

# NCSX

## Construction Overview

NCSX Team

(presented by L. Dudek)

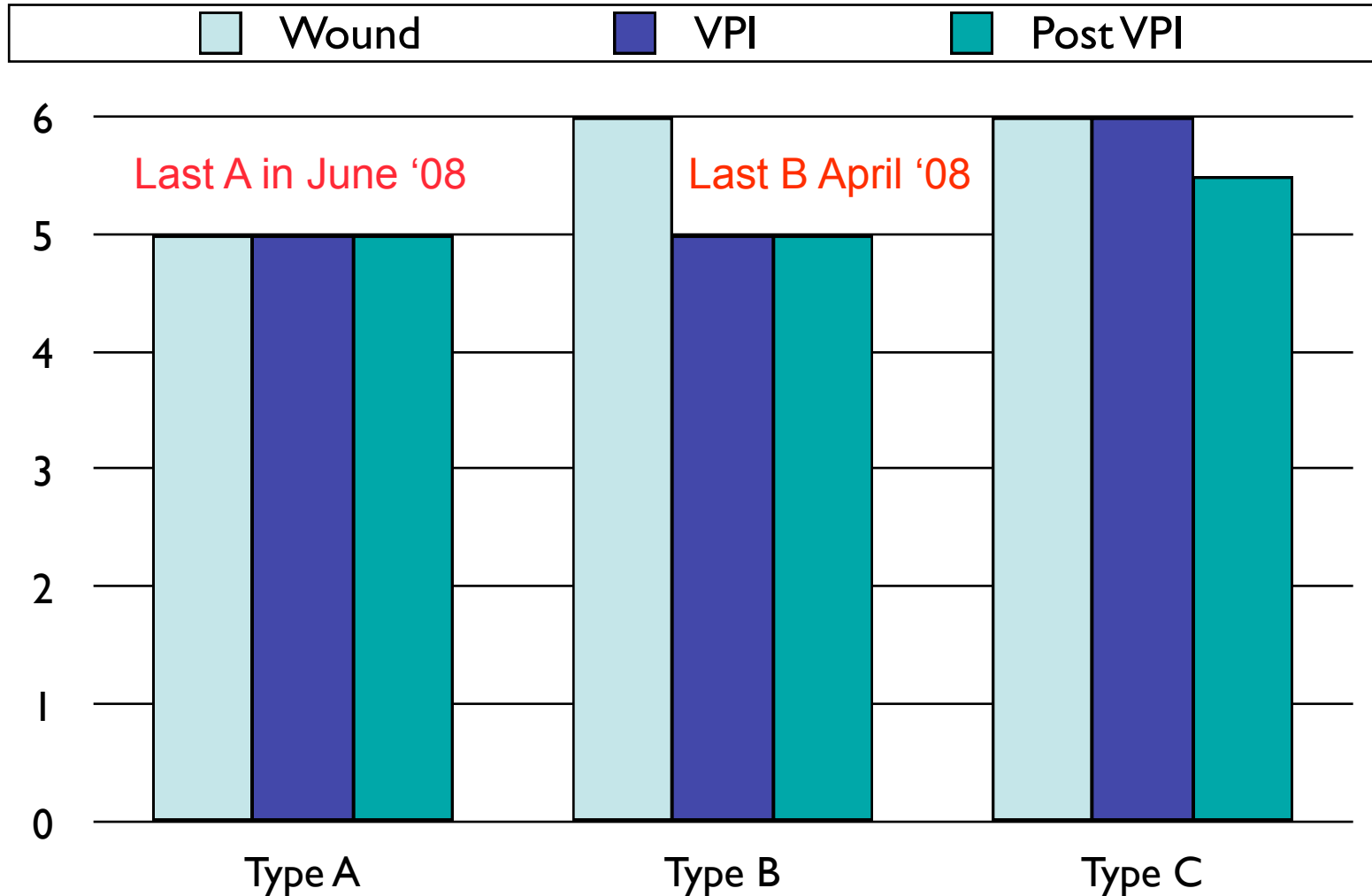
March, 2008

# Outline

- Modular Coil Assembly
- Procurements: TF & PF Coils
- Field Period Assy
  - Metrology
  - Welding
- Machine Assembly
- Startup
- Conclusion

# Modular Coil Assy Status

WBS 14 J. Chrzanowski



# Modular Coil Status & Achievements



- MC production line scheduled to be shut down in August.
  - Sta. 4 & Autoclave will be left in place.
  - Tooling for 1 coil in storage; remainder scrapped.
  - Area is gradually being turned over to Field Period Assembly
    - Sta. 2 now; Sta. 1 B in May; Sta. 3 end of June.
  - Technicians are also gradually being shifted to Assembly.
- Design Goal of  $\pm .020$ " achieved over most of coils but not everywhere (details follow).
- Coils wound to match current center achieved on prior wound coils to minimize symmetry breaking field errors (details follow).

# Metrology usage during modular coil winding

## Dimensional casting characterization



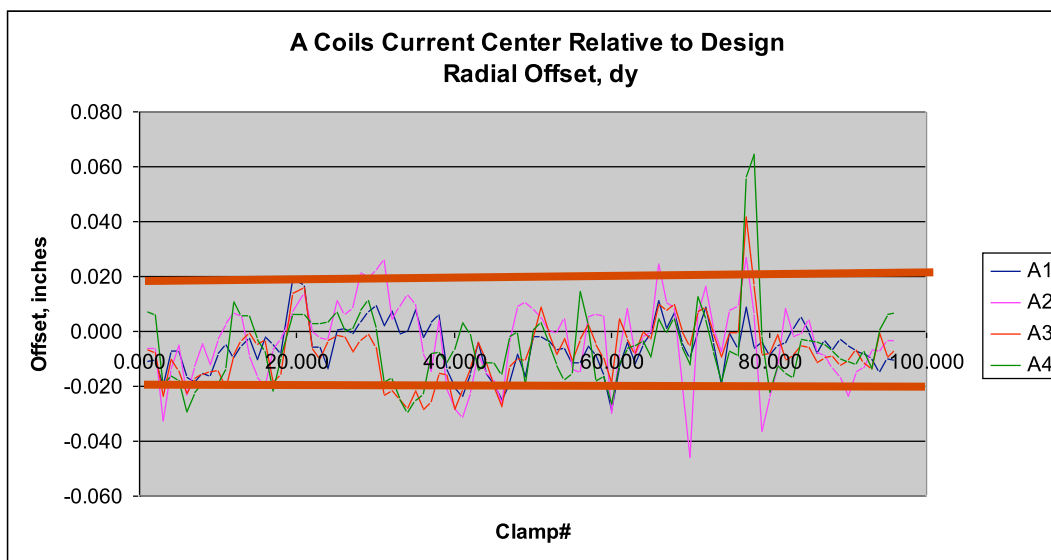
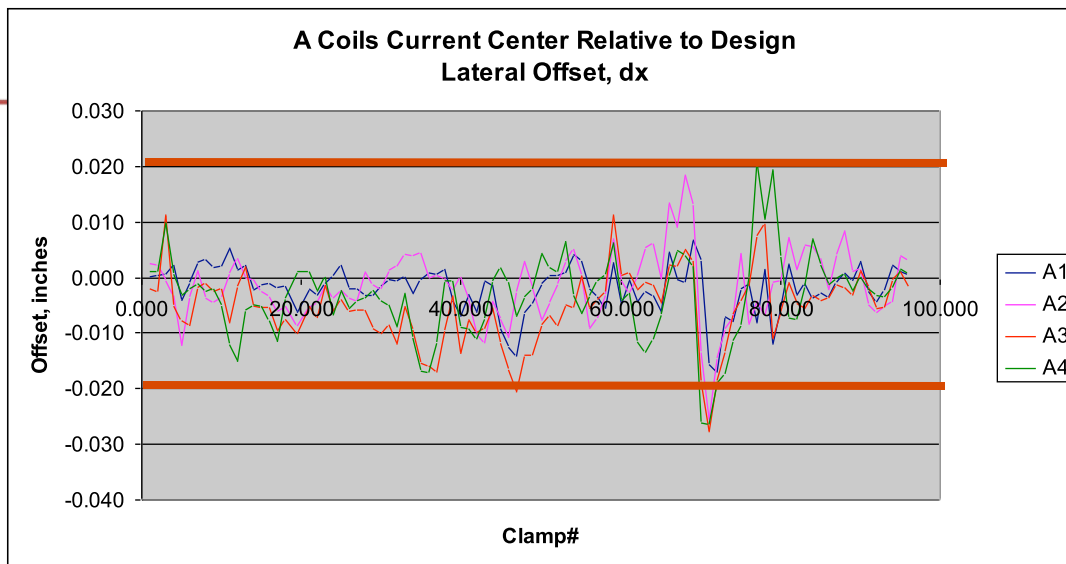
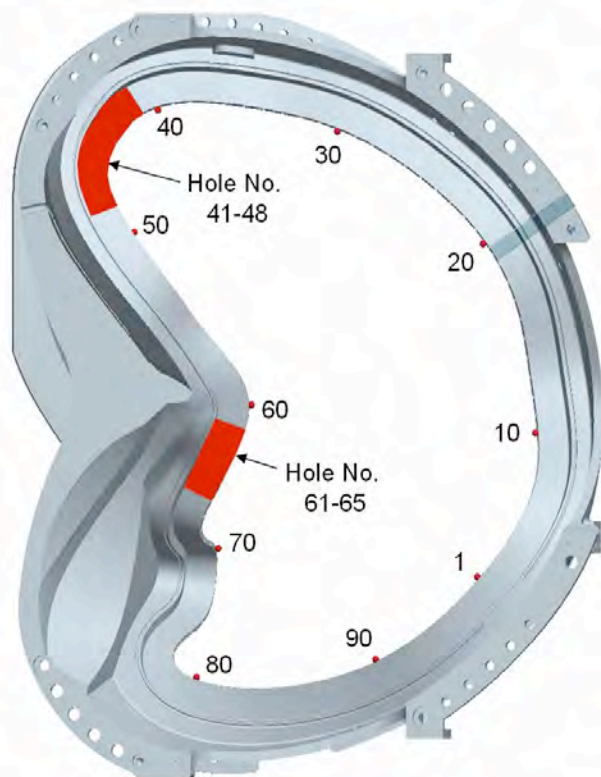
- ~8000 measured points characterize winding surface

## Winding Measurement & Re-Sizing



- Adjustable clamps allow tailoring of the cross section of the winding pack on either side of the septum.
- As-built winding form measurements are used to set clamp positions.
- Clamp positions define a cross section of the winding pack.
- Compliance of the insulation, prior to potting, allows for adjustments.

# Modular Coils - Type A Lateral & Radial Offsets



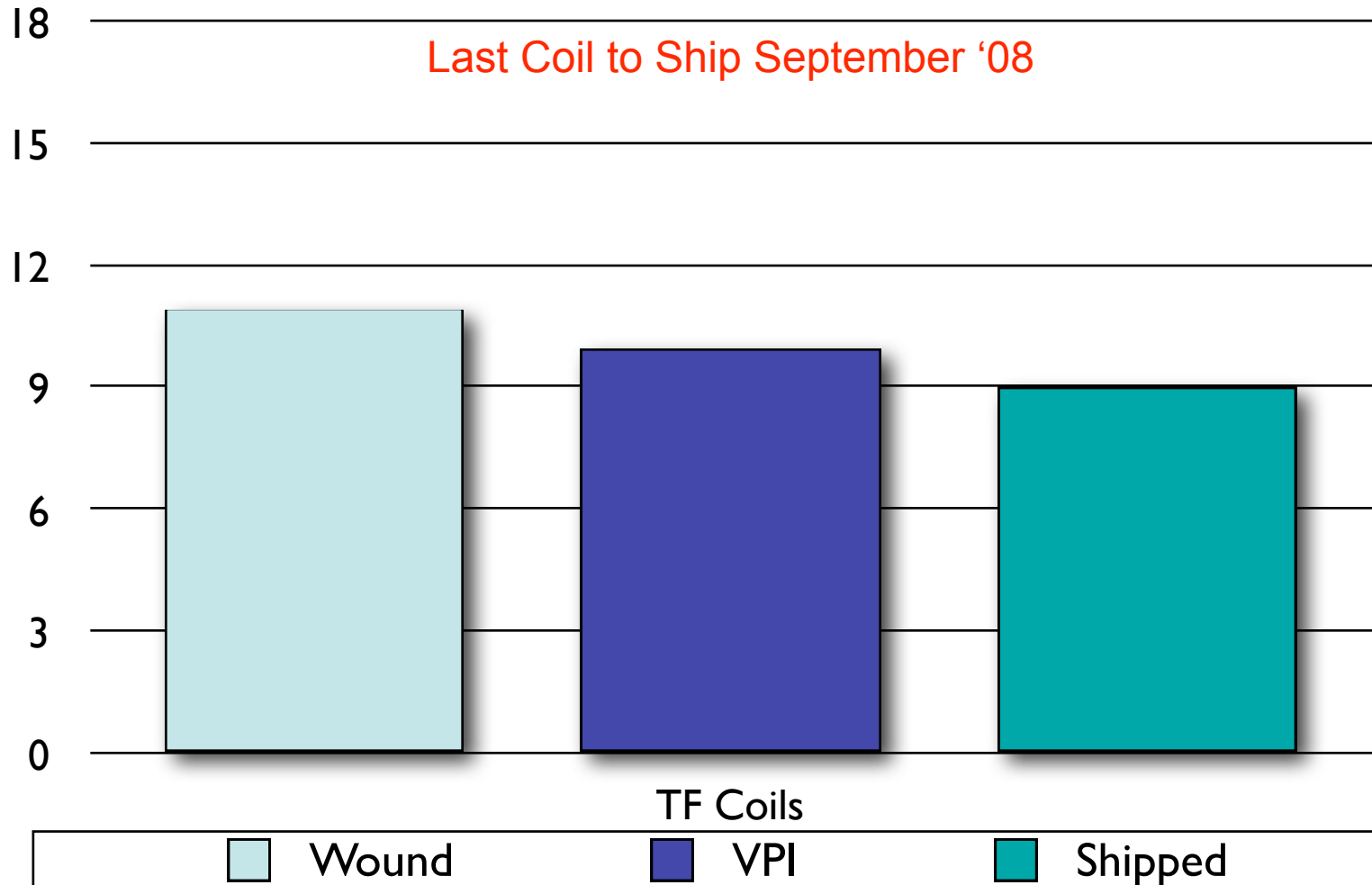
# Modular Coil Tolerance Compensation



- Knowing the as-built dimensions, we are compensating for errors by realigning the coils during FP assembly.
  - In this way, the tolerance allocated to the modular coils is made available for assembly.

# TF Coil Fabrication Status

WBS 13 M. Kalish



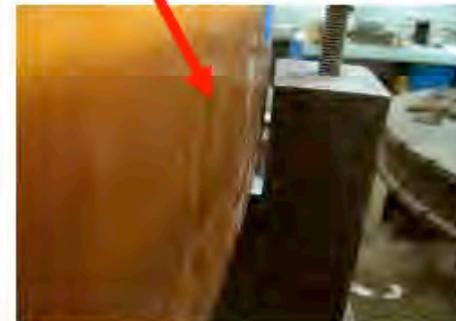


# TF coils are dimensionally checked at the factory

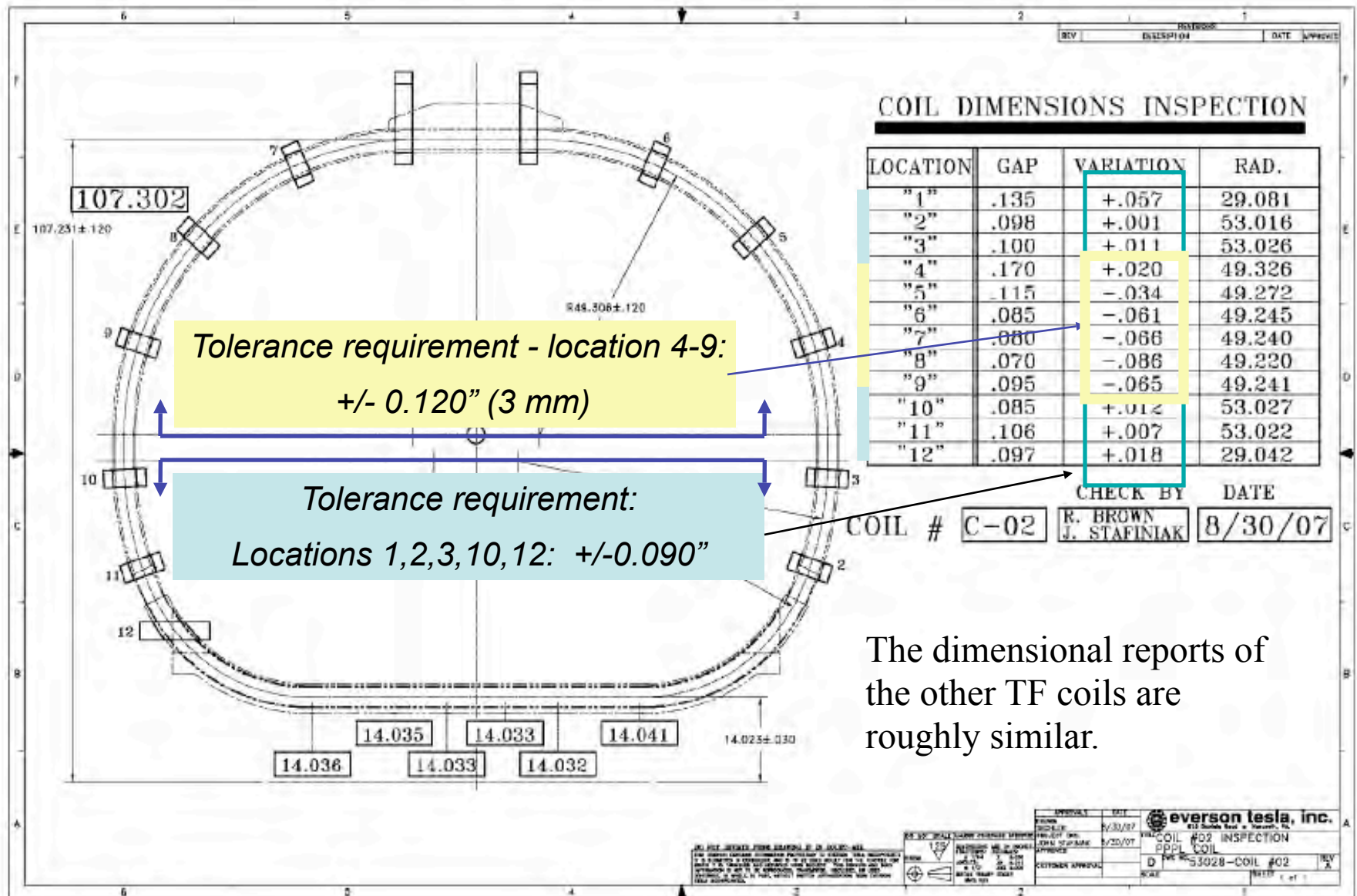


Includes checks of:

- X-Y geometry
- Planarity
- Wedge geometry



# Dimensional Inspection Report Example TF#2



The dimensional reports of the other TF coils are roughly similar.

# PF Coil Procurement Plans



- Subcontract Procurement Evaluation Board is active.
  - Released Request For Proposal by 3/7.
    - Bidder's conference on 3/17
  - Award contract: 5/5.
    - Options : Just PF 5&6's, just PF 4's, all together.
  - Delivery dates: PF 5&6 L Feb. 09
    - Balance 9/09.
- Requisition for conductor is placed
- Kapton and Fiberglass requisition has been placed

# Field Period Assembly

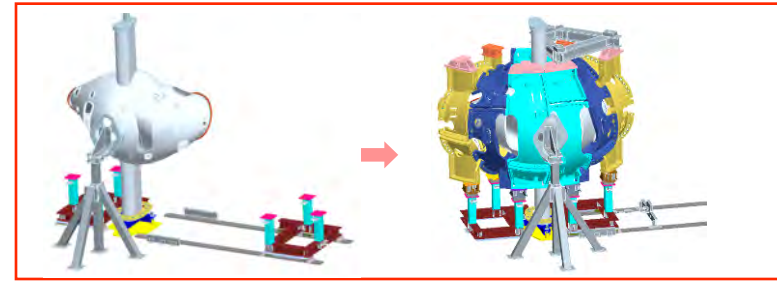
WBS 18 M. Viola



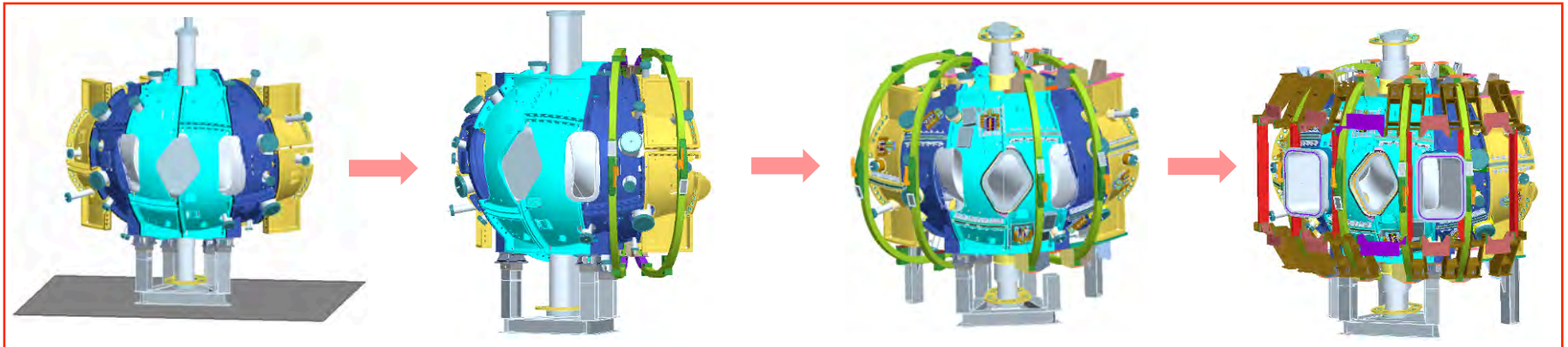
**Station 1 –  
Vacuum Vessel (VV)  
Prep**



**Station 2 –  
Modular Coil Half Period  
(MCHP) Assembly**



**Station 3 - MCHP  
installation over VV Period**



**Station 5 - Final Assembly**

**Station 6 – Final Machine Assembly – Erik Perry**

# Station 1 Assembly Progress

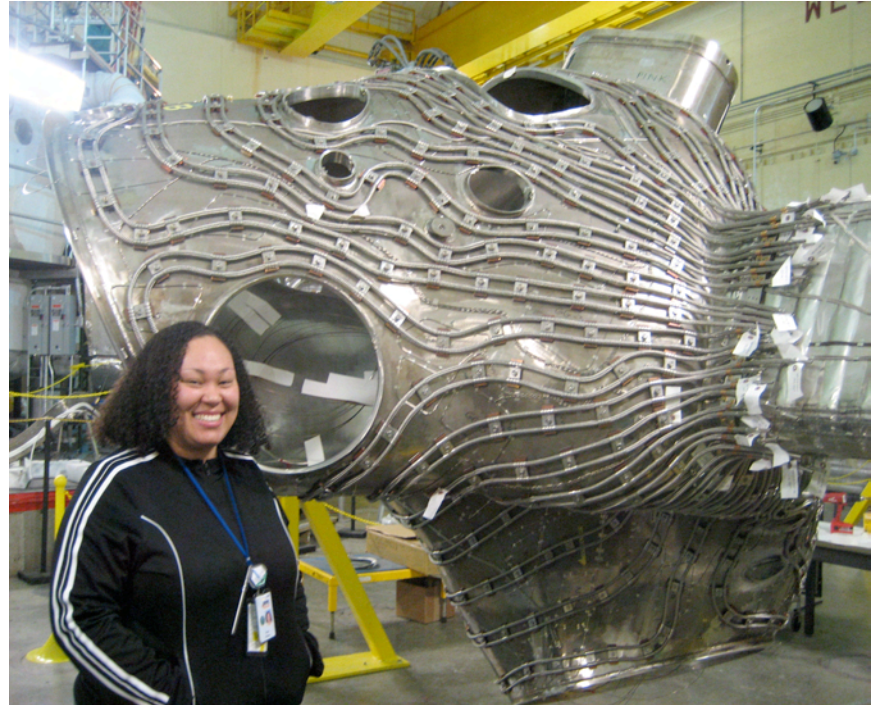


- All 3 vessel segments were delivered by September, '06.
- All 3 VV Segments Ready for Assembly
- Diagnostic loops, heating & cooling lines, and thermocouples have been installed. (Stratton, Labik WBS 3)



# Station 1 Assembly Progress

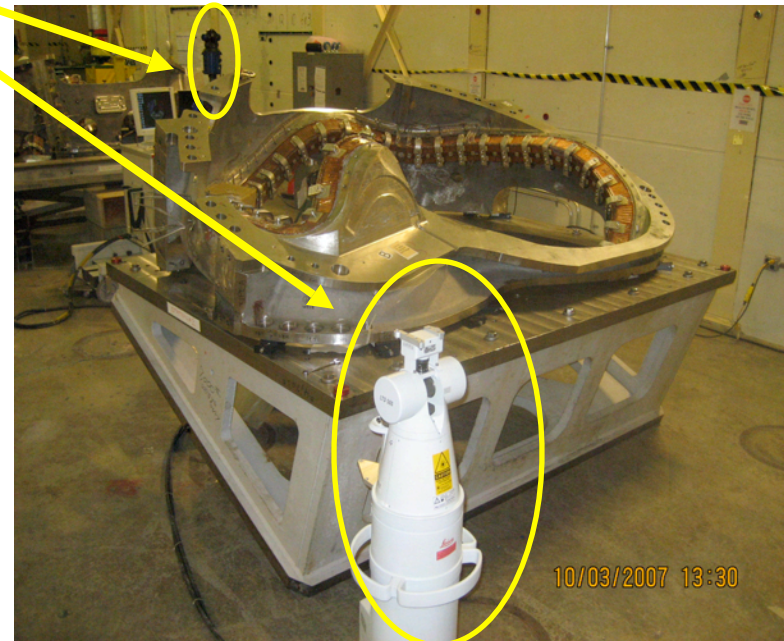
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# Metrology Capabilities



- PPPL has recently added photogrammetry to its array of metrology tools:
  - Mechanical measuring arms are used for the coil manufacturing process.
    - PPPL has four.
  - Laser tracker systems are used for subsequent assembly operations.
    - PPPL has two.
    - A third is on order
  - Photogrammetry -Recent visits to CERN and W7X convinced us that photogrammetry is a very worthwhile addition to NCSX's metrology capabilities.
    - We have procured a GSI VSTARS /E4X.
    - Has the potential of speeding up metrology during assembly operations.



# Accuracy and Repeatability

- Accuracy + repeatability  $\sim \pm 0.10$  mm (0.004") for the laser trackers at the range required for NCSX (typ. 3-5 m.)
- Accuracy + repeatability  $\sim \pm 0.075$  mm (0.003") for the Faro & Romer arms has been realized in the range typically used to measure the coils.



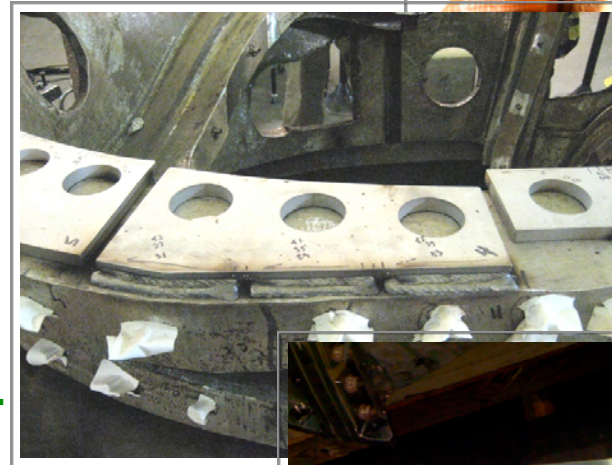
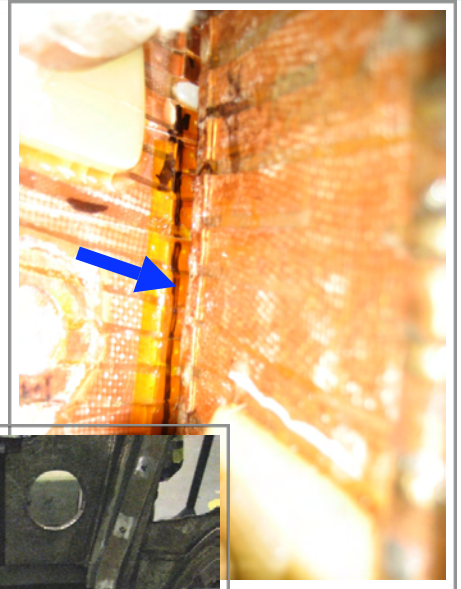
# Station 2 Trials



- Station 2 FPA trials were continued:
  - ✓ Gross fit individual mating coils
    - ✓ found and corrected some minor interferences
- Joint design trials for Station 2 & 3:
  - ✓ Install and torque bolts – assess accessibility **SUCCESSFUL**



- ✓ Develop shim technique **SUCCESSFUL**
- ✓ Pillow shims **SUCCESSFUL**
- ✓ New welded design for inboard interface (nose) **SUCCESSFUL**



# Shim Availability

## Job 1431 MC Procurements (Dudek)

- Alumina shim was the original choice due to early friction tests of  $\mu = 0.6$
- First lot of shims from primary supplier
  - Came in out of flatness up to 0.007"
  - The primary supplier was unable to produce a surface flat enough at required thickness (0.025")
- Contingency plan to use the alternate supplier failed when they declined the work
- The primary supplier was able to produce an acceptable lot of thinner 0.015"
  - Would require thicker metal cores
  - Lead time for coating was approx. 4 weeks
- In parallel a new design using G-10 was developed by design team



# G-10 Insulator and Shim

- Permits insulator and cores to be fabricated in parallel
- Can use various insulator thicknesses to obtain the required size
- G-10 is less expensive (\$1 vs \$50 each)
- Insulators can be cut quickly on waterjet machining center.
- Cores can be simplified by removing cut grooves (\$20/piece)
- Alumina version still required for last C-C joints for higher friction values





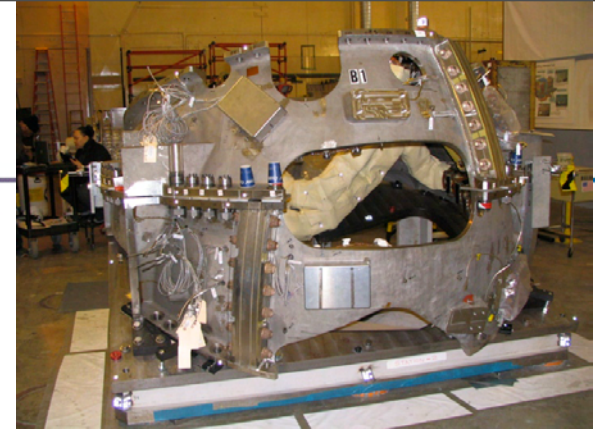
# Station 2 Assy Status



## A-B Modular Coil Assembly

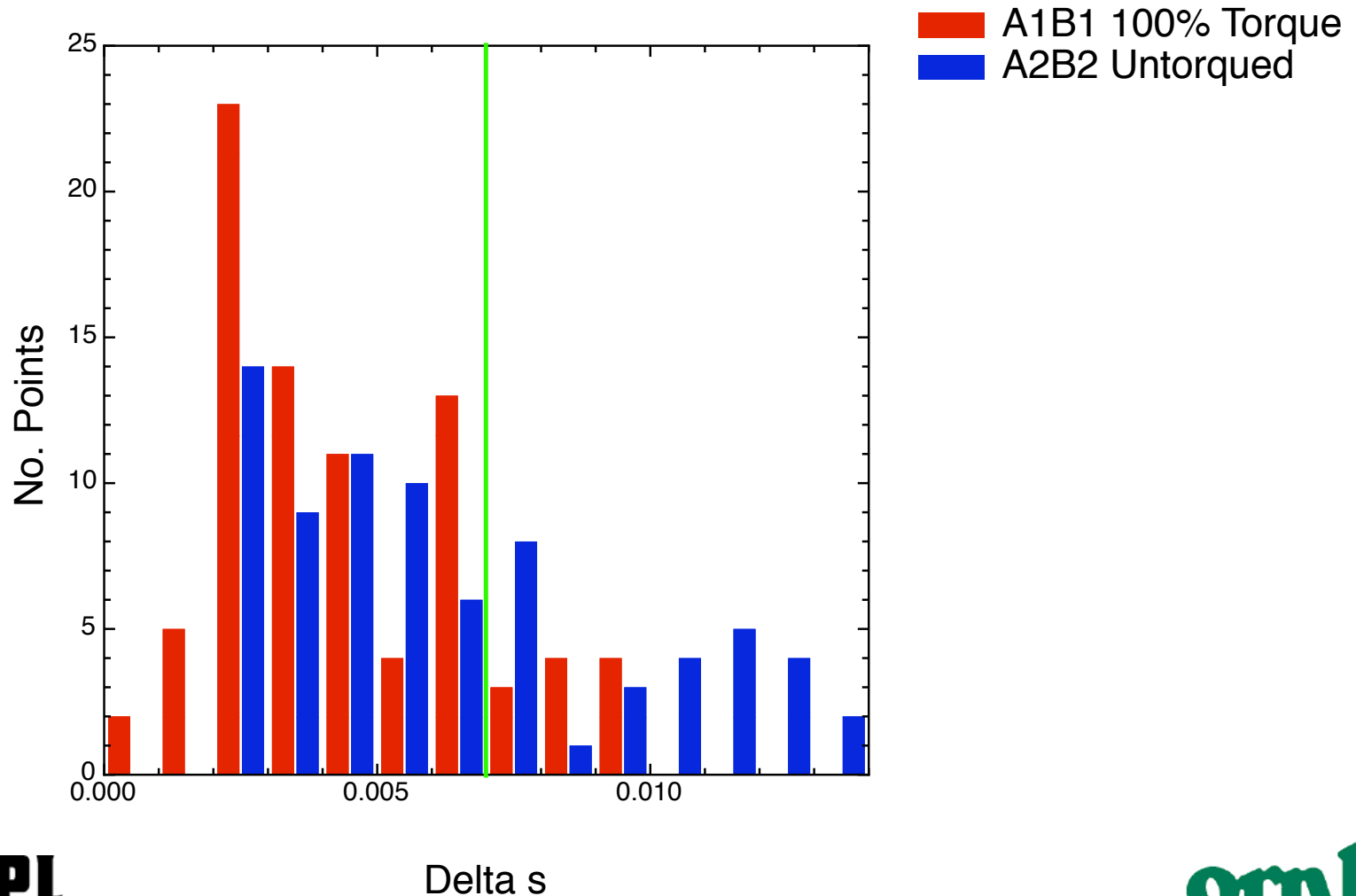
- ✓ Rack A coil & measure fiducials.
- ✓ Lower B coil into place onto outboard shims
- ✓ Measure shim puck height with bore gauge
- ✓ Install nose shear plates & lightly tack weld
- ✓ Lift B & flip to ready for nose welding.
- Establish A & B coil fiducials – weld flex shims to plasma side both coils, recheck fiducials. Back Office assess part for compliance.
- Place B coil back on A coil and align
- Install shims and bushings
- Weld A/B nose region solenoid side & re-measure.

**REPEAT FOR C TO A-B ASSEMBLY**



# First Two Coil Joint Alignments

First two coil alignments were easily achieved  
Approx. 90% of the points  $\Delta s < 0.007$ "



# FPA Fixtures

WBS 1803 Design T. Brown / 1805 Procurements L. Dudek

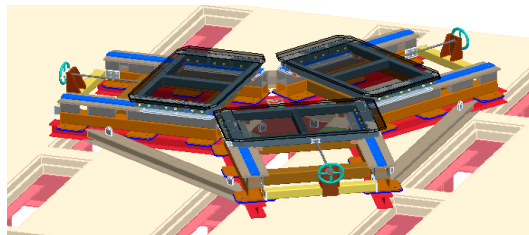
- The station 3 assembly fixture and the digitally controlled crane manipulator have been fabricated and have arrived at PPPL
- Second station 3 assembly fixture and a lifting fixture are in the procurement process
- Station 5 completed FDR, design work to finish Apr 08

# Machine Assembly

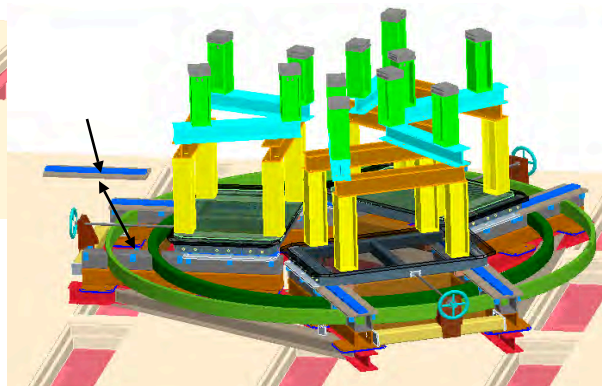
## WBS 7 E. Perry



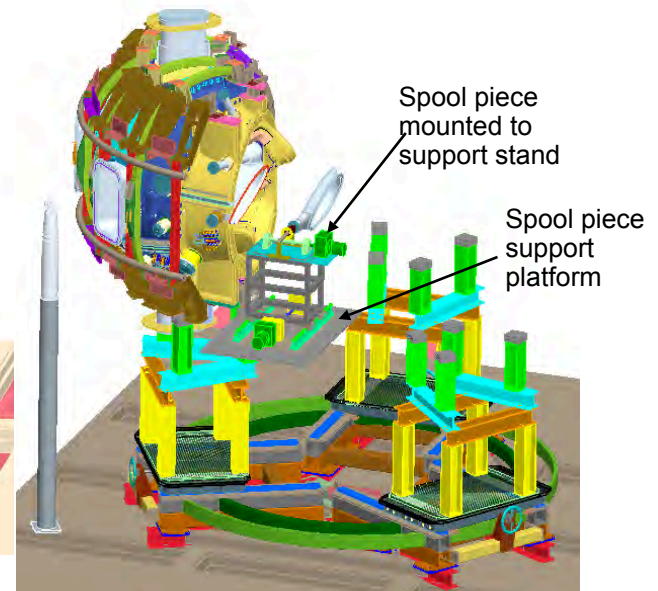
- This assembly plan provides much greater detail than was available at the time of the August Lehman review



FPA assembly carts installed



Lower PF 5 and 6 positioned within the cart rail grooves.



Period 1 retracted with spool and support stand installed

# ISTP / Startup



- Job 8501 Gentile
  - Integrated Systems Testing Procedures
  - Safety Assessment Document (SAD)
  - Startup costs
    - Engineering
    - Technician Labor
- ISTP to begin Nov 2011



# Manpower

- Coil Winding crews are being transferred to FPA as the last few coils are completed
- New Engineer- M. Smith supporting FPA fixtures design
- Metrology
  - Open Metrology Engineer req
  - Training coil winding techs in use of Laser Tracker / Photogrametry

# Construction Budget Increases



## MC Interface Hardware

- Shim cost Growth (multiple designs)
- New holes C-C jnt
- C-C Inboard Jnt

## FPA Station 5

•

## Heater Controls (new)

## Machine Assy Planning & Oversight

Increase due to project stretchout

## FPA fixtures

- Added station 3 lift Fixture
- Added second station 2
- Added second station 3

1810  
28%

## FPA Assy

- Second Metrology crew ~ \$1.5M
- Design & Sequence plan maturity (new shim and welded nose design) ~ \$.75M
- M&S ~\$.5M

1802  
22%

## FPA Oversight & Support

- Additional title 3 (ORNL, PU ME, Drexel)
- Stretchout (LOE HP and supervision)

Total Construction Increase ~\$10M



# Retiring Risks

Risk	Mitigation / Status
316LN Inboard Shim material not available to meet schedule (Job 1431)	Further analysis demonstrated 316L is acceptable
Welding the inboard shims could result in gaps opening up at the plasma-side end of the shims to an unacceptable degree. (Job 1810)	Welded shim design has changed to include a tightly fitted limiter and flex shim to react shear loads; these ensure against relative motion of flanges during operation and minimize cyclic loading of welds.
Station 2. As a result of the development trials for weld distortion, the welding time increases significantly above present allowance (Job 1810)	Welding time estimates consistent with time requirements for first R&D article which appeared to have very low distortion. Risk goes away at conclusion of ongoing weld development effort.
Station 2. Sizing shims will be challenging and will occur during tight schedule constraints. Any false starts will require immediate attention and resolution to solve problems quickly. (Job 1810)	Continue trial assembly with hardware to explore potential problems. Adopt G10 sandwich design.
Station 2. Interferences discovered during assembly; components don't go together as planned. Assemblies have to be taken apart, components moved or re-worked, re-assembled. (Job 1810)	Perform coil-to-coil fitup checks. Coils are being reworked to provide clearance
Station 6. TC floor is not adequately rigid for present metrology plan (Job 1810)	Copper sheet and spongy surface removed from TC floor. Fiducials will be placed. Concrete blocks will be placed to see if floor is adequately stiff. Assess adequacy of TC floor.

# Risks Going Forward

## *“Stuff that Keeps Me Up”*

- Welding
  - Initial tests are good, but problems would have significant potential for cost and schedule growth
- Vacuum Vessel to MC Fitup
  - Original design clearances during assembly have shrunk to  $\sim .2$ ”
- *“The Details”*
  - Significant portions of the design have not yet been detailed
  - The shim is a good example of how a simple part can vary wildly in cost by changing some simple features
    - Prototype alumina coating on shim quote \$20 (16 sq. in)
    - Current alumina coating on shim quotes \$40 - 400 (22 sq. in)
- Metrology
  - Computers are prone to problems
  - Can’t measure locations of anything without a PC

Activity ID	Activity Description	Duration (work days)	Forecast Start	Forecast Finish	FY08					FY09					FY10					FY11					FY12																	
					F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
cc 9450 - NCSX Fabrication (MIE)																																										
1 - Stellarator Core Systems																																										
18 - Field Period Assembly																																										
Job: 1810 - Field Period Assy Station 1,2,3 VIOLA																																										
+ Station 2 MC subassy A1B1C1																																										
		187	27FEB08	18NOV08																																						
+ Station 2 MC subassy A2B2C2																																										
		153	24APR08	01DEC08																																						
+ Station 2 MC subassy A3B3C3																																										
		193	02JUL08	13APR09																																						
+ Station 2 MC subassy A4B4C4																																										
		143	24NOV08	24JUN09																																						
+ Station 2 MC subassy A5B5C5																																										
		173	02DEC08	12AUG09																																						
+ Station 2 MC subassy A6B6C6																																										
		143	14APR09	03NOV09																																						
+ Station 3-Assemble Mod Coils and VVSA-FP#1																																										
		149	15OCT08	22MAY09																																						
+ Station 3-Assemble Mod Coils and VVSA-FP#2																																										
		198	17MAR09	05JAN10																																						
+ Station 3-Assemble Mod Coils and VVSA-FP#3																																										
		159	30JUL09	24MAR10																																						
Job: 1815 - Field Period Assy -Station 5-VIOLA																																										
+ Station 5- Final FP Assy -FP#1 (in NCSX TC)																																										
		130	12MAY09	12NOV09																																						
+ Station 5- Final FP Assy -FP#2 (in NCSX TC)																																										
		117	06JAN10	18JUN10																																						
+ Station 5- Final FP Assy -FP#3 (in NCSX TC)																																										
		98	25MAR10	11AUG10																																						
+ 7 - Test Cell Preparation and Machine Ass																																										
		456	25JAN10	11NOV11																																						
8 - Project Oversight and Support																																										
85 - Integrated Systems Testing																																										
+ Job: 8501 - Integrated Systems Testing-GENTILE																																										
		121	22JUN11	13DEC11																																						

RB08

NCSX Project SUMMARY PLAN

Sheet 1 of 1

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# Conclusion

- One of the most challenging components to fabricate, the Modular Coils, are very near completion with only 2 coils remaining to be potted
- The TF coils are more than 50% complete in fabrication and on schedule for early delivery
- The PF coils about to begin fabrication
- Field Period Assembly got off to a late start but early indications are that Station 2 assembly should progress relatively smoothly
- Risks are being retired as the assembly proceeds
- Future risks are being addressed with contingency plans that will ensure a successful project completion