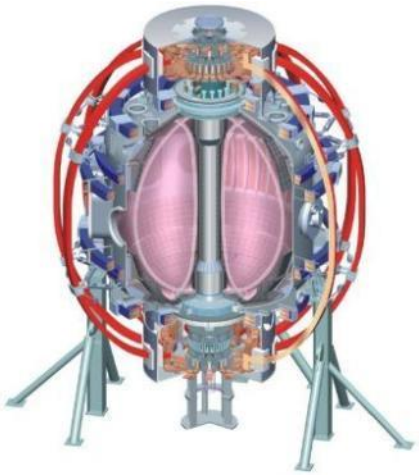
NSTXU Baseline Scope Overview February 7, 2012

Ron Strykowsky



College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
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U Illinois
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Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Second Neutral Beam

NBI BL2 Operating Parameters meet GRD

- *NSTX NBI operates up to 100 keV now @ approx. 2.5 MW per source (15 MW total)*
- *NSTX NBI original spec of 80 keV 5 MW for 5 seconds retained*
- *Approx. 3 MW per source in deuterium at 110 keV achievable…*

NBI Aiming wider tangency radii per GRD achieved

- *Existing BL1 Tangency radii [C=50; B=60; A=70] cm unchanged*
- *BL2 Tangency radii designed to be [C=110; B=120; A=130] cm per GRD*

✓ *Modification of Vacuum Vessel at Bay K required… and included in design*

2 BL 6 sources 18 MW possible… 15 MW required ☑

Tim Stevenson

NSTXU NBI Overview – Scope NOT included

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.

NSTXU NBI Overview – Jobs included

NSTXU NBI Project Cost (all k$)	COG
Job: 2420 - 2nd NBI Sources	Cropper
Job: 2425 - BL Relocation	Denault
Job: 2430 - 2nd NBI Decontamination	Stevenson
Job: 2440 - 2nd NBI Beamline	Denault
Job: 2450 - 2nd NBI Services	Denault
Job: 2460 - 2nd NBI Armor	Tresemer
Job: 2470 - 2nd NBI Power	Ramakrishnan
Job: 2475 - 2nd NBI Controls	Cropper
Job: 2480 - 2nd NBI/TVPS Duct	Denault
Job: 2485 - Vacuum Pumping System	Blanchard
Job: 2490 - NTC Equipt Relocations	Perry

Tim Stevenson

NSTXU NBI – Refurbish Ion Sources

2420

- ***Because BL1 did not support full 2011-2012 operations, BL1 sources are still viable and have been stored in place.***
- ***Therefore, our three spares will be used for upgrade.***
- ***Savings to project of approximately $900k.***

Arc chamber assembly and grid alignment

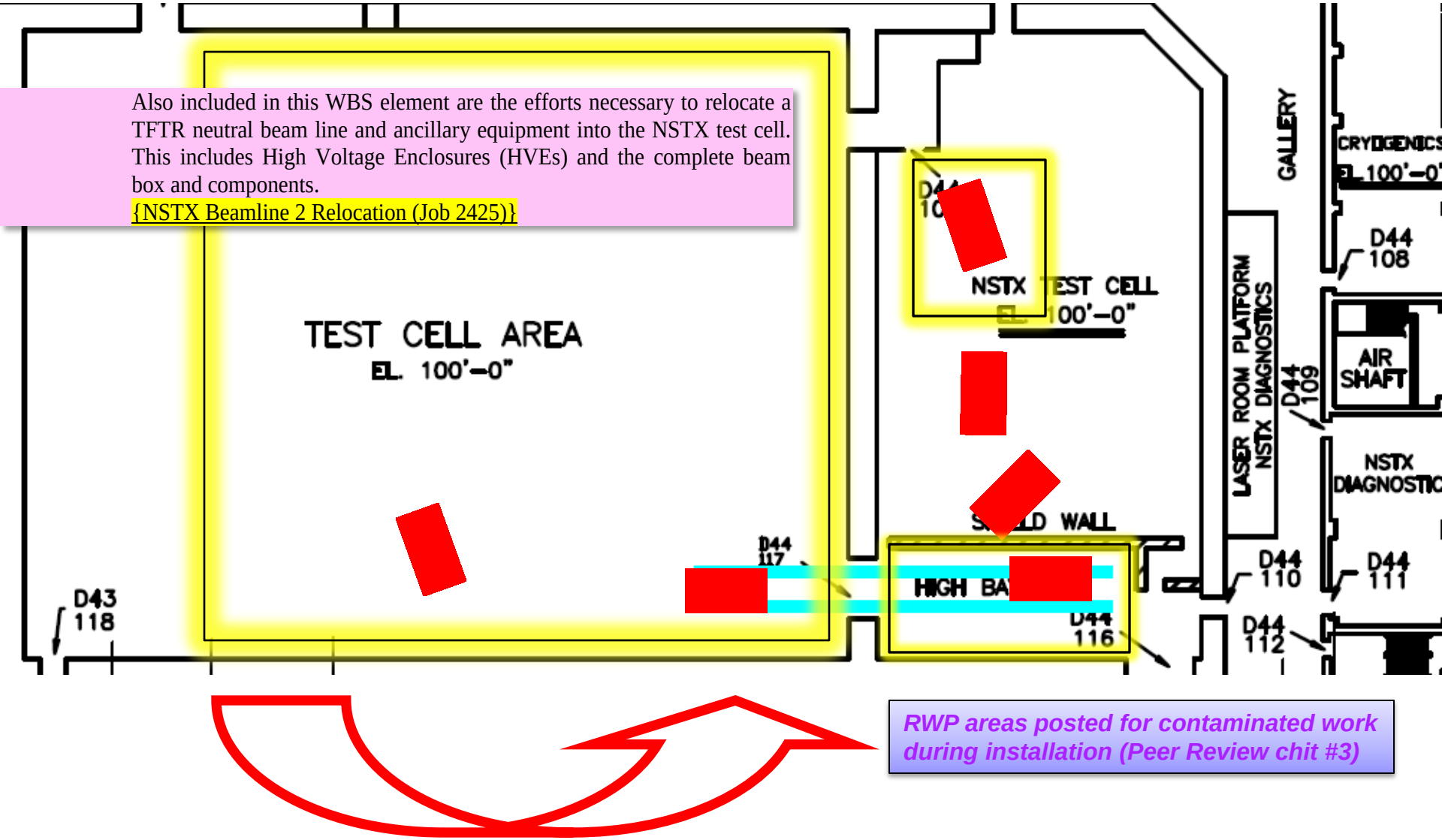
WBS Element: 1.2.4.2 **WBS Level:** 4
WBS Title: **NBI Source Refurbishment**
Definition: This WBS element includes the activities to refurbish three neutral beam ion sources for the 2nd Neutral beamline, as currently being performed for the installed Neutral beamline 1.
{Source Refurbishment (Job 2420)}

Tim Stevenson

BL & Component Relocation

2425

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)}



RWP areas posted for contaminated work during installation (Peer Review chit #3)

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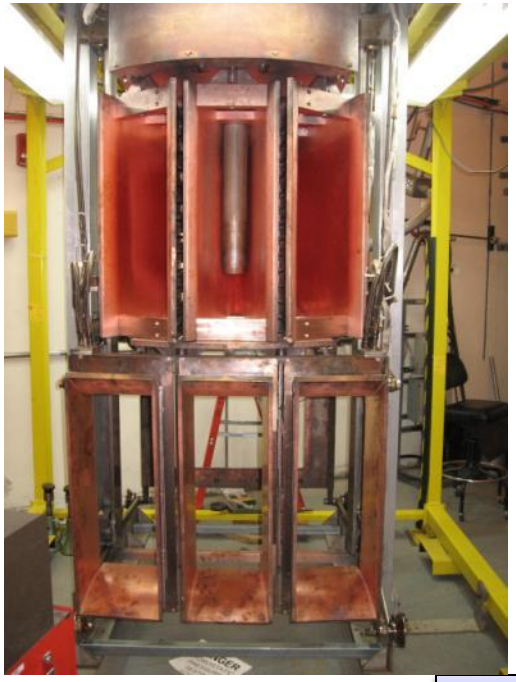
BL Refurbishment: Ion Dump and Calorimeter – in progress

2440



Calorimeter Upgrade

Ion Dump Replacement

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)}

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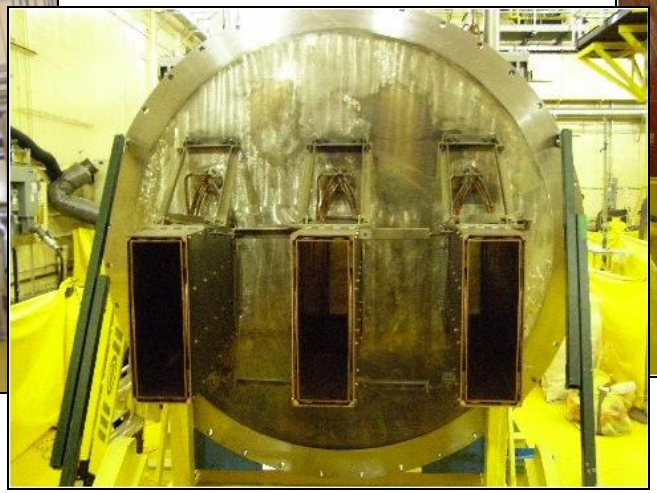
BL Refurbishment: Box, Lid & Cryo panels, 90 inch Flange w/ Neutralizers, and Magnet

2440



Refurbish
Reassemble
New Seals
New TCs
More wipedowns
Package to move

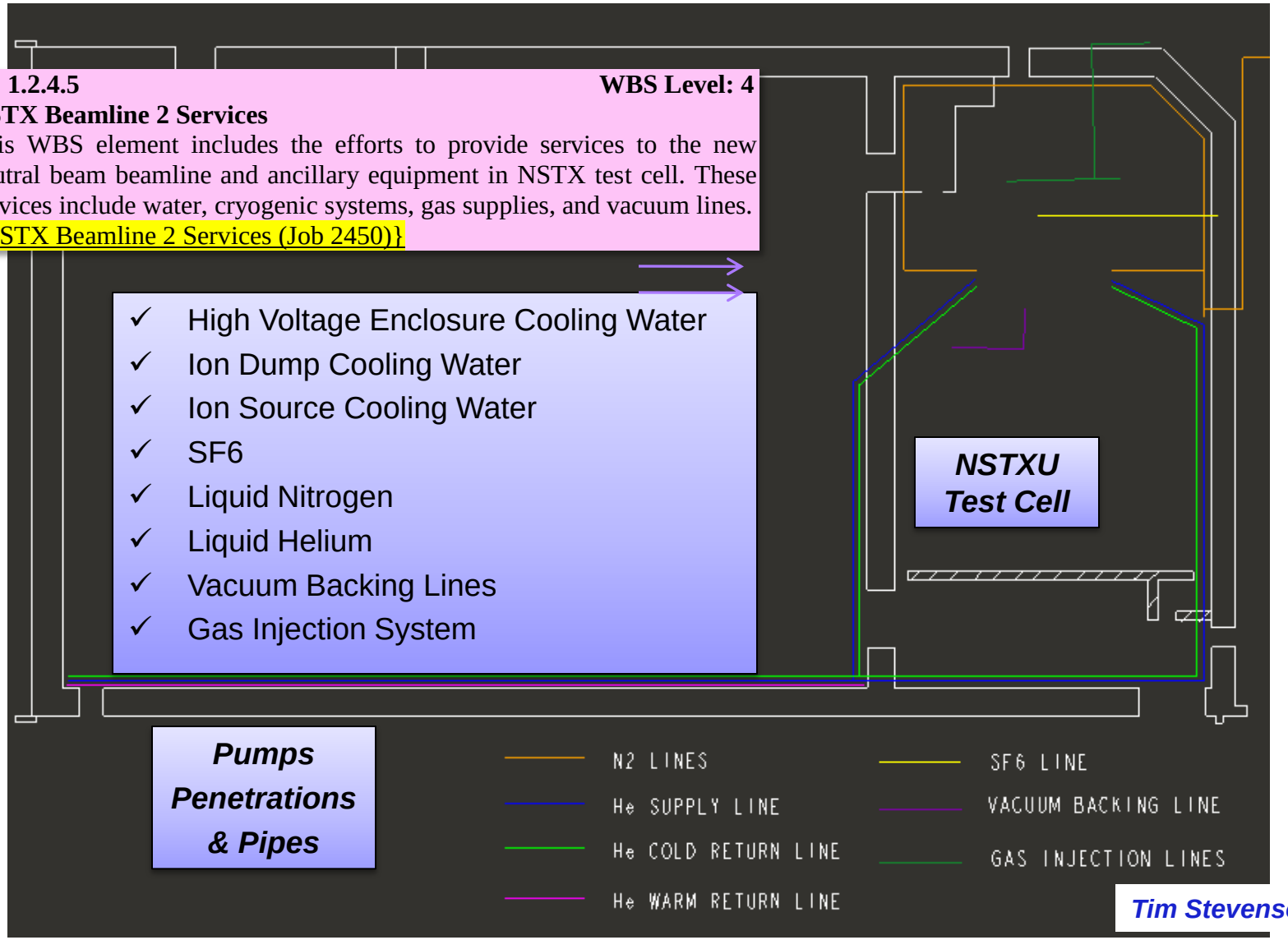
Roll it into NTC
Fly it over
Fit it back together
Align it
Button it all up
Pump down…

Tim Stevenson

NBI Services – new pipes to new location but same technology…

2450

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)}



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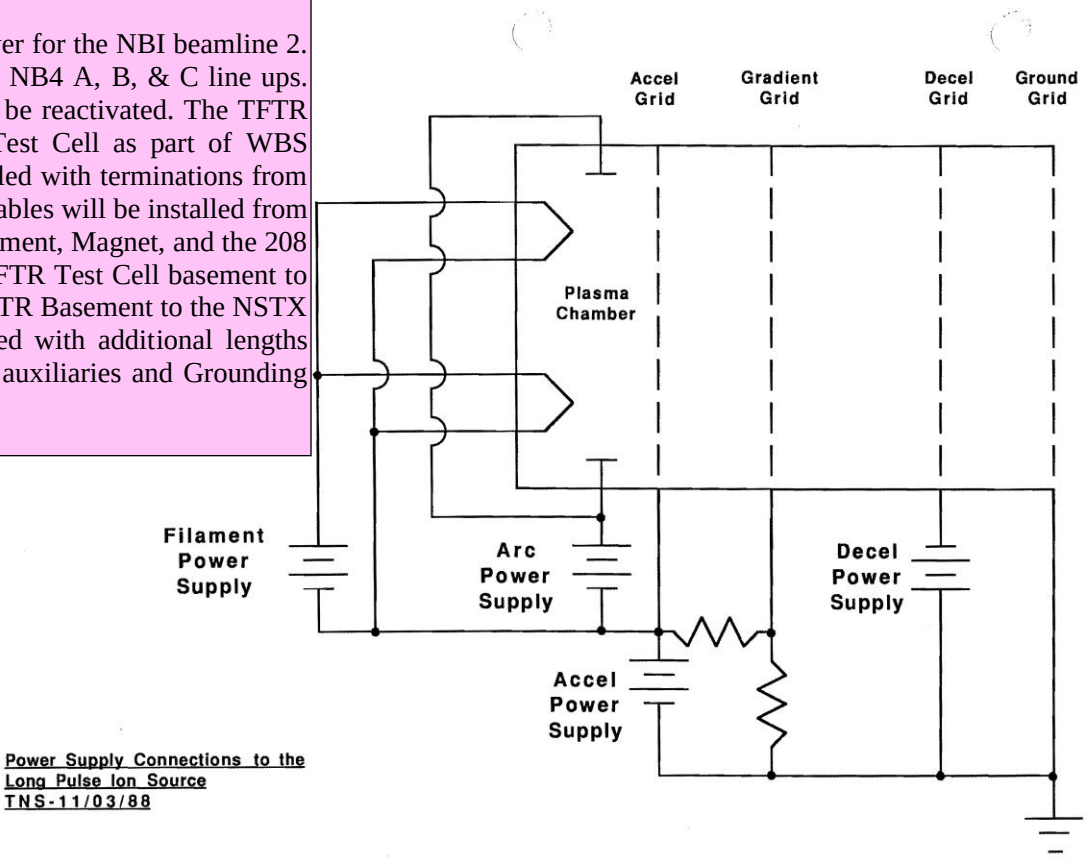
NSTXU NBI Power & Controls - Battery Diagram

2470

NBI Source Battery Diagram

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)}



Power Supply Connections to the Long Pulse Ion Source
TNS-11/03/88

Tim Stevenson

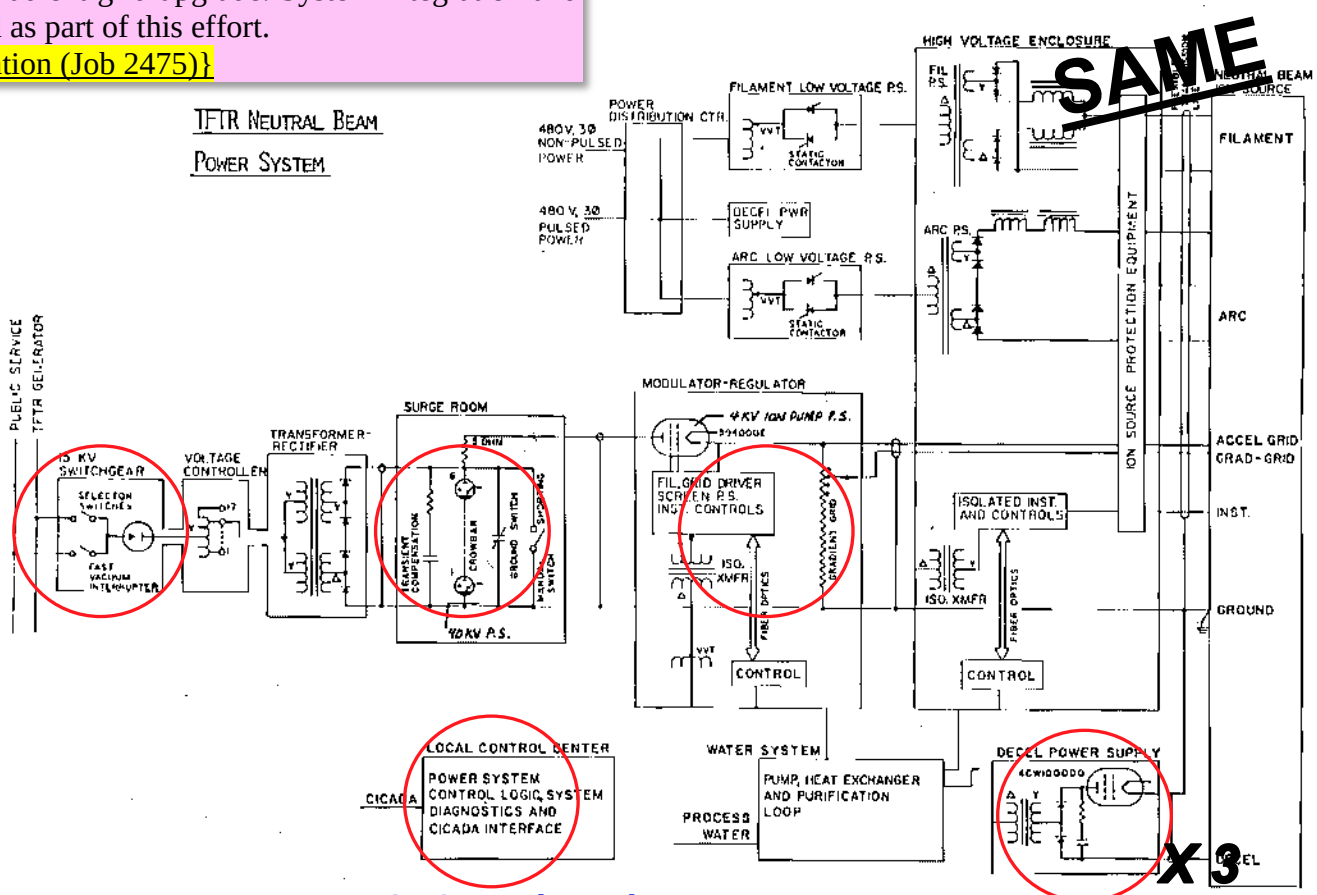
NSTXU NBI Power & Controls - One Line Diagram

2475

Update electronics & control circuits as noted

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)}



NBI NBPS One Line Diagram

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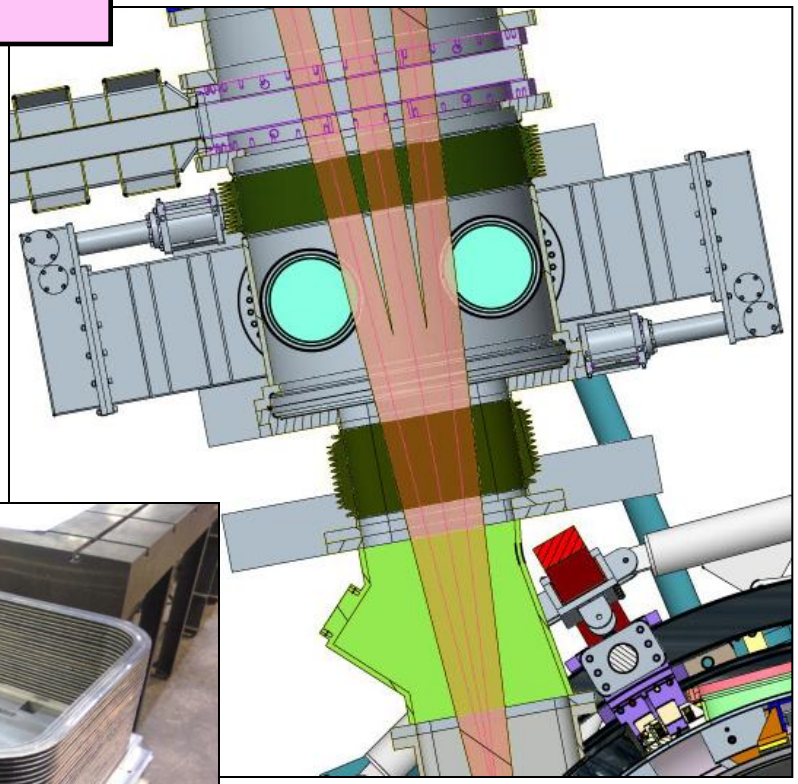
NSTXU NBI Duct – BL to VV

2480

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)}

- BL2 Duct
  - Adapts from 1m TIV to NB rectangular flange
  - Contains bellows and ceramic break similar in design to NSTX NB1
- Port Extension
  - Permanently bolted up to NSTX
  - Extends NB2 Duct and Vessel Pump Duct interface past TF coils
- TVPS connection below NB duct
  - More conductance
  - Same field as existing
- Rectangular bellows ready for use on upgrade…



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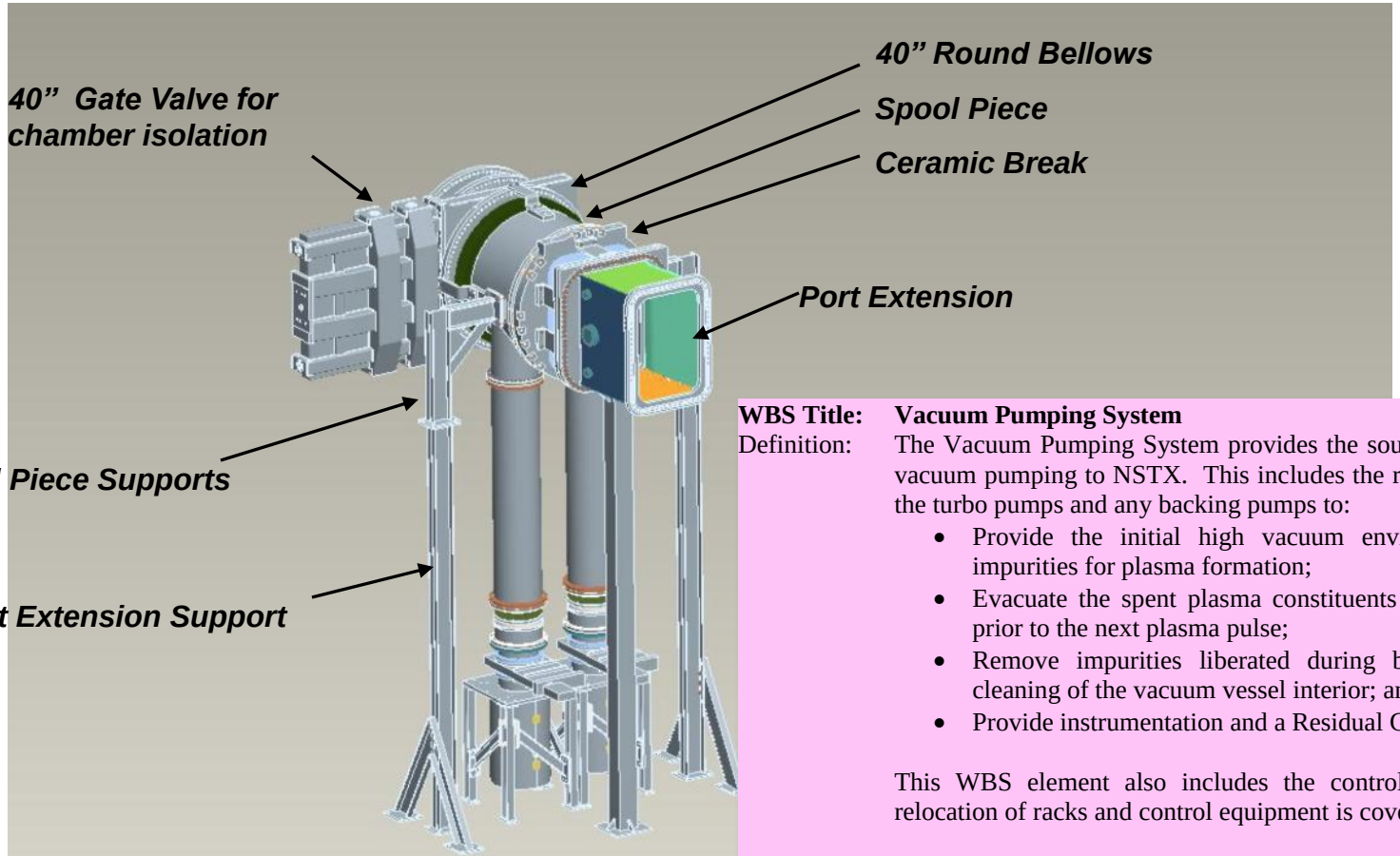
BL2 Duct & TVPS modeled and drawings completed

2480
2485



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)}

Tim Stevenson

Removals & Re-installations

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)}

Job 2490	1) Removal of Racks	2) Removal of Equipment	3) Re-installation of Racks	4) Re-install Equipment
Deposition monitor, fast x-ray - 488	X		X	
Fiber Optics - 447 - 448	X		X	
NPA - From Bay K	X	X		
PSI Camera - From Bay K	X	X	X	
SPREAD and VIPS - 440	X		X Need to find new location	
Transmission Grating Spectrometer -	X		X	
UCLA Reflectometer - 419	X		X	
Ultra Fast X-ray Camera -	X	X	X	
VV ion gages, RGA - 441 - 445	X		X	
X-ray Crystal Spectrometer - From Bay L pump duct	X	X		
Glow Discharge - Bay L	X	X	X	X need diagnostic to confirm will fit at bay L midplane
IR Camera	X	X	X	X need diagnostic to confirm will fit at bay L midplane
Remove Pump Duct (incl turbos) - From Bay L pump duct		X		Job 2480
Gas Delivery Systems - Miscellaneous Removals		X		Job 3400
Bolometer - Bay J		X		X
IR Windows for Camera - From Bay K		X		X
Lights, E-stops, fire alarms - Miscellaneous Removals		X		X
LOWEUS - Bay L		X		X need diagnostic to confirm will fit at bay L midplane
MPTS Beam Dump Window - From Bay L pump duct		X		X
Re-entrant Window - Bay J		X		X
Reflectometer - Bay J		X		X
RF Probe - Bay J		X		X
RGA - From Bay L pump duct to New Pump Duct		X		X
S-Flip - Bay J		X		X
SPRED - Bay L		X		X need diagnostic to confirm will fit at bay L midplane
SSNPA - Bay J		X		X
Transmission Grating Spectrometer - From Bay K		X		X
Two Gas Injectors - Bay J		X		X
Vac Vessel Ion Gages, Filaments, Micro Ion Gages - From Bay L pump duct		X		X
Cat 3 and Cat 4 bus - Miscellaneous Removals		X		
Convenience outlets - Miscellaneous Removals		X		
Fire Tips - From Bay K		X		
High K Scattering - From Bay K		X		
Remove NW section of 109' platform - Miscellaneous Removals		X		
- Fab and Install Five Sections of Platform at EL 118' on West Side of NTC				X
Install New 42 Ckt Panel in NTC and 30 Ckt Panel in Gallery				X
NOTE: Installation of new pump duc, turbos and lines to roughing pumps is covered in NB duct job - New Pump Duct				X
Platform Power (recept), grounding and lighting				X
Reconfigure AC and Diagnostic Trays -			X	
Tank farm, TMB system, Gas solenoid box & diconnects -				X

New Center Stack

Centerstack Upgrade Requirements

- Toroidal magnetic field at the major radius R0 of 1 Tesla (T) compared to 0.6T in the original NSTX
- Plasma current Ip up to 2 Mega-Amp (MA) (presently 1MA rating)
- Increase Pulse length from 0.5 to 5.0 seconds
- Plasma facing components, internal hardware (PP, OBD), CSC, VV, and RF antennae shall be designed to withstand forces due to plasma disruption.

Larry Dudek

Center Stack Jobs

DESCRIPTION	Cog
Job: 1000 - CSU Analytical Support	Titus
Job: 1001 - CS Plasma Facing Components	Tresemer
Job: 1002 -Passive Plate Analysis &Upgrade	Dudek
Job: 1200 - Structures and Supports	Smith
Job: 1300 - Center Stack	Chrzanowski
Job: 1301 - Outer TF Coils	Chrzanowski
Job: 1302 - Center Stack Assembly	Chrzanowski
Job: 1303 - TF Joint Test Stand&Test	Kozub
Job: 1304 - Inner TF Bundle (Ds/Fab)	Chrzanowski
Job: 1305 - OHMIC Heating Coil (OH)	Chrzanowski
Job: 1306 - Inner PF Coils	Chrzanowski
Job: 1307 - CS Casing Assembly	Chrzanowski
Job: 1310 - CSU Magnet Systems	Chrzanowski
Job: 2300 - ECH Analysis-	Titus
Job: 3200 - Water Cooling System Mods	Denault
Job: 3300 - Bakeout System Mods for CSU	Raki
Job: 3400 - Gas Delivery System Mods	Blanchard
Job: 4100 - Center Stack Diagnostics	Kaita
Job: 4500 - MPTS VV Modification	Labik
Job: 5000 - CSU Power Systems	Raki
Job: 5200 - DCPS	Hatcher
Job: 5501 - Coil Bus Runs-SMITH	Smith
Job: 6100 - Control Sys Data Acquisition	Sichta
Job: 8200 - Field Supervision and Oversight	Perry

Larry Dudek

Plasma Facing Components

1001
1002

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.

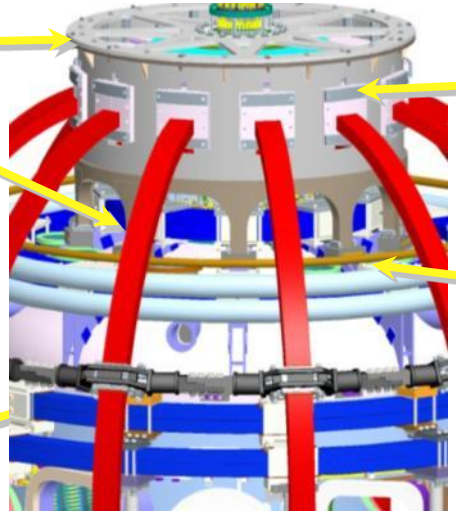
Addendum-
Halo sensors;
- *Includes additional machining for halo sensors.*
- *Excludes external electronics and racks*

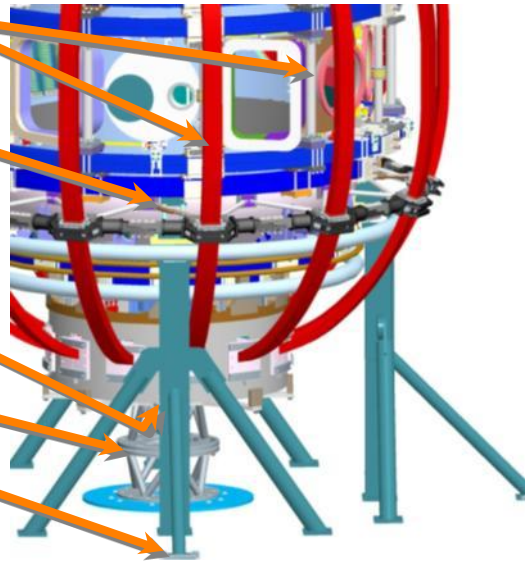
The NSTX Upgrade Project will require new PFCs on the new Center Stack Casing (CSC) and the new Inboard divertor (IBD). This WBS element includes the design and analysis for both the CS and IBD PFCs, design modifications to the PFC tiles to accommodate surface diagnostics, including design of the tile 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)}

Vacuum Vessel and Support Structure

1200





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)}

Larry Dudek

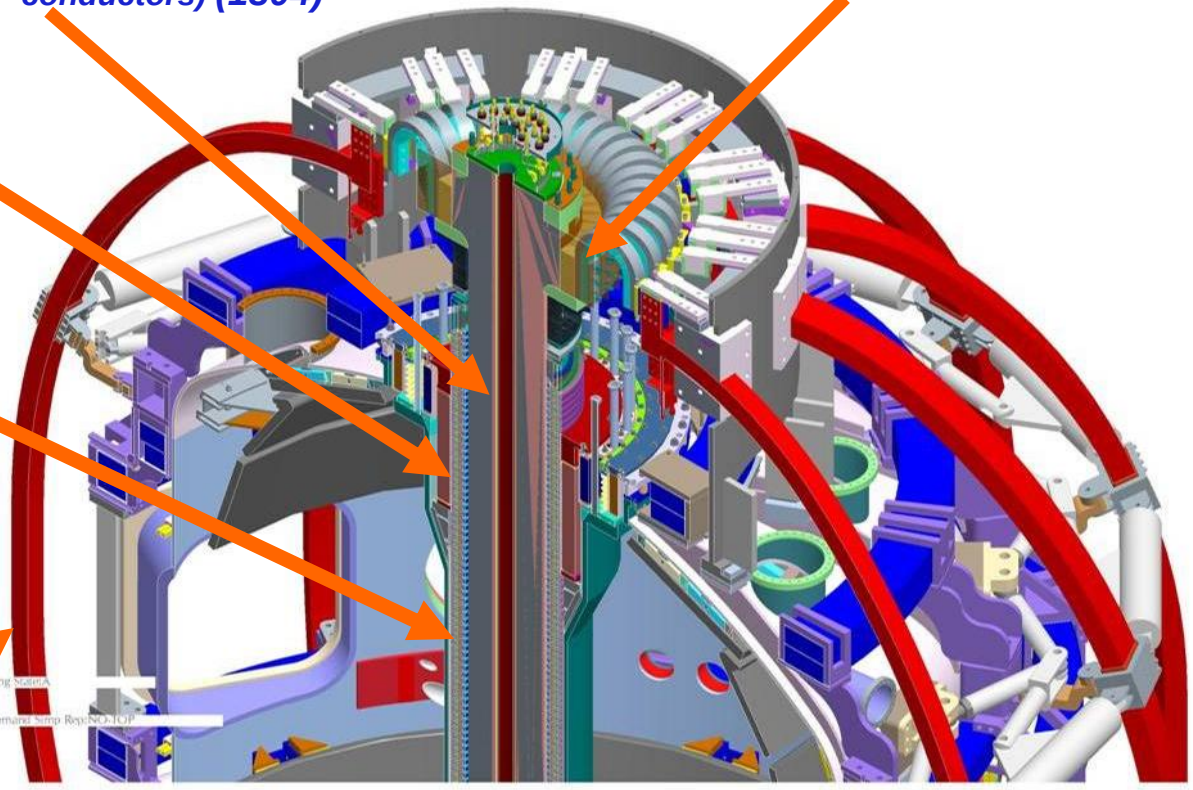
Center Stack Jobs – 1301,1304,1305,1307

Simpler Inner TF design (single layer of TF conductors) (1304)

Improved Joint Design

OH coil wound on TF (1305)

New Centerstack Casing and Tiles (1307)



Existing outer TF WITH water cooling plus 2 new TF coils being fabricated (1301)

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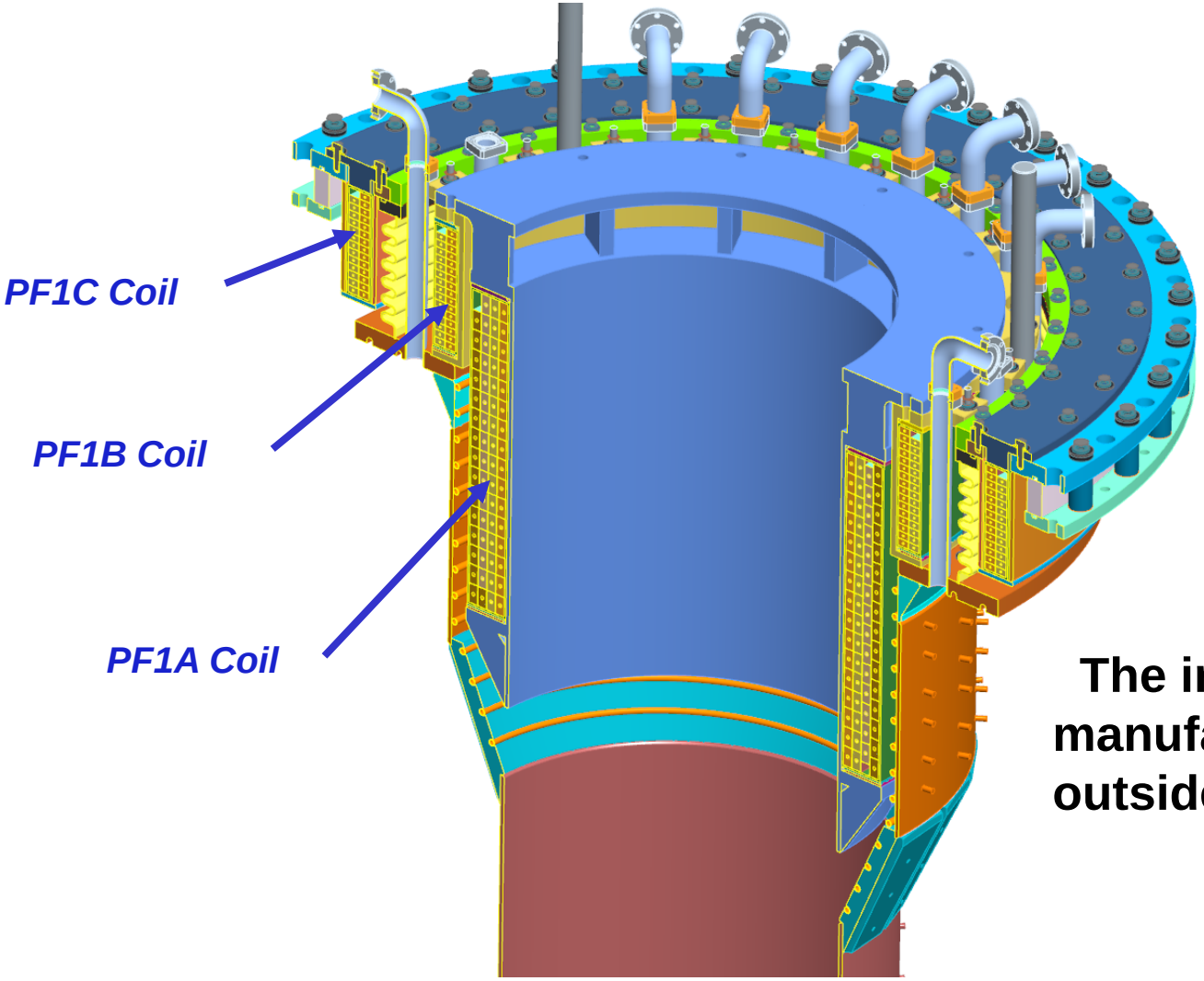
Inner Poloidal Field Coils - 1306



The inner PF coils will be manufactured by an outside vendor.

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Center Stack Jobs

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 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 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)}

Power Systems TF - 5000

- **REQUIREMENTS**
- **TF : 129.8 kA, 1kV, ESW 7.08 sec every 2400 sec (7.05kA rms) ;**

- **Four additional PARALLELS of Transrex power supplies to be provided to existing four parallels**
- **Each parallel - two 1 kV Transrex power supply sections in series.**
  - CLRs will be connected between the supply sections
  - One section of the supply will be used as a Diode
- **Existing four SDS of TF with additional parallel supplies will be used.**
  - two parallels to be fed via each switch.
- **Four more DC reactors (270uH) to be used in the additional 4 parallels.**
  - Since upgraded OH circuit needs reactors of higher inductance,

  the existing 270uH OH CLRs will be reconnected in the TF Circuit.
- **To install reactors in TF wing**
  - (1) Remove PF1a Ripple reduction Reactors & store; and
  - (2) Remove four CICADA Racks in the middle of isle.

- **DCCTs**
  - Existing eight DCCTs will be repositioned to detect current in each of the eight parallels
  - Eight additional DCCTs will be purchased and installed
  - Two new DCCTs to detect total TF Coil Current
  - The Vacuum Control Room presently empty will be used for housing the electronics boxes
- **CABLING**
  - Reconnect existing cabling as needed.
  - Disconnect & Remove part of existing cabling (~12000 ft)
  - Install additional power cabling within FCPC - nearly *6000* feet of 1000mcm 5kV power cables. Limited space makes bus installation difficult
  - Reconnect existing power cabling in Transition Area (TA) - in TFTR Test Cell Basement- to NSTX Test Cell for TF use.
  - Provide Control Cabling as needed
- **Modify Power Cable Termination Structure (PCTS) for TF to handle fault currents & to accept 3 more power cables/pole.**

Raki

Power Systems -OH PWR. LOOP DESIGN & PF PWR. LOOP DESIGN BASIS

5000

EXISTING OH PWR LOOP DESIGN:

- 6kV Anti-parallel configuration
- 24kA for 0.4 seconds every 600 seconds

UPGRADE - OH PWR LOOP DESIGN:

- 6kV Anti-parallel configuration
- 24kA for 1.474 sec every 2400 seconds

Work Required

- The DC CLR values have been optimized to the new requirement based on PSCAD analysis. These new reactors of the required values will be purchased and installed.
- All the other equipment and cabling in the power loop will be used AS IS

•REQUIREMENTS

- **OH : 24kA, ESW *1.474* sec every 2400 sec ; 6kV**
- **PF1a: Eliminate Ripple reduction reactors**
- **Other PF : Existing config. meets requirements for other PF**

PF DESIGN:

- Existing circuits for PF1b, PF2, PF3, PF4,and PF5 will be used AS IS for the upgrade.
- PF1a Changes
  - The ripple reduction reactors in the PF1aU & PF1aL circuits will be eliminated based on the newly designed PF1a Coils
  - Associated power cabling changes will be made

WILL be powered
PF 1 A upper & lower
PF 1 B Lower
PF 2-5 upper & lower
Will NOT be powered
PF 1B upper
PF 1C upper & lower

Raki

Power Systems – excluded from the upgrade project scope

5000

1. **Provide power feed to a) PF1bU, b) PF1cU, c) PF1cL coils.** This involves designing the power loop and providing Power Supplies, CLRs, Disconnect & Ground Switches, DCCTs, Protective relaying etc.

2. **Upgrade PF5 feed such that PF5 coil can be injected up to 34kA**. This would require an additional branch to the existing power supply. Note that PF5 is powered up to 24kA in the current set up.

3. **Upgrade the TF feed such that TF can be pulsed every 20 minutes**. In the current scope the TF can be pulsed only once in 40 minutes. This requires additional power cabling from the Transition area to the NSTX Test Cell, additional changes in the PCTS, enhancing the feed from PCTS to coil terminals. We can also conssider providing a water cooled bus in the NSTX Test Cell Basement from the place the power cables are terminated.

4. **Make changes as needed to operate CHI from the present level of 2kV to 4kV**. In order to address this requirement we must plan right now to choose the appropriate insulation for the CHI leads and the Inner vessel. Note that the Inner Vessel to Outer Vessel will require to be hipotted at 9kV instead of 5kV as at present.

5. **Change DCCT positions such that these measure the coil currents directly.** (At the present time the DCCTs are above the SDS in some circuits.)

6. **Convert PF1a circuit from a 3- Wire scheme to a 2 - Wire scheme**.(This is required to upgrade CHI from 2kV to 4kV). The work involves additional cabling.

7. **Change FD/FG for all the suppliies needed to power NSTX. Eliminate the PC link.** (Note that we are currently performing this task under the operations budget. In this modification we are changing the FD/FG for active rectifiers which will be used for NSTX. Also a slow PLC I/O will be provided in these rectifiers to interface with the main PLC that will be provided in the Cntrol Boards.)

8. **MG Repair**

Raki

Power Systems - CONTROL & PROTECTION

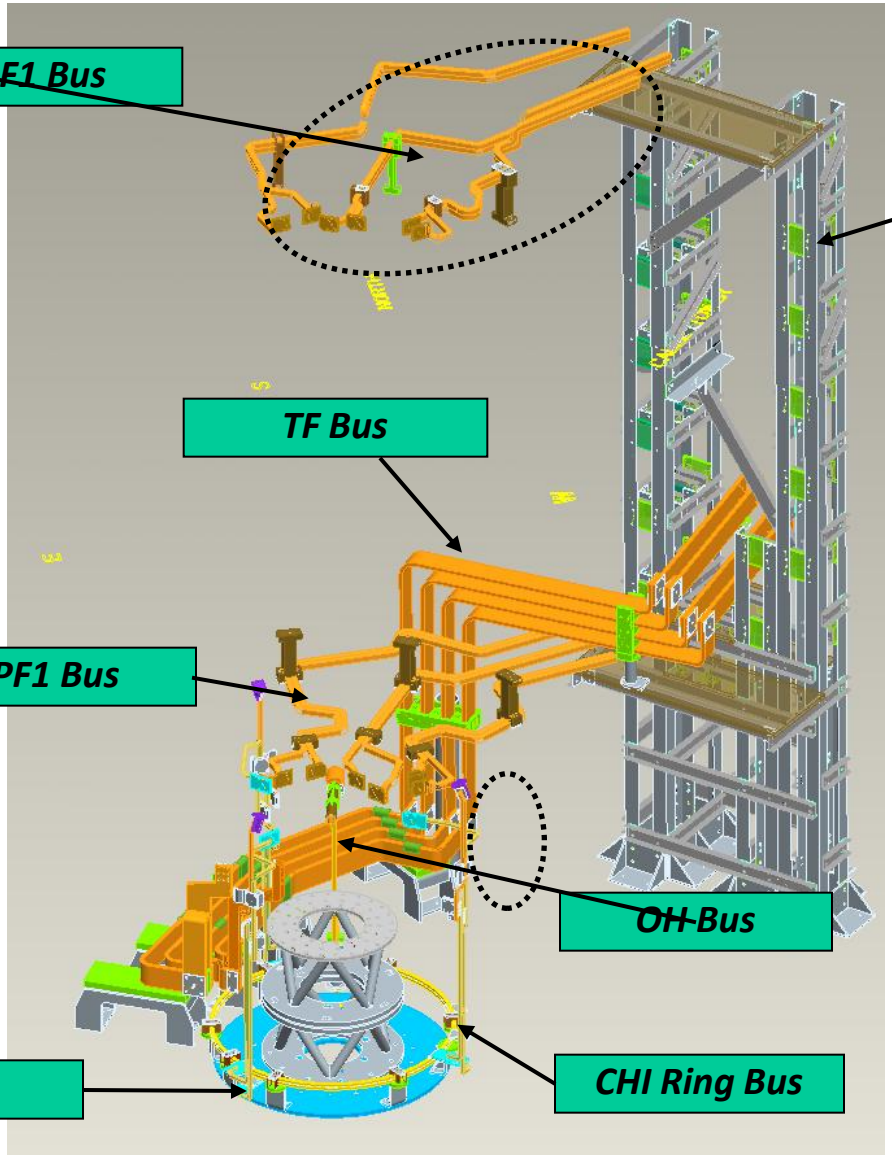
5000
5200

- CONTROLS (Raki)
  - Hardwired Controls will be upgraded
- CIRCUIT PROTECTION (Raki)
  - Analog Coil Protection Units (ACPs) will be modified as needed
- RECTIFIER PROTECTION (Raki)
  - ACCT, DCCT & PT signals along with other interlocks will be processed in the FD. See Block diagram.
  - Fault Detector (FD) in Rectifiers
    - Overcurrent
    - Pulse duration
  - FD will generate Level 1, 2, 3 faults to trip.
- Digital Coil Protection (DCP): (Hatcher-5200)
  - DCP is designed for protecting the machine support system. Reqmnts documented updated with FDR in June 2012

Raki

Power System (Smith)- Buswork

5501



Smith

Control Systems (Sichta) – INCLUDED Scope

~3.5x longer Pulse Length drives real-time control, data acquisition, analysis, networking, and storage.

Real Time Controls

- ***Procure RT computers***
- ***Migrate software to 64-bit operating system***
- ***Implement new control algorithms for NSTX-U***
- ***Support additional Input/Output points***

Data Acquisition: reduce role of CAMAC

Pre-upgrade (Oct. 2010)	Post-Upgrade (Sept. 2014)
(100) 908/3232, (**43**) 907, (9)6810, (9) TR612	(34) 908/3232, (**25**) 907, (9) 6810, (9) TR612
1500 channels, 77 MB	**860** channels, 70 MB
•MDSplus ACQ: 2.5 minutes •EPICS ACQ: 7.5 minutes	•MDSplus ACQ: 2.5 minutes •EPICS ACQ: 5 minutes
	•(11) D-Tacq Networked Digitizers. •(3) PXI-based systems • (24) One Mega-sample memory boards (CAMAC)

Sichta

Control Systems – EXCLUDED Scope

NOT part of upgrade scope

- PCS real-time computer upgrade (more CPU/cores)
- PCS real-time software port to 64-bit OS (memory > 4 GB)
- FPDP_IO support for digital (Transrex) Firing Generator
- Diagnostic CAMAC replacements
- EPICS CAMAC acquisition speedup
- 10 Gbit networking
- Upgrade nstxpool computers

Diagnostics –(4100 Kiata)

Relocation of Centerstack Magnetic diagnostics to new home

- Rogowski Coils
- Mirnov Coils
- Flux Loops
- Langmuir Probes
- Thermocouples

Halo sensors (new)

sensors and installation into PFC tiles only

Electronics , racks , other ex-vessel work EXCLUDED

Auxiliary Systems

3200
3300
3400

- Gas Injection Systems – (3400-Blanchard)
  - Relocate existing center stack gas injection system to the new center stack
- Coil Cooling water modifications (3200-Denault)
  - Restoring of cooling to the outer TF legs for upgraded TF.
  - Reconnect cooling to the TF inner legs, OH and PF coils
  - Provide cooling for the coil buswork
- Bakeout system (3300-Raki)
  - the purchase of a new more powerful power supply, to replace the existing one

Multipoint Thomson Scattering (MPTS)

INCLUDED scope-

The vacuum boundaries closest to the vacuum vessel (VV) define the extent of the NSTXU scope. Vacuum boundaries include;

- ***Port modifications and vessel reinforcements***
- ***Torus interface valves***
- ***Vacuum windows and blank covers***

EXCLUDED scope-

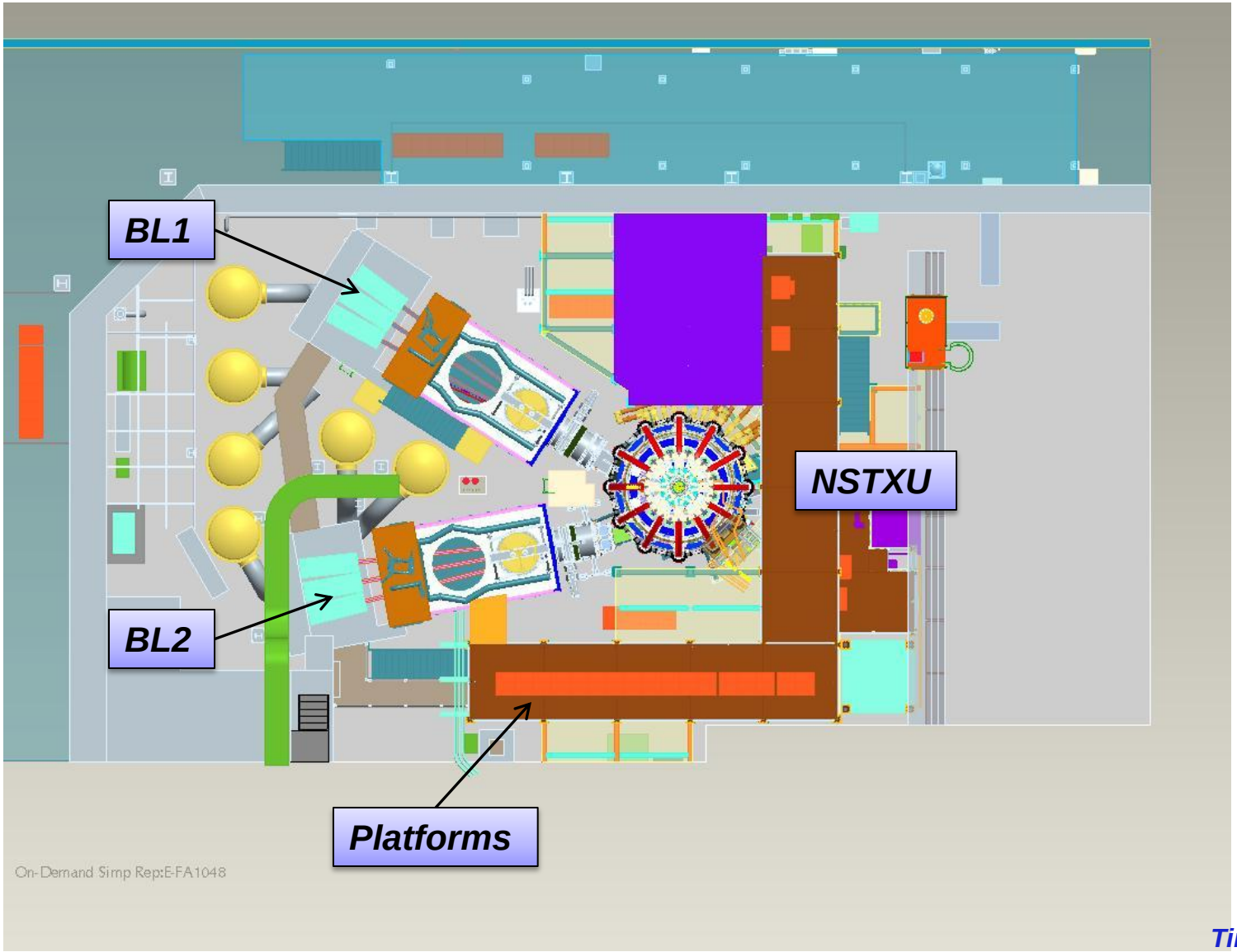
- ***Optics***
- ***Laser optics box***
- ***Laser flight tube***
- ***Laser dump***

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

backup

NSTXU Test Cell General Arrangement…

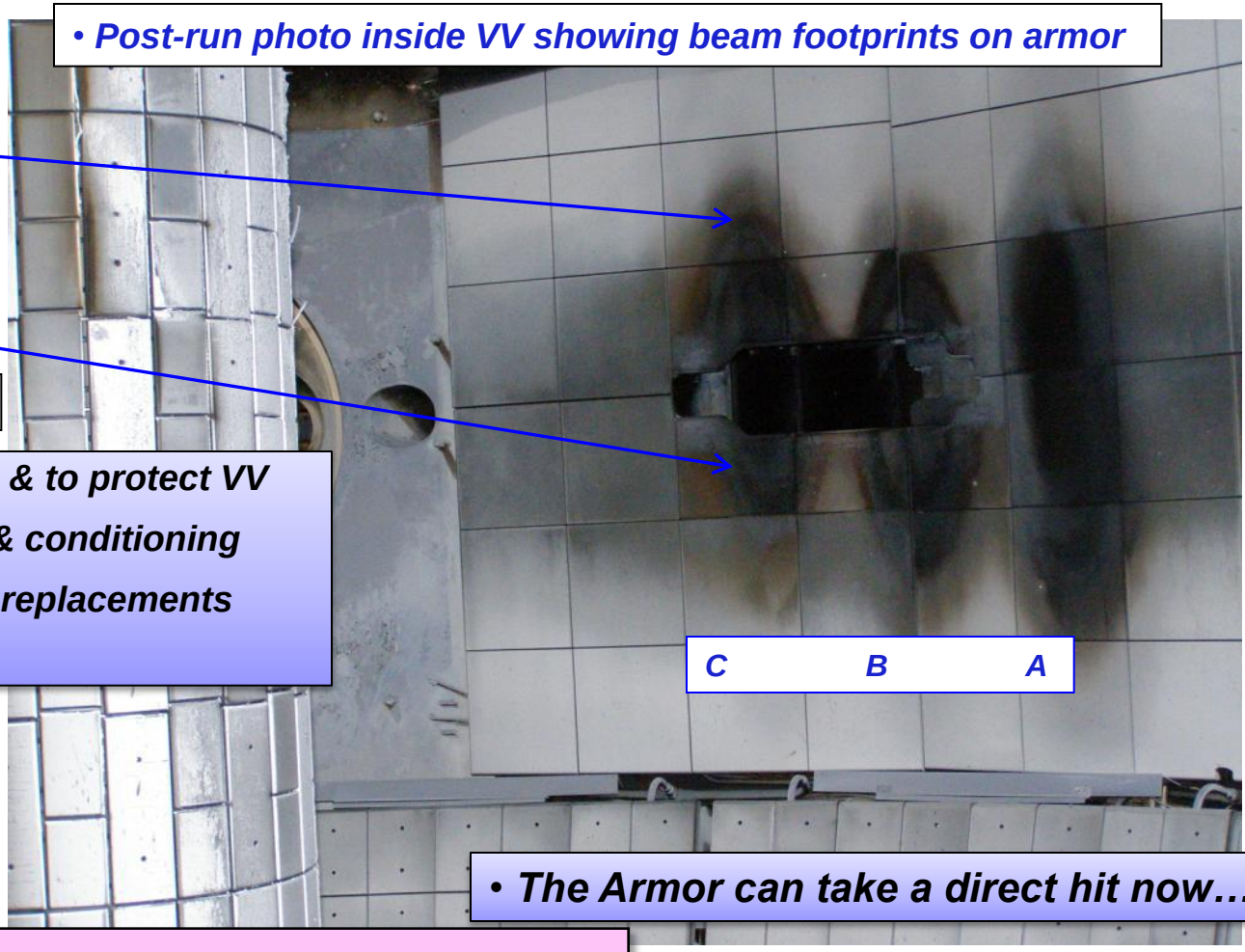


Tim Stevenson

Existing NBI Armor Position - 3 Beams

2460

- Post-run photo inside VV showing beam footprints on armor



If no plasma and no interlocks:

Takes direct hits now for Ops & to protect VV

- *Alignments, MSE cal, & conditioning*

Sacrificial - might require tile replacements

Interlock with Ip and R Ip

- *The Armor can take a direct hit now…*

WBS Title: **NBI Armor**

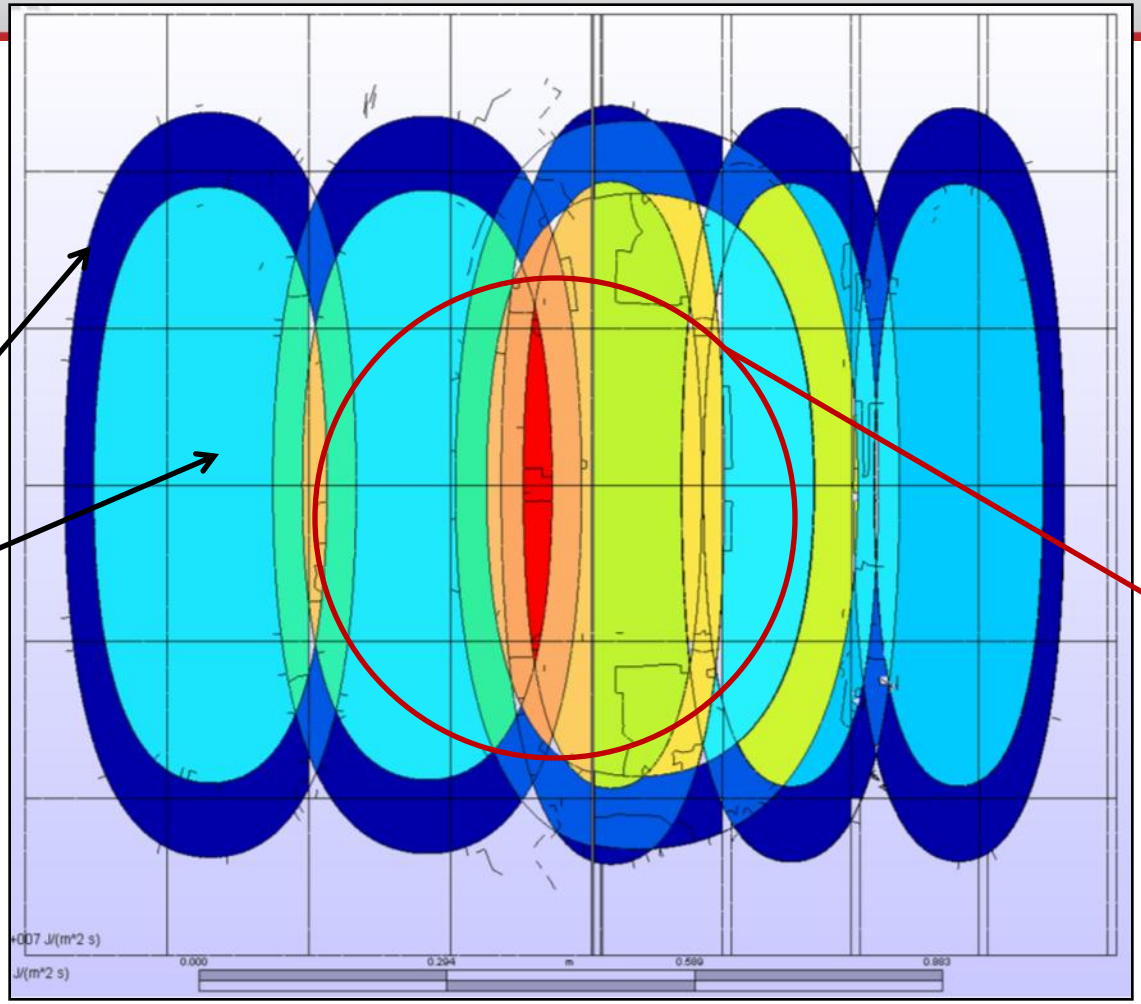
Definition: This WBS element includes the design, fabrication, and installation of upgraded and relocated neutral beam armor including cooling and instrumentation work.
{NBI Armor (Job 2460)}

Tim Stevenson

New Armor with 6 Beams: Shift location, better supports, ATJ & CFCs

2460

- *Outer ring:*
  - *20% total source power*
- *Inner "hotspot":*
  - *80% total source power*



- *Beam overlaps create areas of intense flux*
- *Area of thermal investigation and use of 3D CFC from in house stock…*
- *ATJ everywhere else.*

- *The Armor can still take a direct hit!*

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)}

Tim Stevenson