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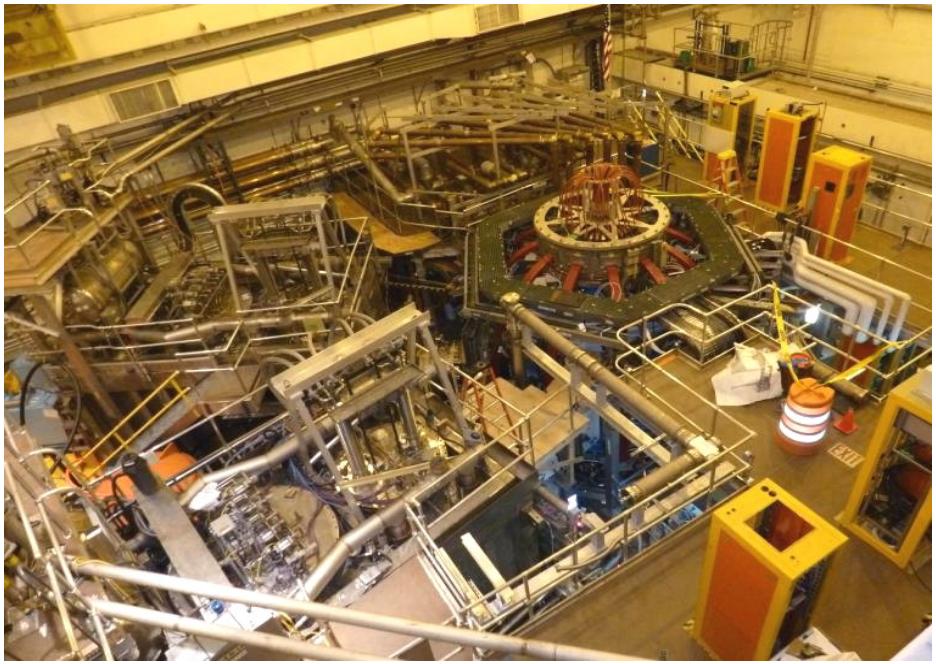
National Spherical Torus Experiment Upgrade (NSTX-U) Project
Princeton Plasma Physics Laboratory



Anthony Indelicato, Federal Project Director

OPA Review Critical Decision - 4

September 2, 2015

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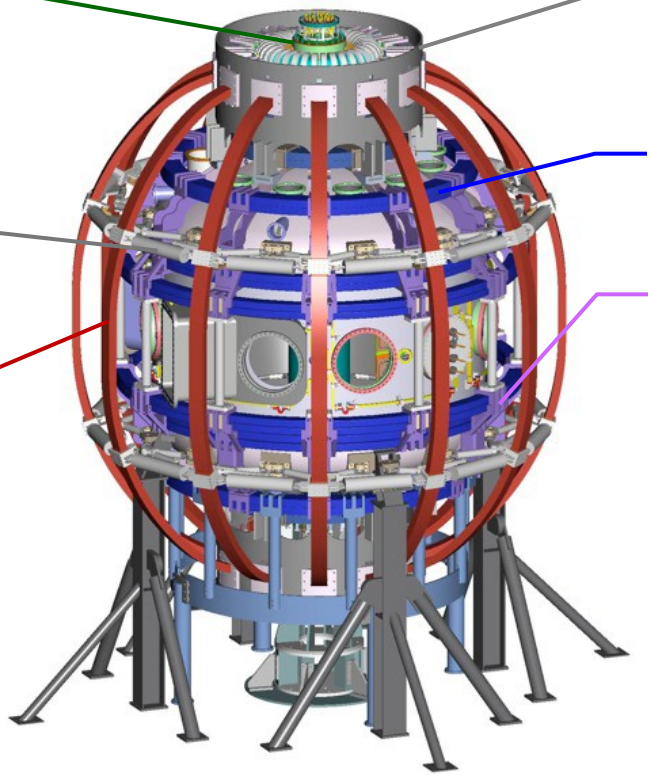
What's the proposed workscope?

Increase toroidal field: 0.5T > 1.0T	Increase plasma current: 1 MA > 2 MA
Increase pulse length: 1.0 s > 5 s	Increase NB heating: 5-7MW > 10-14MW

New Center Stack
Inner TF bundle, TF joint, OH & inner PF coils

Upgraded TF coil support structure

Existing outer TF coils w/ reinstated water cooling



Reinforce umbrella structure

Exst'g outer PF coils – 6 total

New PF coil support structure

Also…modify coil power system, protection system & ancillary support systems

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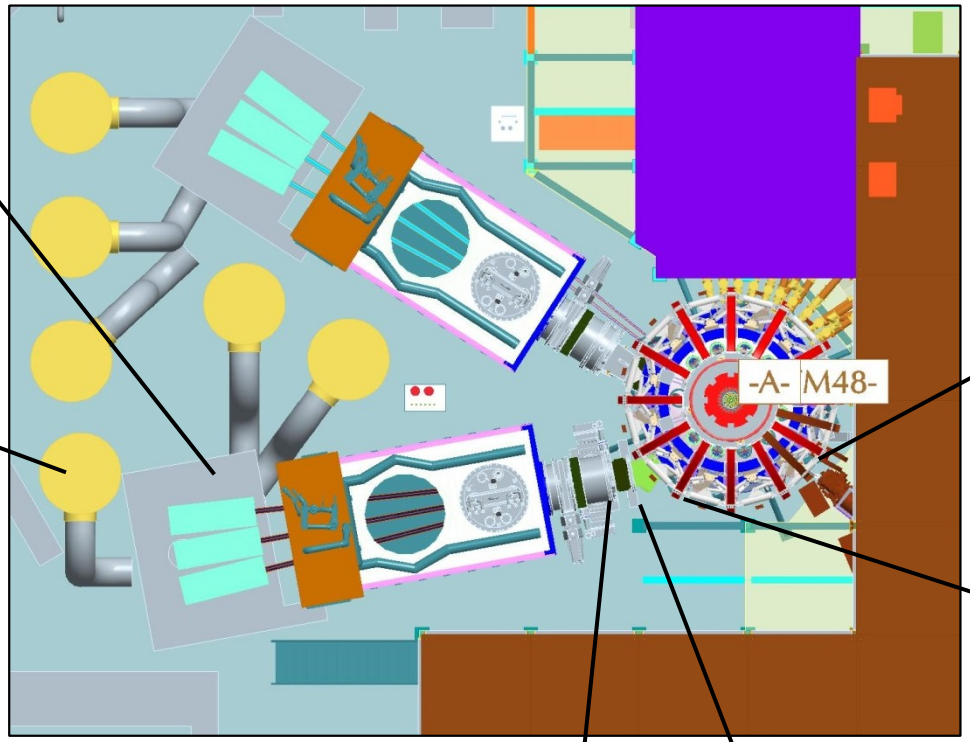
Workscope…*continued*



Add 2nd Beamline
Decon, recondition and install

Install 3 HVEs
Relocate from TC basement

New NB armor

Modify Vacuum Vessel

New NB port

New Vacuum Pump Duct (below)

Also…modify existing power system and ancillary support systems

Project Key Performance Parameters and Critical Decision Milestones

KPP at CD-2	*Demonstrated Performance*	*Current Status*
Toroidal field from 0.5 tesla to 1.0 tesla	First Plasma – Ohmically heated discharge > 50kA at a toroidal magnetic field of > 1kG.	1. Plasma attained on 8/10/15
Pulse Length from ~ 1.0 second to 5.0 seconds		
Plasma Current from 1MA to 2MA		
Neutral Beam heating from 5-7 MW to 10-14 MW	1. NB#2 water, vacuum, cryogenics, and feedstock gas services have been attached 2. A Torus Isolation Valve (TIV) and duct interconnects the NSTX vacuum vessel and NB#2 3. Local Control Centers (LCCs) have been powered on to monitor power supply status 4. A 40,000 electron-volt beam has been produced and injected into the armor for .050 seconds	1. Complete 2. Complete 3. Complete 4. Complete on 5/11/15

Critical Decision Timeline

CD-0 → *2/23/2009;* CD-1 → *4/15/2010;* CD-2 → *12/20/2010;* CD-3 → *12/19/2011*

CD – 4 → September 30, 2015

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Budget and Project Costs

@CD – 2: TPC = $94.3M TEC = $83.5M OPC = $10.8M

BAC = $77.3M Contingency = $17M

Final Costs: BAC = $88.6M EAC = $93.7M

- FPD approved contingency use to cover risks as they were realized
- Unassigned contingency available = $0.6M

Contingency Utilization:

Under-estimated scope

- Centerstack fabrication and Assembly +$12.0M
- Auxiliary systems +$0.2M
- Plasma Diagnostics +$0.4M
- DCPS, Bus bar +$1.9M
- I&C +$0.2M
- Project stretch-out and HP support +$0.4M
- Assembly +$2.0M
- OH Arc Fault Recovery +$0.5M

Scope Enhancements added to the Project:

- PF1c coil protection and Passive plate re-design and fabrication (CHI Gap) $1.2M
- Various Diagnostics accommodations $0.5M
- DCPS redundant computer and improvements $0.3M
- Various I&C enhancements $0.3M

Over-estimated scope

- Neutral Beam over-estimates -$3.5M

Project Lessons Learned

The three most significant "success" lessons for this project.

A. **Technology** – Multiple new technologies utilized in the construction of NSTX-U: Friction stir welding, wire electrical discharge machining (EDM) cutting, Vacuum pressure impregnation (VPI) with cyanide-ester epoxy, as well as electron beam welding and new non-ionic soldering process for TF cooling tubes.
B. **Safety** – The proper planning of work and integration of safety into the work planning and execution of that work resulted in a worker safety record of only 5 minor reportable injuries in over 550,000 man-hours.
C. **Work Planning and Execution** – The work control center provided real value in establishing daily communication and coordination of field activities.

The three areas of potential improvement and how they have or might have impacted the project.

A. **Procurement** – Associated fabricators. Several major welding subcontracts were awarded to one small business that PPPL had not worked with previously. Inferior work product resulted in multiple items requiring rework or award of the contract to a different subcontractor with obvious schedule ramifications.
B. **Loss of Key Personnel** – Loss of DCPS CAM, as well as loss of the senior Center Stack WBS CAM for several weeks resulted in significant impacts to project schedule. There was also a direct impact on cost as less experienced personnel took over these responsibilities.
C. **Technology** – Aquapour. The center stack was designed to maintain a .100" gap between the inner TF bundle and the OH coil that was wrapped around it. This gap was to be established with Aquapour, which could be washed away after the OH coil was VPI'd. Epoxy flowed into the Aquapour during OH potting, solidifying it and making it impossible to remove via planned methods. Several weeks of schedule were lost in dealing with this issue, and some operating restrictions needed to be imposed on NSTX-U due to this situation. All design performance criteria can still be met.

Verification Process

- NSTX-U Readiness to Operate Review (12/14)
- PPPL Activity Certification Committee (ACC) recommended issuance of a Safety Certificate based on construction complete status, closure of Readiness to Operate review action items (4/15)
- PPPL Executive Safety Committee issues Safety Certificate with approved Safety Envelope (4/15)
- PSO concurs with Safety Envelope (4/15)
  - OH Arc occurs on 4/24/15 during Integrated System Testing in support of CD-4 Plasma Ops
    - Internal and external reviews conducted. Internal Root Cause Analysis performed
    - Consolidated Corrective Action Plan (CAP) issued
    - ACC Charged with verifying NSTX-U Readiness for Operations
  - All Cap items complete, ACC recommends restart of ISTP (8/3/15)
  - Plasma shot conducted 8/10/15 that exceeds CD-4 KPP
- Scope Verification of NSTX-U WBS dictionary by Control Account Managers (CAMS).
- PPPL Validation letter of demonstrated performance

CD-4 Requirements

- **Prior to CD-4**
  - Verify achievement of KPPs
  - Conduct Readiness to Operate review and issue a transition to operations plan
  - Finalize the Hazard Analysis Report
  - Revise the Environmental Management System (as appropriate)
  - If Applicable, complete and submit Contractor Evaluation Documents
  - Complete Draft Project Closeout Report
- **Post CD-4**
  - Submit approved CD or equivalent documents to APM
  - Finalize in PARS II project completion
  - Perform final administrative and financial closeouts
  - Prepare an initial Project Closeout Report (90 days after CD-4)
  - Submit Lessons Learned regarding project execution and facility start-up (90 days after CD-4)
  - Complete Facility Sustainment goals and document achievement (within 1 year)
  - Submit Final Project Closeout report
  - Include in Ten Year Site Plan and establish property records in FIMS for facilities

- All Order 413.3B CD-4 Prerequisites met.

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ISSUES:

- NONE
- **Ready for CD-4 ESAAB**