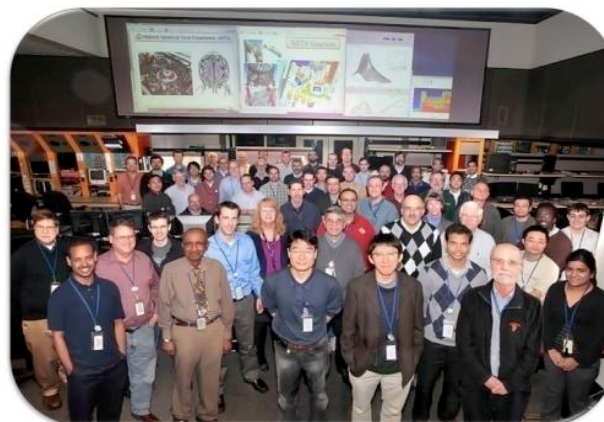
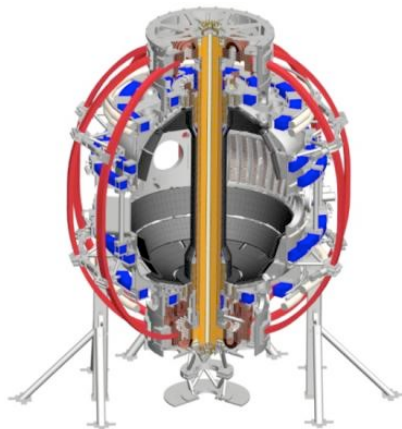


# NSTX Centerstack Ancillary Systems Progress

*Coll of Wm & Mary  
 Columbia U  
 CompX  
 General Atomics  
 FIU  
 INL  
 Johns Hopkins U  
 LANL  
 LLNL  
 Lodestar  
 MIT  
 Lehigh U  
 Nova Photonics  
 Old Dominion  
 ORNL  
 PPPL  
 Princeton U  
 Purdue U  
 SNL  
 Think Tank, Inc.  
 UC Davis  
 UC Irvine  
 UCLA  
 UCSD  
 U Colorado  
 U Illinois  
 U Maryland  
 U Rochester  
 U Tennessee  
 U Tulsa  
 U Washington  
 U Wisconsin  
 X Science LLC*

**L. Dudek**

**Princeton Plasma Physics Laboratory  
 NSTX Upgrade Project  
 Office of Science Review  
 LSB B318  
 December 11-12, 2012**



*Culham Sci Ctr  
 York U  
 Chubu U  
 Fukui U  
 Hiroshima U  
 Hyogo U  
 Kyoto U  
 Kyushu U  
 Kyushu Tokai U  
 NIFS  
 Niigata U  
 U Tokyo  
 JAEA  
 Inst for Nucl Res, Kiev  
 Ioffe Inst  
 TRINITI  
 Chonbuk Natl U  
 NFRI  
 KAIST  
 POSTECH  
 Seoul Natl U  
 ASIPP  
 CIEMAT  
 FOM Inst DIFFER  
 ENEA, Frascati  
 CEA, Cadarache  
 IPP, Jülich  
 IPP, Garching  
 ASCR, Czech Rep*

# Outline

- Power Systems
- Diagnostics
- DCPS
- I & C
- Passive Plates
- Analysis
- Hardware Procurement Coordination

# Power Systems (Ramakrishnan)



- Requirements
  - TF : 129.8 kA, 1kV, ESW 7.08 sec every 2400 sec (7.05kA rms)
  - OH : 24kA, ESW 1.474 sec every 2400 sec ; 6kV
  - PF1a: Eliminate Ripple reduction reactors
- Installation spec. has been written and work is in progress.
  - About 50% of the work completed in FCPC Building
  - Power Cabling changes from Transition Area to NSTX Test Cell completed and tested
  - Requirements document issued for conversion from Hardwire Control System to PLC
- One fiber-optic DCCT (+/-0 to 150kA) has been procured and installed to measure the TF current. Another one is on order
- For OH system , repurposed PLT TF coils have been tested & are planned to be used as DC Current Limiting Reactors
  - Simulation of circuit completed using the PLT TF coils as the current limiting reactors
  - These have been connected in the circuit and a PTP will be conducted

# Most Center Stack Diagnostics Fabricated (Kaita)

- Manufacture of Mirnov coils and Rogowski coils are complete
  - Includes additional Mirnov coils and “segmented” Rogowski coils for halo current measurements
- All copper and thermocouple wires have been procured
  - Satisfy specialized material and insulation requirements for installation under plasma-facing components
- Fabrication drawings for Langmuir probes are complete
  - Awaiting delivery of center stack tiles to begin machining for probes
- Future plans include preparation of installation procedure and execution when center stack is ready

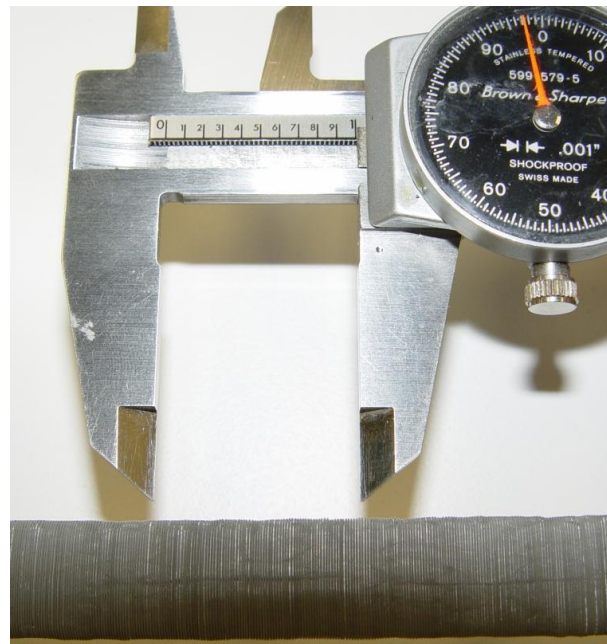
# Plasma and Halo Current Rogowski coil requirements met

- Limited space on air side of center stack and underneath plasma-facing components constrained thickness



*Plasma  
Current  
Rogowski  
Coil*

- Turns needed to be non-overlapping and of correct number per unit length to insure proper gain (“nA”)



*Halo  
Current  
Rogowski  
Coil*

# DCPS Status (Hatcher)

- Early in the design of the coil support structures for the upgrade it was determined that qualifying the structures for the full power handling capacity of the power supplies was not practical
- Instead the existing Rochester Instruments System (RIS) protection system will be replaced by a new Digital Coil Protection System (DCPS).
- The DCPS will include the following features:
  - Protection against instantaneous over-current and  $\int i^2(t)dt$  limits in each coil circuit (same functionality as existing RIS)
  - Simulation of heating and cooling of each coil using the coil currents as input, and protection against over-temperature
  - Simulation of various design-limiting quantities based on algorithms using the coil currents as input, and protection against design limits.



# DCPS Status (contd.)

- Project
  - DCPS project is proceeding with updated plan developed in April 2012
- Cognizant engineers assigned to all major work scopes
  - Software
    - CDR completed, work is progressing towards PDR
    - Software requirements document signed off
    - Algorithms requirements document complete, under review
    - Power Supply Real Time Control (PSRTC) requirements document in progress
    - PDR planned for March 2013
  - Hardware
    - Research 75 % complete
    - Requirements 50 % complete
    - Signal cross-reference 50 % complete
    - Existing system configuration 50 % complete
    - PDR planned for first quarter 2013

# DCPS Status (contd)

## – PDP Timer Update

- Research and design complete
- Preliminary and Final Design reviews successfully completed
- Fabrication started, expected completion date January 31, 2013

## – Water Systems PLC integration

- Design effort is 40 % complete
- CDR successfully completed 2012
- PDR planned for January 2013

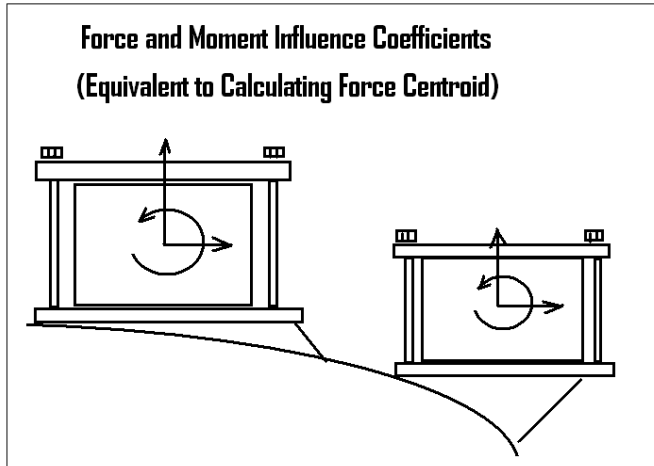
## – Analysis

- Algorithm summary sheets completed (Summer student)
- Algorithms exercised across 96 scenarios (see an example next slide)



# DCPS Status (cont.)

## PF 2 and 3 Bolting Stress from DCPS



PF2/3 DCPS Multipliers

Location/Component	Stress Limit	Fvert (lbs)	Mtheta ( in -lbs)
PF2 1/2 inch Bolts	20,000 psi*	/5.23/4/.1416	/5.23/8in/2/.1416
PF2 Plate to Rib Weld			
PF3 Lower 1/2 inch Bolts	20,000 psi	/9/4/.1416	/9/8in/2/.1416
PF3 Plate to Rib Weld			

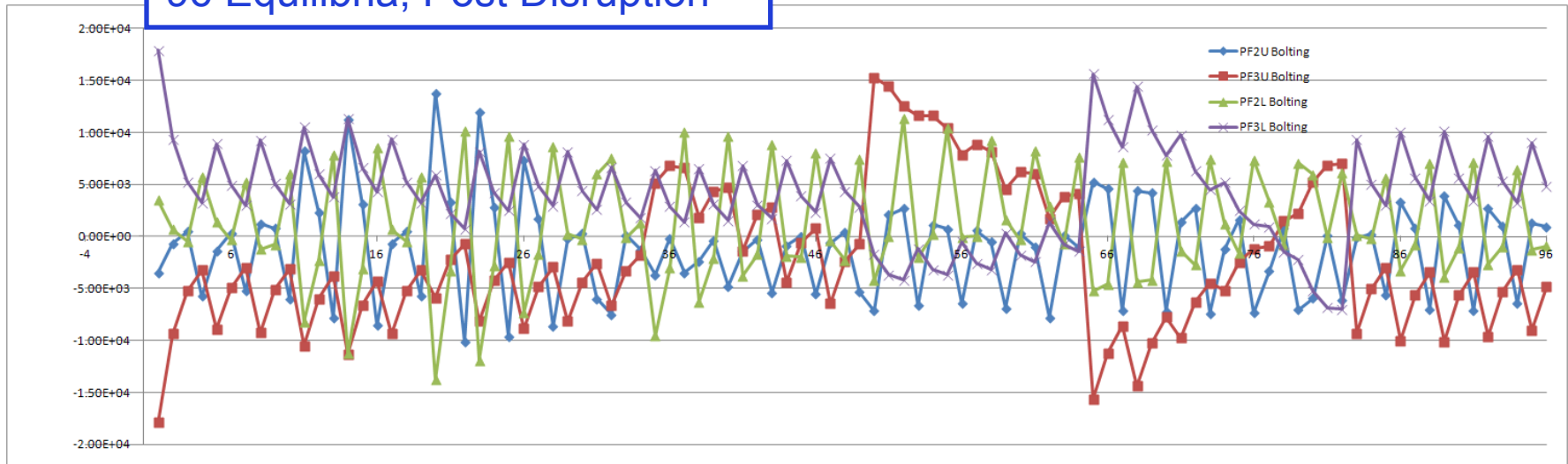
\* This is set by fatigue limits. Fatigue damage should be accumulated by the DCPS every time the bolt load exceeds 20,000 lbs. Static or infrequent limits may be as specified for replacement studs. If these are all ASTM A193 B8M Class 2 Bolts then the allowable would be the lesser of 125/3 or 2/3\*100=41.7 ksi.

PF 2 and 3 clamp bolting stress is the sum of the vertical load divided by the bolt stress area and the coil moment divided by the clamp width, divided by the bolt stress area.

Both force and moment coefficients were implemented

Normal and post disruption equilibria were checked to make sure bolt stresses were acceptable.

## 96 Equilibria, Post Disruption

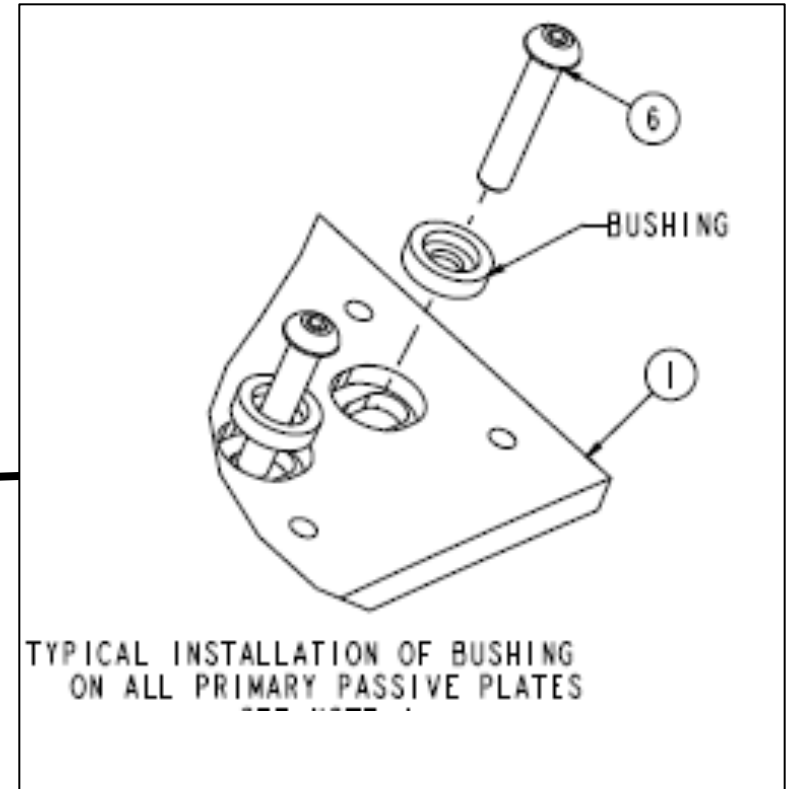
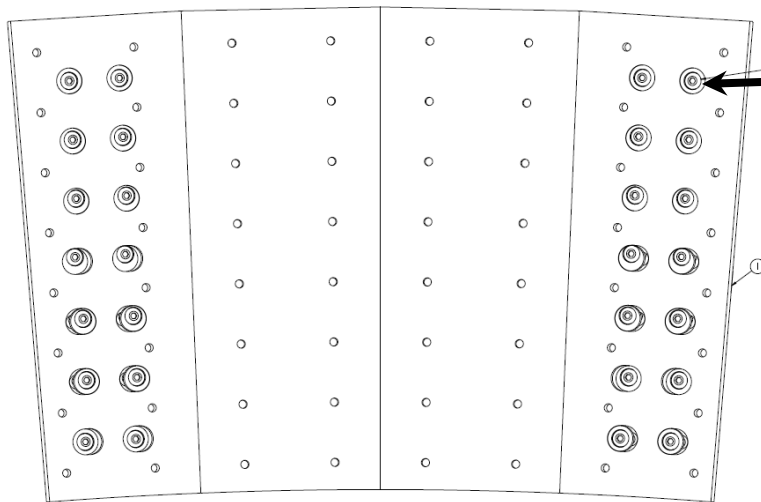


## Controls (Sichta)

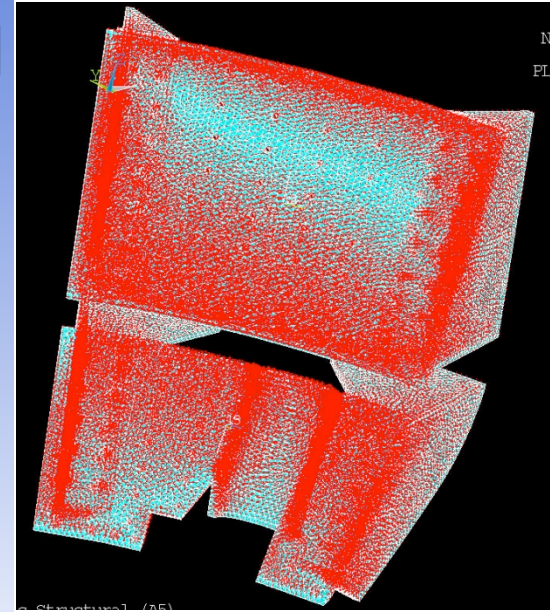
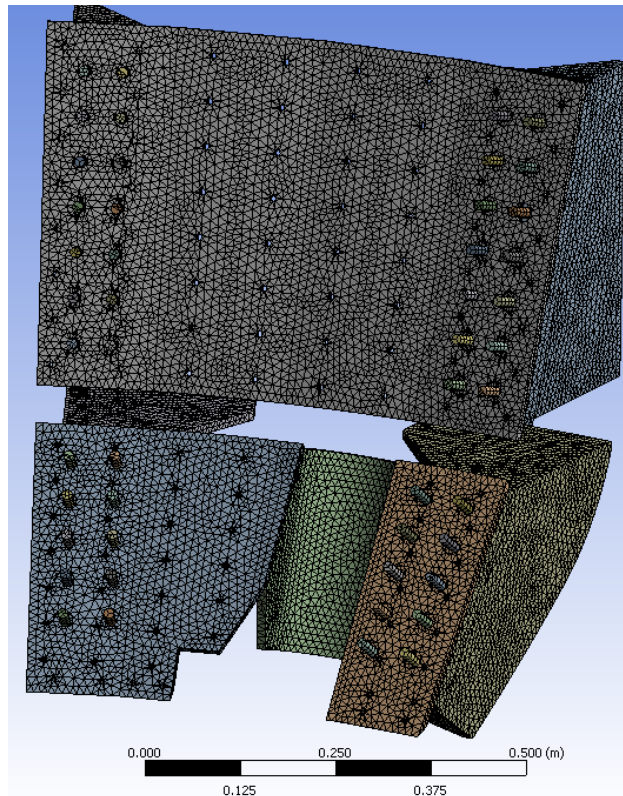
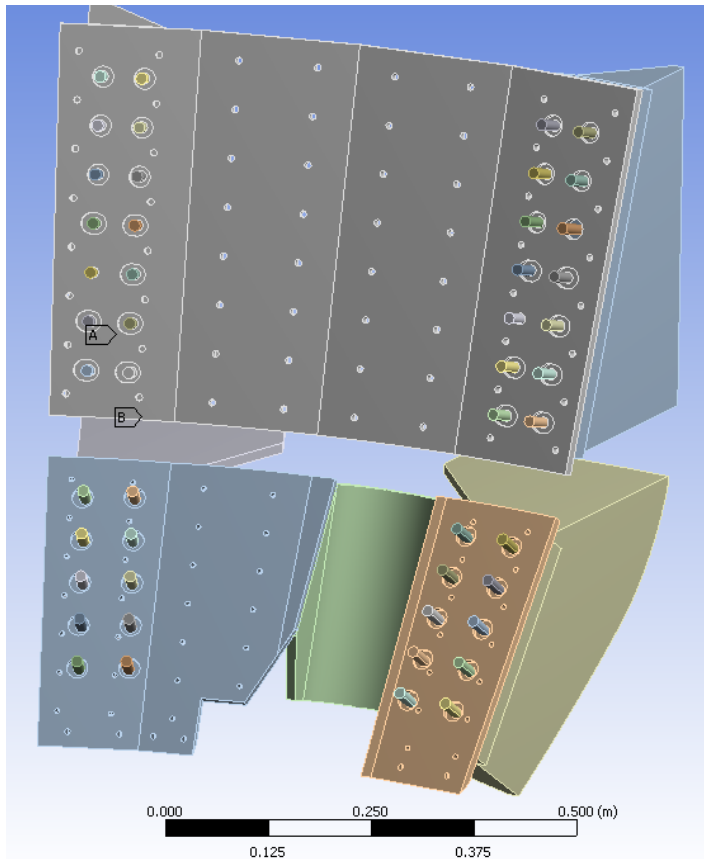
- ~3.5x longer pulse length drives upgrades for data acquisition, networking, and real-time controls.
- NB CAMAC replacement effort 80% complete. Sharing of instrumentation chassis with NB Controls (2475) helped avoid costs.
- Activities recently started:
  - CAMAC replacement for FCPC.
  - Plasma Control System's input-output board software.
  - Networking upgrade: prep for procurement and installation.
- Bulk of work, including procurements, fabrication, software development, and equipment and cabling installation begin in FY13.

# Passive Plate Upgrade

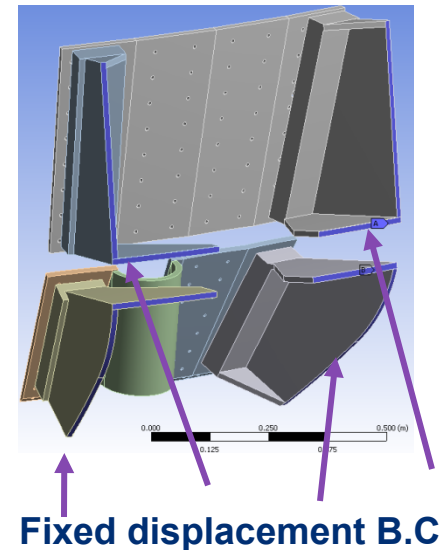
- Progress: Corner fasteners and reinforcement bushings were replaced with Inconel replacements to handle higher disruption loads.



# Further PP Analysis Required



- Two Plates were modified for Diagnostic Views and required additional analysis
  - EM loads are mapped onto the structural model
  - Lower Passive Plate Model with Brackets

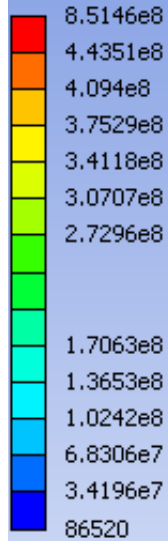


Fixed displacement B.C.

# Stresses on Lower Primary Plate at 11 ms (End of Quench)

## Linearized Stress:

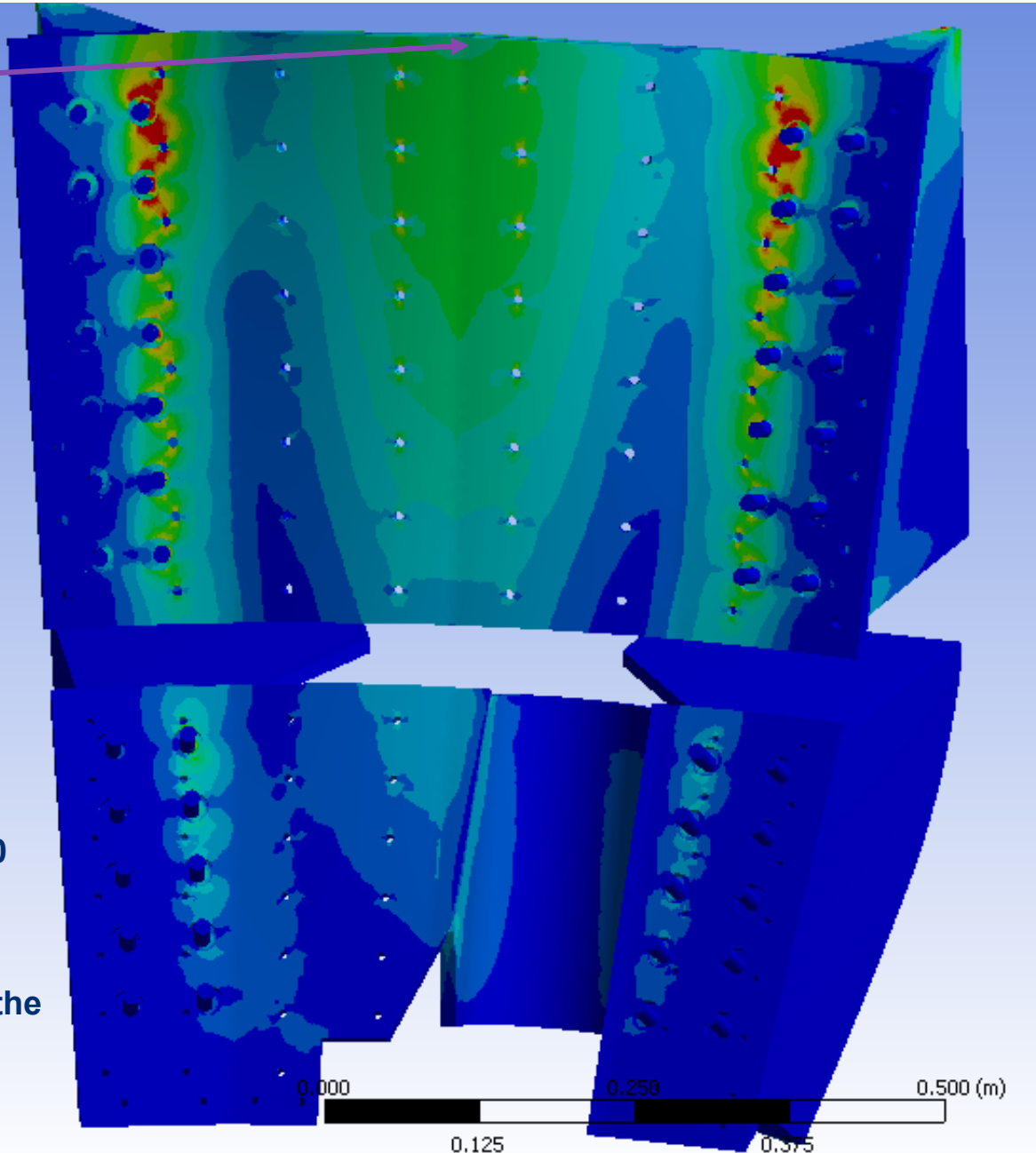
Membrane ~51.6 MPa  
Bending ~211 MPa  
Mem+bend ~260 MPa



## Yield Stress:

CuCrZr Yield Stress ~280 MPa  
Cu Yield Stress ~70 Mpa

Gussets are being added to the model for evaluation and to develop the plan forward






# Analysis

- All FDR calculations are checked and are in various stages of implementation by COGs
- The work remaining for Analysis is Title III update.
  - As-Built Conditions are causing revision to Vessel Weldments and other external structures. Existing calculations are forming the basis for review of the acceptability of field revisions.
- All Calculations are available for review on the NSTU website: [http://nstx-upgrade.pppl.gov/Engineering/Calculations/index\\_Calcs.htm](http://nstx-upgrade.pppl.gov/Engineering/Calculations/index_Calcs.htm)





**National Spherical Torus Experiment (NSTX) Center  
Stack & NBI Upgrade Project**

NSTX NSTXU [Overview](#) | [Conferences](#) |  
 Web Pages  
 NCSX FTP Sites |  
 Navigation Trail [Engineering](#) > [Calculations](#)

**NSTX Center Stack Upgrade Calculations (NSTXU)**

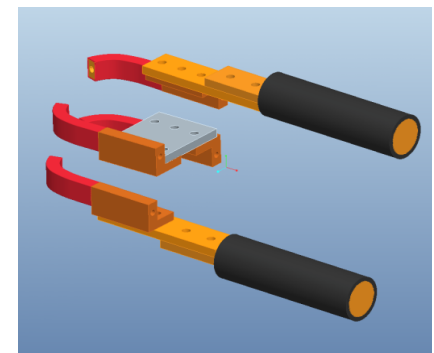
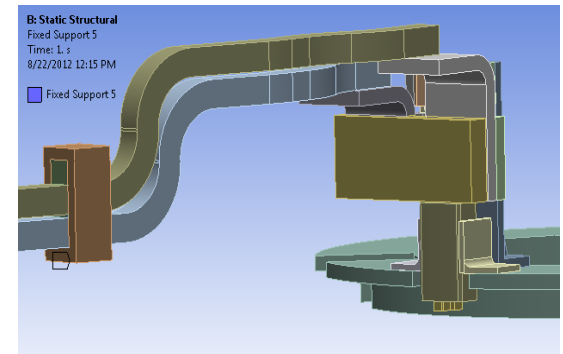
**[NSTXU Final Design Review Calculation Summary \(June 2011\)](#)**

**NOTE: Original NSTX Project Calculations found at:**  
[http://nstx.pppl.gov/nstx/Engineering/NSTX\\_Eng\\_Site/Technical/General/Calculations/NSTX\\_Engr\\_Calcs.html](http://nstx.pppl.gov/nstx/Engineering/NSTX_Eng_Site/Technical/General/Calculations/NSTX_Engr_Calcs.html)

WBS	WAF's	Originator	Calculation Number/Revision	Subject	Finalized?	Proposed Reviewer(s)	Ready for FDR?

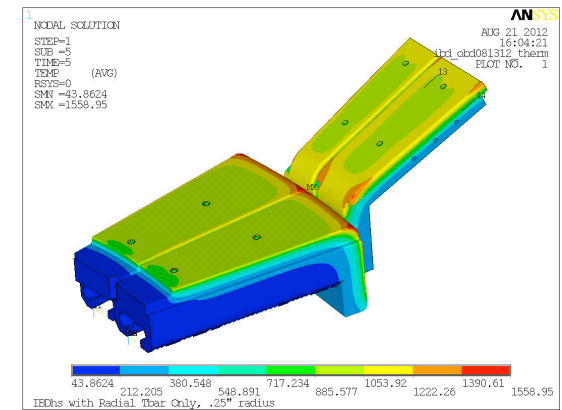
# Analysis (cont'd)

- Title III Updates
  - Umbrella Structure Braze Feet
    - Analysis complete, checking needed
    - Braze Test Complete
    - UT inspection shows no flaws
  - PF 1 a,b,c Final Bus Runs
    - “Tower Design” and Analysis Complete
    - Checking in process
  - PF 2,3,4,5 Final Bus Runs
    - Damage found due to lack of support of power cables

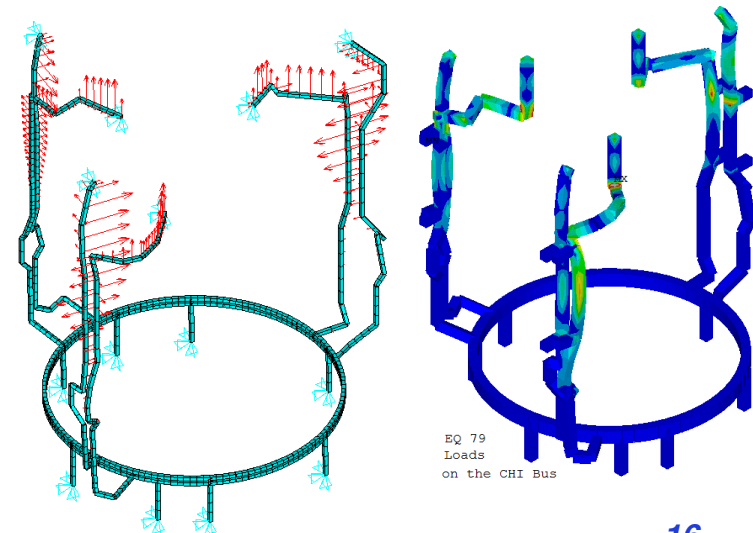
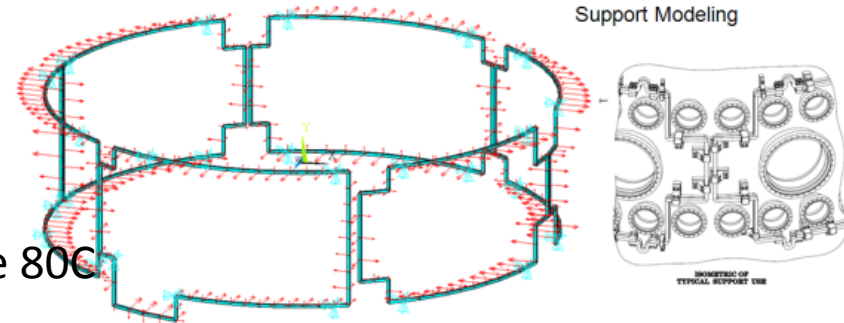




# Analysis (cont'd)

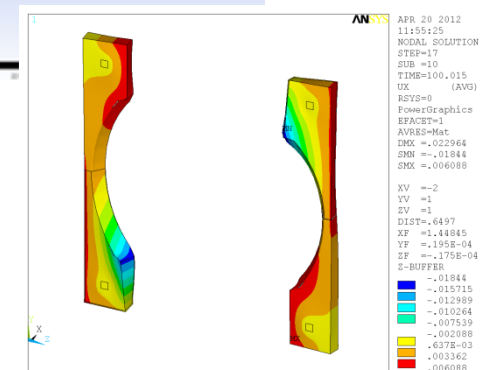
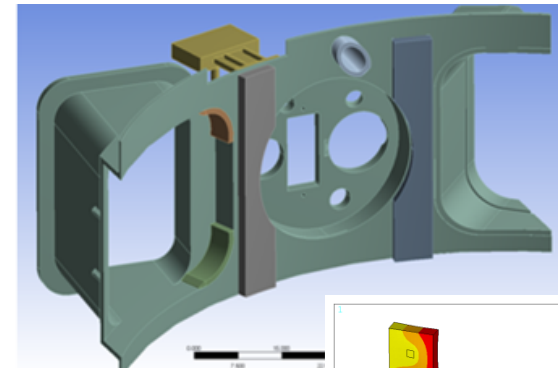
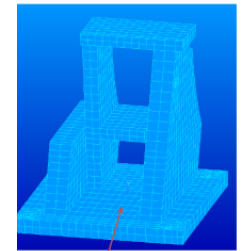
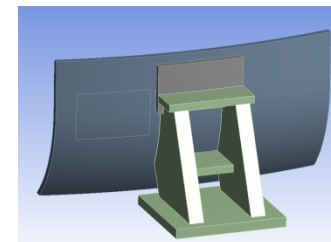
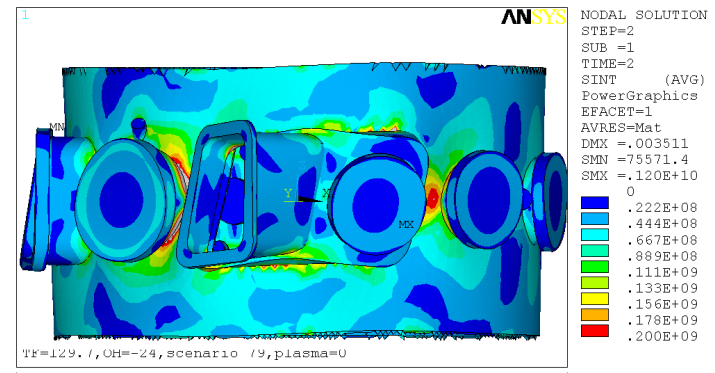


- Title III Updates (Continued)
  - CHI Gap Tile Rework, PF1c Case Thermal Loading
    - Extended tiles have been analyzed
    - Time constant for thermocouples needs calculation
    - CHI Currents have been Analyzed
    - PF1c casing heat up was calculated to be 80C
  - RWM Coil Upgrade loads,
    - Static Loads Acceptable
    - Vibratory response needs qualification
  - CHI Bus Bar
    - Lorentz forces quantified
    - Size and cooling for bakeout are being assessed



# Analysis (cont'd)

- Title III Updates (Continued)
  - Small Port Installation
    - Positions selected based on low stress locations . Equatorial positions are reinforced
  - Vessel Support “Chair”
    - Welds to Clear Clevis Blocks
  - Bay L Moly Shields
    - Design developed, attachment loads quantified, hardware provided for future use.



# Hardware Procurement Coordination

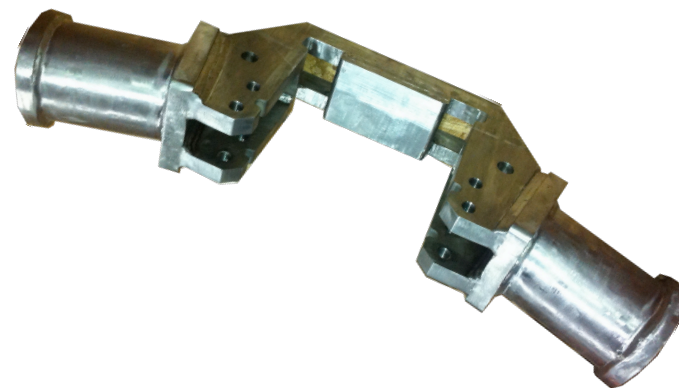
- Hardware is being fabricated in-house or through Procurement, via standard requisition or Blanket Purchase Agreements (BPA)
- An evaluation is made based on the type, size and schedule requirements for the the work.
- In-house fabrications:
  - Over 200 Tech Shop work orders have been written to cover internal work
  - Examples Include
    - Oven brazing of Umbrella Legs
    - OH Belleville support asm
    - Umbrella structure reinforcement rings
    - Mockups and field fitups when required

# Hardware Procurement Coordination (contd)

- BPA Procurements
  - Thirty (30) releases have been awarded to two (2) BPA vendors totaling ~\$740k
  - Examples
    - OTF Clevis Bushings
    - OTF Rod Ends and turnbuckles, and Weldments
    - Umbrella block reinforcements
    - CS Torque Rings and Compression Washers



- Standard Procurement Requisition
  - Approximately 100 requisitions to procurement have been written to cover the remainder
  - Examples include:
    - TF Conductors
    - Centerstack casing
    - Coil Molds
    - Graphite Tiles
    - High grade fasteners
    - Oven brazing



Install Upper & Lower AI Block External-Internal Reinforcements.

Install Upper & Lower Umbrella Arch Reinforcements.

Install New TF Outer Leg (TFOL) Support.

Install New Pf4/5 Support.

Replace existing Pf4/5 Support Column.

# NSTXU Supports Structural Upgrades

Install New Upper & Lower Umbrella Leg/Foot/Slide.

Install New Lower Lid.

Install New Pedestal.

Install New Upper Lid.

Replace Upper & Lower PF2/3 clamp hardware .

Install additional (upper & lower) PF2 Clamp.

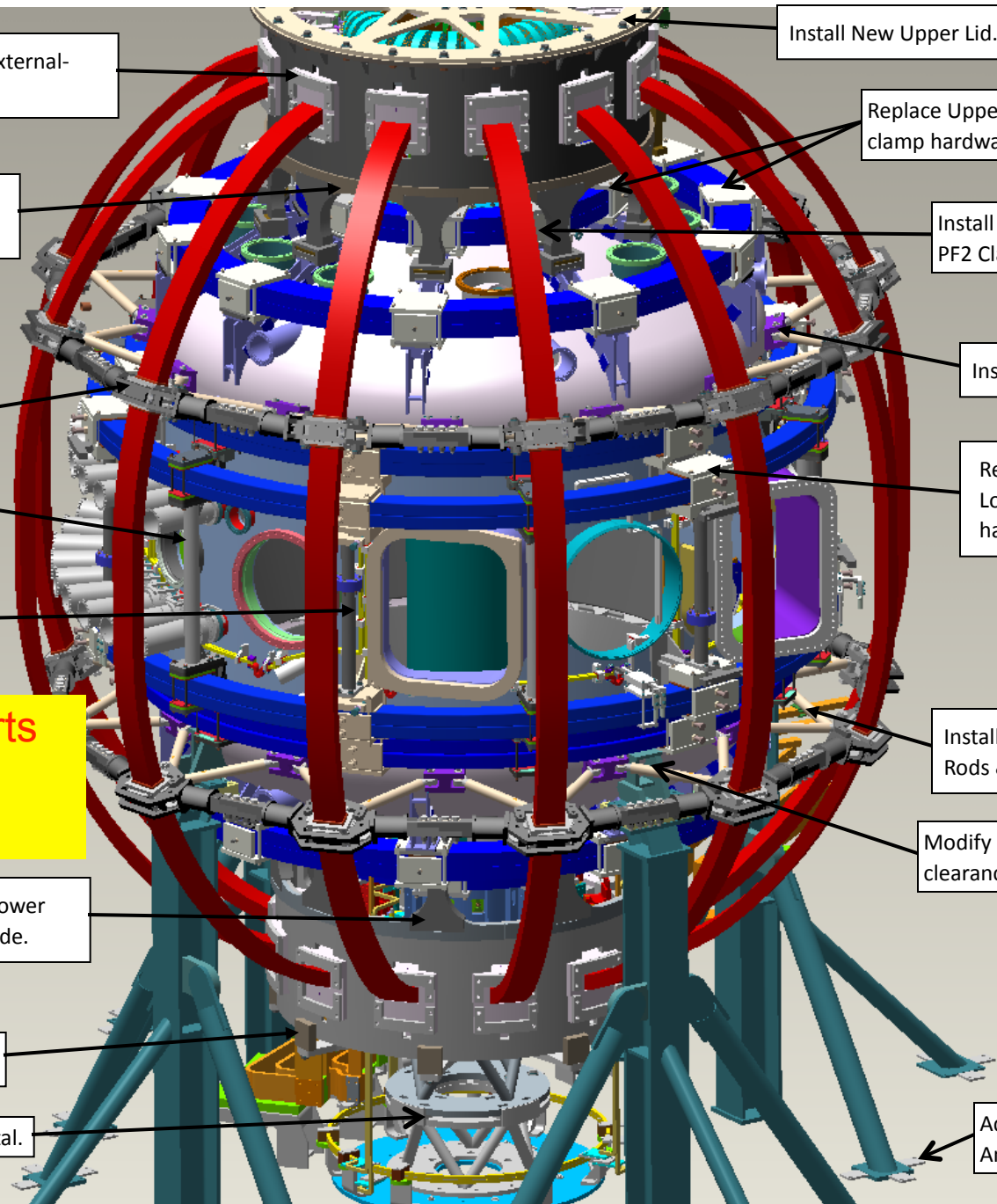
Install new TF-VV Clevis.

Replace existing Upper & Lower Pf4/5 clamp hardware.

Install new TFOL Connecting Rods & Rod Ends.

Modify support to provide clearance for connecting rod.

Add Extensions & Anchors to Supports



# Hardware Procurement Coordination

Upgrade	Ordered	Received
U/L AI Block External Reinforcements	✓	✓
U/L Umbrella Arch Reinforcements	✓	✓
U/L New Clamp Hardware PF2/3 Supports	✓	✓
Additional PF 2 Clamp	✓	✓
New OTF Leg Support Weldments	✓	1/13
New TF VV Clevis	✓	✓
New OTF Rods and Rod Ends	✓	✓
U/L New PF4/5 Supports	✓	✓
Replace Existing PF 4/5 Supports & Hardware	✓	1/13*
U/L New Umbrella Leg, Foot & Slide	✓	✓
U/L New Umbrella Lids	4/13	-
New Pedestal for Centerstack	4/13	-
Add Reinforcement to VV Leg Feet	✓	✓

*\* Parts received needs oven brazing and magnaplate*

# Summary

- Ancillary systems fabrication and installation is well underway
- Analysis is complete, Title III support is keeping up with installation activity as required
- Fabrication and Procurement of hardware is being managed to bring parts to the Test Cell in a timely manner