NCSX Technical Progress and Critical Issues

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SC Project Review
DOE Office of Science, Germantown, MD
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Technical progress and critical issues

- **Much progress has been made in recent months**
  - **Major contracts awarded (MCWF, VVSA, MC conductor)**
  - **Modular Coil Manufacturing Facility (MCMF) operational**
  - **Fabrication of the Twisted Racetrack Coil underway**
  - **TF coil design simplified**
  - **Better and more detailed plans developed for field period assembly and final assembly**
- **Risk identification and mitigation continue to be in the forefront**
  - **Risks related to the work remaining have been identified and mitigation plans incorporated in our work plans**
  - **Critical activities/issues are systematically tracked in weekly meetings**
- **Adequate cost and schedule contingency exists for the work remaining**

Budgeted cost of work remaining (BCWR) is $52.5M

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		ECP18 Budget	BCWP	BCWR	% Complete
11	In Vessel Components	$60	$60	$0	100%
12	Vacuum Vessel Systems	$4,005,043	$2,877,341	$1,127,703	72%
	VVSA	$4,732,000	$138,865	$4,593,140	3%
13	Conventional Coils	$4,441,000	$456,473	$3,984,527	10%
14	Mod Coils	$17,992,000	$9,990,254	$8,001,746	56%
	MCWF	$8,207,990	$111,120	$8,096,870	1%
15	Coil Support Structures	$1,380,706	$53,674	$1,327,032	4%
16	Coil Services	$1,035,440	$0	$1,035,440	0%
17	Cryostat & Base Support Structure	$1,321,940	$164,186	$1,157,754	12%
18	Field Period Assembly	$5,118,000	$613,716	$4,504,284	12%
19	Stellarator Core Mgmt. & Integration	$2,421,000	$998,240	$1,422,760	41%
1 Total	**Stellarator Core Systems**	**$50,655,179**	**$15,403,929**	**$35,251,255**	**30%**
2 Total	**Plasma Heating Fueling & Vac Systems**	**$779,677**	**$369,079**	**$410,598**	**47%**
3 Total	**Diagnostics**	**$1,116,732**	**$239,127**	**$877,606**	**21%**
4 Total	**Electrical Power Systems**	**$3,215,549**	**$335,752**	**$2,879,797**	**10%**
5 Total	**Central I&C Systems**	**$1,916,663**	**$25,342**	**$1,891,321**	**1%**
6 Total	**Facility Systems**	**$825,124**	**$41,600**	**$783,524**	**5%**
7 Total	**Test Cell Preparation & Machine Assy**	**$4,208,342**	**$412,992**	**$3,795,350**	**10%**
8 Total	**Project Oversight & Support**	**$10,578,603**	**$4,004,533**	**$6,574,071**	**38%**
		$73,295,870	**$20,832,354**	**$52,463,522**	**28%**

Work on the Vacuum Vessel (WBS 12) is proceeding well

- **VVSA procurement underway (Heitzenroeder)**
- **The work in WBS 12 (outside the VVSA procurement) is 72% complete with a BCWR of $1.1M**
- **Final design is being completed for non-VVSA equipment**
  - **Thermal insulation**
  - **Cooling tubes**
  - **VV supports**
  - **Local I&C**
- **A comprehensive FDR for the Vacuum Vessel (WBS 12) is scheduled for February 2005 which will cover all non-VVSA equipment**
- **Procurement of non-VVSA equipment to follow the FDR**

VV risks related to the assembly weld are being addressed

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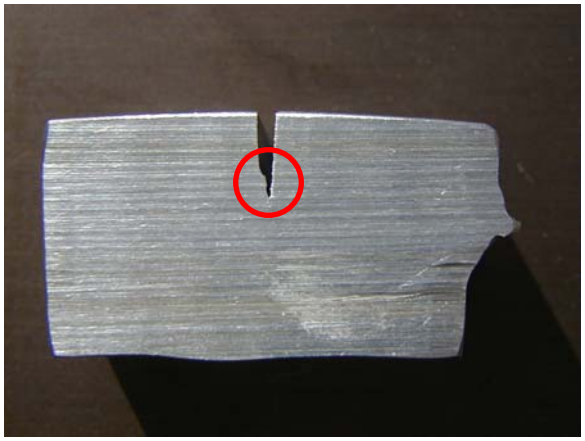
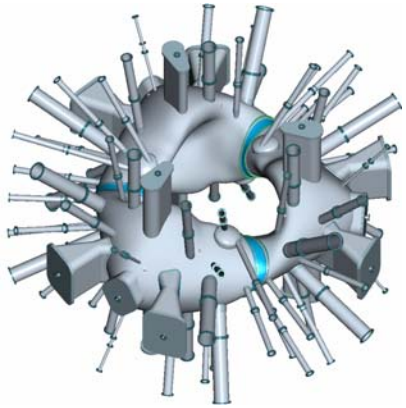
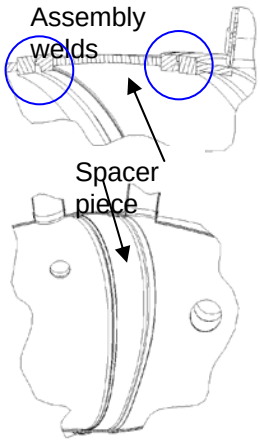
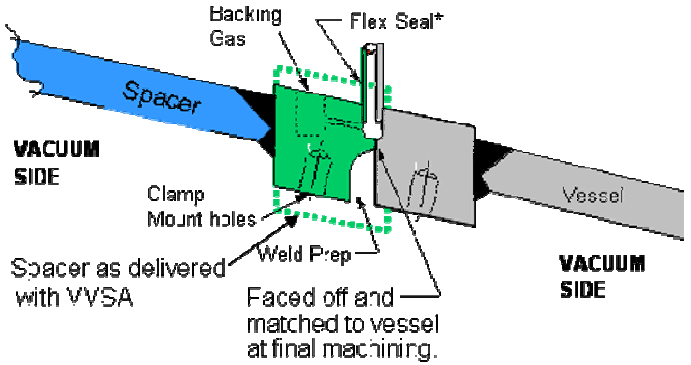
- **Crack propagation due to incomplete fusion at the root of the assembly weld**
  - **Tests are being performed to verify the expectation that the weld joint has ample structural margin**
- **Distortion of the VVSA and spacer piece due to the assembly weld**
  - **Weld configuration and procedures being developed on small test articles with the goal of making the weld easier with lower distortion**
  - **Full scale test article being procured. Will be used to demonstrate adequacy of weld procedures to avoid distortion.**



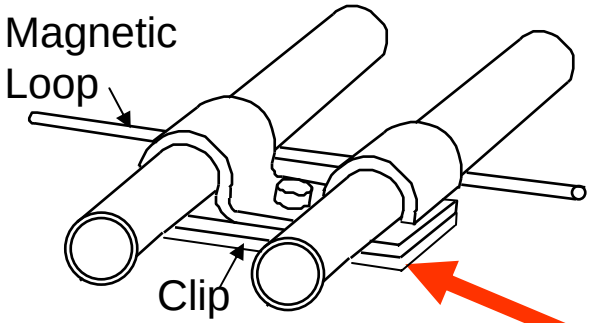




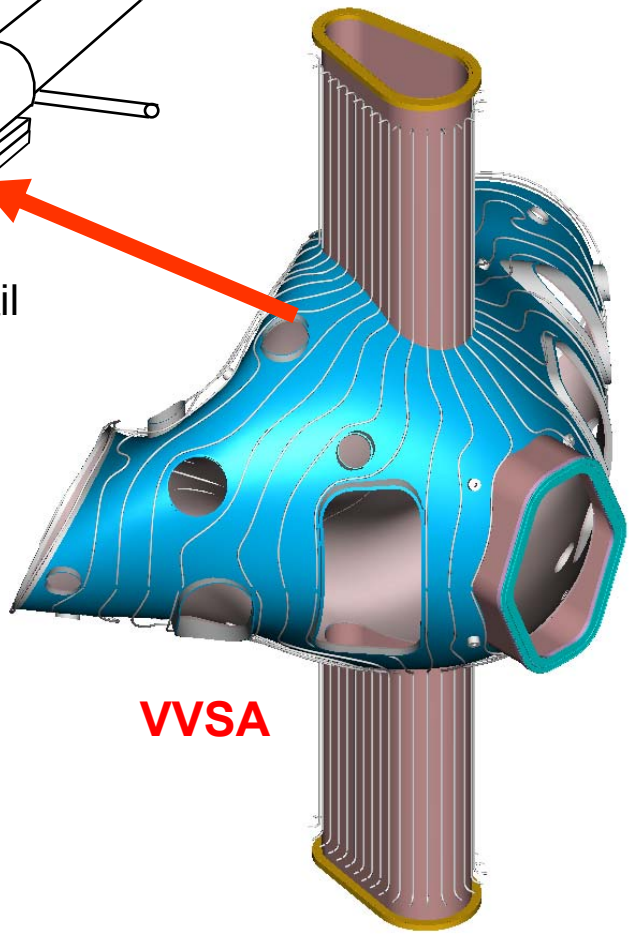


VV risks related to the cooling tubes are also being addressed

- **Concern that cooling tube supplier will not be able to adequately form cooling tubes that conform to the VVSA**



Tracing Mount Detail



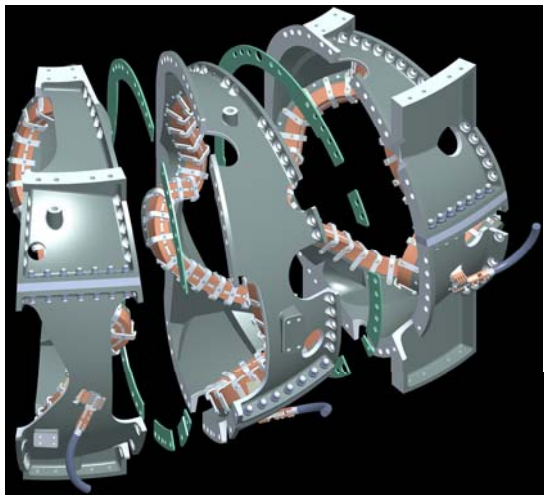
VVSA

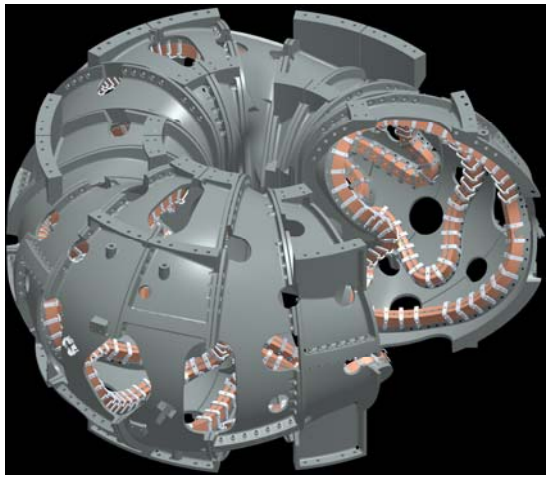
- **Forming a cooling tube that conforms to the Prototype Vacuum Vessel Segment (PVVS) will be required as part of the bid process**

PVVS

Work on the Modular Coils (WBS 14) is proceeding well

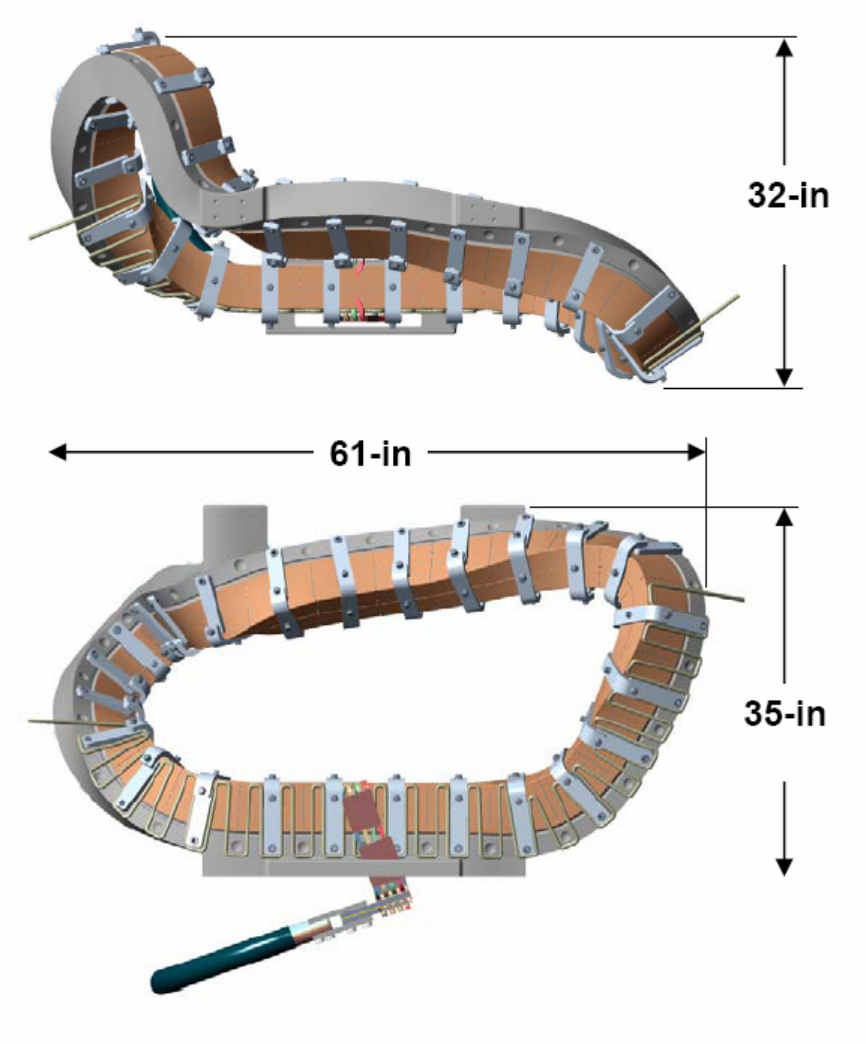
- **MCWF fabrication is underway (Heitzenroeder)**
- **The work in WBS 14 (outside the MCWF procurement) is 56% complete with a BCWR of $8.0M**
- **Work in progress includes…**
  - **Production of the Twisted Racetrack Coil (TRC)**
  - **Completion of the Modular Coil Manufacturing Facility (MCMF) and Coil Test Facility (CTF)**
  - **Completion of Final Design for the Type C winding (cladding, chill plates, cooling tubes, bolts, nuts, shims, etc.)**
- **Future work includes…**
  - **Completion of Final Design of the Type A and Type B windings**
  - **Wind and test production coils**





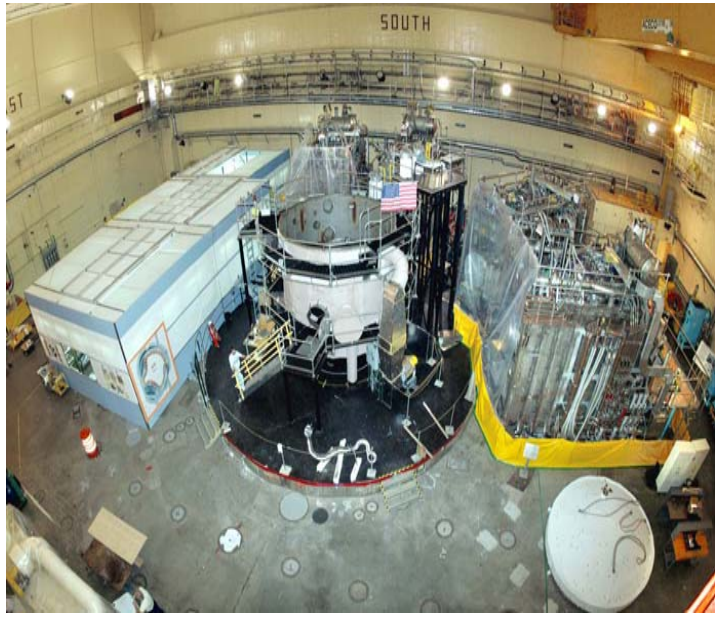
Twisted Racetrack Coil (TRC) fabrication is underway

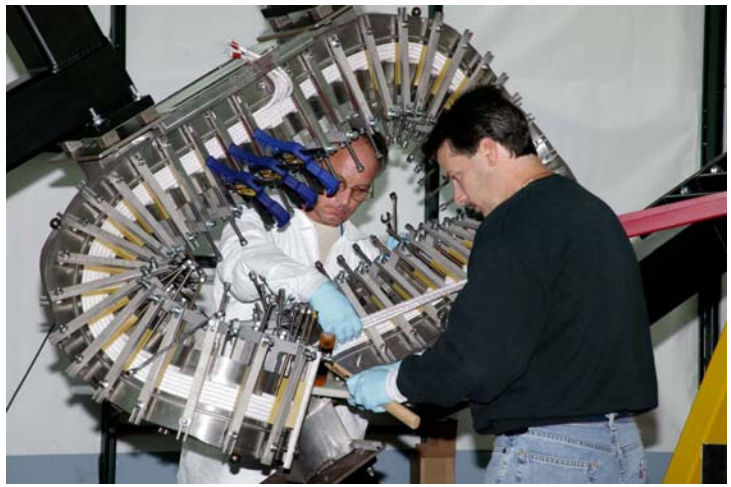
- **The TRC is a prototype of a modular coil only with a shorter length (10’ versus 20’)**
  - **Incorporates all the features of a modular coil**
  - **Will be tested at cryogenic temperature in the Coil Test Facility**
- **The TRC is critical to address risks related to coil winding and demonstrate that**
  - **Modular coils can be fabricated on time and within budget**
  - **Modular coils will work as expected and meet their dimensional and performance requirements**



The TRC is being fabricated in the Modular Coil Manufacturing Facility (MCMF)

- **The MCMF is operational**
  - **Station 2 (a coil winding station) will be used for prepping, winding, and bag molding the TRC.**
  - **Station 5 (the autoclave) will be used for VPI.**
  - **Other stations are being completed for the production coils.**
- **A trial winding of the TRC was done to determine how the conductor deforms with tight bends and twists and what shims will be required for the actual TRC winding**
- **TRC fabrication is scheduled to be completed in April 2005 with testing completed in May 2005**





Provisions to safely operate the MCMF are identified in the MCMF Operations Plan and supporting plans and procedures

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- **The TOC identifies key safety provisions**
  - Well defined responsibilities for production crew
  - Participation of ES&H and QA professionals
  - Job Hazard Analyses (JHAs)
  - Safety walk-throughs
  - Training
  - Protective equipment
  - Daily and safety meetings
  - Pre- and post-job meetings
- **Supporting plans and procedures**
  - MIT/QA Plan for coil manufacture
  - Manufacturing procedures for each station
  - Metrology procedure
  - Emergency response procedure

Excerpt from MCMF Operations Plan TOC

Safety documentation will be developed and reviews conducted before facilities become operational

- **Safety documentation**
  - **Preliminary Hazard Analyses (PHAs) have been prepared for the Autoclave and Coil Test Facility**
- **Safety reviews**
  - **An Activity Certification Committee (ACC) has already been established by the PPPL Director's Office**
  - **The ACC reviewed the MCMF (Stations 2 and 5) in preparation for fabricating the TRC - ACC recommendations are currently being addressed.**
  - **FY05 ACC reviews will include…**
    - **The remaining MCMF stations (Stations 1, 3, and 4)**
    - **The Coil Test Facility**

Fatigue issues are being resolved

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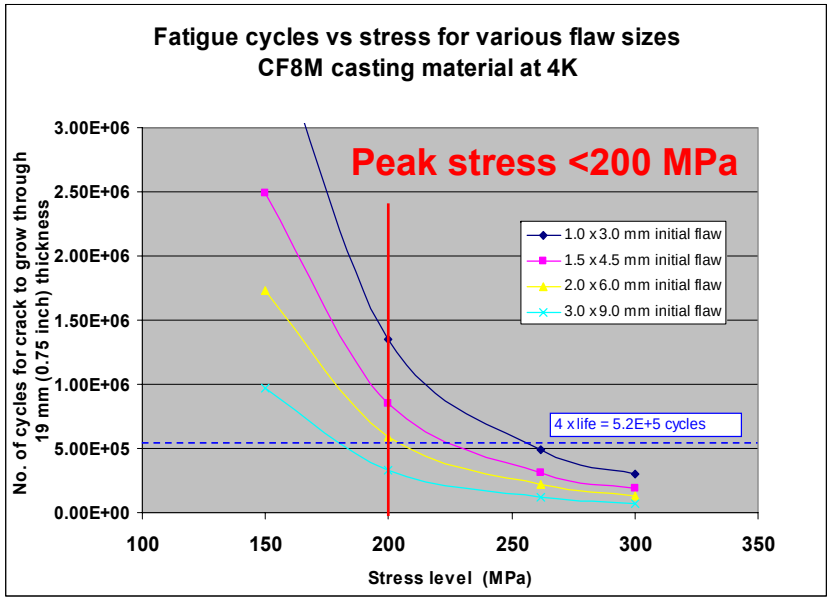
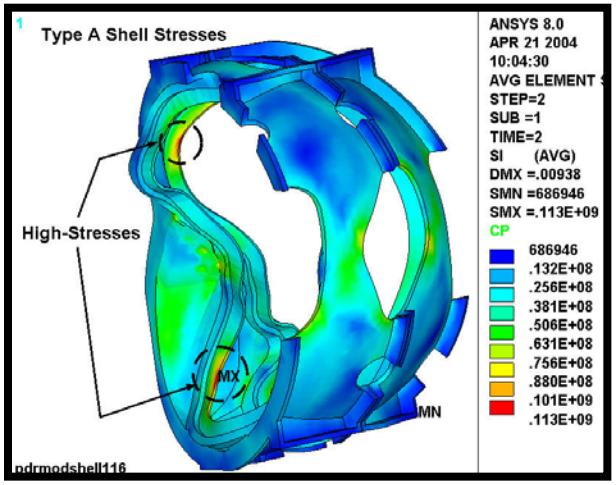
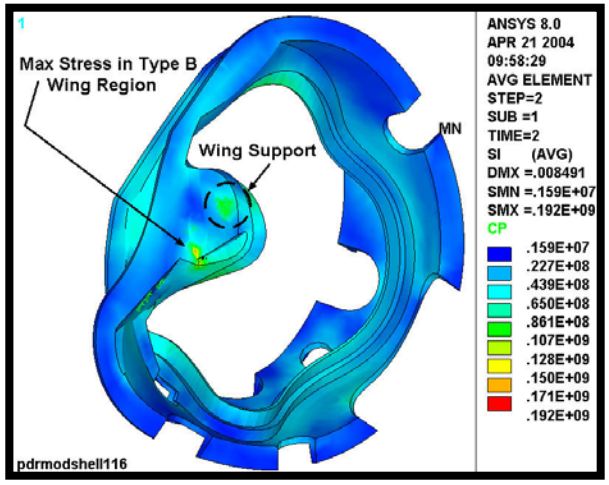
- **Questions about fatigue with the casting alloy were raised at the FDR**
  - **Published properties of CF8M casting alloy appear adequate**
  - **Fast fracture is not an issue**
  - **Work to determine fracture properties of the custom MCWF casting alloy (close in chemistry to CF8M) is in progress**

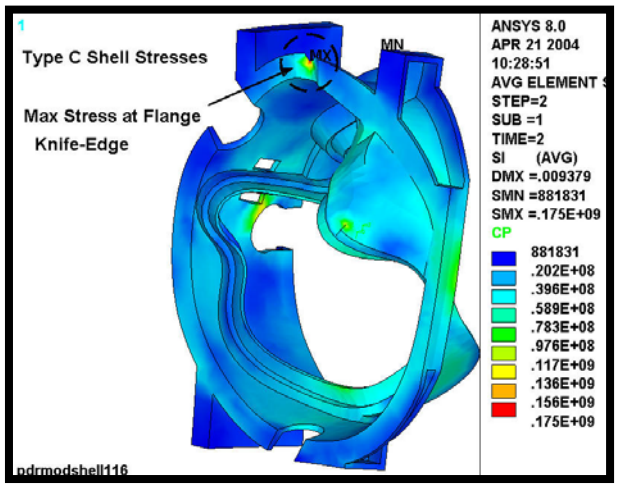




Type A 113 MPa



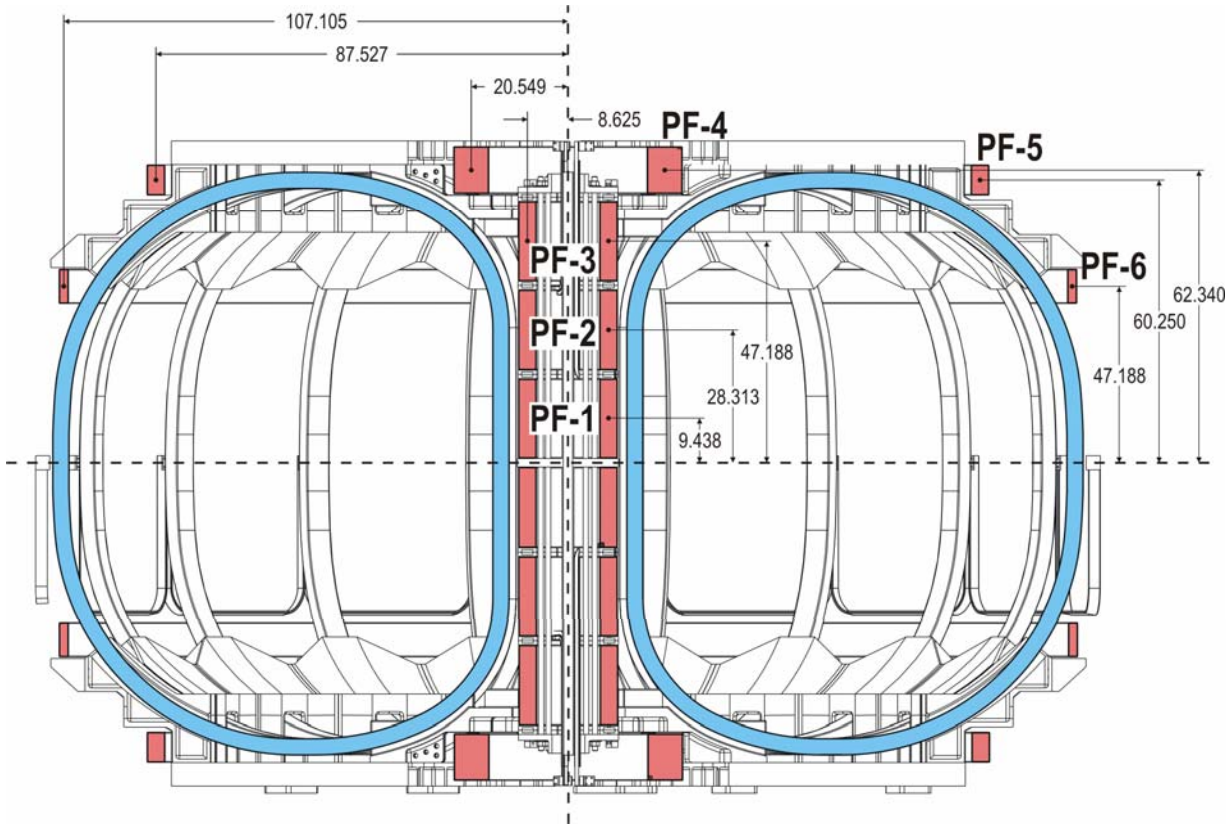
Type B 192 MPa



Type C 175 MPa

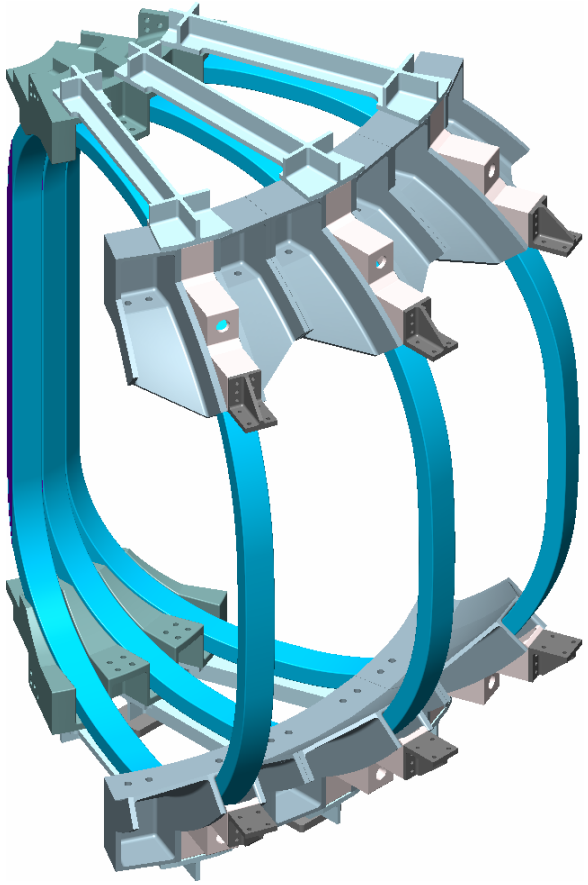
Conventional Coils (WBS 13) includes the TF, PF, and trim coils

- **The work in WBS 13 is 10% complete with $4.0M of work to go**
- **Work in progress is focused on the TF design**
- **Remaining work includes completing preliminary and final design and procuring the TF, PF, and trim coils**



TF coils are the largest and most critical procurement in WBS 13

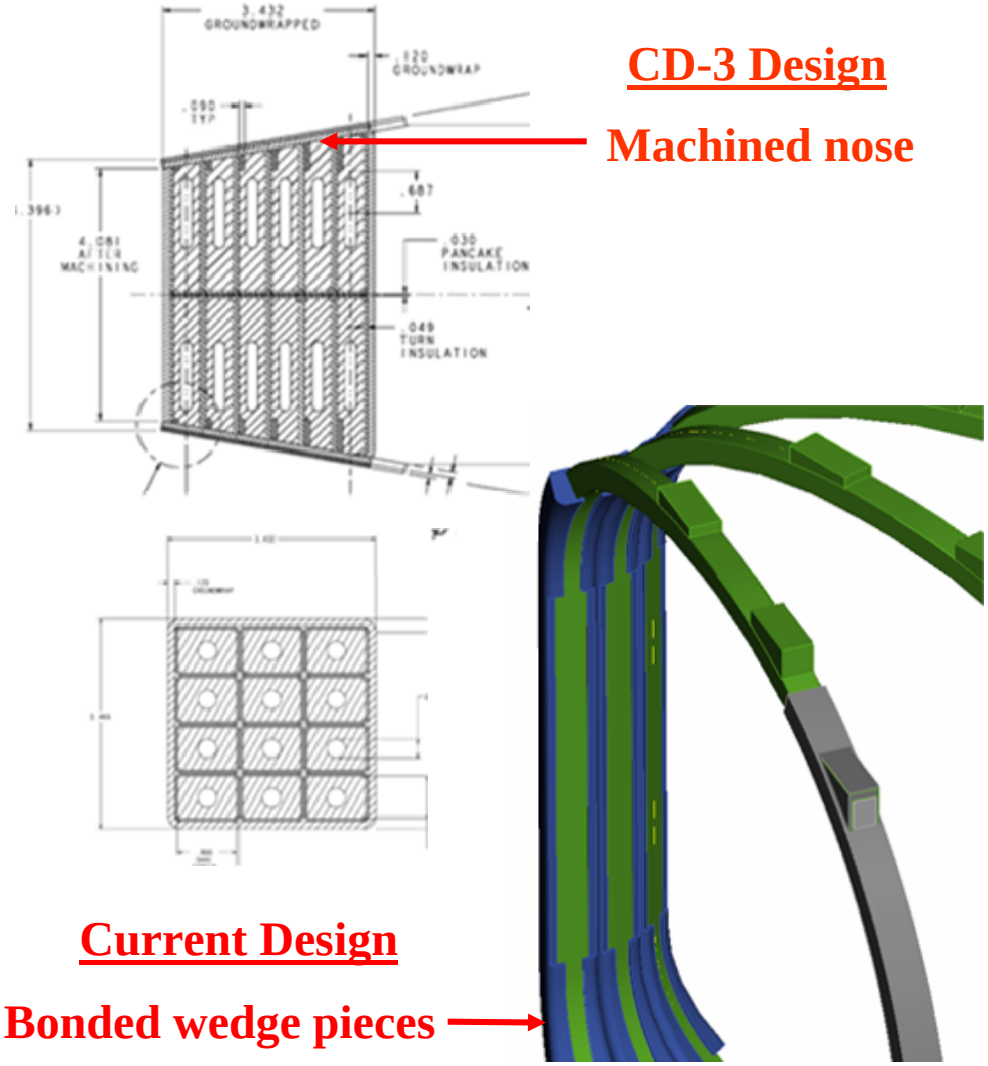
- **TF coils are critical components because failure of a TF coil could require machine disassembly to repair**
- **TF coils must be available for field period assembly and are schedule critical**
- **TF design is nearing the end of preliminary design. The PDR is planned for December 2004 with the FDR in February 2005.**



3-coil TF module

TF design recently revised to reduce fabrication risks

- The CD-3 design featured a rectangular winding pack that was machined in the nose region to permit wedging
- The revised design features
  - a smaller rectangular winding pack with wedge pieces bonded on the sides
  - Squarer, more conventional conductor
- The design change..
  - Avoids the risks associated with machining the winding (e.g. chip inclusions)
  - Makes the part more manufacturable (opens the pool of potential suppliers)



TF procurement risks are being addressed

- **There is concern about finding a qualified supplier interested in bidding on the TF coil procurement**
  - **An extensive list of potential domestic suppliers has been developed**
  - **European suppliers have been recommended by our colleagues**
  - **TF design information posted on Web - all potential suppliers have been contacted and notified of the Web posting.**
  - **Information meeting planned in January 2005**
  - **Site visits are planned as part of the bid evaluation process**
  - **"Make or buy" study concluded that TF coils could be built at PPPL if a qualified and affordable supplier were not found**
- **Substantial (0.3 FTE) engineering oversight budgeted for TF procurement to ensure that adequate QA is provided**

PF and trim coils have less risk than the TF coils

- **The PF and trim coils are…**
  - **Replaceable without requiring machine disassembly**
  - **Less expensive**
  - **More easily fabricated**
  - **Not required to be installed during field period assembly**
- **The pool of potential suppliers is expected to be larger for the trim coils and small diameter PF coils (PF1-4) than for the large diameter PF coils (PF5-6)**
- **Plans are to release three bid packages - for the trim coils, small diameter PF coils (PF1-4), and large diameter PF coils (PF5-6) - in July 2006 and allow companies to bid on one, two, or all three packages.**

Winding the solenoid coils (PF1-3) at PPPL in early 2005 is also being considered because one station is already set up to wind coils for NSTX

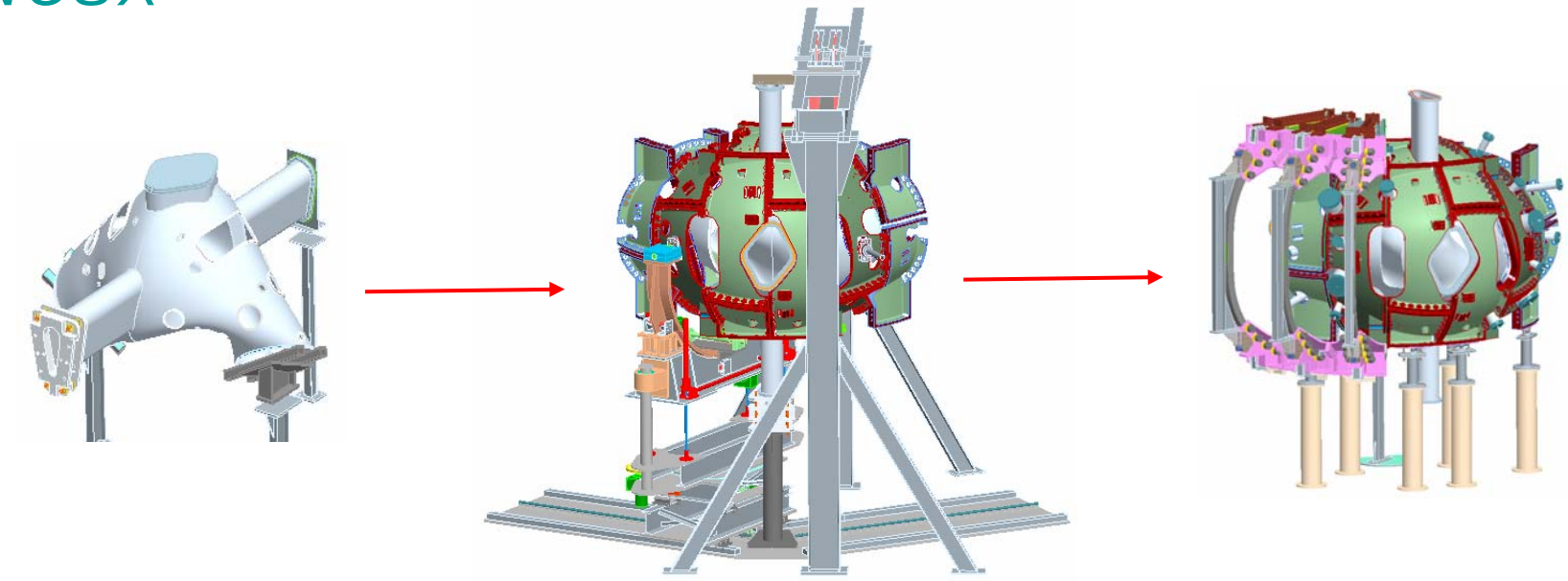
Potential to save time and money and achieve better control of quality

Winding the NSTX PF1a coil

A better, more detailed plan for Field Period Assembly (WBS 18) has recently been developed

- **Plan was developed with the participation of all stakeholders**
- **Plan identifies five stations in the TFTR Test Cell for field period assembly**
- **Provides an excellent basis for planning work to go**
- **Work in WBS 18 is 12% complete with $4.5M of work to go**
- **Remaining work includes…**
  - **Design and fabrication/procurement of tooling and fixtures**
  - **Assembly of field periods (scheduled to take place from December 2005 through April 2007)**

Field period assembly stations



Station 1

Install magnetic diagnostics, cooling tubes, and thermal insulation on VVSA

Station 2 *Not shown*

Assemble modular coils into 3-coil modules

Station 3

Install left and right 3-coil modules over a VVSA

Station 4 *Not shown*

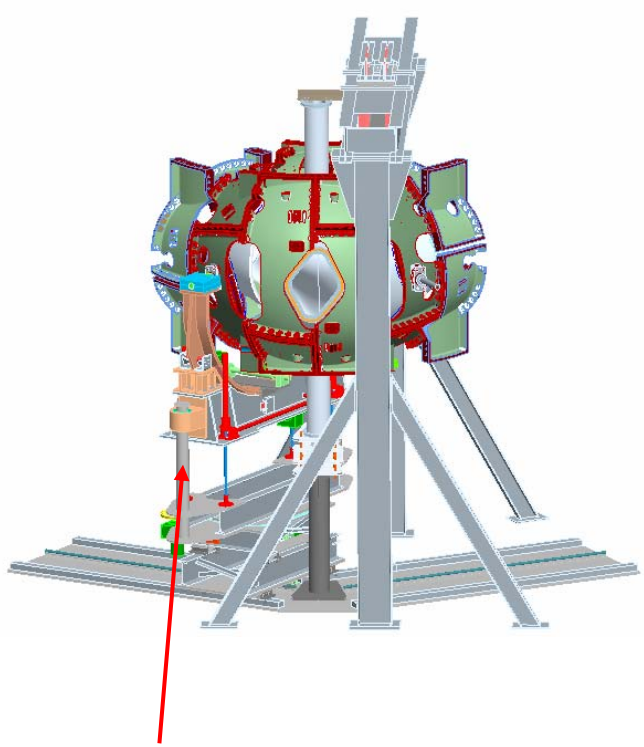
Assemble TF coils and structures into 3-coil TF modules

Station 5

Install TF 3-coil modules and VV port extensions onto field period assembly

FY05 activities will focus on the design and procurement of the fixtures for each station

- **FY05 activities**
  - **Concept and requirements definition**
  - **Metrology requirements and sightline layout**
  - **Structural/seismic analyses**
  - **Safety review**
  - **Preliminary Design Review**
  - **Prepare procurement package (specs and drawings)**
  - **Final Design Review**
  - **Bid, evaluate, and award fabrication contracts for fixtures**



Modular Coil Handling Fixture

The modular coil handling fixture, which moves a 3-coil module on a precise 3D trajectory, is the most complex of the fixtures.

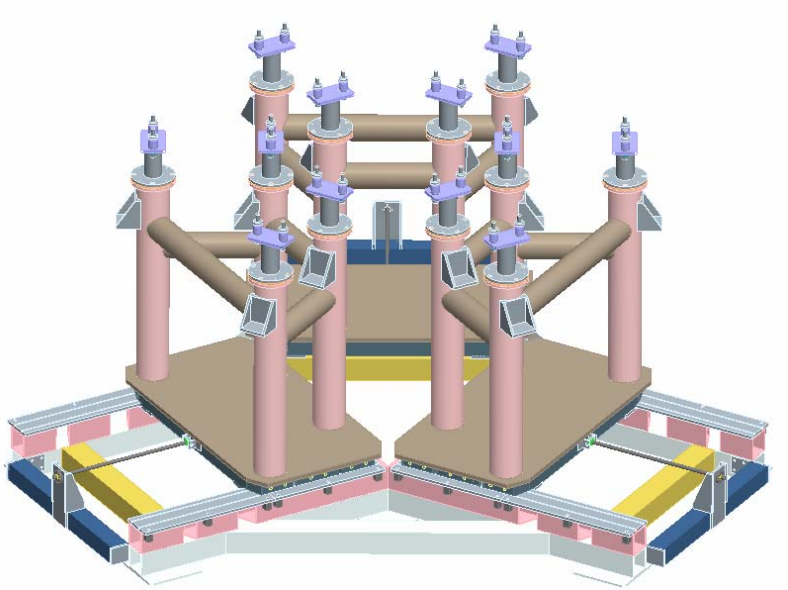
Metrology equipment

- **Metrology equipment is required for winding the modular coils, field period assembly, and final assembly**
- **Metrology equipment includes 2 Romer arms and a Leica laser tracker (purchased by TFTR D&D)**
- **The first Romer arm was recently purchased along with a laser scanner and metrology s/w**
  - **Training has been provided for the lead metrology engineer (Raftopoulos)**
  - **The Romer arm has been successfully used to scan the TRC winding form and winding**

In August, three NCSX engineers attended a metrology workshop for W7-X to learn more about their metrology effort

Final assembly plan revised to better reflect the steps required

- **Final assembly steps…**
  - **Installing the base support structure**
  - **Pre-positioning the support points to receive the field period assemblies (FPAs)**
  - **Simultaneously translating the FPAs and VV spacer pieces to their final positions**
  - **Bolting mating modular coils together**
  - **Welding and leak checking the VV assembly welds (6)**
  - **Connecting the vacuum pumping system and pumping down the vacuum vessel**
  - **Wedging the TF coils together in the nose region and installing the PF coils**
  - **Installing the cryostat and cooling the coils to cryogenic temperature**



Design of the base support structure (WBS 17) which is critical for final assembly will be completed in FY05

Risks in other areas are modest

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	WBS	BCWR	% Complete	
15	Structures	$1,327,032	4%	Conventional structures supporting TF and PF coils. Design to be completed in FY05.
16	Coil Services	$1,035,440	0%	Electrical leads and cooling distribution within cryostat.
17	Cryostat and Base Support Structure	$1,157,754	12%	Cryostat is a demountable fiberglass/foam structure. Base support structure supports stellarator core and provides radial motion for machine assembly.
19	Stellarator Core Management and Integration	$1,422,760	41%	LOE consistent with past experience
2	Plasma Heating, Fueling, and Vacuum Systems	$410,598	47%	Neutral beam work is complete. Vacuum systems will re-use existing equipment.
3	Diagnostics	$877,606	21%	Minimal scope. Involves magnetic diagnostics, e-beam mapping equipment, and camera.
4	Power Systems	$2,879,797	10%	Re-uses existing C-site power supplies, several of which are currently in use. Others will be checked out for serviceability.
5	Central I&C	$1,891,321	1%	Patterned after NSTX
6	Facility Systems	$783,524	5%	Water cooling and utility systems are conventional with minimal scope. Cryogenic system is simple in design. Useful experience with coil cooling gained in CTF.
8	Project Oversight and Support	$6,574,071	38%	LOE consistent with past experience except for Integrated Systems Testing (WBS 85)

Summary

NCSX

- **Work is proceeding well**
  - **Major contracts awarded (MCWF, VVSA, MC conductor)**
  - **Modular Coil Manufacturing Facility (MCMF) operational**
  - **Fabrication of the Twisted Racetrack Coil underway**
  - **TF coil design simplified**
  - **Better and more detailed plans developed for field period assembly and final assembly**
- **Safety is getting appropriate attention in the operation of the MCMF**
- **Risks related to the work remaining have been identified and mitigation plans incorporated into our work plans**
- **Critical activities/issues are systematically tracked in weekly meetings**
- **Adequate cost and schedule contingency exists for the work remaining**