all matters relating to the NCSX Project and its execution.
    - Performing all required project status reporting to both DOE CH and DOE HQ organizations
    - Serving as the Contracting Officer's technical representative.
- Responsible to add additional DOE-PAO personnel as appropriate to ensure the project's success.

4.1.2 DOE Contractor Organizations

4.1.2.1 Princeton Plasma Physics Laboratory (PPPL)

PPPL has overall responsibility for NCSX project execution, reporting to DOE through the Laboratory Director. The NCSX Project is assigned to PPPL's Advanced Projects Department. Project support in the areas of Quality Assurance and Environment, Safety and Health (ES&H) are provided by PPPL. Major hardware procurements will be placed through PPPL's procurement organization.

4.1.2.2 Oak Ridge National Laboratory (ORNL)

ORNL is a partner in the NCSX project with key management responsibilities. ORNL has management responsibility for the stellarator core (WBS 1). At least one Deputy Project

Manager will be from ORNL. Within the ORNL organizational structure, the NCSX Project activities are accomplished within the Fusion Energy Division.

4.1.2.3 Other Organizations

All other participants (i.e., industrial or university organizations) are subcontractors to either PPPL or ORNL.

4.2 NCSX Management Team

Key project positions and responsibilities are as follows:

4.2.1 Senior Laboratory Managers

4.2.1.1 PPPL Director

The PPPL Director has overall responsibility to DOE for the execution of the NCSX Project. He is supported by the Deputy Director.

4.2.1.2 PPPL Advanced Projects Department Head

The responsibility for NCSX is assigned to the PPPL Advanced Projects Department. The PPPL Advanced Projects Department Head reports to the PPPL Director.

4.2.2 NCSX Project Management Team

4.2.2.1 NCSX Laboratory Project Manager

The NCSX Project Manager is responsible for the day-to-day execution of the NCSX project in a cost-effective manner, in accordance with requirements, procedures and standards, as set forth in the PPPL contract with DOE. This includes executing the technical, cost, schedule, project control, risk management, ES&H, and quality assurance aspects of the project within approved cost, schedule, and scope baselines, as defined in the Project Execution Plan and the contract. He is the project's primary point of contact with DOE and with the Program Advisory Committee. He reports to the PPPL Advanced Projects Department Head.

4.2.2.2 Deputy Project Manager for Program

The NCSX Deputy Project Manager for Program supports the Project Manager especially on programmatic issues. The current incumbent in this part-time position is from ORNL. He reports to the Project Manager.

4.2.2.3 Deputy Project Manager for Engineering

The NCSX Deputy Project Manager for Engineering supports the Project Manager, especially on manufacturing and overall engineering issues. He is the project's senior management representative to the PPPL engineering organization. The incumbent in this part-time position reports to the Project Manager.

4.2.2.4 NCSX Project Physics Head

The NCSX Project Physics Head is responsible for the physics requirements and supporting physics analyses as necessary. He reports to the Project Manager. The incumbent in this part-time position reports to the Project Manager.

4.2.2.5 NCSX Project Engineering Manager

The NCSX Project Engineering Manager is responsible for carrying out the NCSX engineering design and fabrication to meet project requirements. He reports to the Project Manager.

4.2.2.6 WBS Managers

The project engineering work organization is structured according to the work breakdown structure (WBS). A WBS Manager will be assigned at the optimal WBS level according to a risk based graded approach. In some instances, this "optimal" level may be a WBS Level 2 and sometimes at a lower level. Each WBS Manager is responsible for the execution of the work scope. The WBS managers report to the Project Engineering Manager. Because of the importance (cost and criticality) and complexity of the Stellarator Core (WBS 1), subsystem WBS Managers (e.g., WBS 11, WBS 12, …) have been assigned.

4.2.2.7 NCSX Project Control Manager

The Project Control Manager reports to the NCSX Project Manager and is responsible for all project control and administrative functions necessary to support NCSX Project activities.

The NCSX Project Control Manager's support responsibilities include:

- Coordinating the development of project plans and administering the centralized Work Authorization system;
- Maintaining up-to-date NCSX cost and schedule baselines that are consistent with the technical baseline;
- Coordinating the preparation of statements of work, sole source justifications (as appropriate), the processing of requisitions, and tracking of procurements and subcontracts supporting the project;
- Establishing, maintaining, and monitoring project budgets and schedules to ensure consistency with project control milestones and funding;
- Operating the PPPL Project Control System (PCS) as the Project Control System for the NCSX Project.
- Assisting the Project Engineering Manager in administering the operation of the NCSX documentation, configuration management, requirements definition, and design description systems;
- Serving as the primary point-of-contact to the PPPL Business Operations Department; and
- Performing administrative functions such as space planning, facility maintenance coordination, travel approvals and vouchers, and overall personnel planning.

4.2.2.8 Quality Assurance (QA) and Environment, Safety & Health (ES&H)

A NCSX QA Engineer and a NCSX ES&H Engineer are assigned to support the NCSX Project Manager. A brief description of their responsibilities follows:

QA Engineer support responsibilities - The NCSX QA Engineer, with the support of the entire QA Division, will assist the project in meeting quality assurance/control objectives. Support tasks include:

- Preparing a project QA plan;
- Assisting in the development of project procedures, policies, and other plans, as requested by project management;
- Providing quality related services such as inspections and support of procurements; and
- Performing both compliance-based and performance-based audits of the project and its associated plans and procedures

ES&H Engineer support responsibilities - The NCSX ES&H Engineer will assist the project in meeting ES&H objectives. These include safe execution of the project and producing a facility that will be safe to operate. He will assist in implementing PPPL ES&H policies and procedures. The NCSX ES&H Engineer will prepare any required National Environmental Policy Act (NEPA) documentation and a Safety Assessment Document (SAD).

While their normal reporting relationship is to the NCSX Project Manager, both individuals have a direct line of reporting to the PPPL Head of ES&H and Infrastructure for items involving overall QA and ES&H impact.

4.3 Program Advisory Committee

Advice by the U.S. and world fusion community on the NCSX Project scientific and technical issues is being obtained through the NCSX Program Advisory Committee (PAC). The NCSX PAC is composed of a broad spectrum of technical experts of the U.S. and world fusion community. The PAC provides this advice to the PPPL Director. It addresses key technical issues identified by the NCSX Project. It meets periodically at the request of the PPPL Director.

4.4 Integrated Project Team

The NCSX Integrated Project Team (IPT) is made up of key DOE and NCSX Project Team personnel. As indicated in Section 4.1.1, the IPT is led by the NCSX Federal Project Director. While the makeup of the IPT will evolve as the project matures, the initial makeup of this cross-functional team includes the following personnel:

- The NCSX Federal Project Director;
- The OFES NCSX Program Manager;
- The NCSX Laboratory Project Manager;
- The NCSX Deputy Project Manager for Program;
- The PPPL Procurement Manager;
- The NCSX Quality Assurance Manager;
- The NCSX ES&H Engineer; and
- The NCSX Project Control Manager
- The NCSX Engineering Manager

Other DOE and NCSX Project Team and PPPL personnel may be added as the need arises in order to accomplish the NCSX Project objectives. For example, as the NCSX Project nears operation, personnel with operational experience will be added to the team.

Additionally, as the need arises, DOE or PPPL personnel with expertise, fiscal, technical, and legal areas may be included in the IPT.

5 WORK BREAKDOWN STRUCTURE (WBS)

The WBS organizes the NCSX project work scope and provides the logical structure that will be used to control the project. The WBS is composed of a few levels as required for work definition and control. By convention, the first digit in the WBS is designated "level 2," the second digit "level 3," etc. The WBS matrix is provided in Table 5-1 below, with the Stellarator Core (WBS 1) expanded due to its importance. While WBS 1 has been expanded to the second digit, all the WBS elements are expanded and more completely defined in a series of separately issued and approved set of WBS dictionaries. The WBS Dictionary for each WBS element contains a brief description of the work scope for each element And also the design work necessary to assure that required future upgrades can be accommodated. The expanded WBS listing and set of WBS dictionaries can be found on the NCSX Engineering Web page:
http://www.ncsx.pppl.gov/SystemsEngineering/WBS/index_WBS.htm.

Table 5-1 NCSX Project Work Breakdown Structure

WBS		Description
1		**Stellarator Core Systems**
	11	In-Vessel Components
	12	Vacuum Vessel Systems
	13	Conventional Coils
	14	Modular Coils
	15	Coil Support Structures
	16	Coil Services
	17	Cryostat and Base Support Structure
	18	Field Period Assembly
	19	Stellarator Core Management and Integration
2		**Auxiliary Systems**
3		**Diagnostic Systems**
4		**Electrical Power Systems**
5		**Central I&C and Data Acquisition Systems**
6		**Facility Systems**
7		**Test Cell Preparation and Machine Assembly**
8		**Project Management and Integration**

6 RESOURCE PLAN

6.1 NCSX Project Costs

As indicated in Section 1.0 of this PEP, the NCSX Project has been designated by the Department of Energy as a Major Item of Equipment (MIE) and will be funded entirely with Capital Equipment Funds. As a result of this decision, the overall cost objective that encompasses all project work scope as defined in Section 2.2.4 is measured in terms of the

Total Estimated Cost (TEC). These TEC cost activities will be used to measure the performance of the NCSX Project against its technical, cost, and schedule baselines. Section 2.2 previously identified the cost objective for this project

6.2 Funding Profiles

Table 6-1 provides the NCSX Budget Authority (BA) funding profiles according to current project planning. Both the NCSX Fabrication (MIE) Project (TEC) and the Research Preparation funding profiles are provided for completeness.

During the NCSX fabrication period (FY2003-FY2008), a parallel research preparation activity, funded separately from the MIE project, will be carried out. The goals are to prepare the analytical and hardware tools that will be needed beyond project completion (CD-4 as measured by first plasma) and the flux-surface mapping phases of the research program, and to maintain an active physics component of the NCSX program during machine fabrication. These research planning and preparations activities are not included in the NCSX Project scope. They will be funded with OPEX funds separate from the TEC. Of necessity, this work will proceed in parallel with the design and fabrication of the NCSX device in order to be fully prepared to conduct the research program. This approach closely mirrors that used on NSTX.

Table 6-1 NCSX Funding Profile (Equipment Funds)

	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	Totals
NCSX MIE Project*	$ 7.9M	$ 15.9M	$ 15.9M	$ 22.1M	$ 19.4M	$ 5.1M	$ 86.3M

* **MIE Project completion scheduled for May, 2008. The baseline TEC equals $86.3M.**

** **Facility operations will begin during FY2008.**

6.3 Life Cycle Costs

The elements of the NCSX life-cycle cost are as follows:

- Major Item of Equipment fabrication (FY-2003-08): $86.3M as spent
- Research preparation (FY-2003 through CD-4: approx. $25M as spent
- Annual Research Operations budgets: $28M/year in constant FY-03 dollars.
  - Facility operations: $12.3M/year
  - Research and upgrades: $15.8M/year
- Decommissioning and disposal: $2M.

<u>Note on Research Operations</u>: Annual research operations costs are for a typical year, and consist of facility operations, equipment upgrades, and research. PPPL will be responsible for facility operations. PPPL and ORNL will be responsible for facility upgrades. Responsibilities for research and diagnostics will be multi-institutional. The national estimate given here is based on operating cost data from the PPPL-operated National Spherical Torus Experiment (NSTX), a facility comparable to NCSX in size, scope, and collaborative aspects. The main uncertainty is that it is not known how long NCSX will operate. Fusion experiments like NCSX are expected to operate for at least 10 years, but

some have operated as long as 25 years, undergoing major reconfigurations in the process. In the absence of a well-defined timeline, the annual operating budget estimates are quoted in constant FY-2003 dollars.

Facility operations component: The estimate assumes that both NCSX and NSTX are operating at PPPL as relatively mature facilities, resulting in cost-saving efficiencies for both projects. The facility operations estimate for the two machines combined is about $25.6M in constant FY-2003 dollars, only $10.2M more than operating NSTX alone. The NSTX project will realize a savings of about $2.2M/year as a benefit of combined operation.

Research and upgrades component: Estimates for annual research and upgrade costs are in the range typical of NCSX-scale experiments, including NSTX. Within the total envelope, the split between research and upgrades is expected to vary over time, with more emphasis on upgrades in the early years and less as end of life is approached.

<u>Note on Decommissioning and Disposal</u>: At the end of NCSX's operating life, the remaining equipment will be removed and it is expected that these activities should be routine and relatively inexpensive, although a small amount of radioactive activation and/or contamination of the structures is expected. The decommissioning and disposal cost estimate is based on the actual costs of removing the Princeton Large Torus (PLT) and Princeton Beta Experiment-Modified (PBX-M) devices in recent years.

7 PROJECT BASELINES

The initial NCSX Project configuration, schedule, and cost baselines were developed in the conceptual design phase of the project. However, in accordance with the DOE's project management policies, the cost and schedule performance baselines are not formally established until the completion of the Title I (Preliminary) design. Section 7.1 which follows addresses the management and control of the configuration (sometimes also called the technical) baseline. At that time, they will come under the configuration control processes that are outlined later in this PEP.

7.1 Configuration Baseline

The configuration or technical baseline is the configuration/technical documentation formally designated at a specific time during the Project. Configuration baselines, plus approved changes to those baselines, constitute the current configuration documentation. Establishment of configuration baselines will follow the industry standard for systems engineering, EIA/IS-632 *Systems Engineering*. There are three formally designated configuration baselines, namely the functional, allocated, and product baselines.

The functional baseline is the initially approved documentation describing the system's functional, performance, and interface requirements and the verification required to demonstrate the achievement of those requirements. The functional baseline is established when the system (top-level) specification, the General Requirements Document, is approved.

Lower level development or "design-to" specifications will be developed from requirements allocated from the system specification. The allocated baseline is the initially approved documentation describing subsystem functional, performance, and interface requirements that are allocated for those of the system or higher level subsystem; interface requirements with interfacing subsystems; design constraints; derived requirements; and verification requirements and methods to demonstrate the achievement of those requirements and constraints. Generally, there is an allocated baseline for each subsystem to be developed.

The product baseline is the initially approved documentation describing all of the necessary functional, performance, and physical requirements of the subsystem; and the functional and physical requirements designated for production acceptance testing. Product or “build to” specifications and engineering drawings are part of the product baseline. Generally, there is a product baseline for each subsystem, component, and part. The product baseline is typically established late in final design or early in the fabrication phase with the validation of the product specification and supporting documentation.

7.2 Cost and Schedule Baselines

The DOE schedule baseline is documented in this PEP as indicated in Table 2-2 (DOE Milestones). First Plasma is scheduled for May, 2008.

The DOE cost baseline consists of the TEC ($86.3M) and the included contingency ($15.9M). The supporting budget estimates by WBS are tabulated in Table 7-1 (Cost by WBS).

The NCSX project resource-loaded schedule provides the schedule and cost details for the Project’s performance measurement baseline. The Primavera Project Planner (P3) commercial scheduling module will be the standard software used for the NCSX project. There will be a minimum of four levels of detail starting with the Project Summary Schedule (Level 1). This summary level schedule will identify significant DOE and project milestones and summary logic for the entire project.

Table 7-1 Budget Estimate by WBS

WBS		Description	Budget Estimate ($M)
1		Stellarator Core Systems	$42.35M
	11	In-Vessel Components	$ 0.07M
	12	Vacuum Vessel	$ 6.07M
	13	Conventional Coils	$ 4.17M
	14	Modular Coils	$ 20.55M
	15	Coil Support Structures	$ 1.45M
	16	Coil Services	$ 1.04M
	17	Cryostat and Base Support Structure	$ 1.31M
	18	Field Period Assembly	$ 5.11M
	19	Stellarator Core Management & Integration	$ 2.66M
2		Auxiliary Systems	$1.63M
3		Diagnostic Systems	$1.68M
4		Power Systems	$5.32M
5		Central I&C Systems	$2.58M
6		Facility Systems	$2.04M
7		Test Cell Preparation & Machine Assembly	$4.25M
8		Project Management and Integration*	$10.57M
		Subtotal	$70.42M
		Contingency (~26% on Remaining: January 2004 - FY2008 Scope)	$15.91M
		TEC	$86.3M

Note: *WBS 8 (Project Management and Integration) also includes $956K of directly allocated laboratory indirect costs.

The other three levels of schedule are as follows and provide increasingly greater level of detail:

- Level II or Intermediate Schedules – will show major milestones and key tasks summarized by WBS, including key interrelationships.
- Level III or Job Level Schedules – are the detailed schedules prepared by the job manager. This schedule is established as part of the Work Authorization process and will span at least the current fiscal year. Since this schedule is the basis for each approved job or task, it is the heart of the cost and schedule baseline. These schedules will be resource loaded at the activity level and will form the basis for the NCSX Project Control System described in Section 10.0 of this PEP. Progress against established technical, cost, and schedule targets will be measured and evaluated monthly using the information contained in the Level III schedules. The activity detail that provides basis for these resource loaded schedules are documented in a separate Cost and Schedule Document. Subsystem-specific contingencies are included and detailed resource-loaded schedules are available. These schedules clearly demonstrate the critical path activities, major milestones at both the summary and detailed levels.
- Level IV or Working Level Schedules – depending on the needs of the project, detailed working level schedules are prepared as needed. As critical tasks occur (e.g., complex hardware procurement, fabrication and installation tasks, etc.),

activities that are covered in the Level III job schedules may be broken down into additional detail to allow for coordination of work by the responsible manager. Level IV schedules may also be developed by cognizant job managers to aid in the performance and control of their jobs. This level of schedule detail is normally not controlled at the same rigor as higher level schedules, but efforts are made to ensure continuity to established project milestones and Level III schedules.

8 Control of Project Baselines

8.1 Configuration Management Approach

Changes to the NCSX configuration, cost, and schedule baselines will be controlled using a disciplined, yet flexible configuration management approach. This approach will ensure that the configuration, cost, and schedule baselines are controlled at the appropriate level for the respective stages of the Project as defined in Office of Science ESAAB equivalent procedures dated January 2001. Changes to the baseline will be carefully considered and evaluated for impact before proceeding. Processes for effecting changes to the configuration, cost, and schedule baselines are described in the Configuration Management Plan (NCSX-PLAN-CMP).

8.2 Change Control Process

The NCSX change control process ensures that changes to the NCSX design and requirements are properly identified, screened, evaluated, implemented, and documented. A formal procedure has been established to implement the process of change classification and submittal of supporting documentation.

Once an Engineering Change Proposal (ECP) has been prepared and the impacts fully documented, the ECP will come before a project Change Control Board (CCB) that is comprised of senior members of the NCSX management team. The NCSX Project Manager or his designee will chair the CCB. The NCSX Systems Engineering Support Manager will serve as the CCB Secretary. Other members of the CCB will be assigned as appropriate, but may include the following:

- NCSX Project Control Manager
- NCSX Engineering Manager
- NCSX Physics Head
- WBS Managers
- ES&H representative
- QA representative
- Other cognizant job managers impacted by the proposed change

The chairperson shall have the ultimate authority to recommend changes for the final approval; other board members act solely as advisors.

Once a proposed change is approved, the project will implement the change in a timely manner. An updated list of approved, disapproved, and pending changes will be maintained electronically by Project Engineering on the NCSX File Share System.

8.3 Change Control Levels

Changes to the NCSX configuration, cost, or schedule baselines will be classified according to their impact on the project. The change approval levels are established consistent with the technical, cost, and schedule risk and are intended to feed into the higher level DOE configuration change system. The following tables summarize the performance baseline change authority for the Deputy Secretary of Energy (Table 8-1) –(Deviations), the Associate Director for Fusion Energy Sciences, Office of Science (Table 8-2) – Level 1, the NCSX Federal Project Director (Table 8-3) – Level 2, and the NCSX Laboratory Project Manager (Table 8-4) – Level 3.

Table 8-1 Performance Baseline Change Authority (Deviation)

Deputy Secretary of Energy

Type of Change	Approval Authority
Technical (Table 2-1 and Annex I)	Any change in scope and/or performance that affects mission need requirements or is not in conformance with the current approved OMB-300.
Schedule (Table 2-2)	6 month or greater increase (cumulative) in the orginal project completion date.
Cost (Sect. 7.2)	Increase in excess of 25% (cumulative) of the original cost baseline.

Table 8-2 Performance Baseline Change Authority (Level 1)

Associate Director for Fusion Energy Sciences, Office of Science

Type of Change	Approval Authority
Technical (Table 2-1 and Annex I)	Changes to technical requirements and parameters that affect safety basis and operation function, but do not affect mission need objectives.
Schedule (Table 2-2)	3-6 month increase (cumulative) in the orginal project completion date.
Cost (Sect. 7.2)	Increase of the original cost baseline.

Table 8-3 Performance Baseline Change Authority (Level 2)

NCSX Federal Project Director

Type of Change	Approval Authority
Technical (Table 2-1 and Annex I)	Changes with ES&H impacts significant enough to affect the approved NEPA/EA documentation.
Schedule (Table 2-2)	• <3 month increase (cumulative) in the original project completion date. • Change in DOE level 2 milestone.
Cost (Sect. 7.2)	Changes requiring the use of contingency funds.

Table 8-4 Performance Baseline Change Authority (Level 3)

NCSX Project Manager

Type of Change	Approval Authority
Technical (Table 2-1 and Annex I)	Changes to the GRD and all other changes not requiring DOE approval.
Schedule (Table 2-2)	All other changes to the performance measurement baseline schedules not requiring DOE approval.
Cost (Sect. 7.2)	All other changes to the performance measurement baseline costs not requiring DOE approval.

8.4 Contingency Management Plan

The amount of contingency is established at the beginning of the project based on a risk assessment performed as part of the cost estimating process. A formal risk-assessment methodology that considers technical, cost, and schedule risks at the subsystem level, is performed, using a high-medium-low risk classification. This methodology is outlined in Annex II to this plan. The initial project contingency level will be approved by the Associate Director for Fusion Energy Sciences as the Acquisition Executive for NCSX at CD-2 as part of establishing the overall cost and schedule baselines.

Based on experience with similar projects, changes in scope of work and schedule, requiring the application of contingency, typically arise as a project proceeds. Changes involving the application of contingency must be approved by the NCSX DOE Federal Project Manager via the configuration control process. Cost and schedule baselines and remaining contingency will be adjusted upon approval of change proposals.

Each fiscal year, not later than the middle of the year, the NCSX Project Manager will assess the status of authorized work, achieved milestones, and current and future risks, to determine how to apply remaining management reserve (See section 10.2) funds under his control. They can be used to authorize as yet un-funded work planned for the current or future years, to fund approved changes, or a combination of these. This decision will occur early enough in the fiscal year to permit effective use of these funds, and will be presented as part of the annual mid-year project review meeting with DOE.

8.5 Value Engineering

Value Engineering (VE) is the systematic application of recognized techniques by a multi-disciplinary team to identify the function of a product or service, establish a worth for that function, generate alternatives through the use of creative thinking, and provide the needed functions to accomplish the original purpose of the project at the lowest life-cycle cost without sacrificing safety, necessary quality, and or environmental attributes of the project. The NCSX Project will apply VE methodologies following a tailored approach to the formal elements of VE. The NCSX approach has included:

- Using a multi-disciplinary team to identify and assess alternates;
- Following a systematic job plan;
- Identifying and evaluating function, cost and worth;

- Developing and evaluating new alternatives for required functions; and
- Developing and implementing recommendations.

The NCSX Project has applied value engineering methods early in the design process, starting with the pre-conceptual design phase. Numerous design studies have been conducted that have significantly shaped and guided the development of the current design. Some specific examples include:

- Evaluating whether to reconfigure the existing PBX-M device vs. building a new machine – it was determined that the mission could best be achieved by building a new device;
- Coil topology studies conducted by a multi-disciplinary team of physicists and engineers that led to the selection of modular coils (vs. saddle coils) for providing helical fields;
- Manufacturing studies of the vacuum vessel and modular coils conducted by manufacturing engineers in industry (and supported by laboratory design engineers) that identified and evaluated a variety of fabrication options. The results from these studies are being used to fine tune design efforts and procurement strategies.
- Selecting to utilize the existing facilities and infrastructure formerly housing the PBX-M and PLT fusion devices (vs. the former TFTR test cell). This decision resulted in optimization of the PPPL infrastructure and facilities, resulting in significant cost savings;
- Evaluating bolted vs. welded vacuum vessel joint designs – welded design selected – resulted in a more robust design;
- Evaluating winding options (multiple conductor, 1-in-hand, and 4-in-hand) – 4-in-hand selected – will result in optimized winding abilities; and
- Dedicated value engineering task force to review and assess numerous design and installation alternatives with each WBS Manager during Preliminary Design Review preparation. For example, savings in the Central I&C System were identified due to the shift from remote to local controls, as is appropriate for the NCSX facility layout.

The project's Value Engineering plan after the Preliminary Design phase is to continue to seek lower-cost alternatives for all phases of subsystem implementation and to follow up on open items documented in the VE task force report during Preliminary Design. Implementation will be accomplished via the project's regular work planning and tracking process and the design planning and review process.

9 Project Management and Control Systems

9.1 Project Management Systems Approach

The NCSX Project Manager will ensure that all project activities are properly controlled using PPPL's Project Control System (PCS). This system will be used as a management aid in planning and executing the project work scope and evaluation of schedule and budget performance. The status of progress and variance in the WBS elements will be reported monthly to the NCSX Project Manager.

The NCSX Project Manager will work to ensure early detection of technical, schedule or cost problems through regular meetings of the Systems Integration Team (SIT). The functions of the SIT are described in the Systems Engineering Management Plan (SEMP).

9.2 Project Control System Overview

The NCSX Project will use the existing PPPL Project Control System (PCS) as described in the PPPL Project Control System Description. This description describes the "graded approach" concept to be applied to PPPL projects and is available as a separate lab document. This document was reviewed and approved by DOE in 1996. The PPPL PCS satisfies the principles of project management and control systems outlined in this PEP and DOE Order 413.3 ("Program and Project Management for the Acquisition of Capital Assets"). ORNL and suppliers will utilize the PPPL PCS to ensure that the entire project cost and schedule performance is measured. The PCS provides a centralized work authorization system that the project will use. The specific NCSX Project PCS was reviewed and approved by an external DOE review team in February of 2003.

The PCS is an integrated earned value management control and reporting system that establishes the documentation, data requirements, information flow, and system disciplines necessary to operate and maintain a system for control of the NCSX Project work, costs, and schedules. The overall objective of the PCS is to provide PPPL and DOE with timely and auditable cost and schedule performance information that can be used to monitor, control and manage Project progress. To accomplish this objective, the PCS provides a formal process for:

- Organizing the project work scope via the WBS;
- Planning and estimating the work scope via the project resource loaded schedule;
- Authorizing work and forecasting resource requirements via the Work Authorization Form (WAF);
- Controlling management reserve and authorized allocated contingency via the change control process;
- Monitoring progress relative to schedule status and completion estimates and reporting cost and schedule performance against established cost and schedule baselines using the Level III schedules;
- Documenting approved changes to the performance measurement technical, cost, and schedule baselines via the change control process; and
- Analyzing variances to the cost and schedule baselines, including critical path analyses resulting from status results of the Level III schedules.

The key planning and measurement tool for the project is the Level III schedule, but the PPPL work authorization process forms the basis for development of these schedules. Through the work authorization process, details of work scope, schedule, budget, and responsibility will be integrated, documented, reviewed, and agreed to by both project management and the performing organization. The cognizant job manager will be responsible and accountable for accomplishing the scope of the work, as defined, with established schedule and cost targets. The vehicle for documenting and authorizing work is the Work Approval Form (WAF). The WAF formally documents the work scope to be performed, establishes a schedule, provides a cost estimate, identifies a responsible person for accomplishing the work, and provides time phased cost and manpower profiles.

9.3 Cost and Schedule Reviews

Nominally the Project will schedule quarterly reviews of Project status with the NCSX Federal Project Director and the OFES Management. Two of these reviews will focus on cost and schedule aspects of the Project; one will be scheduled near the middle of the fiscal year during the period preceding the presentation of the Field Work Proposal and one near the end of the fiscal year. At these meetings the project will report the status of the project in general and the cost variances that potentially impact the level of contingency in particular. Progress on detailed planning will also be reported. Based on these inputs the project will recommend to DOE changes to the Project Baseline. This recommendation will be documented in the form of a formal change. The other two quarterly reviews will focus more deeply on the technical aspects of the Project.

Annually, the NCSX Project will perform a bottoms-up cost estimate to ensure that the current cost and schedule baseline remains up-to-date and self-consistent with the technical baseline.

In addition, as needed to support Critical Decision milestones or as requested by the NCSX Acquisition Executive, these reviews may be expanded to include external reviewers organized by the Office of Science Office of Construction Management Support (the "Lehman" Review).

9.4 Reporting

Quarterly project reports will be prepared for the NCSX Federal Project Director and OFES Program Manager. However, to foster and facilitate visibility into project status all monthly PCS status will be provided to the NCSX Federal Project Director. Additionally, DOE-PAO participation in monthly meetings as well as design reviews will be encouraged.

The DOE NCSX Federal Director is responsible for entering monthly performance data into the DOE Project Assessment and Reporting System (PARS) database.

10 Funds Management

10.1 Project Funding Mechanisms

PPPL and ORNL will each be funded directly via DOE Budget and Reporting (B&R) line. The exact split between PPPL and ORNL will be negotiated each year using the resource-loaded schedule as the guide. Participation of other organizations other than other DOE National Laboratories will be funded by either PPPL or ORNL through subcontracts. Transfer of funds from PPPL to ORNL or vice versa will be accomplished by Financial Plan transfer requests to DOE. All project work and expenditure of project funds will be centrally authorized and controlled by the project office via the PCS. The annual NCSX funding requirements will be updated each year by PPPL and ORNL through their respective DOE Field Work Proposal (FWP) processes.

10.2 Management Reserve Funds

All funds authorized for the Project by the DOE Financial Plan will be disbursed to the Project (PPPL and ORNL). Management reserve funds are a portion of each year's approved funding allowance that are set aside at the beginning of each fiscal year instead of being immediately used to authorize work. Management reserve funds will be held in a unique management reserve account controlled by the NCSX Project Manager. As needs arise, the Project Manager will authorize disbursement of the management reserve funds to authorize as yet un-funded work scheduled for the current year or future years, or resolve approved changes arising within the current year's authorized scope of work. Changes requiring the application of contingency, will be handled via the change control process defined in Chapter 8 and will, as stated there, require DOE approval. As part of the reporting process, the NCSX Project Manager will report on management reserve disbursements regularly, and as part of the cost and schedule project review meetings with DOE.

11 RISK MANAGEMENT

The NCSX project will manage risks, where "risk" refers to factors within the project's control that threaten project performance, namely:

- Technical risk- the possibility that the product might not meet requirements
- Cost risk- the possibility that the cost might exceed the target value.
- Schedule risk- the possibility that the project might take longer to complete than planned.

Control of environment, safety, and health hazards, while part of risk management in a broader sense, is covered in other sections. Risk management is everyone's business and will be factored into every project decision throughout the life of the project.

The responsibility for risk management rests with the NCSX line management. The Systems Integration Team will facilitate the identification of areas of risk; coordinate the development of risk mitigation plans; and the monitoring of performance against those plans. The design engineers, with the appropriate management oversight, establish the specific approaches to addressing the individual risk elements. The early phases of the NCSX project design process is structured to identify risks. These risks are addressed through design improvements, manufacturing studies, prototypes, schedule contingency and cost contingency. The cost contingency methodology is outlined in section 8.4 of this document. In many cases the risk mitigation comprises several of the above listed mitigation elements. A risk listing and tracking approach is applied to avoid overlooking important risks and to assure that the risk mitigation has adequate management oversight.

The NCSX Risk Management Plan provides more details on the NCSX Project risks and approaches to minimizing and mitigating risks. The Risk Management Plan will be managed as a living document that is tracked and updated periodically. As such, it will come under a formal document control and approval process for periodic updates. The project will also use a critical issues tracking list, which is consistent with but has a finer degree of granularity than the Risk Management Plan, for week-to-week tracking and management of risks by the SIT.

12 ACQUISITION STRATEGY

The NCSX Acquisition Execution Plan (AEP) was issued and approved as part of the CD-1 approval process. Since its approval by the Under Secretary of Energy, Science, and Environment, the NCSX Project has followed the strategies and processes outlined in the AEP. The key feature of the NCSX acquisition strategy and planning is the procurement of the critical components that comprise the stellarator core. The stellarator core includes the modular coils, vacuum vessel, supplementary coil systems (e.g., toroidal field, and poloidal field, and trim coils), and cryostat. The procured components will be assembled by Laboratory labor into the completed stellarator core assembly. Although the design of the stellarator core systems will be led by ORNL, all major procurements for all systems will be placed by the PPPL Procurement Department.

The vacuum vessel and the modular coil winding forms are the highest risk components. During the conceptual design, manufacturing studies by industrial participants were conducted to obtain feedback on planned manufacturing processes, input on feasibility issues and technical risks, and suggested manufacturing development activities to mitigate risks. This was followed up by the selection of several vendors to carry out manufacturing development activities (small scale or full size prototypes) for the design and manufacturing of the vacuum vessel and modular coil forms. This activity is ongoing and will be used to down-select a vendor or vendors to fabricate the production units.

Since the majority of the other systems will primarily be upgrades and/or modifications to existing PPPL systems and structures, it is anticipated that simple build-to-print of fixed price procurements based on firm specifications are feasible.

During Final Design, the project, in conjunction with the PPPL Procurement organization, will develop a formal NCSX procurement plan that identifies all planned procurements by type, dollar amount, key dates, and special requirements such as incentive, or shared savings, provisions .

13 DATA MANAGEMENT SYSTEM

A system for controlling documents and drawings, adapted from existing PPPL document and drawing control systems using hard copy and electronic media, will be developed to ensure the organized and consistent treatment and format of NCSX documents including procedures, plans, memos, drawings, calculations, requirement documents, design documents, and procurement documents. This system will utilize web-based file servers for rapid review, authorization, updating, and retrieval of documents and drawings. The majority of project documents (other than drawings) can presently be retrieved from the NCSX web page located at http://www.ncsx.pppl.gov. Drawings in electronic format can be accessed via the Pro/INTRALINK database. Legacy drawings only in hard copy can be obtained from the PPPL Drafting Center. The NCSX project has developed a separate Document and Records Plan (NCSX-PLAN-DOC) that identifies documents to be controlled on the project, including the document's purpose, approval level, format, naming convention, and records retention requirements. The Data Management Plan (NCSX-PLAN-DMP) describes the processes to be used for document and drawing control. Processes for effecting changes to controlled documents are described in the Configuration Management Plan (NCSX-PLAN-CMP). All participants are encouraged to use the project standards for documents of either the MAC or PC versions of Microsoft Word, Microsoft Excel, or Microsoft PowerPoint.

14 SYSTEMS ENGINEERING AND TECHNICAL MANAGEMENT

14.1 Systems Engineering

Project Engineering has responsibility for implementing a systems engineering program on NCSX. The systems engineering program includes the development and allocation of requirements; system design and verification; risk management; value engineering; configuration management; interface management; data management; and technical reviews. The systems engineering program is described in the Systems Engineering Management Plan (NCSX-PLAN-SEMP).

14.2 Quality Assurance

The NCSX Project QA Plan (NCSX-PLAN-QAP) will demonstrate how the existing PPPL and ORNL-FED Quality Assurance Plans and implementing policies and procedures, in conjunction with additional NCSX specific plans, policies, and procedures will satisfy the requirements of the DOE Order on Quality Assurance, 414.1A, and provide an appropriate level of quality on the project.

14.3 NEPA Documentation And Safety Assessment

Input to the NEPA Documentation, the Environmental Evaluation Notification Form (EENF) and the Preliminary Hazards Analysis (PHA) was submitted to DOE and it was determined by DOE that an Environmental Assessment (EA), similar to that done for NSTX, is the appropriate NEPA documentation for NCSX. The EA (DOE/EA-1437)has been prepared and a Finding of No Significant Impact (FONSI) was signed by the DOE-CH Manager on October 25, 2002.. The Safety Assessment Document (SAD) will be prepared and approved by PPPL prior to the start of operations.

15 INTEGRATED SAFETY MANAGEMENT PLAN

PPPL follows the institutional Integrated Safety Management Plan (ISM) that has been approved by DOE. The NCSX Project intends to follow that ISM and to adopt this plan as its own for the conduct of NCSX work performed at PPPL. ORNL and subcontractors/vendors are responsible for safety at their respective sites.

ISM at PPPL is comprised of:

- The governing policy that safety be integrated into work management and work practices at all levels.
- The distinct policies, programs, procedures, and cultural beliefs that PPPL has developed as the structure that PPPL workers utilize in fulfilling PPPL's environmental, safety, and health responsibilities.

The NCSX project will incorporate ISM into its management approach as follows:

- By accepting responsibility for safety as a line management responsibility. The NCSX Project Manager is responsible for safe execution of the project.

- By following PPPL procedures for work planning (e.g., ENG-032, etc.), where applicable. These procedures incorporate the ISM core functions of folding safety into the work planning, establishing appropriate controls, operating within established parameters, feedback. The "core functions" of ISM include the following 5 step process:
    - Defining the scope of work;
    - Analyzing the hazard;
    - Developing and implement hazard controls;
    - Performing the work within these controls; and
    - Providing feedback and continuous improvement to this process.

  Where project-specific procedures must be developed, ISM principles will be incorporated into them.

16 REVISIONS TO THE PROJECT EXECUTION PLAN

This plan, when adopted and approved following completion of the CDR, will remain in effect until the completion of the NCSX fabrication project. An annual review of the NCSX Project Execution Plan will be conducted, jointly by the PPPL Advanced Projects Department Head, the NCSX Project Manager, and the NCSX Engineering Manager to determine possible recommendations for update and/or revision. Revision and/or changes to this document will require approval of all the original signers of this document or their successors

Annex I

NCSX SCOPE

The NCSX Performance Baseline Scope objectives are listed, by WBS, in the first column of the table. The second column lists the upgrades that the system is designed to accommodate, without regard to their implementation schedule

Objective Scope (Performance Baseline)	**Future Upgrades Accommodated By Design**
WBS 1. Stellarator Core	
• Vacuum vessel system including all ports and port covers. • Stellarator magnet system, consisting of modular coils, toroidal field coils, and poloidal field coils. • External trim coils. • Coil services (electrical and coolant feeds) • Support base and structures. • Cryostat	• Plasma-facing component upgrades for: – power handling up to 12 MW – pumped divertor – alternate materials (e.g., C, Li, W). • Internal trim coils
WBS 21, 22, 23. Fueling, Vacuum Pumping and Wall Conditioning Systems	
• Torus vacuum pumping system based on two of the PBX-M turbo-molecular pumps mounted on a single duct. Pumping speed approx. 1,300 l/s. • Residual gas analyzer. • Gas injection system based on 3 injectors @50 torr-l/s each for H, D, and He.	• Two additional turbomolecular pumps on a second duct, bringing the total pumping speed to 2,600 l/s. • Wall conditioning systems: – GDC, boronization, lithiumization. • Pellet injector.
WBS 25 Neutral Beam Injection Systems	
• Refurbishment and testing of equipment for up to 1.5 MW of neutral beam heating based on PBX-M neutral beam legacy equipment.	• Installation and integrated testing of systems for 6 MW of NBI based on PBX-M legacy equipment. • 6 MW of ICRF heating • 3 MW of ECH.
WBS 3. Diagnostics	
• Ex-vessel magnetic sensors installed; eight fully operational. • Fast visible camera on simple mount. • Electron-beam field mapping apparatus	• In-vessel magnetic sensors. • All magnetic diagnostics fully operational. • Permanent installation of fast visible camera. • Physics diagnostic system, per GRD.

Objective Scope (Performance Baseline)	Future Upgrades Accommodated By Design
WBS 4. Power Systems	
• Coil power systems for First Plasma and initial field mapping operation with room temperature coils, consisting of 6 circuits. • Associated AC, DC, control, and protection systems.	• Coil power upgrades of the PPPL D-Site equipment for high-beta plasma operation up to 2 T (short pulse), 1.2 T (long pulse), Ohmic current drive up to 320 kA, and full flexibility with coils cooled to cryogenic temperatures, consisting of 10 circuits (total). • Trim coil power supplies. • Associated AC, DC, control, and protection systems.
WBS 5. Central I&C and Data Acquisition System	
Computer system consistent with control and data acquisition requirements of in-scope equipment: • Computer network infrastructure. • Central instrumentation and control system • Data acquisition and facility computing. • Facility timing and synchronization. • Real-time power supply control. • Central safety interlocks. • Control room facility.	Expansions consistent with requirements of upgrades in other systems.
WBS 6. Facility Systems	
• Water cooling equipment for vacuum pumps and neutral beams. • Cryogenic supply and transfer equipment. • 150 C Vacuum Vessel Bakeout equipment. • Utility equipment (venting, GN2, compressed air) • C-Site water system re-commissioning.	• Water cooling for diagnostics • 350 C PFC Bakeout system.
WBS 7. Test Cell Preparation and Machine Assembly	
• Control Room Refurbishment • Access Platform. • Machine assembly.	N/A

Objective Scope (Performance Baseline)	Future Upgrades Accommodated By Design
WBS 8 Project Management and Integration	
• Project Management • Project Control • System Engineering Management • System analysis • Design integration. • Environment, Safety, and Health • Project physics • Integrated System Tests	N/A

Annex II

NCSX CONTINGENCY GUIDELINES

Cost Contingency Overview

Contingency is the amount of additional money, above and beyond the base cost, that is required to ensure the project's success from a cost perspective.

Contingency Estimating Procedure

The contingency estimate is developed by assessing risk and weighting factors in three areas; technical, schedule, and cost. Although the suggested procedure for determining the appropriate percentage of contingency is outlined below, each WBS Manager has the option to modify it as appropriate to reach a more appropriate level of contingency for his sub-system. The following procedure is utilized as a starting point in determining the contingency:

- Compare the conceptual state of the subsystem with the descriptions contained in Table Annex II-1. There are three factors to consider:
  - A Technical Risk Factor is assigned based on the current state and level of the design;
  - A Schedule Risk Factor is identified based on that subsystem's criticality to the overall schedule;
  - A Cost Risk Factor is assigned based on the overall estimating methodology used to arrive at the cost estimate for that subsystem.
- Compare the potential risk within a subsystem with Table Annex II-2 to determine the appropriate weighting factor.
  - A Technical Weight Factor is assigned based on the overall level of engineering and manufacturing difficulty for the subsystem. Depending on the engineering and manufacturing issues and uncertainties, different Technical Weighting Factors may be applied.
  - A **standard** Schedule Weighting Factor of 1% has been assigned for the NCSX conceptual Cost Estimate.
  - A Cost Weighting Factors is assigned based on whether that subsystem is primarily composed of assembly items, therefore having only possible labor rate impacts, or if material costs are also included meaning raw material prices, vendor estimates, and labor rates may affect the estimate, thus requiring a larger Cost Weighting Factor.
- Once the Risk Factor and Weighting Factor is determined for each of the three areas (technical, schedule, and cost), multiply the individual risk factors by the appropriate weighting factors and then sum to determine the contingency percentage for each area.

  Example: If the technical risk factor is 4 and the technical weighting factor is 4%, the total technical contingency component would be 4 x 4% = 16%. If the schedule risk factor is 4 and the schedule weighting factor is 1% (Standardized), the total schedule contingency component would be 4 x 1% = 4%. If the cost risk factor is 3 and the cost weighting factor is 2%, then the total cost contingency component would be 3 x 2% = 6%. The total calculated contingency would thus be 16% + 4% + 6% = 26%.

- Sum the contingency percentages for each area to arrive at a total contingency percentage. The dollar amount of contingency will be determined by the NCSX Project Costing Team at PPPL by multiplying the base estimate (MIE + OPEX) by the calculated contingency percentage.

Table Annex II-1 Technical, Schedule, & Cost Risk Factors

Risk Factor	*Technical*	*Schedule*	*Cost*
1	Existing Design and Off-the-Shelf H/W	*Not Used*	Off-the-Shelf or Catalog Item
2	Minor Modifications to an Existing design	No Schedule Impact on Any Other Subsystem	Vendor Quote from Established Drawings
3	Extensive Modification to an Existing Design	*Not Used*	Vendor Quote with Some Sketches
4	New Design, but Nothing Exotic	Delays Completion of Non-Critical Path Subsystem Activity	In-House Estimate Based on Previous Similar Experience
6	New Design, Different from Established Design Or Existing Technology	*Not Used*	In-House Estimate with Minimal Experience, but Related to Existing Capabilities
8	New Design that Requires Some R&D, but Does Not Advance the State-of-the Art	Delays Completion of Critical Subsystem Activity	In-House Estimate with Minimal Experience and In-House Capabilities
10	New Design Development of New Technology that Advances the State-of-the Art	*Not Used*	Top-down Estimate Based on Experience from Analogous Programs
15	New Design, Way Beyond the Current State-of-the-Art	*Not Used*	Engineering Judgment

Table Annex II-2 Technical, Schedule & Cost Weighting Factors

Area	Condition	Weight %
Technical	Design OR Manufacturing Uncertainties	2%
	Design AND Manufacturing Uncertainties	4%
Schedule	Same for All Cases	1%
Cost	Material Cost OR Labor Rate Uncertainties	1%
	Material Cost AND Labor Rate Uncertainties	2%

Contingency Specification Rationale Worksheet

WBS Level 4 Identifier:		**Title:**		
Originator:		**Date:**		
	Technical	**Schedule**	**Cost**	**Total**
Risk Factor (Table 2-1):				
Weighting Factor (Table 2-2):				
Percent				

Recommended Contingency Allowance (%):

Rationale for Selection of Contingency Allowance: