Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

National Spherical Torus Experiment (NSTX) Upgrade Project

December 2012

EXECUTIVE SUMMARY

A Department of Energy Office of Science (DOE/SC) review of the National Spherical Tokomak Experiment (NSTX) Upgrade project was conducted at Princeton Plasma Physics Laboratory (PPPL) on December 11-12, 2012. The review was conducted by the Office of Project Assessment (OPA) at the request of Dr. Edmund Synakowski, Associate Director of Science for the Office of Fusion Energy Sciences (FES). Stephen Meador, OPA, chaired the review. The purpose of the review was to evaluate the overall status of the project with emphasis on construction progress.

The Committee found good progress in executing all aspects of the planned upgrades. Safety performance is good, and the work control center is mature and functioning well. At present, the project has adequate resources and the necessary skill mix to successfully complete the project. Concerns identified by the Committee include need for additional electrical tests and prototyping of key Center Stack (CS) components; a four-month schedule slippage due to difficulties with various CS fabrication activities; and potential impact to the staffing skill mix if funding shortfalls cause projected staffing reductions (60-80 positions) at PPPL. However, the Committee judged the project remains on track for an early project completion.

Technical

Additional electrical tests and prototyping of components for the new CS are needed to reduce risk and potential for rework, especially for activities not performed in prior upgrade projects. There is a need to more formally document and review fabrication and assembly processes. Unacceptable quality of several vendor deliverables has highlighted the importance to the project of promptly inspecting and testing hardware upon receipt. The Digital Coil Protection System is behind schedule and now close to critical path; consequently, adequate staff should be assigned to get the task back on track and advance the schedule if possible. Finally, a comprehensive readiness review process is needed to ensure all activities (on project and off) are in place for successful start-up.

Cost and Schedule

The project is approximately 53% complete. Loss of four months of schedule contingency and use of cost contingency is a concern, but remaining cost and schedule contingency is adequate for remaining risks. The critical path continues to run through conductor fabrication, CS fabrication, and CS installation.

Management

Overall, the project is performing well. Safety performance is good. Installation and construction appear very well planned and executed thus far. A more detailed plan to ensure facility readiness for operation, acceptable to the DOE Princeton Site Office (PSO), is needed. The potential risks related to loss of key personnel and critical skills at PPPL appear to be overly optimistic. Proposed impacts to the project from the President's FY 2013 budget and out-year program guidance have been analyzed and funding uncertainties are well understood. There is a comprehensive strategy between PPPL, DOE/PSO, and DOE/FES to address the funding uncertainties.

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Appendices

1. INTRODUCTION

The mission of the National Spherical Torus Experiment (NSTX) program is to explore the properties of compact and high normalized pressure 'spherical torus' (ST) magnetic fusion plasmas. The compact and accessible ST configuration is potentially advantageous for the development of fusion energy and also broadens and improves the scientific understanding of plasma confinement at the ITER project. The plasma confinement capability, and the achievable plasma temperature, scale strongly with plasma current in the tokamak and ST. Plasma current in the range of 1 MA (million amperes or 1 mega ampere or MA) is required to access plasma temperatures needed to understand ST physics under fusion-relevant conditions. The only existing Department of Energy (DOE) facility capable of producing MA-class ST plasmas is the NSTX facility.

The ST shares many features in common with the conventional tokamak, but several important differences have also been identified—for example the scaling of turbulent energy transport with the frequency of inter-particle collisions. Understanding the causes of these differences is important not only to ST research, but also for developing a predictive capability for magnetic confinement generally. The new Center Stack (CS) would double the NSTX toroidal magnetic field (TF) to 1 Tesla and enable a doubling of the maximum plasma current to 2 MA for the first time in STs. The Center Stack Upgrade (CSU) combined with the installation of a second Neutral Beam Injection (NBI) will enable operation at higher magnetic field, current, and plasma temperature, thereby reducing the plasma collisionality to values substantially closer to those projected for next-step ST facilities and for ITER. Access to reduced collisionality will extend the plasma physics understanding of the ST and aid in the development of predictive capability for plasma confinement. Further, controllable fully-non-inductive-current-sustainment is predicted to be provided by the second NBI, and would enable tests of the potential for steady-state.

The ST operation will contribute to assessing the ST as a cost-effective path to fusion energy. The ST is particularly well suited to provide a cost effective test-bed to bridge several gaps from successful ITER operations to a demonstration fusion power plant (demo) as identified in the Fusion Energy Sciences Advisory Committee (FESAC) report issued October 2007 and entitled: "Priorities, Gaps and Opportunities: Towards A Long-Range Strategic Plan for Magnetic Fusion Energy". More recently, in November 2008, the "Report of the FESAC Toroidal Alternates Panel" also found that the ST offers the potential for an attractive test facility for developing fusion components. Upgrading the NSTX facility could significantly narrow or close capability gaps identified above. In support of these upgrades, the NSTX collaborative research team developed its Five Year Program Plan for 2009-2013, which was favorably peer reviewed

and strongly endorsed during the DOE/Office of Science (SC) review conducted July 28-31, 2008. The review committee specifically endorsed the NSTX Upgrade plans, which form the central elements of the NSTX Five-Year Program Plan.

2. TECHNICAL STATUS

2.1 Findings

The Committee reviewed the documentation submitted by the Princeton Plasma Physics Laboratory (PPPL) for this review and identified a few key findings.

There have been no recordable injuries to date on the NSTX Upgrade project.

The project realized a schedule slip of four months in the last six months attributed to issues in the central stack fabrication process. Specifically, additional process development was necessary for fixing flaws in the stir welding, process refinement continued for soldering the cooling tube into the toroidal field (TF) conductor channel and the TF quadrant mold top had flaws that forced remanufacturing.

The Center Stack (CS) fabrication remains on the critical path, but significant progress was made on both CS procurement and fabrication. A total of 38 TF conductors have been delivered, cooling tubes have been soldered into 28, and 13 are primed and wrapped. A total of 36 conductors are required for a full TF bundle. Sufficient material has been ordered for six quadrants but only four will be fabricated, unless one does not pass tests.

The Vacuum Pressure Impregnation (VPI) process trial was successful. The first quadrant VPI is scheduled for January 2013.

A successful test application and removal of the Aquapour process on a TF-scale mockup was performed. No tests or development was presented on the effects of the removal liquid on the insulation properties of the insulations systems.

Ultrasonic inspection of the outer TF coils identified two coils that need repair due to damage in the braze joint.

The Neutral Beam Injection (NBI) Upgrade is progressing well. The task is under cost and ahead of schedule. The second Neutral Beamline was successfully moved into the NSTX test cell in September after completion of the decontamination process. After significant rework of poor welds on the large NBI port weldment, it is ready for installation.

No technical problems were identified in any of the ancillary systems

2.2 Comments

Construction efforts continue to be executed safely. The work processes developed and implemented by the Work Control Center are mature and combined with the strong ES&H participation assure safe, efficient, and correct task performance.

The project has the key people needed for the CS fabrication and assembly. Both engineering and technician backup personnel have been identified for critical tasks. Judicious use of overtime and second shift has been used to date and should continue.

Since the impacts from an electrical fault are so significant, additional electrical tests should be considered. Consider testing the standoff between adjacent TF quadrants without Vacuum Pressure Impregnation (VPI) to test the electrical integrity of small sections that might remain dry after VPI. A test to failure could be performed on test conductors appropriately wrapped and clamped.

A more comprehensive electrical test plan for the TF bundle to Ohmic Heating (OH) coil and for the OH coil alone needs to be developed and reviewed by the electrical group. The plan should include an impulse test and plans for obtaining and/or building the required test setup must be prepared soon to assure readiness of test equipment when needed.

All aspects of the production process should be tested and optimized prior to beginning the winding of the OH on the TF bundle. A small-scale mockup of the OH winding, including winding on Aquapour, should be considered. The process for winding the OH coil is new, the winding machine is new, and insulation requirements are much higher than the TF (9 kV vs. 1 kV).

While the Committee did not observe obvious technical problems with the proposed CS assembly, the recent schedule slips in the TF fabrication, indicate that final development of the remaining CS assembly tasks will take longer than the present schedule, especially if additional prototypes are built. The project should support additional prototyping to reduce technical risk.

Many processes are being developed as the project progresses. Both formal and informal internal reviews of these procedures should continue to ensure thoroughness before proceeding with critical processes.

While numerous improvements to NSTX hardware and much of the diagnostic relocation, reinstallation, and calibrations are not part of the upgrade project, a comprehensive facility readiness plan should be developed. Discussion of this should be presented at the next review.

Recent vendor problems with the NBI port weldment and the TF quadrant mold case has led to a management review of Quality Assurance (QA) inspection for vendor progress and delivered parts. The lessons learned are being applied to all aspects of the remaining procurement. Prompt inspection and testing of hardware upon arrival will be performed and a full-time QA person has been provided to ensure this is done. Additional opportunities should be explored for verification of vendor performance prior to final delivery.

The Digital Coil Protection System has fallen behind schedule. At the May 2012 review, the software final design review (FDR) was scheduled for July 2012 but both the software and hardware preliminary design reviews (PDR) are now scheduled for first quarter FY 2013. Forecast completion of this task is July 2014, making this very close to critical path. Adequate personnel should be assigned to get this task back on schedule and strong consideration should be given to advance this task.

2.3 Recommendations

1. Develop a comprehensive facility readiness plan and schedule including both project and non-project items. Present plan at the next review.

2. Assign adequate personnel to ensure completion of the Digital Coil Protection System on the original baseline schedule.

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3. COST and SCHEDULE

3.1 Findings

Project Status as of October 31, 2012		
Project Type	MIE	
CD-1	Planned: Dec 2009	Actual: Apr 2010
CD-2	Planned: Dec 2010	Actual: Jan 2011
CD-3	Planned: Jan 2012	Actual: Dec 2011
CD-4	Planned: Sep 2015	Actual: on schedule
TPC Percent Complete	Planned: 50.7%	Actual: 53.4%
TPC Cost to Date	$44.3.0M	
TPC Committed to Date	$46.1M	
TPC	$94.3M	
TEC	$83.5M	
Contingency Cost (no Mgmt Reserve)	$11.8M	30.7% to go
Contingency Schedule on CD-4	12 months baseline	55.6% to go
CPI Cumulative	1.00	
SPI Cumulative	1.06	

Funding Profile at CD-2 with Accelerated Funding

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Total ($M)
Baseline at CD-2	$5.1	$8.3	$9.6	$14.6	$25.3	$27.5	$3.8	$94.3
Accelerated Funds	$5.2	$9.0	$9.9	$20.5	$22.8	$23.1	$3.8	$94.3

The project's critical path is through the TF coils, the CS, digital coil protection, and vessel closure and pump down. The standing army cost is approximately $250K per month. The project performs a bottom-up estimate every six months with the last estimate in July 2012.

At Critical Decision (CD) 2, the project had $17 million cost in and 12 months of contingency. Since then, the project has used approximately $5.7 million of cost contingency, with majority of this contingency usage resulting from magnet related activities. The accelerated funding allowed the project to gain additional 6-months of schedule contingency. However, since the May 2012 DOE/SC review, four months of schedule contingency has been utilized for magnet activities.

Since the May review, the project discovered that four of the outer TF coils sustained some damage. Two of the coils will be repaired and two will be replaced. Although the outer TF coil repair and replacement activities are being performed outside the project scope of work, the

completion of these activities are directly tied to the success of the project and the project is closely tracking the progress of the outer TF coil repair and replacement.

The project identified lessons learned related to procurements, specifically the delivery of items that meet specifications.

3.2 Comments

The current project cost and schedule projections are consistent with the approved cost and schedule baseline.

The project had difficulties meeting cost and schedule on multiple activities related to the CS fabrication. This rate of productivity might be an indicator for future planned work related to CS fabrication and have an impact to the overall project schedule, since it is on the critical path.

The utilization of four months of schedule contingency in the past six months along with the amount of cost contingency associated with the magnet activities is a concern. However, the Committee judged that that contingency remaining is adequate for the remaining risks.

The Integrated Project Team has implemented the cost and schedule actions in from the May 2012 review.

3.3 Recommendations

None.

4. MANAGEMENT

4.1 Findings and Comments

The management structure is adequate to deliver the scope within budget and schedule. The Integrated Project Team (IPT) responded to the previous recommendation to develop a strategy to address impacts of potential changes to the project funding profile and/or the broader NSTX Program. Risks are being actively managed, but the project has entered the riskiest technical phase during a period of funding uncertainty. The DOE/FES, PPPL, IPT and DOE/PSO should continue to evaluate all impacts to the baseline from potential changes to funding profiles once these are better understood and communicated by DOE/FES.

The University's Advisory Committee visited PPPL and reviewed the project, along with other programs at the laboratory in October 2012. There have been no project-sponsored peer reviews since CD-3. The key management personnel required to deliver the baseline are in place within the project organization. This includes the DOE Federal Project Director (FPD), senior laboratory and M&O contractor leadership. The roles of two key individuals changed and one additional person was added to the project since the May 2012 review. The Deputy FPD assumed the role and responsibilities of the Project Director on June 12, 2012; the previous FPD is actively involved in a support role. A receipt inspector within the M&O contractor organization was assigned to provide additional quality assurance of vendor sub-contracts. For the most part, these personnel have been closely associated with the project since its inception. More importantly, these personnel are highly experienced with the NSTX facility.

Fabrication of major technical components has made good progress but encountered some complications that are being actively managed. Procurements have proceeded generally well with the exception of one vendor. Installation and construction of the neutral beam (NB) and ancillary systems have proceeded very well and disassembly is nearly finished and reassembly has begun. Fabrication and assembly of the CS has made progress but encountered problems since the May review that has adversely affected schedule performance.

The project has generally performed well with respect to schedule since the May review. The accelerated schedule early finish date slipped from six months to two months early relative to the CD-2 approved baseline early finish date. The recent consumption of four months of schedule contingency was due to a combination of technological, design, and procurement issues related to the CS. About half of the schedule slippage was caused by problems with the design, procurement, and fabrication of the CS quadrant "v" mold and lid. The project team has taken

corrective actions to resolve these issues and implemented measures to increase vendor oversight (e.g., additional receipt inspector labor) as a way to mitigate risk for remaining procurements.

Construction efforts are being executed safely and the project organization currently has an adequate skills mix to execute the project. The ES&H performance by the project continues to be good and there were no project related recordable injuries or significant radiological incidents since CD-3 and the May review.

Despite the coordinated planning to account for budget uncertainty, the project appears to be at increased risk of losing key personnel and critical skills. These risks would be triggered if PPPL is forced to implement a Reduction in Force due to reduced funding to the overall NSTX Program or to broader PPPL operations during FY 2013 and beyond. Although these two risks are distinctly listed on the current risk registry, the combined impacts appeared to be overly optimistic. The Committee understood that the magnitude of funding reductions equate to the loss of between 60 and 80 full time employees. The Committee judged that the combined impacts of these two risks being realized would probably exceed a critical path schedule delay of 2 months and additional costs of $137,000 indicated in the risk registry. The Committee therefore recommended that the IPT reassess the consequences with respect to cost and schedule, and update the risk registry accordingly by February 1, 2013.

The project will soon enter the second half of the upgrade schedule and naturally shift focus towards completion and start of operations. The Committee judged that this is an appropriate time in the project schedule to conduct detailed planning to transition to start-up and operations. The Committee acknowledged that the NSTX is a unique device that does not cleanly fit into an existing nuclear or accelerator safety category. The Committee therefore believes that the IPT must refine the plan for start-up readiness before the next review, and to a degree acceptable to the DOE/PSO.

In summary, the management team remains in place, with some positive additions, and is functioning well with adequate systems and resources to deliver the baseline. The project generally performed very well since CD-3 with respect to cost and schedule as measured by Earned Value Management System (EVMS) metrics. The project appears on track to successfully achieve early completion based on performance to date but is subject to increased project appears to be at increased risk of losing key personnel and critical skills if funding levels to the overall NSTX and other PPPL programs are reduced during FY 2013 or FY 2014. The project should begin detailed planning on readiness for start-up to a degree acceptable to DOE/PSO.

4.2 Recommendations

3. Reassess the potential impacts of the loss of critical skills and personnel and update the risk registry by February 1, 2013.

4. Prepare a plan for startup readiness that is acceptable to the Site Office prior to the next review.

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APPENDIX A

CHARGE MEMORANDUM

Department of Energy
Washington, DC 20585

October 4, 2012

MEMORANDUM FOR DANIEL R. LEHMAN
DIRECTOR
OFFICE OF PROJECT ASSESSMENT
OFFICE OF SCIENCE

FROM: EDMUND J. SYNAKOWSKI for EJ Synakowski James W. Van Dam
ASSOCIATE DIRECTOR OF THE OFFICE OF SCIENCE
FOR FUSION ENERGY SCIENCES

SUBJECT: OFFICE OF SCIENCE PROJECT REVIEW FOR THE NATIONAL SPHERICAL TORUS EXPERIMENT (NSTX) UPGRADE PROJECT

I request that your office organize and lead an Office of Science (SC) project review of the NSTX Upgrade Project at PPPL on December 12-13, 2012. The purpose of this review will be to assess the current status of the Project's performance.

The NSTX Upgrade Project received Critical Decision (CD-0) approval in February 2009, CD-1 approval in April 2010, CD-2 approval in October 2010, and CD-3 approval in December 2011. The project is currently in the construction/execution phase, with significant field construction, fabrication and procurement activities underway.

In carrying out its charge, the review committee is requested to consider the following questions:

1. Construction Efforts: Are construction efforts being executed safely? Does the project have adequate resources and the appropriate skills mix to execute the project per the plan?
2. Baseline Cost and Schedule: Are the current project cost and schedule projections consistent with the approved baseline cost and schedule? Is the contingency remaining adequate for the risks that remain?
3. Management: Evaluate the management structure as to its adequacy to deliver the scope within budget and schedule. Are risks being actively managed?

4. Response to Prior Reviews: Has the Integrated Project team implemented all required actions in the Corrective Action Plan that was developed following the Project Status review from April 2012?

Barry Sullivan is the program manager for this project and will serve as the contact person for this review. He can be reached at 301-903-8438. I would appreciate receiving your committee's report within 60 days of the review's conclusion.

cc:

M. Dikeakos, SC-PSO
J. Makiel, SC-PSO
A. Indelicato, SC-PSO
J. Van Dam, SC-FES
B. Sullivan SC-FES
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M. Williams, PPPL
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E. Perry, PPPL
M. Ono, PPPL
J. Menard, PPPL

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy/Office of Science Review of the
National Spherical Torus Experiment (NSTX) Upgrade Project
December 11-12, 2012

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Stephen Meador, SC, Chairperson

Review Committee

Subcommittee 1: Technical
*Arnie Kellman, General Atomics
Will Oren, TJNAF
Bruce Strauss, DOE/SC

Subcommittee 2: Cost and Schedule
*Kin Chao, DOE/SC
Tim Maier, DOE/BHSO
Rick Blaisdall, DOE/APM

Subcommittee 3: Management
*Frank Crescenzo, DOE/BHSO
Chris Ackerman, DOE/SC

*Lead

Observers

Ed Synakowski, DOE/SC
Barry Sullivan, DOE/SC
Tony Indelicato, DOE/PSO
Maria Dikeakos, DOE/PSO

APPENDIX C

REVIEW AGENDA

Department of Energy/Office of Science Review of the
National Spherical Torus Experiment (NSTX) Upgrade Project
December 11-12, 2012

AGENDA

Tuesday, December 11, 2012—LSB, Room B318

8:00 am	Executive Session	
9:00 am	Laboratory Perspective	Stewart Prager
9:05 am	Project Overview	Ron Strykowsky
9:45 am	NSTX Centerstack Fabrication	Jim Chrzanowski
10:10 am	Break	
10:25 am	Second Neutral Beam on NSTX	Tim Stevenson
10:50 am	NSTX Centerstack Ancillary Systems Progress	Larry Dudek
11:15 am	Machine Installations and Construction Management	Erik Perry
11:40 am	Safety	Jerry Levine
11:50 am	Lunch	
12:50 pm	Tour NSTXU test cell, CS High Bay, CS Fab Shop, CAS/RESA	
1:50 pm	Break-out Sessions	
3:50 pm	Executive Session	
5:00 pm	Adjourn	

Wednesday, December 12, 2012

8:00 am	Follow-up and Report Writing
10:00 am	Dry Run
11:30 am	Closeout Presentation
12:00 pm	Adjourn

APPENDIX D

COST TABLE

NSTX Upgrade Cost Table

NSTX-U BASE CASE (i.e., Case 2 FY13/14 President's Budget) - $M BA

Excludes FY 2012 Carry Over of $2.8M)

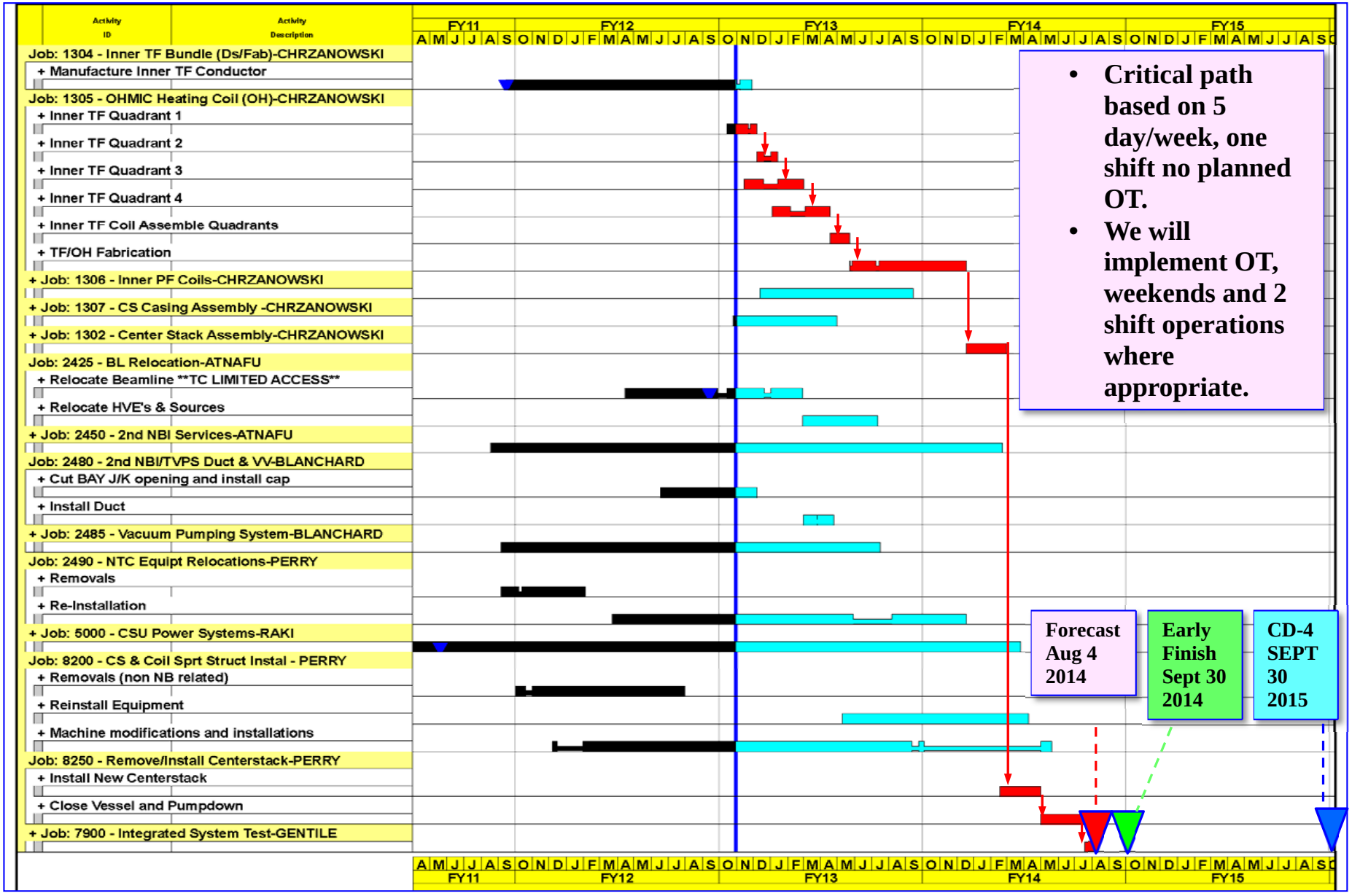
	FY 2013	FY 2014	FY 2015	
NSTXU	**$22.8**	**$23.1**	**$3.8**	Sep-14
NSTX Facility Ops	**$9.2**	**$8.3**	**$27.1**	
NSTX Improvements			**$2.4**	
NSTX Science	**$8.2**	**$9.2**	**$13.6**	
NSTX Collab	**$5.8**	**$5.8**	**$6.4**	
Total	**$46.0**	**$46.3**	**$53.2**	

Impact
1) Distribution of funds to NSTX-U consistent with CD-2 levels in FY2013 and FY2014 and allows CD-4 completion in Sept 2014.
2) However, insufficient funding to support both the needed base program operations staff and to cover the Research Staff necessary to support resumption of operations in Sept 2014.
3) Institutional funding consistent with the presidents budget will require a reduction in staff at PPPL. This could have an impact on the upgrade project should critical skills be lost.

APPENDIX E

SCHEDULE CHART

NSTX Upgrade Schedule



APPENDIX F

MANAGEMENT CHART

NSTX Upgrade Project Team