# NCSX

# Systems Engineering Management Plan

## NCSX-PLAN-SEMP

Revision 0 - Draft B

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# 1 INTRODUCTION

## 1.1 PURPOSE

This document has been prepared for the National Compact Stellarator Experiment (NCSX) Project to describe the systems engineering process and management practices to be utilized by the NCSX Project in accomplishing its mission.

Systems engineering (SE) basically consists of three elements[1]:

- **SE Management** plans, organizes, controls, and directs the technical development of a system
- **Requirements and Architecture Definition** defines the technical requirements, defines a structure (or architecture) for the system components, and allocates these requirements to the components of the architecture
- **System Integration and Verification** integrates the components of the architecture at each level of the architecture and verifies that the requirements for those components are met

Concurrent engineering is inherent in the SE process. Concurrent engineering avoids expensive design changes late in the development cycle by addressing concerns such as manufacturability, assembly, and maintenance early in the development cycle when they are less expensive to correct.

The NCSX Systems Engineering Management Plan (SEMP) has the following key features:

- **The NCSX Project will be executed by a fully integrated project team (IPT),** even though the participants may be geographically and institutionally distributed. Work will be governed by project-wide plans and procedures.
- **SE responsibilities will be assumed by IPT members,** not by a separate SE organization.
- **Common databases will be established** for documents and drawings to ensure that everyone is using the same information.
- **Design-to-cost objectives will be established** to contain costs.

[1] Martin, J.M., *Systems Engineering Guidebook*, CRC Press, 1996, pg. 3

- **System requirements will be developed through an iterative process** in which the overall objective is to develop an optimally balanced and robust design that meets cost and schedule objectives.
- **System requirements and design constraints will be allocated to subsystems and configuration items (CIs)** through a hierarchy of specifications defined in a specification tree. Requirements will be traceable and testable.
- **Testing will be performed to verify that each requirement is met.** Qualification testing demonstrates that the design meets the functional requirements. Acceptance testing demonstrates that the product meets acceptance criteria.
- **Design reviews and audits will be conducted** at transition points in the development process to identify deficiencies and allow correction in a timely manner.
- **All work will be planned and statused.** Actual performance will be measured against planned expected performance to allow early identification of problem areas.

## 1.2 SCOPE

The NCSX fabrication project formally begins with Title I (Preliminary) Design and ends at first plasma. The NCSX Systems Engineering Management Plan (SEMP) defines the processes, organization and procedures used by the NCSX fabrication project to accomplish the systems engineering objectives. This plan is divided into three major parts[1]:

- Technical Program Planning and Control
- Systems Engineering Process
- Engineering Specialty Integration

## 1.3 APPLICABLE DOCUMENTS

This Systems Engineering Management Plan draws on the documents listed below. Where discussion in addition to that contained in these documents is required, it is provided. In most cases, only a brief discussion along with a note directing the reader to refer to the referenced document is provided. Documents referenced are the latest issues of the:

- Project Execution Plan (NCSX-PLAN-PEP)
- Work Breakdown Structure (WBS) Dictionaries (NCSX-WBS-X where X is the Level 2, i.e., 1-digit, WBS identifier)

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[1] *Systems Engineering Management Guide*, Defense Systems Management College, 1990

- PPPL Project Control System Description
- Quality Assurance Plan (NCSX-PLAN-QAP)
- Data Management Plan (NCSX-PLAN-DMP)
- Document and Records Plan (NCSX-PLAN-DOC)
- Configuration Management Plan (NCSX-PLAN-CMP)
- Interface Control Management Plan (NCSX-PLAN-ICMP)
- Test and Evaluation Plan (NCSX-PLAN-TEP)
- Reliability, Availability, and Maintainability Plan (NCSX-PLAN-RAM)

# 2 TECHNICAL PROGRAM PLANNING AND CONTROL

An in-depth discussion of the Project organizational responsibilities and the Project WBS can be found in the NCSX Project Execution Plan (PEP). Project Engineering has overall responsibility for implementing the SE program on the NCSX Project. Systems engineering functions include:

- Systems engineering management
- Coordination of the generation of the systems requirements documentation
- Coordination of design reviews and follow-up
- Coordination of configuration management and change control
- Data management
- Interface control
- Coordination of Reliability, Availability and Maintainability (RAM)
- Planning, scheduling and cost baseline maintenance support
- Coordination of operations and maintenance procedure development
- Coordination of integrated system test planning

## 2.1 SYSTEMS INTEGRATION TEAM

To accomplish the systems engineering functions, it is necessary to have broad participation among project participants. A Systems Integration Team (SIT) is planned to facilitate this integration. **The purpose of the SIT is to make sure everyone is working to the same ground rules and understandings and to identify problems/issues and plans for resolution**. The SIT will review systems engineering progress, coordinate interfacing participants' activities, identify system issues, develop needed action plans, and assign and track action items. The SIT will also manage the conduct of system trade studies, providing a forum for identifying, prioritizing, tracking, and implementing the needed actions resulting from trade studies.

The SIT will orchestrate the risk management activities described in Section 3. In this capacity, the SIT will determine what the project risks are; identify appropriate risk mitigation plans/activities; and coordinate and track the progress of the risk management activities. The SIT is supported by ad hoc working groups formed as needed to address and resolve specific issues.

The Project Engineer will chair the SIT. Members will also include the Project Manager, the Deputy Project Manager for Engineering, the Project Control Manager, the Project Physics Manager, the ORNL Project Engineer (who is also the WBS manager for WBS 1), and the Construction Manager (WBS 7). The DOE Project Manager will be invited to all SIT meetings to keep DOE well informed on plans, progress, and issues. Specialty disciplines, other WBS managers, and other project personnel will participate as needed to support the agenda topics. It is the intent that this team ensure that all participating organizations have a forum to provide inputs on and discussion of systems engineering matters such as requirements interpretation, potential areas of risk, system level trade studies/analyses, coordination of processes, etc. Resolutions are worked outside the SIT by the responsible organizations and designated working groups. Results are reported back to the SIT. The SIT will make decisions or facilitate obtaining project decisions relative to any implementing actions required.

The SIT will meet on a regularly scheduled basis with a frequency appropriate to the phase of the program and magnitude of system related activities in progress. The agenda will normally consist of a standard set of agenda items and one or two special topics of interest. The standard part of the agenda will usually consist of a review of schedule status including the critical path schedules to first plasma and major, near term milestones; a review of the near term project calendar relative to upcoming events of significance to systems engineering; status reports from the ad hoc working groups and WBS Managers; and a brief around the table summary of items of interest by SIT members. **All standard agenda item status reports are by exception only, i.e., the focus is on problem areas needing attention by the SIT, not a review of on schedule and business as usual activities**. Special topics are selected to allow a more in-depth review of particularly important issues or activities. Special agenda items are coordinated with the Project Engineering Manager. Examples might include the results of a major trade study, progress in preparation for a major milestone, or risk management issues. Systems engineering status will include a summary of system trade study progress relative to schedule, system requirements development and allocation progress, design review readiness and closeout progress, a review of recent decisions made and baseline changes, and risk management activity status.

## 2.2 WORK AUTHORIZATION AND PROJECT CONTROL PROCESS

The NCSX Project is responsible for developing and maintaining an integrated cost and schedule management process. NCSX will use the existing PPPL Project Control System (PCS) as described in the PPPL Project Control System Description. Implementation of the PCS is discussed in the **Project Execution Plan (NCSX-PLAN-PEP).** Key features of this system include the following:

- **Work is organized** through the establishment of a Work Breakdown Structure (WBS)
- **Work is planned and estimated** in a resource-loaded project schedule
- **Work is authorized** with Work Approval Forms (WAFs) that document the work scope, schedule, resource requirements, and deliverables, and identify the cognizant job manager
- **Work is tracked** by regularly comparing reported cost and schedule performance against the cost and schedule baselines as documented in the resource-loaded project schedule

## 2.3 DECISION-MAKING PROCESS

**The decision-making philosophy used on the NCSX program is allowing decisions to be made at the lowest practical levels of line management with responsibility for all the affected participants.** If a situation arises where a higher approval authority is required to resolve conflicts, the NCSX Project Manager will be the review and approval authority. The SIT shall provide guidance and coordination for the resolution of unresolved integration related issues.

# 3 SYSTEMS ENGINEERING PROCESS

The systems engineering process is a comprehensive and iterative problem solving process that is designed to transform validated user requirements and project objectives into a balanced set of product and process designs and ultimately, a functional system that optimally meets the mission requirements. Figure 3-1 depicts the systems engineering process flow. At a top level, this process can be considered as consisting of an iterative flow of effort. The requirements analysis efforts define the problem and the success criteria for a system that can address the problem. The development of alternatives, the selection of a life cycle balanced solution, and the description of the solution as a design package is accomplished via design definition and systems analysis and

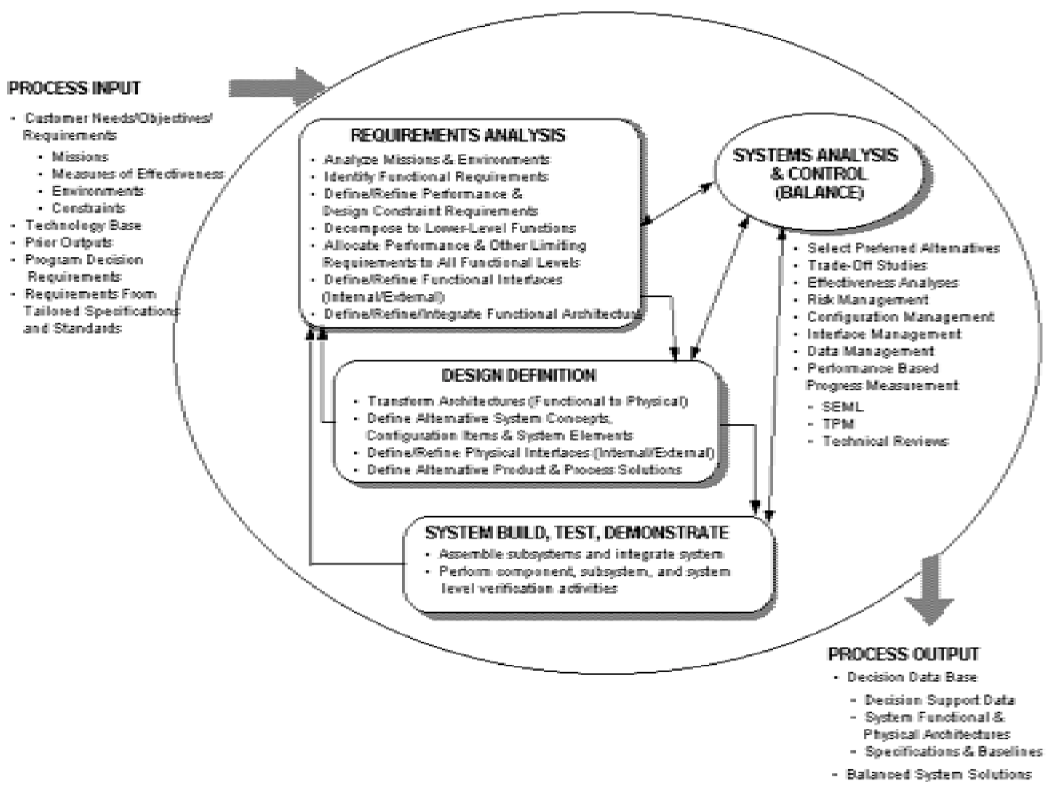


**Figure 3-1 Systems Engineering Process**

control.

As depicted graphically in Figures 3-1, the elements of this process are performed iteratively, with the products of one element feeding another. Feedback from the process output is reviewed to assure that the requirements placed on ensuing processes are compatible and executable. Through this process, the system definition evolves from initial user and project requirements into a complete design capable of satisfying the mission requirements. These elements will be further described as they are specifically tailored and implemented for the NCSX program in the sections to follow.

## 3.1 REQUIREMENTS ANALYSIS

The conceptual design of NCSX was developed through a process of trade studies, trading performance requirements (size, magnetic field, confinement, and stability) against cost and risk (manufacturability and technical feasibility). Early design concepts were based on 2-period plasma configurations with saddle coils that re-used the PBX coils. These concepts evolved to a 3-period plasma configuration with modular coils. This configuration was further evolved to generate a point design with the allocation of functions and requirements to individual subsystems. This process resulted in the General Requirements Document (GRD), which is the system (top-level) specification for the NCSX Project. Upon approval, the GRD will be placed under the control of the Change Control Board (CCB). It will be maintained through the process described in Section 3.4.

### 3.1.1 Requirements Documentation Hierarchy

Requirements for the NCSX Project are captured in a hierarchy of requirements documents, which begin with the system (top-level) requirements in the General Requirements Document (GRD). The GRD represents a complete set of performance requirements and constraints at the system level and initial subsystem allocations. The initial subsystem requirement allocations in the GRD are expanded and developed in subsystem and lower level specifications as described in Section 3.1.2. WBS Managers are responsible for the preparation and maintenance of specifications below the GRD.

The approval process for the GRD and lower level specifications is defined in the Configuration Management Plan (NCSX-PLAN-CMP). WBS Managers shall ensure that all applicable system level requirements allocated to their system elements are properly treated and accounted for and shall document the traceability of these requirements and their rationale.

### 3.1.2 Specification Approach

The NCSX Project shall develop and implement a project-specific approach for developing specifications that meets that requirements set forth in the PPPL ENG-006 "Review and Approval of Specifications & Statements of Work" Rev. 1. This approach will have the following two features:

- Specifications with different functions will have different formats. Five types of specifications have been identified for NCSX as shown in Figure 3-2.
- A specification tree shall be used to identify and plan for each specification required by the NCSX Project. WBS Managers shall provide specification tree inputs to the Project Engineering Manager for their respective system elements. For each specification, the specification tree will identify the scope, specification type, and the organization responsible for its development.

The Project Engineering Manager shall ensure that particular attention is given to the role of specifications and interface control documents in the development process. Configuration control of subsystem interface design solution agreements among WBS areas is handled through the interface control document (ICD) development process (see Section 3.6).

The Project Engineering Manager will assist the WBS Managers in aligning their configuration items and specification tree organization to be consistent with their procurement strategy, the planned design integration steps, the design qualification approach, and the component acceptance test need. The early focus on the specification tree organization assists the Project in giving attention to structuring a procurement strategy and associated specifications and statements of work that facilitate design integration, design qualification, and acceptance testing of production hardware and software. **The goal is to have as few specifications as possible,**

| SPECIFICATION | PURPOSE |
|---|---|
| SYSTEM | • Establishes the requirements for the System and characteristics of WBS elements<br>• Defines requirements based upon user's mission needs as defined in the GRD |
| DEVELOPMENT | • Allocation of development requirements to the WBS items from the system specification<br>• The performance document applicable to subcontractor's contracts<br>• Defines the methods used to verify the requirements have been met |
| PRODUCT | • Product acceptance requirements<br>• Includes design disclosure package for the fabrication requirements |
| PROCESS | • Covers manufacturing techniques that require a specific procedure in order that a satisfactory result may be achieved.<br>• Normally applies to production but may cover "process" development. |
| MATERIALS | • Prepared to control the development of a material.<br>• Normally a material spec applies to product. |

**Figure 3-2 NCSX Specification Types**

**but still have sufficient specifications to support meaningful design qualification testing and analysis and production acceptance testing**.

### 3.1.3 Requirements Allocation and Flow-down

The NCSX system requirements defined in the GRD must be allocated and flowed down into the lower-tier specifications for each system element as defined in the specification tree. Each WBS Manager is responsible for developing the lower-tier specifications for their system elements in order to support continued development and procurement as described in Section 3.1.2. **WBS Managers will capture the source and rationale of each requirement and ensure that traceability is maintained between each specification and higher-level specifications**.

### 3.1.4 Design Constraints Development

As the requirements of the GRD are primarily reflected in the form of functional or performance requirements, additional requirements in the form of design constraints must be developed to

| DESIGN CONSTRAINTS | | APPLICABILITY | | | | |
|---|---|---|---|---|---|---|
| # | CATEGORY | SYSTEM | CI XX | CI YY | CI ZZ | CI . . . |
| ... | | | | | | |
| 4.0 | ENVIRONMENTAL CONDITIONS | | | | | |
| 4.1 | NATURAL ENVIRONMENTS | | | | | |
| 4.2 | INDUCED ENVIRONMENTS | | | | | |
| 5.0 | TRANSPORTABILITY | | | | | |
| 6.0 | FLEXIBILITY AND EXPANSION | | | | | |
| 7.0 | PORTABILITY | | | | | |
| 8.0 | DESIGN AND CONSTRUCTION | | | | | |
| 8.1 | WORKMANSHIP | | | | | |
| 8.2 | PARTS, MATERIALS AND PROCESSES | | | | | |
| 8.3 | MANUFACTURING STANDARDS | | | | | |
| 8.4 | ELECTROMAGNETIC RADIATION | | | | | |
| 8.5 | INTERCHANGEABILITY | | | | | |
| 8.6 | ENVIRONMENTAL SAFETY & HEALTH | | | | | |
| 8.7 | HUMAN ENGINEERING | | | | | |
| 8.8 | SECURITY | | | | | |
| 8.9 | ETC. | | | | | |
| ... | | | | | | |

APPLICABILITY KEY

N NOT APPLICABLE
Y APPLICABLE
TBD NEEDS ANALYSIS TO DETERMINE

**Figure 3-3 Typical Design Constraint Categories**

completely define the system requirements. Design constraints are a class of non-functionally derived requirements. Requirements that do not have to be derived and cannot be modified or dropped as a result of a tradeoff study can generally be considered a constraint. For example, most requirements contained within DOE orders (e.g., DOE 6430.1A), standards, and regulations can be treated as constraints. Typical design constraint categories are shown in Figure 3-3.

The Project Engineering Manager is responsible for defining an overall project approach to the implementation of a design constraints methodology and for developing a complete set of system level design constraints for incorporation into the system specification. **WBS Managers are responsible for properly treating system level design constraints allocated to their subsystem and for any additional constraint definition that may be required.**

## 3.2 DESIGN DEFINITION AND INTEGRATION

Design definition is that point in the systems engineering process where a design concept is created to satisfy a given set of requirements. This step is performed iteratively with the requirements analysis process, resulting in increasingly more detailed design concepts as the requirements grow more detailed and become allocated to lower levels within the system. Typically, a set of alternative concepts will be developed and each in turn evaluated to develop the most cost-effective solution based on specific evaluation criteria. This process will culminate in a detailed design of the entire NCSX system including all subsystem elements.

## 3.3 RISK MANAGEMENT

Risk management is a process to assure that the system design is feasible and can be built in a timely and cost effective manner. For purposes of the risk management process, risk is defined as the probability of an undesirable event occurring multiplied by the severity of the event. Unmitigated risk could have an adverse effect on program cost and schedule.

As part of the NCSX development program, PPPL will provide a risk management program to minimize the NCSX risks. This program will provide for early identification of risk and initiation of mitigation activities. Minimization of risk will be provided through early management oversight allowing the application of additional resources or development of alternative technologies. **The Systems Integration Team (SIT) will be responsible to identify areas of risk, coordinate the development of risk mitigation plans, and monitor performance against these plans.**

## 3.4 SYSTEM BUILD, TEST, AND DEMONSTRATION

The system build process begins with design definition and continues until the system is constructed and is ready for its first demonstration. As part of the systems engineering process, the "build" of this system is an extension of the requirements analysis and design tasks for all subsystems and components.

### 3.4.1 System Build

Development models are an extension of the systems requirements allocation process. These models provide, at the top level, a hardware implementation of the design requirements as defined in the General Requirements Document (NCSX-ASPEC-GRD).

A development model of the stellarator core and facility will be provided. These models provide representations of the overall design configuration and provide the allocation of volumetric space to each of the subsystems. The models have two basic functions: a “top down” design function and a composite representation of the “bottoms up” design. The “top down” design function is accomplished in conceptual design to develop a general layout of the stellarator core and facility and to provide routing and space allocations requirements and constraints. The composite representation of the "bottoms up" design is used in conjunction with the "top down" design model to check for compliance of the "bottoms up" designs with the space allocations.

Maintenance of the development model of the stellarator core is the responsibility of WBS 1. Maintenance of the development model of the facility (which includes the model of the stellarator core provided by WBS 1) is the responsibility of Project Engineering.

### 3.4.2 System Test

System verification is accomplished through a combination of inspection, demonstration, test and analysis activities. The Project Engineering Manager will establish a cost effective approach to verifying system performance. Emphasis will be placed on the reduction of overall verification costs and timelines by performing verification at the lowest level of system assembly possible and by maximizing the number of test objectives that may be satisfied by each test. A verification compliance matrix will be developed and maintained that identifies the verification method and status of each system requirement in order to ensure that all system performance requirements, as documented in the GRD, are verified and all maintenance and operations procedures are validated.

As a large number of system requirements will require verification via test methods, an integrated test planning approach will be utilized in which the various program participants, including Engineering and WBS Managers, play a significant role. System level tests will include activities to verify that subsystems interface properly and individual performance requirements are met, as well as verifying full system operation. A Test and Evaluation Plan (TEP) will be developed and maintained by Project Engineering to establish how the integrated system testing will be performed and managed. The TEP will include an overview and schedule of the integrated system test program and the purpose, scope, and objective of each system test; test configurations; and test responsibilities.

The TEP will be developed during the early stages of the project to provide the WBS Managers knowledge as to what their system test responsibilities are and within what time frame they occur. This will enable the WBS Managers to do the long range planning necessary to support system testing. It is expected that, as the design evolves, the system test program may go through changes and the TEP will need to be updated.

In support of specific system test activities, Project Engineering will conduct test readiness reviews (TRRs), track test activities, and resolve test issues.

### 3.4.3 Demonstrations

Demonstration or prototyping of critical technologies and development hardware is a cost effective method of reducing risk and will be monitored and controlled through the Risk Management process described in Section 3.3. Demonstrations provide assurance that the system under development is feasible. Prototypes will be developed and evaluated in the earliest stages of the NCSX project to assure that the critical components of the system can be manufactured to meet performance requirements. It is recommended that the Final Design Reviews of these critical components not be considered complete until prototype demonstrations have been successfully performed.

## 3.5 CONFIGURATION MANAGEMENT

Configuration management (CM) is the process for establishing and controlling changes to cost, schedule and configuration baselines. On NCSX, **the plan for effecting configuration management is described in the NCSX Configuration Management Plan (NCSX-PLAN-CMP). Key elements of this plan are summarized in the NCSX Project Execution Plan (NCSX-PLAN-PEP).**

### 3.5.1 Data Management

Data management is provided through defined procedures and the document and drawing control systems. The Data Management Plan (NCSX-PLAN-DMP) describes the processes to be used for document and drawing control.

Project documents will be accessible to all project participants through the Internet. The NCSX Project Web site is the central facility for storage and retrieval of NCSX documents. The Web site is physically located on a PPPL file server with automated backup.

The NCSX Document and Records Plan (NCSX-PLAN-DOC) identifies the controlled documents on the NCSX Project. It defines the following:

- Identifiers of all project documents, including controlled documents and memoranda
- Approval authority for controlled documents
- Location for storage and retrieval
- Records retention requirements

Processes for effecting changes to controlled documents are described in the Configuration Management Plan (NCSX-PLAN-CMP).

NCSX will feature a single electronic database for the storage and retrieval of models and drawings. All models and drawings will exist in electronic form. Mechanical models (3D) and drawings (2D) will be generated in Pro/Engineer to facilitate the building of assemblies and to establish a single, unified database defining the NCSX facility. Electrical drawings (2D) will be generated in Pro/Engineer, AutoCAD, or other Project-approved software. **The Data Management Plan (NCSX-PLAN-DMP) describes the processes that will be used to govern the orderly development, verification, and release of models and drawings on the NCSX Project. The Data Management Plan also identifies the drawing standards that will be used on the Project. Changes to models and drawings that have been placed under configuration control will be effected through processes identified in the Configuration Management Plan (NCSX-PLAN-CMP).**

## 3.6 INTERFACE CONTROL

Interface Control is that part of system design integration that generates and administers technical agreements between two or more activities, when the products must assemble and/or function together. Working groups shall be established to support the development, modification and maintenance of selected interfaces. Interface control documents (ICDs) will be established to document both functional and physical interface characteristics. **The Interface Control Management Plan (NCSX-PLAN-ICMP) will describe the processes to be used in managing interfaces.**

## 3.7 DESIGN REVIEWS AND AUDITS

On NCSX, both external and internal design reviews are planned. **External design reviews are determined by DOE and conducted to support DOE Critical Decisions.** They are coordinated with the DOE budget cycle. Internal design reviews are determined by the Project and conducted to assess the technical adequacy of the system baseline as it is developed. Internal design reviews are scheduled when entrance criteria for the review are satisfied.

### 3.7.1 External Design Reviews

Major external reviews will be conducted to support DOE Critical Decisions. The Critical Decisions are important for determining DOE Budget Requests so the timing of major reviews is coordinated with the DOE budget cycle. Major external reviews are listed in Table 3-1. DOE determines the scope and deliverables for the major reviews. The PVR was successfully conducted in April 2001. The CDR is scheduled for May, 2002.

### 3.7.2 Internal Design Reviews and Audits

Internal design reviews are conducted to assess the technical adequacy of the configuration baseline as it is developed. These reviews verify the proper development, establishment, and control of the configuration baseline. They are used to verify conformance with requirements at the system, subsystem, and configuration item (CI) levels. They also serve as an appropriate point to update cost and schedule estimates and verify conformance with cost and schedule baselines.

Unlike external design reviews, internal design reviews may be conducted at the system level, subsystem level, or CI level, depending on the purpose of the review. Common design reviews are planned for system level reviews such as the Conceptual Design Review (CDR) and Operational Readiness Review (ORR). Internal design reviews at the subsystem and CI levels will be coordinated (but not concurrent) with the other major external reviews.

The review process is continual throughout design, fabrication, and assembly. There will be a series of specification validations and design reviews during Preliminary and Final Design as the design evolves from the system level to the CI level. During the fabrication and assembly phases, the results of tests to validate conformance with performance requirements and acceptance criteria will be audited as the facility is built up from CI level to the system level. The final review, which follows completion of integrated systems testing, will be the ORR. The design review data package, provided prior to the actual conduct of the review, will be the primary vehicle for communicating the information necessary for the review.

The overall strategy and schedule for NCSX design reviews is the responsibility of the Project Engineering Manager. The planning, preparation, and conduct of each design review are the responsibility of the cognizant WBS Manager for the system element(s) under review. Reviews held at the system level are the responsibility of the Project Engineering Manager.

#### 3.7.2.1 Systems Engineering Master Logic

Successful completion of a design review requires that the design has matured to a level appropriate for the review and that all data necessary to properly evaluate that design is complete. To facilitate this goal, a systems engineering master logic (SEML) approach will be implemented

| Design Review | Critical Decision | Date Conducted |
|---|---|---|
| Physics Validation Review (PVR) | Approval of Mission Need (CD-0) | March, 2001 |
| Conceptual Design Review (CDR) | Approval of Baseline Range (CD-1) | May, 2002 (planned) |
| Preliminary Design Review (PDR) | Approval of Performance Baseline (CD-2) | |
| Final Design Review (FDR) | Approval of Construction Start (CD-3) | |
| Operational Readiness Review (ORR) | Completion Acceptance (CD-4) | |

**Table 3-1 Major External Reviews**

for NCSX. The SEML approach is based on the identification of entry requirements that indicate readiness for a review and exit requirements that define review closeout. Success criteria are then established to provide a means to assess satisfaction of the entry and exit requirements. These data items, as captured by the SEML, establish the essential workflow for successful review of system development.

#### 3.7.2.2 Data Package Review Process

Each WBS Manager is responsible for ensuring all necessary tasks are completed in time to support the preparation of the design review data package and the review itself. Status with respect to SEML task completion will be captured in the regular work plan updates. As a goal, WBS Managers will ensure that design review data packages are scheduled for delivery 30 days prior to the start of the review. This will ensure reviewers have sufficient time to prepare chits against the data package and return them to the performing organization 15 days prior to the review. This, in turn, allows the performing organization(s) time to prepare responses that can be presented at the review.

# 4 ENGINEERING SPECIALTY INTEGRATION

## 4.1 RELIABILITY, AVAILABILITY, MAINTAINABILITY (RAM)

The NCSX RAM Plan (NCSX-PLAN-RAM) describes the requirements, functions, processes and procedures required to effectively implement a RAM Program for the NCSX Project. RAM applies to all NCSX Project hardware design, development, production, operations, and support equipment and software.

Project Engineering shall prepare, publish and maintain the NCSX RAM Plan to provide a description of how the RAM effort and tasks will be conducted and integrated into the NCSX design to ensure that quantitative reliability requirements and program objectives are met. WBS Managers are responsible for optimizing designs for reliability and maintainability through systematic evaluation of design options, and for performing failure modes, effects and criticality analysis (FMECAs) for RAM design improvement and verification. Project Engineering will conduct in-process audits and review completed WBS subsystem FMECAs to validate the adequacy of FMECA conduct.

## 4.2 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 key elements of value engineering are:

- Use of a multi-disciplinary team,
- Following a systematic job plan,
- Identifying and evaluating function, cost and worth,
- Develop and evaluate new alternatives for required functions, and
- Developing and implementing recommendations

Value engineering is best applied early in the design, typically during conceptual and preliminary design, when the system architecture is being developed and design changes can be most readily accommodated. On NCSX, value engineering methods have been applied during Conceptual Design. Specific examples include:

- Coil topology studies conducted by a multi-disciplinary team of physicists and engineers that led to the selection of modular 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

In Preliminary Design, value engineering will be conducted at the subsystem level. Project Engineering and the individual WBS Managers will review each subsystem at the start of Preliminary Design and determine what design areas would likely benefit from value engineering. These value engineering studies would be completed prior to the subsystem Preliminary Design Review (PDR).

## 4.3 QUALITY ASSURANCE (QA)

The NCSX QA program provides a framework that defines quality in terms of goals and expectations and establishes processes to fully integrate the quality function into all phases of the program by providing continual, independent, and disciplined reviews/audits of all processes, products, and services. **The Quality Assurance Plan (NCSX-PLAN-QAP) establishes the requirements for measuring and controlling work and for providing management and independent self-assessments to find, report, and solve problems.** The plan identifies implementing policies, plans, and procedures for the NCSX QA program.

While performing their assigned duties and responsibilities, workers, line management, and immediate supervisors are assigned immediate responsibility for the quality of the project's efforts. Personnel independent of the activities being performed are assigned the responsibility of verifying and validating that the project's efforts are commensurate with project standards. All personnel have a responsibility to identify quality problems and to recommend solutions.

## 4.4 PARTS, MATERIALS AND PROCESS STANDARDIZATION AND CONTROL

The purpose of the NCSX parts standardization program is to reduce the number of part types, improve system maintainability, and optimize logistics support by standardizing part types and selecting parts with two or more reliable sources wherever practical. Project Engineering will maintain a Master Parts List of NCSX parts and materials.

In addition to the Master Parts List, the NCSX Project will develop a Vacuum Materials List. A Vacuum Materials Review Committee will be established. This committee will establish the suitability of all parts and materials to be used in the plasma vacuum.

### 4.5 MANUFACTURABILITY

A Manufacturing, Inspection, and Test Plan (MITP) shall be produced for each configuration item. This plan will be the controlling document by which the manufacturability of each configuration item will be evaluated. The plan shall include a process flow diagram showing each of the major manufacturing operations. The plan will identify any special process procedures required to produce the configuration item to be fabricated. Inspection and test plans shall also be described. A draft MITP will be provided for review at the Preliminary Design Review (PDR). The MITP will be reviewed and approved as part of the Final Design Review (FDR). Cognizant WBS managers are responsible for the development of MITPs for each of their configuration items. The MITPs along with product specifications provide the technical basis for the procurement of configuration items.

### 4.6 CONSTRUCTABILITY

A Construction Manager (CM) shall be identified in Conceptual Design to provide guidance and requirements on all matters related to the on-site assembly, installation, and test of equipment in the pre-assembly area (the TFTR Test Cell) and the NCSX Test Cell and Basement. **The CM will be a member of the Systems Integration Team (SIT), provide input for risk management, and participate in all design reviews for issues of constructability.** The CM shall have discussions with designers and review designs for constructability, covering the following topics:

- Space allocations for ease of construction and maintenance
- Access for assembly
- Required assembly sequence
- Early identification and mitigation of constructability risk issues
- Design features to reduce construction costs

**During the assembly, installation, and test phase, the CM will be responsible for ALL operations in the pre-assembly area (the TFTR Test Cell) and the NCSX Test Cell and Basement, including the coordination of integrated systems testing.**

## 4.7 TRAINING

Training for the NCSX Project will lie within two primary areas. These are: Safety and Operation and Maintenance.

### 4.7.1 Safety Training

Safety training is an important aspect of the Project's program. The Project's training program will follow the PPPL policy stated in P-008 ("Staff Training"), P-028 ("Subcontractor Training Requirements for the PPPL Site"), and P-029 ("Testing for Training Courses"). Safety training will be coordinated by the PPPL Certification and Training Division and the PPPL ES&H Division.

### 4.7.2 Operations and Maintenance (O & M) Training

Cognizant WBS Managers shall be responsible for providing initial training and training materials for the operation and maintenance of the subsystems they provide. They shall create a plan to provide training on the operation and maintenance of their system. This plan shall include details of the training to be provided including documentation materials and a schedule for the training of experimenters as well as the end user operators. This plan shall be included as part of the Final Design Review Data Package and shall reviewed and approved by the NCSX Project and PPPL Management.

As an integral part of O&M activities, Project Engineering will provide training of personnel from NCSX O&M in use and maintenance of the NCSX Document and Drawing Control Systems so as to provide a seamless transition from the fabrication project to operations.

## 4.8 TECHNICAL PUBLICATIONS (O&M MANUALS, ETC.)

Project Engineering will be responsible for the collection and maintenance of a NCSX Library containing all technical publications/documents created by support organizations. This library shall contain all documentation required for the operation and maintenance of the NCSX System including plans, procedures and training materials.

Project Engineering will be responsible for coordinating of the writing and implementation of the NCSX operating and maintenance procedures. Project Engineering shall: review procedures for applicability; identify areas where these procedures are deficient; and assist in the correction/upgrades of these procedures. In addition, Project Engineering shall identify those areas where no procedures are in existence and coordinate the development of the missing procedures. Creation and maintenance of the O&M Manuals including operation and maintenance plans and procedures will be the responsibility of cognizant WBS Managers.

### 4.9 ES&H

NCSX fully subscribes to the PPPL policy on Integrated Safety Management (ISM) as indicated in the Project Execution Plan (NCSX-PLAN-PEP). PPPL will furthermore ensure that the design, development, procurement, manufacture, fabrication, construction, installation, testing, operation, maintenance, modification, and eventual decommissioning of the NCSX is accomplished in accordance with the Environment, Safety and Health (ES&H) provisions of: applicable DOE Orders and other requirements the PPPL Environmental, Safety, and Health Directives (ESHDs); environmental regulations and guidelines of the U. S. Environmental Protection Agency (EPA); and, state and local requirements.

The PPPL Environment, Safety, and Health Division (ES&HD) is the ultimate authority for ES&H on the NCSX Project, and will monitor all aspects of the project to assure that potential hazards are minimized. Potential hazards will be identified and evaluated, techniques for elimination and/or control of such hazards will be studied, alternatives will be proposed, and risks will be assessed. The goals of the ES&H function will be the accomplishment of NCSX program objectives, within reasonable and acceptable risk, and with the least practicable number of undesirable results (i.e., occurrences, incidents, accidents).

The ES&H review and approval process for NCSX will begin with review under the National Environmental Policy Act (NEPA) as prescribed by 10 CFR 1021, DOE Order 451.1B, and PPPL Procedure ESH-014. An Environmental Assessment (EA) will be prepared by PPPL and submitted to DOE-PAO and DOE-CH (including review by the New Jersey Department of Environmental Protection), and a Finding of No Significant Impact (FONSI) sought from DOE-CH. The NCSX NEPA process should be completed within about 12 months.

**ES&H review of systems designs, drawings and procedures will be conducted by the NCSX ES&H representative and other ES&H professionals throughout the course of the design**

**and installation stages**. Field removals and installation activities will be reviewed and inspected by electrical safety, industrial safety, construction safety and industrial hygiene staff. During the design stage, the NCSX Project Manager will make a determination as to the hazard level of upcoming NCSX operations, in accordance with PPPL ES&H Directive 5008, Section 11, Chapter 1. If this determination is for "High Hazard", the PPPL ES&H Executive Board will appoint an Activity Certification Committee (ACC) to perform an independent ES&H review of the NCSX Project's readiness for operation. The NCSX project, lead by the ES&H representative, will prepare a Safety Assessment Document (SAD) to provide an overview of the operation; descriptions of structures, systems and components relevant to the operation, with emphasis on environment, safety and health (ES&H) features; identification of hazards associated with the operation and methods employed for their mitigation; and a description of how operations will be conducted with emphasis on ES&H features. The SAD will be reviewed and approved by the PPPL Safety Review Committee and the ACC. Based on the its review of the SAD and operating plans and procedures, and physical walkdowns of the facility, the ACC will recommend to the PPPL ES&H Executive Board whether to issue a Safety Certificate to commence NCSX operations, including any limiting conditions (see ES&H Directive 5008, Section 11, Chapter 2). DOE will likely conduct its own review of operational readiness before allowing NCSX first plasma operations. Any Project modifications after first plasma that require changes to the approved Safety Certificate will require additional ACC reviews.