Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

National Spherical Torus Experiment (NSTX) Upgrade Project

October 2013

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 October 2-3, 2013. The review was conducted by the Office of Project Assessment (OPA) and chaired by Stephen Meador, OPA, at the request of Dr. Edmund Synakowski, Associate Director of Science for the Office of Fusion Energy Sciences (FES). 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 on the NSTX Upgrade is very good. The work control center is functioning well. The project has adequate resources and the necessary skill mix to successfully complete the project. Concerns identified by the Committee include prior and ongoing schedule slippage due to difficulties with various center stack (CS) fabrication activities; ensuring a coil protection system is in place prior to initial startup; and rate of contingency usage. The Committee judged that the project's current forecast for completing the CS in May 2014 and achieving the early finish date of November 2014 is optimistic. Absent a catastrophic failure of the CS, the CD-4 milestone is not in jeopardy.

The Committee was concerned about the project's use of contingency from two perspectives—first the project did not convey a complete understanding of the potential impacts to the overall schedule as a result of significant use of cost and schedule contingency on the CS fabrication activities (leading to the project's optimistic completion forecasts). Second, differences in Princeton Site Office and project analyses regarding adequacy of remaining cost contingency highlighted a need for them to work together closely on an end game plan to monitor and effectively communicate critical project activities necessary to assure project success. Despite concerns about the historical trend in contingency usage, absent a catastrophic failure of the CS, the Committee judged the CD-4 milestone is not in jeopardy.

Technical

The CS fabrication continues to be on the critical path. CS work is high quality, but continually draws on contingency. Project management should redistribute lower risk CS tasks from the CS technical lead to others on the CS team to maintain high quality work and improve schedule performance. A simplified version of the Digital Coil Protection System (DCPS) should be available before initial startup. Transition to operations planning is well underway.

Cost and Schedule

Overall the project is approximately 72% complete. The Committee judged that the project is on track for successful project completion; however, the Estimate at Complete (EAC) appears optimistic and risk management requires additional attention by the project team and PPPL management.

Management

Fabrication of major technical components is making good progress. Reassembly of the machine is well underway. Safety performance is good. Some worrisome, low probability-high risk events (potential CS electrical test failures) could impact the ability of the project to complete on cost and schedule. Based on the historical schedule contingency usage and ongoing slips in the CS fabrication, the November 2014 early finish date is optimistic. The project should consider whether there are elements of the DOE Accelerator Order that would be beneficial for NSTX Upgrade startup and operations.

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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 the ST. Plasma current in the range of 1 MA (million amperes) 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.

The safety record of the project continues to be outstanding with only one recordable incident and no DART (Days Away/Restricted or Transfer Rate) cases since the December 2012 DOE/SC review.

Excellent progress has been made on the CS fabrication since the December 2012 review. Major tasks with considerable technical risk have been completed successfully including the fabrication and Vacuum Pressure Impregnation (VPI) of all four TF quadrants and the full TF bundle, two new TF coils, delivery of major tooling for the OH solenoid, and the preparation of the Ohmic Heating (OH) winding facility, including the pivot beam and CS tilt fixture.

Fabrication of the inner Poloidal Field (PF) coils (1A, B, C) was delayed by several months due to a problem with a subcontractor for the prime vendor, but the delivery will not affect the critical path.

Overall, the Neutron Beam (NB) project is progressing on task, under cost (Cost Performance Index =1.06) and on time (Schedule Performance Index=1.0). The Beamline #2 (BL2) internal component relocation is complete, the J-K port welding is complete, and the NB duct and Torus Vacuum Pumping System duct fabrications are complete, leak checked, and ready for installation. The cryogenic and water piping installation are complete. Relocation of three High Voltage Enclosures (HVE) for BL2 is complete.

Installation schedules for the machine hall are based on a five-day work week with options for increasing the number of shifts as necessary.

Additional manpower (5.5 FTE) has been provided to the Digital Coil Protection System (DCPS) in response to a recommendation from the December 2012 review. Good progress has been made and full system commissioning is scheduled to begin in June 2014 to be ready to support Integrated System Testing in the fall of 2014. The DCPS system must be in place before operations can begin.

Secondary passive plates in section A/L, located inside the Tokamak vacuum vessel, were found to be weaker than acceptable for the higher NSTX Upgrade parameters. A new design using e-beam welding has been developed to address the problem. Installation is anticipated for July 2014—CD-4 can be completed even if this installation slips.

A Facility Startup Plan was presented in response to a recommendation from the December 2012 review. The startup plan presented utilizes the system developed and successfully implemented over the past 13 years of NSTX operation.

2.2 Comments

Installation planning and scheduling of activities in the test cell are well planned. Schedules are realistic with built-in contingency anticipating possible fit-up problems.

CS fabrication continues to be on the critical path. Work-to-date has been of a high quality, but the task continues to use schedule contingency. Care must be exercised not to risk the technical success of the overall project in order to improve schedule margin. However, management should identify lower risk tasks (non-winding) that might be more amenable to being performed by additional personnel to gain schedule contingency.

A comprehensive electrical test plan for the TF bundle to OH coil, and for the OH coil alone, needs to be finalized soon to assure readiness of test equipment when needed.

The project identified three areas with poor quality welds from the same vendor after delivery to PPPL. All welds were ground out and re-welded in house. This emphasizes the importance of evaluating vendor quality performance in process and before delivery to PPPL. In this regard, the Committee supported the planned weekly visits to Everson-Telsa during the fabrication of the inner PF coils and commended the project for continuing to support additional quality assurance oversight for vendors.

Because the new DCPS is required for NSTX Upgrade operations to begin, a reduced scope or simplified version of the DCPS should be considered, that has a very high probability of completion, well before the planned start of operations and testing.

Components in the NSTX Upgrade will experience higher forces, torques, power, and energy fluxes due to the installation of new or upgraded systems and most will not be fully realized for two to three years. It was suggested that NSTX Upgrade management begin the

process of how to confirm that all new systems are performing as expected before parameters are raised. This would include: 1) evaluations of measurement techniques; 2) simulations with which to compare the measurements; and 3) when during the multi-year system commissioning period key evaluations should be performed.

2.3 Recommendations

1. Identify lower risk CS tasks that can be performed by additional personnel or off-shift to gain schedule contingency.

2. Generate an interim milestone for DCPS for earlier commissioning of a reduced scope system able to support all system testing and initial machine operation.

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3. COST and SCHEDULE

3.1 Findings

Project Status as of August 30, 2013		
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: 74%	Actual: 72%
TPC Cost to Date	$63.4M	
TPC Committed to Date	$65.5M	
TPC	$94.3M	
TEC	$83.5M	
Contingency Cost (no Mgmt Reserve)	$7.1M	29 % to go
Contingency Schedule on CD-4	10.5 months	78.7% to go
CPI Cumulative	0.98	
SPI Cumulative	0.97	

In July 2013, the project team performed an estimate, which resulted in an Estimate-at-Complete (EAC) of $87.6 million and a November 2014 forecast CD-4 date.

Prior to the review, the project provided the necessary documentation for the Committee to perform analysis on project performance. Documentation included: the risk registry, Engineering Change Proposal (ECP) log, monthly cost performance reports, budget profile, and the latest resource loaded schedule.

The critical path for the project continues to be through the TF coils, the CS, DCPS, and vessel closure and pump down activities. The standing army cost remains approximately $250K per month. However, it is expected to be reduced to approximately $150K to $100K for the remainder of the project as activities are completed and personnel no longer charge to the project.

At CD-2, the project had $17 million in cost contingency and 12 months of schedule contingency. Of the $17 million, approximately $6.1 million has been identified in the risk registry. To date, the project has retired $2.4 million in cost contingency, leaving roughly $3.7 million remaining. The project analysis indicated that the project may consume the bulk of the contingency by May 2015, which is six months beyond forecast November 2014 CD-4 early finish date. At the December 2012 review, the project indicated it had used four months of

schedule contingency on magnet activities. Since the December 2012 review, the project has utilized an additional 3.5 months of schedule contingency for magnet activities.

3.2 Comments

Based on the information presented, the cost and schedule projections by the project are consistent with the approved cost and schedule baseline. The contingency remaining is probably adequate for the risks that remain; however, the continuing trend in contingency usage is a concern.

Considering the likelihood of occurrence of some activities, the EAC estimate appears to be too optimistic. For example, the project stated that there was a high probability that the project would not make its current projected CD-4 of November 2015 and was significantly more confident in a January 2015 CD-4 date. Other examples include the amount of overhead rate that will be reduced, PF quality issues, and the OH winding takes longer than planned. The Committee judged that these should be reflected in the EAC and risk registry.

Although there is an updated ECP log, which contains cost impact of the proposed changes, the log does not show the schedule impact in durations. As a result, it is difficult to determine what the actual delays in the activities are.

Finally, the Committee concluded that the risk identification, analysis, and tracking should be more rigorous. For example, of the risks that have not been retired, most have not been updated since 2010. In addition, new risks that have been identified are not captured in the registry. Instead, the cost impacts are directly included in the EAC. Most of the contingency usage was from activities not identified in the registry, but came from what the project defined as uncertainty. The project defines uncertainties as those items that are unknown or quantified.

3.3 Recommendations

3. Include schedule contingency impacts in the ECP forms for the future ECPs.

4. Include items and activities that are likely to occur in the EAC calculation.

5. Ensure that the risk register is updated and maintained.

4. MANAGEMENT

4.1 Findings and Comments

The management structure remains stable and adequate to deliver the scope within budget and schedule. The key management personnel required to deliver the baseline are in place within the project organization. As noted in previous reviews, these personnel have been closely associated with the project since its inception and are highly experienced with the NSTX facility. The Integrated Project Team (IPT) responded adequately to the previous recommendations. Previous concerns regarding staffing and funding are now resolved. At the time of this review, the Federal budget had lapsed and DOE and its M&O contractors were busy making plans for a possible shutdown. While it was generally understood that such a shutdown would impact the project significantly, this was not evaluated in any way during this review.

Fabrication and assembly of the CS made good technical progress but performance to date has shown a steady draw on cost and schedule contingencies. Fabrication of the CS, as during prior reviews, is the most challenging scope remaining on the project and completion and installation of the CS is on the project critical path. There remains some low likelihood, high impact risks associated with fabrication and assembly of the CS. These risks are mostly related to fabrication flaws resulting in electrical failures that require reassembly of major components to repair. The laboratory is mitigating these risks primarily through very rigorous quality assurance during assembly of the CS components. These risks will be mostly retired upon delivery of the CS to the test cell, now scheduled for May 2014. However, as noted earlier, the CS performance has consistently slipped and simple projections would have it in the test cell no sooner than August 2014. To assist in addressing this performance and these risks, the project sought external expert advice from the National High Magnetic Field Laboratory on the plans for the CS. That review found the project plans to be sound with no major suggestions to improve schedules or reduce risks beyond what is already planned by the project. However, considering the CS past performance, remaining risks, and available contingencies, the Committee was concerned by the optimistic projections for the CS. Moreover the project did not demonstrate to the Committee a full understanding of possible project outcomes driven by CS schedule delivery beyond expected dates. Also, the Committee found that communications between the project and DOE regarding the CS performance and how this will be monitored and managed could be improved. Accordingly, the Committee makes two recommendation related to the CS and also an action item for DOE to revisit these issues in January 2014.

Fabrication of other major technical components has made excellent progress. Installation and construction is extremely well planned and executed so far. The neutral beam and ancillary systems have proceeded very well and reassembly is well underway. The Committee's visit to the test cell showed remarkable reassembly progress since the December 2012 DOE/SC review. Procurements have proceeded generally well. As with most projects, there were the usual vendor problems however, the project was able to successfully overcome these challenges.

Safety performance is excellent. There was one recordable injury and no radiological incidents since the December 2012 review. Planning for startup and transition to operations is well underway with external independent DOE-led oversight of startup authorizations planned. As a suggestion only, the facility should consider whether there are elements of the DOE Accelerator Safety Order that are absent from NSTX that could add quality to startup and operations.

In summary, the management team remains in place, and is functioning well with adequate systems and resources to deliver the baseline. The project appears on track to successfully achieve completion. There is concern regarding the CS performance, available contingencies and plans to monitor and manage these.

4.2 Recommendations

6. Evaluate a broader range of likely project outcomes to better understand and communicate with DOE the limits of cost and schedule contingencies to ensure project success by November 1, 2013.

7. Work with the Site Office and program to develop a focused "end game plan" to monitor and communicate critical project activities to better ensure project success by November 1, 2013.

Action Item

1. The Princeton Site Office should schedule a status review in mid-January 2014.

APPENDIX A

CHARGE MEMORANDUM

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Department of Energy
Washington, DC 20585

June 27, 2013

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

FROM: EDMUND J. SYNAKOWSKI
ASSOCIATE DIRECTOR OF THE OFFICE OF SCIENCE
FOR THE OFFICE OF 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 October 2-3, 2013. 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 ely managed? Has the project responded satisfactorily to the recommendations from ... previous project reviews?
4. Transition to Operations: Is the Project appropriately aligned for completion of construction efforts and transitioning NSTX-U for CD-4 approval?

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
B. Sullivan SC-FES
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J. Menard, PPPL

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy/Office of Science Review of the
National Spherical Torus Experiment (NSTX) Upgrade Project
October 2-3, 2013

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Stephen Meador, SC, Chairperson

Review Committee

Subcommittee 1: Technical
*Arnie Kellman, General Atomics
Will Oren, TJNAF

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

Subcommittee 3: Management
*Frank Crescenzo, DOE/BHSO
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*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
October 2-3, 2013

AGENDA

Wednesday, October 2, 2013—LSB, Room B318

8:00 am	Executive Session	Stephen Meador
8:45 am	Laboratory Perspective	Stewart Prager
9:05 am	Project Overview	Ron Strykowsky
9:35 am	NSTX Centerstack Fabrication	Jim Chrzanowski
10:10 am	Break	
10:30 am	Second Neutral Beam on NSTX	Tim Stevenson
10:50 am	NSTX Centerstack Ancillary Systems Progress	Larry Dudek
11:10 am	Machine Installations and Construction Management	Erik Perry
11:35 am	Transition to Operations/Operational Readiness Review	Al vonHalle
11:55 am	Safety	Jerry Levine
12:05 pm	Lunch	
1:05 pm	Tour NSTXU Test Cell and CS Fabrication Area	
2:05 pm	Subcommittee Breakout Sessions (B318 and DCR)	
2:50 pm	DOE Full Committee Executive Session	
5:00 pm	Adjourn	

Thursday, October 3, 2013

8:00 am	Follow-up and Report Writing
9:00 am	Dry Run
11:30 am	Closeout Presentation
12:00 pm	Adjourn

APPENDIX D

FUNDING TABLE

NSTX Upgrade Funding Table

Monthly $M

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
BA	$5.2	$9.0	$9.9	$20.4	$22.8	$23.7	$3.3	$94.3
BO	$5.1	$8.3	$7.6	$21.9	$23.2	*$20.7*	$0.7	$87.6

Thru SEPT

Cumulative $M

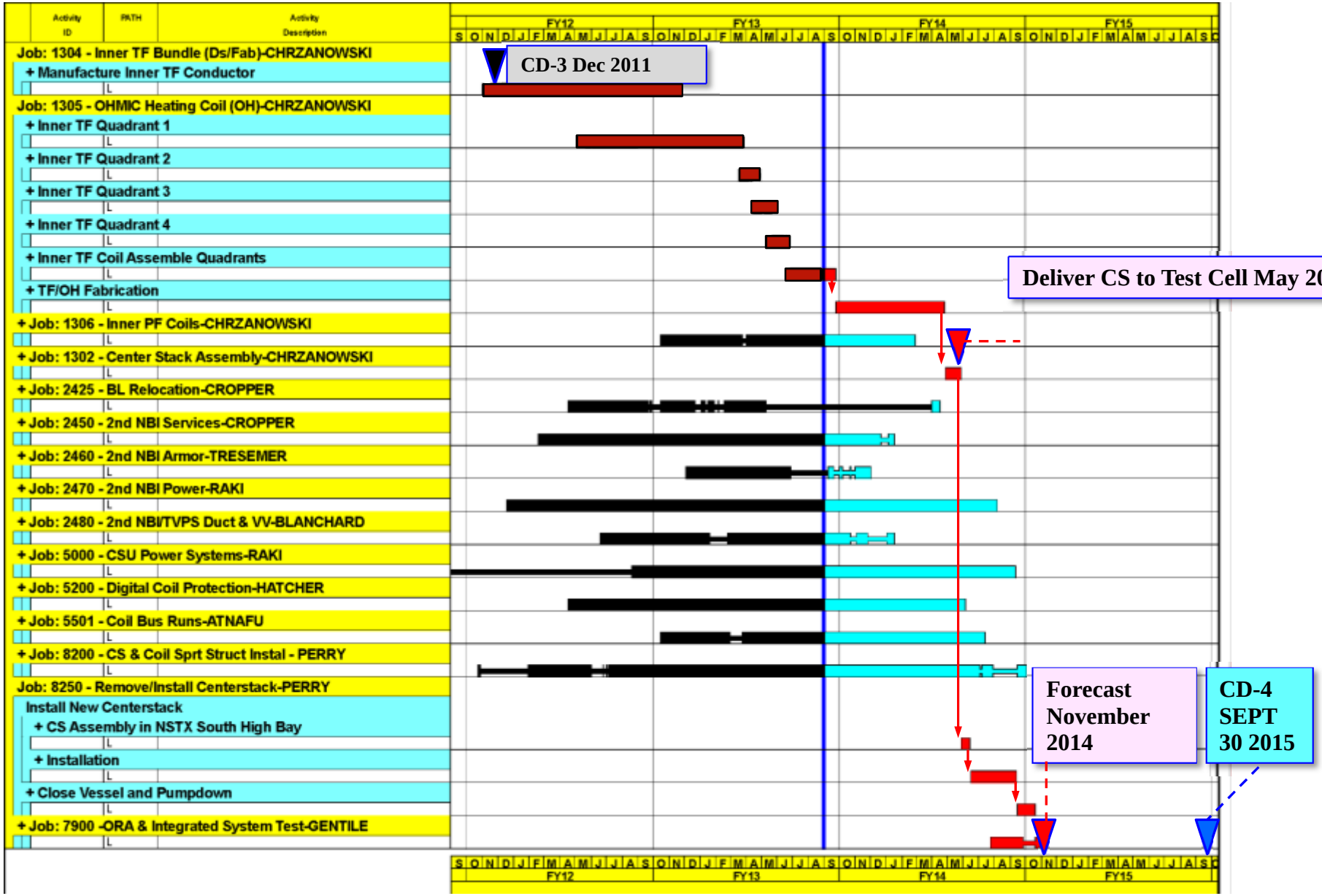
	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
BA	$5.2	$14.2	$24.1	$44.5	$67.3	$91.0	$94.3
BO	$5.1	$13.5	$21.1	$43.0	$66.2	*$86.9*	*$87.6*

Thru SEPT

APPENDIX E

SCHEDULE CHART

NSTX Upgrade Schedule



APPENDIX F

MANAGEMENT CHART

NSTX Upgrade Project Team