National Spherical Torus Experiment (NSTX) Upgrade
Project Execution Plan

Revision 3

October 12, 2012

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Record of Revisions

Revision	Date	Description of Changes
A	1/11/10	PPEP Initial Issue by PPPL & PSO, but not approved by OFES
B	4/5/10	PPEP Cost and schedule range & comments by SC-OPA
C	6/10/2010	Final PEP Draft
D	7/30/2010	Cost and schedule updates
E	11/24/10	Lehman review comment incorporation including cost/schedule baseline updates
1	6/22/2011	OBS (page 6)and WBS (page 37-39) updates, and variance thresholds (page 20)
2	10/12/2012	Update to WBS Level 2 Threshold (top of page 20), Change DOE Federal Project Director and Deputy Federal Project Director. Various OBS changes.

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1. INTRODUCTION AND SCOPE OF THIS DOCUMENT

1.1 Introduction

The National Spherical Torus Experiment (NSTX) is an experimental research facility funded by Fusion Energy Sciences (FES) that is operating at the Department of Energy's Princeton Plasma Physics Laboratory (PPPL).

The scope of the NSTX Upgrade Project includes design, fabrication, installation, and integrated system testing for the systems affected by the project. The Department of Energy has identified the NSTX Upgrade Project as a Major Item of Equipment (MIE) Project instead of a Line Item construction project. The device will be located 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 NSTX Upgrade Project device, with only minor additional ancillary equipment needed.

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 NSTX Upgrade Project. DOE Order 413.3B will provide the basis for the overall management of the Project.

1.2 Key Documents

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

1.2.1 DOE-approved project documents:

Acquisition Strategy (AS)--The Acquisition Strategy describes how the project as defined is consistent with the DOE's strategic goals, plans, and objectives, and how it meets those goals, plans, and objectives cost effectively and efficiently.

Project Execution Plan (PEP)--The Project Execution Plan is a required baseline project document that establishes roles and responsibilities, and describes in detail the manner in which a project is to be managed and executed. The PEP serves as the primary agreement on project planning and objectives between FES, the Federal Project Director, and PPPL.

1.2.2 DOE certified institutional systems or plans:

PPPL Project Management System Program Description (PMSPD)--Describes PPPL's system for planning, authorizing, and tracking project work.

PPPL Integrated Safety Management Plan (ISMP)--Describes the structure and implementation of Integrated Safety Management at PPPL, consistent with DOE policy, requirements, and guidance.

1.2.3 NSTX Upgrade Project approved documents:

General Requirements Documents (GRDs)--The GRDs define the overall engineering requirements for the NSTX Upgrade Project.

2. MISSION NEED JUSTIFICATION / PROJECT OBJECTIVES

2.1 Mission Need

An improved understanding of the Spherical Torus (ST) magnetic confinement configuration is needed to establish the physics basis for next-step ST facilities, broaden the scientific understanding of plasma confinement for ITER, and maintain U.S. world leadership in ST research capabilities. In particular, operation at higher magnetic field with reduced plasma collisionality is needed to extend the plasma physics understanding of the ST toward next-step ST facilities and ITER. Controllable fully-non-inductive current-drive will also contribute to assessing the ST as a potentially cost-effective path to fusion energy.

The NSTX Upgrade Project mission need (Critical Decision 0) was approved by the acting Director of the Office of Science (acting SC-1) in February 2009.

The Alternate Selection and Cost Range (Critical Decision 1) was approved by the Deputy Director for Science Programs Office of Science April 10, 2010.

2.2 Project Objectives

The key technical objectives of the NSTX Upgrade Project are as follows:

2.2.1 Technical Performance Baseline Parameters

To meet the mission need objective, the existing NSTX machine at PPPL will be upgraded to permit operation at the following increased levels;

- Toroidal field from 0.5 tesla to 1.0 tesla;
- Pulse length from ~1.0 second to 5.0 seconds;
- Plasma current from 1MA to 2MA;
- Neutral beam heating from 5-7MW to 10-14MW.

2.2.2 Project Completion Criteria

2.2.2.1 Scope

The scope includes Title I through Title III engineering, fabrication, assembly and installation, integrated systems testing, and project management associated with producing the in-scope equipment to meet the baseline parameters outlined above. The scope consists of two primary elements:

Center Stack (CS) Upgrade. Design, build and install new CS assembly including a new toroidal field (TF) hub assembly, new TF flag assemblies, new ceramic break, new inner TF bundle, new ohmic heating coil, new inconel casing and insulation, new plasma facing component (PFC) tiles, and new poloidal field (PF) 1a, b & c coils.

2nd Neutral Beam-line (NBL). Decontaminate and prepare a TFTR neutral beam-line (NBL) for installation on NSTX. Evaluate and refurbish internal components as necessary (cryogenic panels, beam dumps, bending magnets, beam scrapers, calorimeter, etc.). Relocate the NBL and provide a second set of beam-line services (e.g., power, water, vacuum, cryogenics, etc.).

2.2.2.2 Demonstrated Performance

The major milestone marking the transition from a fabrication project to an operating facility is the first plasma milestone (CD-4). First plasma is defined as an ohmically heated discharge > 50 kA at a toroidal magnetic field of > 1 kG. The operations phase will resume upon completion of the first plasma milestone.

The installation of the second neutral beam on NSTX shall be considered complete at the stage where each item below has been demonstrated:

a. Beamline water, vacuum, cryogenics, and feedstock gas services have been attached to the beamline;

b. A Torus Isolation Valve and duct interconnects the NSTX vacuum vessel and the neutral beamline;

c. Local Control Centers have been powered on to monitor power supply status, and;

d. Project will be verified as complete when a 40,000 electron-volt beam has been produced and injected into the armor for .050 seconds

2.2.3 Fabrication Project Cost

As indicated in Section 1.1 of this PEP, the NSTX Upgrade 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-2 request, a baseline total project cost (TPC) of $94.3 for the project has been established as shown in Table 1 below:

NSTX UPGRADE BASELINE COST ESTIMATE ($M)								
						OUTAGE		
	CD-2 TOTAL	FY 2009 Actual Cost	FY 2010 Actual Cost	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Base Estimate =	**$77.3**	**$5.1**	**$8.3**	**$8.7**	**$12.0**	**$20.7**	**$22.5**	**$0.0**
Contingency % =	**27%**			*11%*	*22%*	*22%*	*23%*	
Contingency	**$17.0**			$0.9	$2.7	$4.5	$5.1	$3.8
Baseline Plan =	**$94.3**	**$5.1**	**$8.3**	**$9.6**	**$14.6**	**$25.3**	**$27.5**	**$3.8**
	Available Funding =			**$9.6**	**$14.6**	**$25.3**	**$27.5**	**$28.0**

Table 1: NSTX Upgrade Project Funding Profile.

The cost and schedule shown above assumes the following:

- The extended maintenance period at the beginning of FY12 does not require a machine vent, or;
- No major repairs or upgrades are required after the FY11 run.

The Project's cost and schedule baseline are supported by bottom-up estimates of costs, task durations, and risk-based contingencies, whose technical basis is consistent with the performance and scope parameters. The implementation of changes in the baseline will be made in accordance with the change control procedures and approval thresholds specified in this Project Execution Plan at CD-2.

2.2.4 Fabrication Project Schedule

The Project's schedule objective is to complete the project by September 2015 which includes 12 months of schedule contingency. The DOE level I & II milestones are summarized below. It should be noted that these milestones assume early award of critical long lead procurements as defined in Section 11.2 of this PEP.

DOE Level I Milestones

Receive CD-1 approval..... Apr-2010 (A)
Receive CD-2 approval..... Jan-2011
Receive CD-3 approval..... Jan-2012
CD-4 Project Complete..... Sep-2015

DOE Level II Milestones

Project preliminary design review	Jun-2010 (A)
Neutral beam #2 decontamination program complete	Nov-2010 (A)
Project final design review	Sep-2011
Friction stir-weld coil leads TF conductors	Jun-2012
NSTX completes operations	Jul-2012
Begin upgrade outage	Aug-2012
Begin inner TF fabrication (apply turn insulation #1 quadrant)	Apr-2013
Neutral beam vacuum vessel port cap awarded	Jun-2013
Complete assembly and pot of 4th inner TF quadrant	Oct-2013
Complete fab & test inner TF/OH coil assembly	Jun-2014
Neutral beam cap installed	Oct-2014
Lift in new centerstack	Jan-2015
Complete ISTP	Aug-2015
Resume operations	Sep-2015

2.2.5 Project Close-out

As required by DOE, a Project Close-out Report will be prepared and submitted to the Federal Project Director within six months of completion of the Project. This report will provide the following information:

- Scope, cost and schedule baseline accomplishments;
- Financial closeout, including a final cost report;
- The technical performance of the systems at project completion;
- Itemized changes in cost, schedule, and technical parameters as compared to the initial baseline (baseline change control log), and;
- Subcontract closeout status.

3. MANAGEMENT STRUCTURE AND RESPONSIBILITIES

3.1 NSTX Upgrade Project Organization

The NSTX Upgrade Project is being executed by the Princeton Plasma Physics Laboratory (PPPL) for Fusion Energy Science. Figure 1 depicts the organizational structure from the DOE Acquisition Executive to the NSTX Upgrade Project Management team.

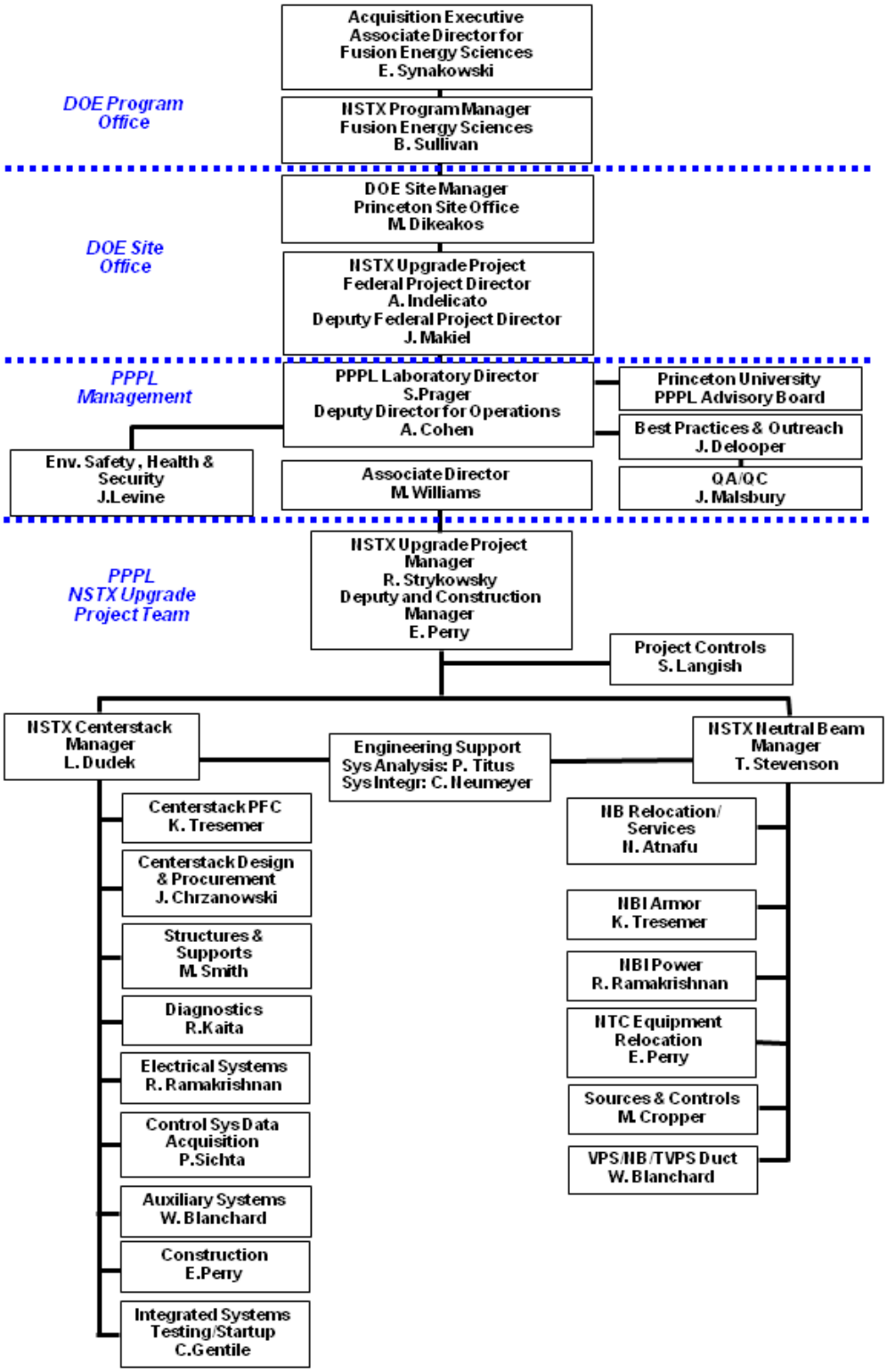

Figure 1: Organizational Structure between the DOE Program Office and PPPL.

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

3.1.1 U.S. Department of Energy (DOE)

Within the DOE, the responsibility for the NSTX Upgrade Project resides in Fusion Energy Science (FES). FES will also maintain executive level awareness of project progress, and an FES NSTX Upgrade Project Program Manager has been assigned. The management responsibility, authority, and accountability for the day-to-day execution of the NSTX Upgrade Project within the DOE are the responsibility of the Manager of the Princeton Site Office (SC-PSO), who has designated a DOE Federal Project Director and a Deputy Federal Project Director for the NSTX Upgrade Project.

The Associate Director for Fusion Energy Sciences has been designated as the Acquisition Executive (AE) for the NSTX Upgrade Project. The responsibility of the AE includes:

- Approve Critical Decisions (with the exception of CD-0 which was approved by Acting SC-1);
- Approve PEP;
- Approve appointment of the FPD, and;
- Conduct quarterly project reviews.

The FES NSTX Upgrade Project Program Manager 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, and;
- Responsible for project oversight at an executive level.

The NSTX Upgrade Project Federal Project Director (SC-PSO) is responsible to the Acquisition Executive/Program Secretarial Office for overseeing the execution of the project. The Federal Project Director is responsible for:

- Ensuring that the planning, implementing, and completing of the project is based on a systems engineering approach;
- Organizing and directing the Integrated Project Team (IPT) that is comprised of both DOE and NSTX Upgrade Project team personnel to implement and achieve the overall project objectives and goals;
- 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 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 NSTX Upgrade Project and its execution;
- Performing all required project status reporting to DOE HQ organizations and database management systems;
- Evaluates and verifies reported progress; makes projections of progress and identifies trends, and;
- Serving as the Contracting Officer's technical representative.

The NSTX Upgrade Deputy Federal Project Director is responsible for acting on behalf of and providing support to the Federal Project Director.

3.1.2 Performing Organizations

3.1.2.1 Princeton Plasma Physics Laboratory (PPPL)

PPPL has overall responsibility for NSTX Upgrade Project execution, reporting to DOE through the Laboratory Director. The NSTX Upgrade Project reports directly to the PPPL Associate Laboratory Director for Engineering and Infrastructure. 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.

3.1.2.2 Other Organizations

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

3.2 NSTX Upgrade Project Management Team

Key project positions and responsibilities are as follows:

3.2.1 Senior Laboratory Managers

3.2.1.1 PPPL Director

The PPPL Director has overall responsibility to DOE for the execution of the NSTX Upgrade Project. The PPPL Director is supported by the Deputy Director for Operations and the Associate Laboratory Director for Engineering and Infrastructure.

3.2.1.2 NSTX Upgrade Project Office

The NSTX Upgrade Project Office is headed by the NSTX Upgrade Project Manager, who reports to the Associate Laboratory Director for Engineering and Infrastructure.

3.2.2 NSTX Upgrade Project Management Team

3.2.2.1.a NSTX Upgrade Project Manager

The NSTX Upgrade Project Manager is responsible for the day-to-day execution of the NSTX Upgrade Project in a safe and 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. The Project Manager will instill a culture of personal accountability within the project team, focusing on driving schedule, without compromising safety and quality. The Project Manager is the Project's primary point of contact with DOE and with the Program Advisory Committee. The Project Manager reports to the Associate Laboratory Director for Engineering and Infrastructure.

3.2.2.1.b NSTX Upgrade Deputy Project and Construction Manager

The NSTX Upgrade Deputy Project Manager is responsible for acting on behalf of and providing support to the Project manager with specific responsibility of:

- Risk management including maintaining the risk registry;
- Oversee maintenance of the overall general arrangement drawing system;
- Coordinate and supervise all construction activities and;
- Coordination and ensure implementation of the project recommendations and implementation log.

3.2.2.2 Centerstack Upgrade Engineering Manager

The Centerstack Upgrade Engineering Manager is responsible for carrying out the centerstack upgrade engineering, design and fabrication to meet requirements specified in the General Requirements Document for the Centerstack Upgrade and the requirements called out in the Project Execution Plan. The Centerstack Upgrade Engineering Manager reports to the Project Manager. Additionally, the Centerstack Upgrade Engineering Manager is responsible for cost and schedule performance and providing technical direction to the job managers.

3.2.2.3 Second Neutral Beam Engineering Manager

The Second Neutral Beam Engineering Manager is responsible for carrying out the second neutral beam upgrade engineering, design, decontamination, rework and fabrication to meet requirements specified in the General Requirements Document for the Second Neutral Beam and the requirements called out in the Project Execution Plan. The Second Neutral Beam Engineering Manager reports to the Project Manager. Additionally, the Second Neutral Beam Engineering Manager is responsible for cost and schedule performance and providing technical direction to the job managers.

3.2.2.4 Job Managers

The Job Manager is responsible for estimating, executing and managing the work scope consistent with technical, cost, and schedule objectives defined within each job. The WBS manager is responsible for overseeing and supervising multiple jobs within the WBS.

3.2.2.5 NSTX Upgrade Project Control Manager

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

The NSTX Upgrade Project Control Manager's responsibilities include:

- Coordinating the development of project plans and administering the centralized work authorization system;
- Maintaining up-to-date NSTX Upgrade Project 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, and;
- 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 NSTX Upgrade Project. Assisting the Project Engineering Managers in administering the operation of the NSTX Upgrade Project 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.

3.2.2.6 Engineering Support Team

The Engineering Support Team reports to the NSTX Upgrade Engineering Managers and is responsible for engineering support activities, including:

- Systems Engineering;
- Design Integration;
- Systems Analyses and Technical Assurance, and;
- Metrology Coordination.

3.2.2.7 Quality Assurance (QA)

The PPPL Quality Assurance Division will support the NSTX Upgrade Project Manager. The QA Division will assist the project in meeting quality assurance/control objectives. Support tasks include:

- Preparing vendor specific QA plans;
- 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;
- Performing both compliance-based and performance-based audits of the project and its associated plans and procedures, and;
- Coordinate DCMA inspections on project industrial subcontracts. Provide assurance to DOE-PSO of DCMA activity and deliverables.

3.2.2.8 ES&H

The PPPL ES&H Division will support the NSTX Upgrade Project Manager. The ES&H Division 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. The ES&H Division will assist in implementing PPPL ES&H policies and procedures. The ES&H Division will also prepare any required National Environmental Policy Act (NEPA) documentation and necessary revisions to the NSTX Safety Assessment Document (SAD). It should also be noted that there are separate lines of reporting to the PPPL's Deputy Director for Operations for items involving overall QA and ES&H impact.

3.3 Program Advisory Committee

Advice by the U.S. fusion community on the NSTX Upgrade Project's scientific and technical issues is obtained through the NSTX Program Advisory Committee (PAC). The NSTX PAC is composed of a broad spectrum of technical experts from the U.S. fusion community. The NSTX PAC provides this advice to the PPPL Director. It meets periodically at the request of the PPPL Director.

3.4 Integrated Project Team

The NSTX Upgrade Project Integrated Project Team (IPT) is made up of key DOE, PPPL and NSTX Upgrade Project Team personnel. The IPT is led by the NSTX Upgrade Project 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 DOE Project Federal Project Director
- The DOE Deputy Federal Project Director
- The DOE-OFES NSTX Upgrade Project Program Manager
- The PPPL Associate Laboratory Director for Engineering and Infrastructure

- The NSTX Overall Project Director
- The NSTX Overall Program Director
- The NSTX Upgrade Project Laboratory Project Manager
- The NSTX Upgrade Project Laboratory Deputy Project Manager
- The PPPL Procurement Manager
- The PPPL Quality Assurance Manager
- The PPPL ES&H Manager
- The NSTX Upgrade Project Control Manager
- The NSTX Program Control Manager
- The NSTX Centerstack Upgrade Engineering Manager
- The NSTX Second Neutral Beam Engineering Manager

Other DOE, PPPL and NSTX Upgrade Project Team personnel may be added as the need arises in order to accomplish the NSTX Upgrade Project objectives. For example, as the NSTX Upgrade 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.

4. WORK BREAKDOWN STRUCTURE (WBS)

The WBS organizes the NSTX Upgrade Project work scope and provides the logical structure that will be used to control the project. The WBS is composed of as few levels as required for work definition and control. All the WBS elements are expanded and completely defined in the WBS dictionary in Appendix 1. The WBS Dictionary entry for each WBS element contains a brief description of the work scope for each element.

5. RESOURCE PLAN

5.1 NSTX Upgrade Project Costs

As indicated in Section 1.1 of this PEP, the NSTX Upgrade Project has been designated by the Department of Energy as a Major Item of Equipment (MIE) and will be funded primarily with Capital Equipment Funds. As a result of this decision, the overall cost objective that encompasses all project work scope as defined in Appendix 1.

5.2 Life Cycle Costs

The NSTX Upgrade Project life-cycle costs are in Table 2 below:

	No Upgrade Project	Upgrade Project
Initial Investment	$0M	$94M
Machine Operations (yrs.)	9	9
Ops & Maintenance	$419	$419
D&D	$11	$17
	$430	$539

Table 2: Life Cycle Cost Comparison

Note on Research Operations: Operations costs for NSTX are only expected to increase modestly because of the upgrades (minor additional costs for operating a second neutral beam).

A more detailed life cycle analysis is provided in Table 3-1 of the NSTX Upgrade Project Acquisition Strategy.

6. PROJECT BASELINES

The initial NSTX Upgrade Project configuration, schedule, and cost baselines were developed in the conceptual design phase of the project. Section 6.1 addresses the management and control of the configuration baseline, (sometimes also called the technical baseline). The project baseline comes under the configuration control processes that are outlined in Section 7 of this PEP.

6.1 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 Documents, are approved.

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 (CSPECS and PRLs) 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.

6.2 Cost and Schedule

The DOE schedule milestones are documented in this preliminary PEP as indicated in Section 2. The supporting budget estimates by WBS are tabulated in Table 3 below (Cost by WBS).

NSTX UPGRADE BASELINE COST ESTIMATE ($M)				
DESCRIPTION	CD-2 TOTAL	CONTINGENCY	TOTAL TPC	cont % on etc from 10/1/2010
Job: 1000 - CSU Analytical Support-TITUS	$0.4	$0.1	$0.5	40%
Job: 1001 - CS Plasma Facing Components-TRESEMER	$2.2	$0.5	$2.7	29%
Job: 1002 -Passive Plate Analysis &Upgrade-TITUS	$0.3	$0.0	$0.3	34%
Job: 1200 - Vacuum Vsl & Struct Support-SMITH	$1.5	$0.0	$1.5	-
Job: 1201 - Outer TF Structures-SMITH	$0.7	$0.2	$0.9	23%
Job: 1202 - Outer PF2 Coil Structures-SMITH	$0.0	$0.0	$0.0	22%
Job: 1203 - PF3 Support.-SMITH	$0.0	$0.0	$0.0	24%
Job: 1204 - PF4/5 Leads & Radial Supports-SMITH	$0.0	$0.0	$0.0	29%
Job: 1205 - Umbrella-SMITH	$0.6	$0.1	$0.7	13%
Job: 1206 - Pedestal -SMITH	$0.1	$0.0	$0.2	26%
Job: 1207 - Vessel Legs -SMITH	$0.0	$0.0	$0.0	21%
Job: 1208 - PF4&5 Verticle Support-SMITH	$0.3	$0.1	$0.3	27%
Job: 1220 - Misc Structural Design-SMITH	$0.2	$0.1	$0.3	43%
Job: 1300 - Center Stack-CHRZANOWSKI	$1.1	$0.1	$1.2	10%
Job: 1301 - Outer TF Coils-CHRZANOWSKI	$0.3	$0.1	$0.4	33%
Job: 1303 - TF Joint Test Stand&Test-KOZUB	$0.4	$0.1	$0.4	30%
Job: 1304 - Inner TF Bundle (Ds/Fab)-CHRZANOWSKI	$2.6	$0.8	$3.4	36%
Job: 1305 - OHMIC Heating Coil (OH)-CHRZANOWSKI	$4.6	$1.5	$6.1	48%
Job: 1306 - Inner PF Coils-CHRZANOWSKI	$0.7	$0.2	$0.8	29%
Job: 1307 - CS Casing Assembly -CHRZANOWSKI	$0.9	$0.2	$1.1	29%
Job: 1310 - CSU Magnet Systems-CHRZANOWSKI	$0.4	$0.0	$0.4	0%
Job: 1302 - Center Stack Assembly-CHRZANOWSKI	$1.0	$0.3	$1.3	28%
Job: 2300 - ECH Analysis-TITUS	$0.1	$0.1	$0.1	103%
Job: 2420 - 2nd NBI Sources-CROPPER	$1.1	$0.2	$1.3	16%
Job: 2425 - BL Relocation-DENAULT	$1.9	$0.3	$2.1	14%
Job: 2430 - 2nd NBI Decontamination-STEVENSON	$2.1	$0.0	$2.1	15%
Job: 2440 - 2nd NBI Beamline-DENAULT	$2.6	$0.4	$3.0	14%
Job: 2450 - 2nd NBI Services-DENAULT	$4.5	$1.0	$5.5	23%
Job: 2460 - 2nd NBI Armor-PRINISKI	$0.7	$0.1	$0.8	24%
Job: 2470 - 2nd NBI Power-RAKI	$3.3	$0.6	$3.9	18%
Job: 2475 - 2nd NBI Controls-CROPPER	$2.1	$0.3	$2.3	12%
Job: 2480 - 2nd NBI/TVPS Duct-PRINISKI	$2.3	$0.5	$2.7	25%
Job: 2485 - Vacuum Pumping System-PRINISKI	$0.4	$0.1	$0.4	16%
Job: 2490 - NTC Equipt Relocations-PERRY	$3.6	$0.6	$4.2	17%
Job: 3200 - Water Cooling System Mods-DENAULT	$0.2	$0.0	$0.2	10%
Job: 3300 - Bakeout System Mods for CSU-RAKI	$0.1	$0.0	$0.1	20%
Job: 3400 - Gas Delivery System Mods-BLANCHARD	$0.1	$0.0	$0.1	22%
Job: 4100 - Center Stack Diagnostics-KAITA	$0.8	$0.1	$1.0	17%
Job: 4500 - MPTS VV Modification -LABIK	$0.9	$0.3	$1.2	33%
Job: 5000 - CSU Power Systems-RAKI	$1.1	$0.0	$1.1	0%
Job: 5001 - AC Power-RAKI	$0.2	$0.0	$0.2	10%
Job: 5002 - AC/DC Converters-RAKI	$0.1	$0.0	$0.1	10%
Job: 5003 - FCPC PF5 DC Systems-RAKI	$0.0	$0.0	$0.0	0%
Job: 5004 - TA-NTC DC Systems-RAKI	$0.1	$0.0	$0.1	25%
Job: 5005 - FCPC DC PF1 & TF Systems-RAKI	$1.7	$0.4	$2.1	24%
Job: 5006 - Control & Protection-RAKI	$1.9	$0.3	$2.2	16%
Job: 5007 - Systems Design & Integration-RAKI	$0.7	$0.1	$0.7	10%
Job: 5008 - Digital Coil Protection-RAKI	$2.5	$1.0	$3.5	41%
Job: 5501 - Coil Bus Runs-SMITH	$1.1	$0.3	$1.4	29%
Job: 6100 - Control Sys Data Acquisition -SICHTA	$0.9	$0.2	$1.1	20%
Job: 7100 - Project Mgt & Integration-STRYKOWSKY	$5.8	$0.5	$6.3	11%
Job: 7200 - Center Stack Management-DUDEK	$1.5	$0.2	$1.7	15%
Job: 7300 - NB2 Management-STEVENSON	$1.5	$0.2	$1.6	14%
Job: 7400 - Health Physics Support-STEVENSON	$2.5	$0.3	$2.8	14%
JOB: 7700 - NSTX-U HP Allocations-STRYKOWSKY	$2.6	$0.3	$2.9	14%
Job: 7710 - Upgrade Allocations-STRYKOWSKY	$0.4	$0.1	$0.4	143%
Job; 8200 - CS & Coil Sprt Struc Install- VIOLA	$6.5	$2.3	$8.7	35%
Job: 8250 - Remove/Install Centerstack-PERRY	$1.2	$0.2	$1.4	20%
Job: 7900 - Integrated System-GENTILE	$0.1	$0.0	$0.1	25%
schedule contingency=		$2.0	$2.0	
Base Estimate(early schedule)=	$77.3	$17.0	$94.3	
Contingency % =		27%		

Table 3: Budget Estimate by WBS

7. CONTROL OF PROJECT BASELINES

7.1 Configuration Management Approach

Changes to the NSTX Upgrade Project configuration, cost, and schedule baselines are controlled using a disciplined, yet flexible configuration management approach. Changes to the baseline are carefully considered and evaluated for impact before proceeding. Processes for effecting changes to the configuration, cost, and schedule baselines are described below.

7.2 Change Control Process

The NSTX Upgrade Project change control process ensures that changes to the NSTX Upgrade Project 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 be forwarded to the project Change Control Board (CCB) that is comprised of senior members of the NSTX Upgrade Project management team. The NSTX Upgrade Project Manager or his designee will chair the CCB. The NSTX Upgrade Project 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:

- NSTX Upgrade Project Control Manager;
- NSTX Upgrade Project Engineering Managers;
- WBS Managers;
- ES&H representative;
- QA representative, and;
- 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 NSTX Upgrade Project web site.

7.3 Change Control Levels

Changes to the NSTX Upgrade Project 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. Program directed changes will be approved at an appropriate level as determined within the Office of Science. For project baseline deviations, Table 4 below summarizes the performance baseline change authority for the Deputy Secretary of Energy (Level 0), the Associate Director of Fusion Energy Sciences (Level 1), the NSTX

Upgrade Project Federal Project Director (Level 2), and the NSTX Upgrade Project Laboratory Project Manager (Level 3).

Change Level	Approval Level	Technical Scope	Schedule	Cost
0	**Deputy Secretary of Energy**	Any change in scope and/or performance that affects mission need requirements as show in Section 2.2.2 or is not in conformance with the current approved OMB-300.	6 month or greater increase (cumulative) in the original project completion date as show in Section 2.2.4.	Increase in excess of 25% (cumulative) of the original cost baseline as show in Table 1**,** Section 2.
1	**Director of Science, SC-1**	Changes to technical requirements and parameters that affect safety basis and operation function, but do not affect mission need objectives**.**	Less than a 6 month increase (cumulative) in the original project completion date as show in Section 2.2.4.	Increase of the original cost baseline as show in Table 1**,** Section 2.
2	**NSTX Upgrade Project Federal Project Director**	Changes with ES&H impacts significant enough to affect the approved NEPA/EA documentation**.**	Change in DOE level II milestones discussed in Section 2.2.4	Changes requiring the use of contingency funds as referenced in Table 1, Section 2.
3	**NSTX Upgrade Project Manager**	Changes not requiring DOE approval**.**	All other changes to the performance measurement baseline that do not affect level II milestones.	All other changes to the performance measurement baseline costs not requiring DOE approval.

Table 4: NSTX Upgrade Project Change Classification Matrix.

7.4 Contingency Management Plan

The amount of contingency established at the beginning of the project is based on a risk assessment performed as part of the cost estimating process. Total cost contingency includes 3 elements: 1) a task-by-task subjective contingency assessment for unknowns; 2) a weighted assessment of tabulated risk events, and; 3) schedule contingency applied to the "standing army". Schedule contingency (in months) was calculated by applying the task-by-task contingencies to the task durations to calculate the longest path within the project. This was offset partially by the option of using second shift and overtime to maintain schedule. The initial project contingency level will be approved by the Associate Director for Fusion Energy Sciences as the Acquisition Executive for NSTX Upgrade Project at CD-2 as part of establishing the overall cost and schedule baseline.

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 NSTX Upgrade Project DOE Federal Project Director 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 NSTX Upgrade Project Manager will assess the status of authorized work, achieved milestones, and current and future risks, to determine how to utilize unused contingency set-aside. 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.

7.5 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 NSTX Upgrade Project will apply VE methodologies following a tailored approach to the formal elements of VE. The NSTX Upgrade Project approach will include:

- Using a multi-disciplinary team to identify and assess alternates;
- Following a systematic job planning process;
- Identifying and evaluating function, cost and worth;
- Developing and evaluating new alternatives for required functions, and;
- Developing and implementing recommendations.

The NSTX Upgrade Project has applied value engineering methods from early on 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.

8. Project Management and Control Systems

8.1 Project Management Systems Approach

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

The NSTX Upgrade Project Manager will work to ensure early detection of technical, schedule or cost problems.

8.2 Project Control System Overview

The NSTX Upgrade Project will use the existing PPPL PMSPD. The PPPL PMSPD satisfies the principles of project management and control systems outlined in this PEP and DOE Order 413.3B ("Program and Project Management for the Acquisition of Capital Assets"). The PMSPD provides a centralized work authorization system that the project will use.

The PMSPD describes 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 NSTX Upgrade Project work, costs, and schedules. The overall objective of the PMSPD 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 PMSPD 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) and Work Authorization Document (WAD);
- 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. 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 Level III schedule milestones and cost targets. The vehicle for documenting and authorizing work is the Work Authorization Form (WAF). The WAF formally documents the work scope to be performed, establishes a schedule, provides a resource estimate, identifies a responsible person for accomplishing the work, and defines the estimate uncertainty and risks.

8.3 Cost and Schedule Reviews

The Project schedules quarterly reviews and/or reports of Project status with the NSTX Upgrade Project Federal Project Director and the FES Management. These reviews will focus on cost and schedule aspects of the project. 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 Performance Measurement Baseline. This recommendation will be documented in the form of a formal change. In addition, as needed to support Critical Decision milestones, or as requested by the NSTX Upgrade Project Acquisition Executive, these reviews may be expanded to include external reviewers organized by the Office of Science Office of Project Assessment, (i.e., the "Lehman" Review).

Every six months a bottom-up estimate at completion (EAC) will be performed for the entire project. This may involve the re-scheduling of work previously scheduled but not completed. This is done in order to ensure that the current performance measurement baseline remains up-to-date and consistent with the approved performance baseline parameters (TEC, completion date, etc.), and remains a reliable basis for budgeting, resource planning, and measurement of future performance.

8.4 Reporting

Quarterly project reports to OFES are prepared by the NSTX Upgrade Project Federal Project Director. All monthly progress status will be provided to the NSTX Upgrade Project Federal Project Director. The data should include, but not limited to, the following:

- Actual cost of work performed (ACWP) - cumulative and incremental for overall project and lower tier WBS work packages;
- Budgeted cost of work performed (BCWP) - cumulative and incremental for overall project and lower tier WBS work packages;
- Budgeted cost of work scheduled (BCWS) - cumulative and incremental for overall project and lower tier WBS work packages;
- Schedule variance (SV) and cost variance (CV) with explanation and planned corrective action;
- Cost performance indices (CPI) and schedule performance indices (SPI) (cumulative and incremental) for overall project and lower tier 3 active WBS work packages;
- Cost and schedule contingency analysis reconciled against CV and SV with an updated risk registry changes;
- Critical path analysis and near term 'look ahead', and;
- Status of near term Level 2 milestones.

- Explanations of variance to plan will be submitted to the FPD and into PARS II on a monthly basis when any WBS level 2 cumulative to date variance exceeds the following thresholds:

  SV +40% or -10% or >$50K and > 10% of BAC or any impact on any DOE Level 1 or 2 Milestone

  CV +15% or -10% or > $50K. and > 10% of BAC

If a WBS level II VAR is required the VAR will be prepared at the control account level for those CA's that drive the WBS II variance. The project manager may also selectively, at his/her discretion, request VAR's for CA's that he/she feels requires further explanation even if the WBS Level II threshold has not been exceeded.. Currently, The DOE NSTX Upgrade Project Federal Project Director is responsible for entering monthly performance data and narrative into the DOE Project Assessment and Reporting System II (PARS II) database. The project office will ensure input to and compliance with future changes to the PARS II system as they arise and are finalized.

9. Funds Management

9.1 Project Funding Mechanisms

All project work and expenditure of project funds will be centrally authorized and controlled by the project office via the PMS. The annual NSTX Upgrade Project funding requirements will be updated each year by PPPL through the DOE Field Work Proposal (FWP) processes. All funds authorized for the Project by the DOE Financial Plan will be disbursed to the Project. Changes requiring the application of contingency, will be handled via the change control process defined in Section 7 and will, as stated there, require DOE Federal Project Director or higher DOE approval.

10. RISK MANAGEMENT

"Risk" refers to factors within the Project's control that both threaten and provide opportunities to improve project cost and schedule performance and the achievement of project technical objectives. The NSTX Upgrade Project Manager will manage risks. Risk will be documented in a risk registry which will be updated at least monthly via the normal project status meeting, technical meetings and as part of normal project communications. During all phases of the NSTX Upgrade Project, priority is placed on identifying and mitigating risks. Risk mitigation activities are incorporated into the project's cost and schedule baselines, as appropriate. Contingency is used to address realized risks that could not be mitigated. A quantitative, analysis of outstanding risks and estimating uncertainties is used to estimate the amount of contingency required.

Control of the environment, safety, and health hazards, while part of risk management in a broader sense, are not unique to the NSTX Upgrade Project and are enveloped by the Princeton Plasma Physics Laboratory (PPPL) Integrated Safety Management (ISM) program that is

applicable to all PPPL projects and operations. The PPPL ISM clearly indicates that risk management is everybody's business and will be factored into every project decision throughout the life of the NSTX Upgrade Project. The PPPL ISM program is discussed further in Section 14.

While any member of the NSTX Upgrade Project Team is expected to identify risks that become apparent, the responsibility for risk management for the NSTX Upgrade Project rests with the NSTX Upgrade Project line management.

Details of the Risk Management Plan for the NSTX Upgrade Project are in Appendix 2.

11. ACQUISITION PLAN

11.1 Procurement Strategy

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

At this time, it is anticipated that the following work/acquisitions will be performed as follows:

- Project Management: In-house staff;
- Construction Management: In-house staff;
- Engineering and Design: In-house staff;
- Large Components: Combination of fixed price vendor contracts & in-house fabrication;
- Assembly: In-house staff and fixed price vendor contracts;
- Decontamination: In-house staff;
- Ancillary Systems: Combination of vendor contracts and in-house staff, and;
- System Start-up, Test and Troubleshoot: In-house staff.

11.2 Critical Long Lead Procurements

Long lead procurements have been identified for the procurement of critical components. The following items are considered jugular to the critical path and are in advance of CD-3 thus requiring special approval to proceed. NOTE: The baseline cost and schedules contained in this PEP are based upon early award of these items;

1. TF Inner Copper Extrusions material;
2. TF Inner Lead Extensions;
3. TF conductor machining, and;
4. Plasma Facing Component Tiles for the Center Stack.

12. 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 NSTX Upgrade Project 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 NSTX Upgrade Project web page located at http://nstx-upgrade.pppl.gov/index.htm. 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.

13. SYSTEMS ENGINEERING AND TECHNICAL MANAGEMENT

13.1 Systems Engineering

The Engineering Support group has responsibility for implementing a systems engineering program on the NSTX Upgrade Project. 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.

13.2 Quality Assurance

The NSTX Upgrade Project is a 'major-item-of-equipment' project having workscope that modifies an existing, operating device within a functioning research program at PPPL that is over 10 years old. Hence, quality assurance will be provided thru the overarching PPPL Quality Assurance Program without need of a unique quality assurance plan for the project.

13.3 NEPA Documentation and Safety Assessment

A NEPA determination (NEPA Planning Form #1443) exercised 'categorical exclusion' as per 10CFR1021, Appendix B, B3.13, was determined on March 30, 2009. The NSTX Safety Assessment Document (SAD) will be updated and approved by PPPL prior to the restart of operations.

14. INTEGRATED SAFETY MANAGEMENT

PPPL follows the institutional Integrated Safety Management System Description (ISMS) that has been approved by DOE. The NSTX Upgrade Project intends to follow the ISMS and to adopt this as its own for the conduct of NSTX Upgrade Project work performed at PPPL.

ISM at PPPL is comprised of:

- The governing policy that safety be integrated into work management and work practices at all levels, and;
- 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 NSTX Upgrade Project will incorporate ISM into its management approach as follows:

- By accepting responsibility for safety as a line management responsibility. The NSTX Upgrade 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, and 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 core functions will be incorporated into them.

The ISMS is incorporated into the DOE-approved PPPL Worker Safety and Health Program (WSHP), which describes an integrated system that complies with the pertinent requirements of 10CFR851, the Worker Safety and Health Program Final Rule. In addition, the DOE-approved PPPL Radiation Protection Program (RPP) indicates the Laboratory's methods for implementing the requirements of 10CFR835, Occupational Radiation Protection. The NSTX Upgrade Project will implement the relevant requirements of the PPPL WSHP and RPP in the execution of the project. This will include preparation of a construction project health and safety plan for this project as required under the WHSP.

15. SAFEGUARDS AND SECURITY

A physical security vulnerability assessment of the NSTX Upgrade Project was conducted to determine if any negative impact and associated cost increases to the safeguards and security program would occur as a result of the upgrades. The assessment did not indicate any negative impact or increased cost to the physical protection, personnel security, emergency operations or protective forces. The Design Basis Threat (DBT) was included in this assessment.

16. REVISIONS TO THE PROJECT EXECUTION PLAN

This plan, when adopted and approved in its final version at CD-2, will remain in effect until the completion of the NSTX Upgrade Project. Revision and/or changes to this document will require approval in accordance with the project's change approval level.

Appendix 1 - NSTX Upgrade Project Work Breakdown Structure

This Work Breakdown Structure (WBS) organizes and defines the scope of the NSTX Upgrade using the WBS as established by the original NSTX project and modified to accommodate the NSTX Upgrade.

WBS L1	L2	L3	Description
1			**NSTX UPGRADE PROJECT**
	1.1		**Torus Systems**
		1.1.0	Project Integrated Model
		1.1.1	Plasma Facing Components
		1.1.2	Vacuum Vessel and Support Structure
		1.1.3	Magnet Systems
	1.2		**Plasma Heating and Current Drive Systems**
		1.2.1	High Harmonic Fast Wave (HHFW)
		1.2.2	Coaxial Helicity Injection (CHI) Current Drive
		1.2.3	Electron Cyclotron Heating (ECH)
		1.2.4	Neutral Beam Injection (NBI)
	1.3		**Auxiliary Systems**
		1.3.1	Vacuum Pumping System
		1.3.2	Coolant Systems
		1.3.3	Bakeout Heating System
		1.3.4	Gas Delivery System
		1.3.5	Glow Discharge Cleaning System
	1.4		**Plasma Diagnostics**
		1.4.1	Plasma Diagnostics
	1.5		**Power Systems**
		1.5.1	AC Power Systems
		1.5.2	AC/DC Converters
		1.5.3	DC Systems
		1.5.4	Control and Protection System
		1.5.5	General Power Systems and Integration
	1.6		**Central Instrumentation and Controls (I&C)**
		1.6.1	Control System
		1.6.2	Data Acquisition System
	1.7		**Project Support & Integration**
		1.7.1	Project Management and Integration
		1.7.2	Project Physics
		1.7.3	Integrated Systems Tests
	1.8		**Site Preparation and Assembly**
		1.8.1	Site Preparation
		1.8.2	Torus Assembly and Construction

WBS Element: 1 **WBS Level: 1**
WBS Title: NSTX Upgrade Project
Definition: The replacement of the entire Center Stack Assembly (CSA) and installation of a second Neutral Beam Injection (NBI) system on NSTX is planned to allow an improved understanding of the Spherical Torus (ST) magnetic confinement configuration which is needed to establish the physics basis for next-step ST facilities, broaden the scientific understanding of plasma confinement for ITER, and maintain U.S. world leadership in ST research capabilities. In particular, operation at higher magnetic field with reduced plasma collisionality is needed to extend the plasma physics understanding of the ST toward next-step ST facilities and ITER. Controllable fully-non-inductive current-drive will also contribute to assessing the ST as a potentially cost-effective path to fusion energy.

WBS Element: 1.1 **WBS Level: 2**
WBS Title: Torus Systems
Definition: The torus systems include all the systems and related elements within the boundary of the NSTX support structure. This WBS element includes the Plasma Facing Components (WBS 1.1), Vacuum Vessel & Support Structure (WBS 1.2), and Magnet Systems (WBS 1.3). The scope of the work contains engineering design, R&D, mockups, procurement activities, and component fabrication. Assembly of the Torus System is included in WBS 1.8.

WBS Element: 1.1.0 **WBS Level: 3**
WBS Title: Project Integrated Model
Definition: This WBS element includes development of a project integrated model and the associated analysis support of the overall NSTX Upgrade Project.

As a result of the NSTX Upgrade Project, the NSTX global models and analyses will need to be updated. This WBS element includes analytical support for global models and analysis not presently identified. The global model will provide the basis for updating the analysis to qualify components and identify areas of the tokamak requiring further analysis. Identified plasma scenarios and power supply current limit analyses will be run in the global model and current sets that require further analysis will be identified. These analyses also serve to check the results of more detailed analyses.
{Center Stack Upgrade (CSU) analytical Support (Job 1000)}

WBS Element: 1.1.1 **WBS Level: 3**
WBS Title: Plasma Facing Components
Definition: The plasma facing components (PFCs) include all the systems and related elements that serve to protect the vacuum vessel from the charged particles and radiation flux from the plasma. These include the plasma facing tiles and mounting components, passive stabilizers, inner wall

protection, divertor area strike plates, and local I&C. This element consists of the engineering design, analysis, procurement activities and component fabrication.

The NSTX Upgrade Project will require new PFCs on the new Center Stack Casing (CSC) and the new Inboard divertor (IBD). This WBS element includes the design and analysis for both the CS and IBD PFCs, design modifications to the PFC tiles to accommodate surface diagnostics, including design of the tile mounting schemes and routing plans for diagnostic wires, generation of required documentation such as checked calculations, specifications and procedures, the procurement and installation of all PFC tiles and hardware on the CSC and IBD.
{Center Stack Upgrade (CSU) PFCs (Job 1001)}

In addition the NSTX Upgrade will require analysis of the passive plates for disruption and thermal loads. CDR level calculations were performed that addressed one of five disruptions. The remaining identified disruptions are to be completed during Preliminary Design. During Final design, analysis updates are expected as a result of preliminary design evolution. Modest hardware upgrades are anticipated as part of this task. Additions of accelerometers or other diagnostics to benchmark calculations with actual performance in NSTX are also anticipated. This analysis effort is included in this WBS element.
{Passive Plate Analysis and Upgrade Activity (Job 1002)}

With the exception of the modifications identified above, no additional modifications to the PFCs are anticipated.

WBS Element: 1.1.2 **WBS Level: 3**
WBS Title: Vacuum Vessel and Support Structure

Definition: The vacuum vessel & support structure (VVSS) consists of the vacuum chamber, not including the PFCs, all ports and vacuum boundary closures and the torus support structure which provides the overall supporting mechanism for the torus components to the test cell floor. This WBS element includes the engineering design, analysis, procurement activities and component fabrication.

The NSTX Upgrade Project will require that the existing VVSS be modified to accommodate the new center stack structure, including the umbrella structure and the new center stack support structure. This WBS element includes the analytical and CAD design of the support structures associated with the Magnet upgrade activities. The scope includes; the Vacuum Vessel & Structural Support, the Outer TF Structures, the Outer PF Coil Structures, the Umbrella Structural Reinforcement, the CS Support Pedestal and miscellaneous Vacuum Vessel Structural Supports. It also includes the procurement and fabrication of these structures, but

does not include installation costs. Installations costs are included in WBS 1.8. {Vacuum Vessel & Support Structure (Job 1200)}

WBS Element: 1.1.3 **WBS Level: 3**
WBS Title: Magnet Systems
Definition: The magnet system consists of the outer Poloidal Field (PF) coils (PF#2-5), the outer Toroidal Field (TF) coil legs, and the Center Stack Assembly (CSA). The CSA contains the inner TF coil legs, the TF coil joint (flex bus assembly), the OH solenoid, the shaping coils, and the center stack casing. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication of the magnet systems up to and including the magnet system coil buswork, but does not include installation costs. Installations costs are included in WBS 1.8

The NSTX Upgrade Project will require engineering, analysis, design procurement and fabrication of a new CSA, replacement of two outer TF coil legs, and a fabrication of a new TF coil joint

This WBS element provides CAD design support for the overall assembly drawings associated with the CSA upgrade. It also includes some time for space allocation studies associated with the magnet upgrades. CAD design support for individual components is included in the specific component jobs.
{Center Stack Upgrade Project Design Support (Job 1300)}
{Center Stack Upgrade Magnet Systems for Conceptual and Prelim Design (Job 1310)}

WBS Element: 1.1.3.1 **WBS Level: 4**
WBS Title: Outer Poloidal Field Coils (PF #3-5)
Definition: The outer Poloidal Field coils (PF 3-5) consist of 5 poloidal field coils PF 3 upper and lower, PF 4 upper and lower and PF 5 upper and lower. There are no changes to the outer PF coils as part of the NSTX Upgrade Project scope.

WBS Element: 1.1.3.2 **WBS Level: 4**
WBS Title: Outer Toroidal Field Coils
Definition: The outer Toroidal Field coils subsystem consists of the coil sections that make up the 12 TF outer legs. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication. For the NSTX Upgrade Project two (2) new Outer TF coils will be fabricated to replace existing ones. This WBS element includes the fabrication of (2) new Outer TF coils to replace the existing leaking OTF#7 and OTF#11 that will be removed during the Neutral Beam port upgrade. This coil will then be used as a spare for future operations in NSTX. The scope includes the procurement of conductor, insulation material, aluminum castings and supports necessary

to fabricate a new OTF coils. Coil fabrication will be performed by an outside vendor. This scope does not include costs associated with installation. Installations costs are included in WBS 1.8
{Outer Toroidal Field Coil Repairs (Job 1301)}

WBS Element: 1.1.3.3 **WBS Level: 4**
WBS Title: Center Stack Assembly (CSA)
Definition: The CSA consists of the inner TF coil legs, the OH solenoid, the inner PF shaping coils [PF1a, 1b and 1c], and the center stack casing. Also included in this WBS element are the TF coil joint (flex bus assembly) and the ceramic break assembly. The scope of this WBS element includes the design, analysis, prototypes (as required), procurement activities, fabrication and assembly of the Center Stack.

WBS Element: 1.1.3.3.1 **WBS Level: 5**
WBS Title: Center Stack - TF Inner Legs/Bundle
Definition: The TF inner leg subsystem consists of the new coil sections that will make up the TF inner bore and bundle. Also included in the scope of this WBS element is the TF coil joint (flex bus assembly) and testing of the new TF coil joint design.

For the NSTX Upgrade Project a new TF Inner Leg will be fabricated. This WBS element includes the design of the TF Bundle, the TF flex bus and flex bus supports and includes all analytical and CAD design efforts for these components. It also includes the early procurement of the TF conductor [80 lengths] and procurement of the TF flex bus and supports. It does not include the procurement/fabrication of the Inner TF bundle, which is included as part of the OH procurement in WBS 1.1.3.3.2.
{Inner Toroidal Field Bundle (Job 1304)}

. For the NSTX Upgrade Project a test stand to measure the required performance parameters on the new NSTX TF joint design will be designed and fabricated. Test parameter measurements and cyclic lifetime tests of the new TF joint materials will be performed and testing data will be compiled.
{TF Joint Stand & Performance Test (Job 1303)}

WBS Element: 1.1.3.3.2 **WBS Level: 5**
WBS Title: Ohmic Heating Solenoid
Definition: The ohmic heating solenoid subsystem consists of the new coils that will make up the center solenoid. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade a new OH Solenoid will be fabricated. This WBS element includes the design & fabrication of a new OH solenoid and associated components including a Belleville washer spring assembly and

support structures for the NSTX upgrades. It also includes all analytical & CAD design efforts. Includes advance procurement of the copper conductor and co-wound [glass/Kapton] insulation. Also includes the procurement of the Micro-therm insulation, conductive paint. Includes the in-house fabrication for the combined OH and TF bundle assembly. A single vendor will fabricate both components. {Ohmic Heating Solenoid (Job 1305)}

WBS Element: 1.1.3.3.3 **WBS Level: 5**
WBS Title: Inner Poloidal Field Coils
Definition: The inner poloidal/shaping coils subsystem consists of the new coils that will make up the poloidal field coils 1A, 1B and 1C. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade three new sets of inner poloidal field coils will be installed. This WBS element includes the design and procurement of the Inner poloidal field coils and supports which includes all analytical and CAD design efforts for these components. It includes the early procurement of the PF conductor and co-wound [Glass/Kapton] insulation. {Inner Poloidal Field Coils (Job 1306)}

WBS Element: 1.1.3.3.4 **WBS Level: 5**
WBS Title: Center Stack Casing and Assembly
Definition: This WBS element includes the design and fabrication of the Center Stack casing and ceramic break assembly for the upgraded Center Stack as well as the assembly of the new Center Stack.

The Center Stack Casing effort includes analysis and CAD design for the casing components; the procurement of the Inconel tubing, forgings, bellows and organ pipes; the fabrication of Center Stack support legs; the procurement/fabrication of a new ceramic break assembly; the in-house assembly of the casing components; and mounting of the PF1A and PF1B structure/coils to the casing.
{CS Casing (Job 1307)}

The Center Stack Assembly effort involves all activities associated with the assembly of the Center Stack and includes design modifications and upgrade of the coil assembly stand; procedures for assembling the Center Stack and for installation; assembly of the Center Stack components including the OH/TF coil supports, mounting of the OH Solenoid surface diagnostics and thermal blanket, inconel casing and inner PF coils and setup and tear down of the Center Stack assembly area.
{Center Stack Assembly (Job 1302)}

WBS Element: 1.2 **WBS Level: 2**

WBS Title: Plasma Heating and Current Drive Systems

Definition: The heating and current drive systems include all the auxiliary plasma heating and current drive systems. This WBS element includes the High Harmonic Fast Wave (HHFW) Current Drive System, the Coaxial Helicity Injection (CHI) Current Drive System, the Electron Cyclotron Heating (ECH) System, and the Neutral Beam Injection (NBI) System. Only ECH (WBS 1.2.3) and Neutral Beam Injection (WBS 1.2.4) are impacted by the NSTX Upgrade Project. The scope of the work contains engineering design, R&D, mockups, procurement activities, component fabrication, installation, and System Testing. Installation of the WBS 2 systems is included in the individual WBS 2, level 3 elements.

WBS Element: 1.2.1 **WBS Level: 3**

WBS Title: High Harmonic Fast Wave (HHFW)

Definition: The High Harmonic Fast Wave System provides radio frequency (RF) energy to the plasma for the purpose of plasma heating and current drive. The components of such a system include generators, transmission lines, tuning systems, antennas and their associated diagnostic and control systems. The system includes components inside the vacuum vessel (antennas and feed-throughs) in the test cell (transmission and tuning components) and in the RF power rooms (AC/DC power conversion system, RF generators, switches and loads). There are no changes to the HHFW System as part of the NSTX Upgrade Project.

WBS Element: 1.2.2 **WBS Level: 3**

WBS Title: Coaxial Helicity Injection (CHI) Current Drive

Definition: The Coaxial Helicity Injection System is to provide helicity injection to aid startup and provide edge current profile control. The main hardware elements required fall under other WBS's. These include a ceramic break in the vacuum vessel (WBS 1.1.3) the poloidal coil system (WBS 1.1.3) and a power supply (WBS 1.5). In this WBS element the task is to assure that the various components of the system are compatible with helicity injection and that the Central I&C required is provided. There are no changes to the CHI System as part of the NSTX Upgrade Project.

WBS Element: 1.2.3 **WBS Level: 3**

WBS Title: Electron Cyclotron Heating (ECH)

Definition: The Electron Cyclotron Heating System provides breakdown and startup assist through an electron cyclotron heating system. The system will be composed of an AC/DC power conversion system, gyrotron source, transmission system, vacuum window and launcher. Any ECH specific diagnostics will be included and interfaced to Central I&C.

This scope of the WBS element for the NSTX Upgrade covers the ECH and other antenna systems, and miscellaneous diagnostics and components

attached to the vessel which will be affected by the increases in EM and thermal loading. Disruption loads on the ECH waveguide will be evaluated for the Center Stack Upgrade Fields and field transients. Discussions with heating system experts regarding the performance of the ECH system for the higher Center Stack Upgrade fields indicate that no modification to the resonant frequency or other operational characteristic for the system will require upgrade. Only disruption qualification is planned. No previous qualification has been identified, so the resources include creation of a new calculation – not a review of an existing calculation as is the case for ICRH.
{Electron Cyclotron Heating (Job 2300)}

WBS Element: 1.2.4 **WBS Level: 3**
WBS Title: Neutral Beam Injection (NBI)
Definition: The Neutral Beam Injection System Upgrade provides a second Neutral Beam as part of the NSTX Upgrade Project. The second NBI is identical to the one already installed on NSTX. An existing TFTR beam will be decontaminated, refurbished, and installed on NSTX. This WBS element includes the NBI source refurbishment; the TFTR beamline decontamination, refurbishment and relocation to the NSTX Test Cell; the 2nd NBI Services; the NBI armor modifications; the 2nd NBI Power, Controls and Instrumentation; the 2nd NBI Duct and vacuum vessel modifications; and the NSTX Test Cell equipment removals and relocations necessary to accommodate the 2nd NBI. Vacuum Pumping System Modifications necessary to accommodate the 2nd NBI are included in WBS element 1.3. NBI Management and Health Physics support are included in element WBS 1.7.

WBS Element: 1.2.4.2 **WBS Level: 4**
WBS Title: NBI Source Refurbishment
Definition: This WBS element includes the activities to refurbish three neutral beam ion sources for the 2nd Neutral beamline, as currently being performed for the installed Neutral beamline 1.
{Source Refurbishment (Job 2420)}

WBS Element: 1.2.4.3 **WBS Level: 4**
WBS Title: NSTX Beamline 2 Decontamination
Definition: This WBS element includes the disassembly and decontamination activities of a TFTR Neutral Beam beamline in preparation for beamline refurbishment and reuse as an NSTX upgrade.
{NSTX Beamline 2 Decontamination (Job 2430)}

WBS Element: 1.2.4.4 **WBS Level: 4**
WBS Title: NBI Beamline Refurbishment and Relocation
Definition: This WBS element includes refurbishment of a TFTR NBI and its relocation to the NSTX test cell.

Included in this WBS element are the activities necessary to refurbish a TFTR Neutral Beam beamline for use on NSTX. This scope includes replacing the ion dump and calorimeter bellows as required and refurbishment of of the seals, thermocouple wiring, and bellows (cal and spool) as needed.
{NSTX Beamline 2 Refurbishment (Job 2440)}

Also included in this WBS element are the efforts necessary to relocate a TFTR neutral beam line and ancillary equipment into the NSTX test cell. This includes High Voltage Enclosures (HVEs) and the complete beam box and components.
{NSTX Beamline 2 Relocation (Job 2425)}

WBS Element: 1.2.4.5 **WBS Level: 4**
WBS Title: NSTX Beamline 2 Services
Definition: This WBS element includes the efforts to provide services to the new neutral beam beamline and ancillary equipment in NSTX test cell. These services include water, cryogenic systems, gas supplies, and vacuum lines.
{NSTX Beamline 2 Services (Job 2450)}

WBS Element: 1.2.4.6 **WBS Level: 4**
WBS Title: NBI Armor
Definition: This WBS element includes the design, fabrication, and installation of upgraded and relocated neutral beam armor including cooling and instrumentation work.
{NBI Armor (Job 2460)}

WBS Element: 1.2.4.7 **WBS Level: 4**
WBS Title: NBI Beamline 2 Power and Controls
Definition: This WBS element includes providing power, controls and instrumentation for the 2nd Neutral beamline.

Included in this WBS element is providing power for the NBI beamline 2. NB2 is planned to be powered from the TFTR NB4 A, B, & C line ups. The electrical equipment in these line ups will be reactivated. The TFTR NB4 HVEs will be relocated to the NSTX Test Cell as part of WBS element 1.2.4.4. New triax cables will be installed with terminations from the Modregs to the HVEs. New Decel coaxial cables will be installed from the Decel supplies to the Sources. The Arc, Filament, Magnet, and the 208 feeds, to HVEs cables, will be spliced in the TFTR Test Cell basement to new cabling designed and installed from the TFTR Basement to the NSTX Test Cell. The fiber cables also will be spliced with additional lengths recovered from other TFTR line ups. The AC auxiliaries and Grounding for the NB2 will be designed and installed.
{NBI Power System (Job 2470)}

Also included in this WBS element are the controls and instrumentation for the NB2. The work covers PLC, programming, control racks, new thermocouples, TC scanner, miscellaneous controls, and control cabling. The work also includes the gradient grid upgrade. System integration and testing will also be performed as part of this effort.
{NBI Controls & Instrumentation (Job 2475)}

WBS Element: 1.2.4.8 **WBS Level: 4**
WBS Title: NSTX Beamline 2 Duct & vacuum Vessel Modifications
Definition: This WBS element includes the design, and fabrication of all components connecting the Neutral Beam Box to NSTX, and the connecting ductwork and modifications to NSTX Vacuum Vessel to accommodate the second beamline.
{NSTX NB2 Duct & VV Mods (Job 2480)}

WBS Element: 1.2.4.9 **WBS Level: 4**
WBS Title: NSTX Test Cell Equipment Removals/Relocations
Definition: This WBS element covers moving of racks and diagnostics to clear space in the NSTX Test Cell (NTC) for the second Neutral Beamline. Racks to be removed and re-installed in a new location are #419, 431-435, 440-445, 447-449, 488. Racks 456 and 489 will be removed and excess. This scope also includes the fabrication and installation of five sections of platform at elevation 118' on the west side of the NTC to accommodate the racks being re-installed in the NTC. Racks #441-445 will be relocated to the Gallery east of the NTC. Diagnostics to be removed are those from the midplanes of Bay J and Bay K as well as those on the present pump duct. The diagnostics from Bay J will be re-installed ~5" outboard of their present position. IR windows and the Transmission Grating Spectrometer will be relocated to the new NB duct. Ion gages, filaments and the RGA will be relocated to the new pump duct under the NB2 duct. SPRED and LOWEUS will be relocated to Bay L. The Thomson Scattering Beam Dump Window will be relocated to between Bays K and L.
{NTC Equipment Removals/Relocations (Job 2490)}

WBS Element: 1.2.4.0 **WBS Level: 4**
WBS Title: Vacuum Pumping System
Definition: The Vacuum Pumping System provides the source and distribution of all vacuum pumping to NSTX. This includes the roughing pumps as well as the turbo pumps and any backing pumps to:

- Provide the initial high vacuum environment with minimum impurities for plasma formation;
- Evacuate the spent plasma constituents at the end of each pulse prior to the next plasma pulse;
- Remove impurities liberated during bakeout and/or discharge cleaning of the vacuum vessel interior; and

- Provide instrumentation and a Residual Gas Analyzer.

This WBS element also includes the controllers for all pumps. The relocation of racks and control equipment is covered under WBS 1.2.4.9

In order to accommodate the installation of the 2nd NBI on NSTX the existing Vacuum Pumping System will be modified. This WBS element includes the design, fabrication, and installation of a new vessel pumping system and includes new pump ducts off of the Neutral Beamline 2 duct, mechanical and electrical isolation of the system, vacuum diagnostic relocation, magnetic.
{NSTX NB2 TVPS (Job 2485)}

WBS Element: 1.3 **WBS Level: 2**
WBS Title: Auxiliary Systems
Definition: This WBS element includes the Coolant Systems, the Bakeout Heating System, Gas Delivery System and the Glow Discharge Cleaning System. The scope of the work contains engineering design, procurement activities, component fabrication, and System Testing. Installation of the WBS 3 systems is included in the individual WBS 3, level 3 elements.

WBS Element: 1.3.2 **WBS Level: 3**
WBS Title: Coolant Systems
Definition: The Coolant System provides cooling water to remove heat generated from NSTX systems during experimental operations. The systems include the:

- TF/PF bus and coil cooling water system;
- Center stack cooling water system;
- Component cooling water system; and the
- Ohmic heating cooling water system.

These systems will provide cooling water for normal operations and discharge cleaning of the vacuum vessel. This WBS includes engineering design, analysis, procurement activities, component fabrication and installation to the coil, bus and component cooling manifolds at the torus.

The new Center Stack on NSTX will require modifications to the existing coolant system. This WBS element will provide water cooling services to the new Center Stack and ancillary equipment in the NSTX test cell.
{Water System Coolant Modifications for CSU (Job 3200)}

WBS Element: 1.3.3 **WBS Level: 3**
WBS Title: Bakeout Heating System
Definition: The bakeout heating system's function is to bakeout the vacuum vessel and center stack in vacuum components at high temperature while keeping the outer vacuum vessel wall and ports within cooler design temperature

limits. The system includes a pressurized hot water system to maintain the vessel wall temperature, a high pressure hot helium system to heat the in-vessel components, and a power supply for resistively heating the center stack walls. The controls and interlocks for safe operation of this system are included. This WBS element includes the engineering design, analysis, procurement activities and component fabrication.

This WBS element includes the purchase of a new more powerful power supply, to replace the existing one, to be used for electrical heating of the vessel. It is proposed to buy a 0-8V, 8000 amps for the application. Suitable cable leads will be fabricated and necessary interlocks will be incorporated.leads will be fabricated and necessary interlocks will be incorporated.
{NSTX CSU Bakeout System Mods (Job 3300)}

WBS Element: 1.3.4 **WBS Level: 3**
WBS Title: Gas Delivery Systems
Definition: The Gas Delivery Systems provides storage and delivery of gases to and from NSTX systems during experimental operations. These systems provide:

- Storage of on-site inventories of gases for use in NSTX plasma physics and future neutral beam experiments;
- Delivery of prescribed quantities of gases at prescribed purity levels and flow rates;
- Delivery of gases continuously or in pulses of prescribed shape and duration; and
- Evacuation of delivery lines and components required for delivery.

This WBS includes engineering design, analysis, procurement activities, component fabrication and installation to the coil, bus and component cooling manifolds at the torus. The relocation of racks, control equipment and external delivery system is covered under WBS 1.2.4.9.

This WBS element includes the design, fabrication and installation, and test of up to four center stack fueling lines and modifications of the gas delivery assemblies.
{Gas delivery system modifications (Job 3400)}

WBS Element: 1.3.5 **WBS Level: 3**
WBS Title: Glow Discharge Cleaning System
Definition: The Glow Discharge Cleaning (GDC) System establishes and controls the GDC process in NSTX. GDC is a mode of vacuum conditioning in which the vacuum vessel internal surfaces are cleaned by the bombardment of ions formed during the glow process. This WBS includes engineering design, analysis, procurement activities, component fabrication and installation of the GDC system. The relocation of racks and control

equipment is covered under WBS 1.2.4.9. There are no changes to the Glow Discharge Cleaning system as part of the NSTX Upgrade Project.

WBS Element: 1.4 **WBS Level: 2**
WBS Title: Plasma Diagnostics
Definition: The Plasma Diagnostics provide information on discharge parameters to characterize NSTX plasmas and guide its operation for optimized performance. The near term emphasis will be on detailed measurements of plasma profiles, using equipment presently available at PPPL. The long term objective will be to provide input for advanced plasma control systems, using new concepts and systems developed by the national NSTX team.

WBS Element: 1.4.1 **WBS Level: 3**
WBS Title: Plasma Diagnostics
Definition: The Plasma Diagnostics provide information on discharge parameters to characterize NSTX plasmas and guide its operation for optimized performance. The diagnostic subsystems included in this WBS are:

- Magnetic measurement diagnostics;
- Current density profile diagnostics;
- Laser and microwave diagnostics;
- Visible and total radiation diagnostics;
- Ultra violet and x-ray diagnostics;
- Particle measurement diagnostics;
- Divertor diagnostics; and
- Plasma Edge and vacuum diagnostics.

The NSTX Center Stack Upgrade will require new magnetic diagnostics to be installed This WBS element includes the design and fabrications of Center Stack magnetics diagnostics to replace units removed with the old Center Stack. Installation of these diagnostics is included in WBS element 1.1.3.3.4.
{Center Stack Upgrade Diagnostics (Job 4100)}

The increased diameter of the Center Stack Upgrade requires changes to the laser beam path, which requires a new laser input vessel penetration, and plugging of the existing penetration. Increasing the nozzle diameter of the L port to accommodate an external laser dump, furnishing a vacuum boundary for the extension tube. Modifications are to anticipate a third laser in the future and a new penetration for a FIDA diagnostic above and slightly offset from Bay L. The laser input location may require a special design of the PF coil support column between Bays F and G
Center Stack Diagnostic Job 4500

WBS Element: 1.5 **WBS Level: 2**
WBS Title: Power Systems

Definition: The Power Systems WBS element includes the engineering, design, prototyping, procurement and installation of all the systems and related elements that provide conditioned electrical power and energy to the NSTX systems. It includes the AC Power Systems, the AC/DC Convertors, the DC Systems, the Control and Protection System, and System Design and Integration as well as the coil bus runs..

WBS Element: 1.5.1 **WBS Level: 3**

WBS Title: AC Power Systems

Definition: The scope of the AC Power Systems WBS element is to provide the supply and distribution of all AC power to NSTX. This includes all the experimental and auxiliary loads.

AC/DC Converters

: The scope of the AC/DC Converters WBS element is to reactivate existing AC/DC Converters that have not been used since the shutdown of TFTR for use by NSTX.

DC Systems

The scope of the DC Systems WBS element is to receive AC input power and deliver controlled DC output power to the NSTX coil systems. This includes power cabling changes, DC Reactor changes, associated raceway changes, and changes required in the Power Cable Termination Structure (PCTS) inside the NSTX Test Cell.

Power Systems Integration and Testing

This WBS element covers general power systems activities including interaction with the designers of other WBS elements, design review support and procedure preparations as well as the administrative and supervisory efforts for the NSTX Power Systems.

{NSTX Center Stack Upgrade Power Systems (Job 5000)}

WBS Element: 1.5.2 **WBS Level: 3**

WBS Title: Control and Protection System

Definition: The scope of the Control and Protection System WBS element is to control and protect the power loop components for all magnet circuits. This includes the design of hardwired interlock system, kirk-keys, real time controls, the PC Link, Firing Generator, and Fault Detector changes, measurement of signals, changes to existing coil protection devices and design of a new digital coil *protection system. The Center stack upgrade entails the TF feed to be 1kV, 129.8kA for 7.45 seconds every 2400 seconds. Design shall be such that the pulse period can be reduced to 1200 seconds. This requires complete redesign of the TF power system. Replacement of the fault detector (FD) and the Firing*

generator (FG) is required for fast and reliable response to fault conditions. The FD and FG are not included in the project work scope but part of the NSTX Program power supply reliability future upgrade. The HCS will be upgraded with a PLC. The OH power supply is designed to have the capability of 6kV, +/-24kA; OH CLRs will be replaced with calculated optimum requirements. A Digital Coil Protection (DCP) System will be designed and implemented. A Digital Coil Protection (DCP) System will be designed and implemented.

{NSTX Digital Coil Protection System (Job 5200)}

WBS Element: 1.5.3 **WBS Level: 3**
WBS Title: Coil Bus Runs

Definition: This WBS element includes the design and fabrication of the coil bus runs/supports between the NSTX coils and the FCPC cable terminations located in the NSTX test cell.

{Coil Bus Runs (Job 5501)}

WBS Element: 1.6 **WBS Level: 2**
WBS Title: Central Instrumentation and Controls (I&C)

Definition: This upgrade will be capable of producing plasmas on the order of 6.5 seconds; to-date they are less than two seconds. For dozens of CAMAC and PC-based data acquisition systems this will require an upgrade, and, in some cases, replacement. The real-time plasma control system will require an upgrade to accommodate additional input/output signals, control loops, and a longer control period. The networks and analysis pool computers will need to be upgraded to achieve reasonable performance for time-sensitive functions. Some test cell racks will be relocated; there will be a modest effort required to route the control, timing, and communication cabling and qualify the systems.

{Central I&C and Data Acquisition (Job 6100)}

WBS Element: 1.7 **WBS Level: 2**
WBS Title: Project Support & Integration

Definition: Project support and integration includes the non-hardware related subsystems such as overall Project Management and Administration, Project Physics as well as Integrated Systems Testing support.

WBS Element: 1.7.1 **WBS Level: 3**
WBS Title: Project Management and Integration

Definition: The project management and integration WBS element consists of all the activities necessary to plan, monitor, integrate and control, and report on the progress of the NSTX Upgrade Project which

includes technical, business, and administrative planning and support; organizing, directing, coordinating, controlling, reviewing and approving project actions.

WBS Element: 1.7.1.1 **WBS Level: 4**
WBS Title: Project Management & Integration
This WBS element includes overall management; a Project Manager, Deputy Project Manager, and Project Controls support to manage, monitor, integrate, control, and report on the progress on the NSTX Upgrade. Also included in this WBS element is System Engineering support and support for updating of the General Arrangement Drawings for the NSTX Test Cell as well as funds for independent reviewers as necessary.
{Project Management and Integration (Job 7100)}

WBS Element: 1.7.1.2 **WBS Level: 4**
WBS Title: Center Stack Upgrade Management
Definition: Level of Effort job to cover the oversight of Center Stack Upgrade work which includes a Manager, Project Engineering support and support and to cover Center Stack engineer's time to prepare for and participate in project cost and schedule reviews.
{NSTX CSU Project Management (Job 7200)}

WBS Element: 1.7.1.3 **WBS Level: 4**
WBS Title: Neutral Beam Upgrade Management
Definition: Level of Effort job to cover the oversight of the 2nd Neutral Beam Upgrade work which includes a Manager, Engineering support and support and to cover Neutral Beam engineer's time to prepare for and participate in project cost and schedule reviews.
{NBI Project Support & Integration (Job 7300)}

WBS Element: 1.7.1.4 **WBS Level: 4**
WBS Title: Health Physics Support
Definition: This WBS element includes the effort necessary for continuous health physics (HP) support for the Neutral beamline decontamination, refurbishment, and relocation to the NTC as well as the HP support for equipment removal and relocations being accomplished under WBS 1.2.4.
{Health Physics Technical Support (Job 7400)}

WBS Element: 1.7.1.5 **WBS Level: 4**
WBS Title: Direct Allocations (Job 7710)
Definition: This WBS element includes the costs to cover Laboratory Engineering and Scientific Computing and Environmental Services that are allocated to all Laboratory projects based on their funding levels. Also included in this WBS element are the home office Health Physics efforts

necessary to support the collection of radiological analyses of various environmental samples and bioassay samples, and the collection of analyses of data on the gamma radiation spectra of radioactive material at PPPL that are allocated to all Laboratory projects based on their usage of Health Physics staff.

{NSTX Upgrade Direct Allocations (Job 7710)}

WBS Element: 1.7.2 **WBS Level: 3**
WBS Title: Project Physics
Definition: Project Physics includes the definition of requirements necessary to meet the overall NSTX mission and supporting objectives, physics analysis supporting the project's design and construction activities, and definition of R&D needs. In addition it includes the provision of hardware and software required for plasma control.
Project Physics is not included in the scope of the Upgrade Project.

WBS Element: 1.7.3 **WBS Level: 3**
WBS Title: Integrated Systems Tests
Definition: This element includes all of the activities associated with the support of development of all necessary procedures and documents to support the integrated tests, and to support performance of the pre-operational integrated system tests culminating in first plasma.

The WBS element includes Convening the NSTX Activity Certification Committee (ACC) for comprehensive review the upgrades. Prepare and make presentation to the PPPL ES&H Executive Safety Board for issuance of appropriate Safety Certificate parameters for operation of NSTX with new enhanced operating capabilities; preparation of documentation (procedures) for safely integrating the upgrades for operations within NSTX safe operating parameters; working with NSTX Operations Group for the successful integration of the upgrades.
{Integrated Systems Test (Job 7900)}

WBS Element: 1.8 **WBS Level: 2**
WBS Title: Site Preparation and Assembly
Definition: Site preparation and torus assembly includes modifications to the existing NSTX Test Cell components and subsystems and the assembly and installation of all Torus Systems (WBS 1.1). Modifications to other PPPL facilities, components, and subsystems outside the NSTX Test Cell and the assembly and installation of non-torus components and subsystems are included in the individual components and subsystems.

WBS Element: 1.8.1 **WBS Level: 3**
WBS Title: Site Preparation

Definition: This WBS element includes construction of the NSTX machine platform and the modifications to the NSTX Test Cell. There are no activities in this WBS element as part of the NSTX Upgrade Project. NTC equipment removals, relocations and platform modifications necessary to support installation of the 2nd NBI are included in WBS element 1.2.4.2.

WBS Element: 1.8.2 **WBS Level: 3**

WBS Title: Torus Assembly and Construction

Definition: Torus Assembly and construction includes the assembly and installation of the NSTX torus, coils systems and all associated supports including construction management. This WBS element includes removal of equipment for clearance and accessibility, moving existing coils, modifying existing supports mounted on the vacuum vessel and installing a new external coil support structure.
{Installation of the Coil Support System (Job 8200 loe tasks & 8210 discrete tasks)}

Also included in this WBS element is the removal of the existing Center Stack and installation of the NSTX Upgraded Center Stack, followed by closing up the vacuum vessel, pumping down, leak checking, bakeout and machine area scrubs to be ready for Integrated System Testing.
{CS Removal & Re-Installation/Pumpdown/Bakeout (Job 8250)}

Appendix 2 - Risk Management for the NSTX Upgrade Project

1. Background

1.1 Background

The NSTX Upgrade Project will manage risks, where "risk" refers to factors within the Project's control that both threaten and provide opportunities to improve project cost and schedule performance and the achievement of project technical objectives. During all phases of the NSTX Upgrade project, priority is placed on identifying and mitigating risks. Risk mitigation activities are incorporated into the project's cost and schedule baselines, as appropriate. Contingency is used to address realized risks. A quantitative, analysis of outstanding risks and estimating uncertainties is used to estimate the amount of contingency required. Control of the environment, safety, and health hazards, while part of risk management in a broader sense, are not unique to the NSTX Project and are enveloped by the Princeton Plasma Physics Laboratory (PPPL) Integrated Safety Management (ISM) program that is applicable to all PPPL projects and operations. The PPPL ISM clearly indicates that risk management is line management responsibility and will be factored into every project decision at all levels throughout the life of the NSTX Project.

1.2 References

The DOE Order on Project Management (DOE Order 413.3) emphasizes the importance of risk management. Risk management is the driving force in establishing and for maintaining the technical, cost, and schedule baselines for NSTX. In addition, PPPL Engineering Procedure, *ENG-032, "Work Planning*," provides the lab's overall guidance in establishing project requirements based on risk management approaches and consequences.

1.3 Bounding Conditions

The following key assumptions form the basis for project plans and the Performance Baseline for the project. Project contingency allowances are not intended to address or cover conditions that differ from this planning basis or events that occur in violation of these assumptions. In such cases a Baseline Change will be requested.

- Funding will be made available by DOE and the Congressional budget process in accordance with the profile which forms the basis for the baseline resource loaded schedule, as presented in the Project Execution Plan.

- There will be no changes to PPPL funding or programs that would have a major impact on the overhead rates upon which the baseline is based.

- There will be no extraordinary ESH incident or other event that causes an extended shutdown of the Laboratory or a stand down of laboratory activities.

- Certain risks with very significant potential consequences but a very low likelihood of occurrence are not covered by the contingency allowance for the project. Although these risks will be tracked and managed within the project, the project contingency allowances are not intended to cover the impacts of these risks if they are realized. The currently identified risks that fall in this category, and which are assumed will not occur for baseline planning purposes, are:

    - *Major technical events not associated with execution of project scope that requires disassembly of the machine*
    - *Damage requiring re-fabrication of a coil (but damage requiring re-work in accessible areas is covered.)*
    - *Failure of a key component or system during integrated system testing.*
    - *CD-4 Project Completion criteria and requirements change from those described in the Project Execution Plan.*

2 Responsibilities

While any member of the NSTX Project Team is expected to identify risks that become apparent, the responsibility for risk management for the NSTX Project rests with the NSTX line management.

Job Managers and WBS Managers
Identify risks that can impact their work packages; assess the likelihood and potential cost and schedule impacts of the risk; identify and execute risk mitigation activities, and report on the status of both risks and mitigation activities.

Risk Owners
The person assigned by the Project to be responsible for reporting the status of the risk. This person can be the job manager responsible for the mitigation effort, the job manager of the affected job, or a line manager. This person can change with time.

Project Manager
The Project Manager has overall responsibility for managing project risks.

Deputy Project Manager
The Deputy Project Manager supports the implementation of the project's risk management program by maintaining the risk registry.

3 Risk

3.1 Risk Definition

A risk is typically a negative outcome that, if it occurs, would adversely affect the project's ability to achieve overall project objectives within defined cost, schedule, and technical constraints. Risk can be categorized in two broad classes – Management and Organization Risks involving financial factors (e.g., funding profiles, escalation, labor and overhead rates, etc.) or loss of key personnel; and Technical Risks that have the potential to impact the performance of the machine (e.g., Assembly – both generic and specific, systems and components, startup, and systems). In the end, any risk has the potential to affect either or both cost and schedule and the NSTX Upgrade Project has distilled all risks down to this basic accounting. In NSTX, the definition is broadened to include opportunities, i.e. positive outcomes that, if they occur, would improve the project's ability to achieve overall project objectives. Hereafter, we use "risk" to cover both negative and positive outcomes.

Terms associated with risk and its management are:

- Risk Management – the act or practice of dealing with risk. It involves assessments and planning for risk, implementing workable risk mitigation strategies and plans, monitoring risks to determine how they have changed, and updating risk documentation to assist in the overall project's ability to manage its risks.

- Risk Identification – the process of examining project areas and associated technical areas to identify and document risk items.

- Risk Analysis – the process of examining each identified risk item to refine the description of the risk, isolate the root causes of the risk item, and determine the effects and consequences should the risk item become a reality. It involves an assessment of each risk item in terms of the probability/likelihood of occurrence, severity of the consequence/impact in terms of cost and schedule, and any relationships to other risk items.

- Risk Mitigation – the process that describes the actions and/or plans to control an identified risk by risk reduction, contingency allowances, or elimination

3.2 Risk Management Processes

3.2.1 Risk Identification

Risk identification begins by compiling the project's risk items. Job managers identify potential risk items for their jobs at a level of detail that permits an evaluator to understand the significance of any risk, identify its causes, and estimate potential consequences.

3.2.2 Risk Analysis

Risk analysis is a systematic evaluation of identified risk events by determining the probability of occurrence and consequences, assigning a risk rating based on established criteria, and prioritizing the risks. The first step in the risk analysis process is to determine for each risk event the probability that the risk item will actually occur. Table 3-1 provides guidelines for classifying risks in terms of likelihood that they will occur.

Table 3-1 Likelihood of Risk Occurring

Classification	Probability of Occurrence
Very Likely (VL)	P≥ 80%
Likely (L)	80%< P ≥ 40%
Unlikely (U)	40% < P ≥ 10%
Very Unlikely (VU)	10% < P ≥ 1%
Not Credible (NC)	P < 1%

The next step in the risk analysis process is to determine for each risk item the magnitude of the consequences should the event occur. For the NSTX Upgrade Project, consequences will be assessed in terms of cost and schedule impacts, and classified in accordance with Table 3-2.

Table 3-2 Risk Consequences

Impacts	Negligible	Marginal	Significant	Critical	Crisis
Technical Performance	**No impact**	**Minor degradation**	**Moderate degradation**	**Moderate degradation**	**In doubt**
Cost	**< $100K**	**≥$100K**	**≥$500K**	**≥$1M**	**≥$5M**
Schedule	**<0.5 Months**	**≥0.5 Months**	**≥1 Months**	**≥3 Months**	**≥ 6 Months**

Once the risk likelihood and consequences are established, a risk ranking is assigned to each risk item. This rating is a qualitative measure of the severity of the risk item and provides a starting point for development of risk management priorities. The risk ranking is assessed based on likelihood and consequences, and classified as high, medium, or low in accordance with Table 3-3.

Table 3-3 Risk Ranking Matrix

Impact	Negligible	Marginal	Significant	Critical	Crisis
VL	**Low**	**Moderate**	**High**	**High**	**High**
L	**Low**	**Moderate**	**Moderate**	**High**	**High**
U	**Low**	**Low**	**Moderate**	**Moderate**	**High**
VU	**Low**	**Low**	**Low**	**Moderate**	**High**
NC	**Low**	**Low**	**Low**	**Low**	**Low**

3.2.3 Risk Handling

There are four approaches to handling risk: avoidance, transfer, mitigation, and acceptance.

3.2.3.1 Risk Avoidance

Risk avoidance is a change in the concept, requirements, specifications, and/or practices that reduce risk to an acceptable level. Simply stated, it eliminates the sources of high or possibly moderate risk and replaces them with a lower risk solution and may be supported by a cost/benefit
analysis.

3.2.3.2 Risk Transfer

Risk transfer is a reallocation of the risk to other activities outside the NSTX MIE project, thereby reducing the overall project risk. In certain instances, risks may also be transferred to vendors through appropriate contract language and terms.

3.2.3.3 Risk Mitigation

Risk mitigation is an implementation of activities to reduce the consequences (likelihood and/or impact) of a risk event. The goal of mitigation is to retire risks so that their consequences do not affect the project or to minimize those consequences to the project. Mitigation activities are typically budgeted and scheduled in the project baseline unless those activities are on hold pending further project development or the occurrence of certain risk triggers.

3.2.3.4 Risk Acceptance

Risk acceptance is an acknowledgment of the existence of a particular risk situation and a conscious decision to accept the impact on the project's baseline. Acceptance can entail a decision not to mitigate a risk, or a decision to accept a residual risk after mitigation activities are completed. The impacts of an accepted risk must be budgeted and scheduled in the project baseline. Cost and schedule contingency allowances are included in the project baseline to cover the impacts of accepted risks.

3.3 Risk Documentation

The NSTX Upgrade Risk Register is the vehicle for documenting identified risks, risk mitigation activities, affected jobs, ownership responsibilities, retirement deadlines, likelihood, consequences, estimated impacts and their bases, and the risk level classification. These items are tabulated in columns as follows:

Affected Job - the job that will be impacted if the risk outcome occurs.

Risk Description - the negative outcome (or in the case of an opportunity, the positive outcome), that might occur if not successfully mitigated.

Mitigation Plan - budgeted tasks or activities to reduce the consequences.
Identifies the job number where the mitigation activity is budgeted in the project baseline. Note that the mitigation responsibility is sometimes in a different job from the affected job.

Deadline - sets a date (or event) when the risk will be retired. If not retired, then the consequences will be accepted and contingency drawn, if necessary, to cover it.

Owner - the person assigned by the Project to be responsible for reporting the status of the risk. The owner can be the job manager responsible for the mitigation effort, the job manager of the affected job, or a line manager. The owner can change with time.

Current Status - status of the risk and any mitigation activities. The owner is responsible for keeping this information up to date.

Likelihood - probability that the risk will materialize (See Table 3-1).

Consequences - categorization of impact (See Table 3-2).

Risk Ranking - categorization dependent on likelihood and impact (See Table 3-3).

Impacts - Cost Impact, Schedule Impact, and Basis of Estimate. Provides estimates in terms of dollars for cost impact and months for schedule (only maximum impact shown – minimum assumed to be zero). Indicator of the impacts/calls on cost or schedule contingency if the risk materializes. Basis estimate briefly describes what these impacts were based upon.

3.4 The NSTX Project Risk Management Approach

The NSTX Risk Management approach consists of a three step process:

- Managing risk;
- Identifying potential areas of risk;
- Active use and maintenance of the Risk Register

3.4.1 Managing Risk

Most NSTX Upgrade activities related to the fabrication project require the preparation and completion of reviews, work planning, hazard analysis, and controls to properly manage the job. The first step in this process is to recognize the potential risk consequences and to assign ownership for the specific work. PPPL Engineering Procedure, *ENG-032, "Work Planning"*, provides the guidelines to be used to plan the anticipated requirements of a job; define the scope of the work; perform hazard analysis; provide for all environmental, safety, and health issues as part of the work planning and review process, establish procedural and testing requirements; and make other determinations, as necessary, to provide clear approvals indicating ownership of the work. Table 1 of *ENG-032* provides guidelines on how risk shall be managed with ascending levels of required approval based on three classifications of risk: standard, serious, and major category of risk as it pertains to mission and programmatic impact, ES&H, Cost, and Compliance factors. This procedure shall be followed whenever planning new or modifying existing work for the NSTX Upgrade Project.

3.4.2 Identifying, Mitigating, and Retiring Risk

The NSTX Risk Management process begins with the WBS Managers evaluating potential project risk for each work package. The process for identifying risk items is ongoing and is part of day-to-day interactions of the project team. Table 4-1, Table 4-2, and Table 4-3 below provide generic tables of common risk areas to assist the WBS Managers in this task. Risk mitigation activities are planned to reduce (or in the case of an opportunity, increase) the likelihood or consequences of a risk. The success criterion for risk mitigation activities is progress in reducing the risk and, ideally, retiring the risk altogether. A deadline is established by which time the risk will be accepted if not retired. Acceptance means the residual consequences (cost and schedule impacts) are accepted and included in the project baseline.

3.4.3 Active Use and Maintenance of the Risk Register

The Risk Register is a living document with Job Managers continually updating/adding/retiring risks as they become known. Monthly the WAFs will be statused as part of the NSTX Project Management System process and the status of existing Risk Register items and potentially any new items will be addresses as part of this statusing function. In addition, the job managers and risk owners are also responsible for reporting potential risk items more frequently in their day-to-day discussions with line management. As an ongoing process, they will monitor performance relative to risk and evaluate the success of the risk mitigation strategies. WAFs and mitigation strategies will be adjusted as necessary to take advantage of lessons learned and to maximize the probability for successful project completion.

4 Estimate Uncertainty

Each Job Manager is responsible for developing a detailed and thorough estimate of the resources (labor and materials and services) and time durations necessary to accomplish the assigned scope of work. Both cost estimates and schedule durations have inherent levels of uncertainty. In general, this uncertainty is a direct result of the degree of design maturity and complexity of the elements involved – in effect, how much definition exists to provide a basis for the estimate. This is a practical way of addressing the large and diverse number of potential uncertainties that often occur in acquisition projects. As a means to measure this uncertainty, the NSTX Upgrade Project developed standard definitions for both design maturity and complexity categorizations (as shown in Table 4-1 and Table 4-2).

Table 4-1 Design Maturity Definitions

Design Maturity	Definition
High	**Final design available. All design features/requirements are well known. No further significant design development or evolution is expected that will impact the estimate => relatively low probability of change.**
Medium	**Preliminary design is available. Some additional design evolution is likely. Further developments can be anticipate and will impact the estimate => relatively moderate probability of change.**
Low	**At the conceptual design level. Design details still need much development and evolution of requirements beyond the current estimate basis is anticipated and very likely => relatively high probability of change.**

Table 4-2 Design Complexity Definitions

Design Maturity	Definition
Low	**Work is fairly well understood – either standard construction or repetition of activities performed in the past. Little likelihood of estimate not being well understood and requirements not being well defined**
Medium	**More complex work requirements that have potential to impact cost and schedule estimates. Relatively limited experience performing similar tasks, so ability to estimate accurately is somewhat limited.**
High	**Extremely challenging tasks and/or requirements. Unique or first-of-a-kind assembly or work tasks. Very limited basis for estimating this work exists, so there is a high degree of uncertainty.**

Using accepted industry and DOE practices and guidelines, Table 4-3 below translates the combination of design maturity and design complexity into uncertainty ranges that are used in the contingency analysis.

Table 4-3 NSTX Estimate Uncertainty Ranges

	Design Complexity		
Design Maturity	**Low**	**Medium**	**High**
Low	**- 15% to +25%**	**-20% to +40%**	**-30% to +60%**
Medium	**-10% to +15%**	**-15% to +25%**	**-20% to +40%**
High	**-5% to +10%**	**-10% to +15%**	**-15% to +25%**

5 Contingency

The NSTX Project employs a structured process to assess and analyze all areas of risk and uncertainty that might affect the cost and schedule estimates.
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. Total cost contingency includes 3 elements; 1) a task-by-task subjective contingency assessment for unknowns, 2) a weighted assessment of tabulated risk events, plus 3) schedule contingency applied to the "standing army". Schedule contingency (in months) was calculated by applying the task-by-task contingencies to the task durations to calculate the longest path within the project. This was offset partially by the option of using second shift and overtime to maintain schedule. The initial project contingency level will be approved by the Associate Director for Fusion Energy Sciences as the Acquisition Executive for NSTX Upgrade Project at CD-2 as part of establishing the overall cost and schedule baseline.

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