

# **NCSX Stellarator Core Design Progress and Plans**

**B. Nelson for the NCSX Team**

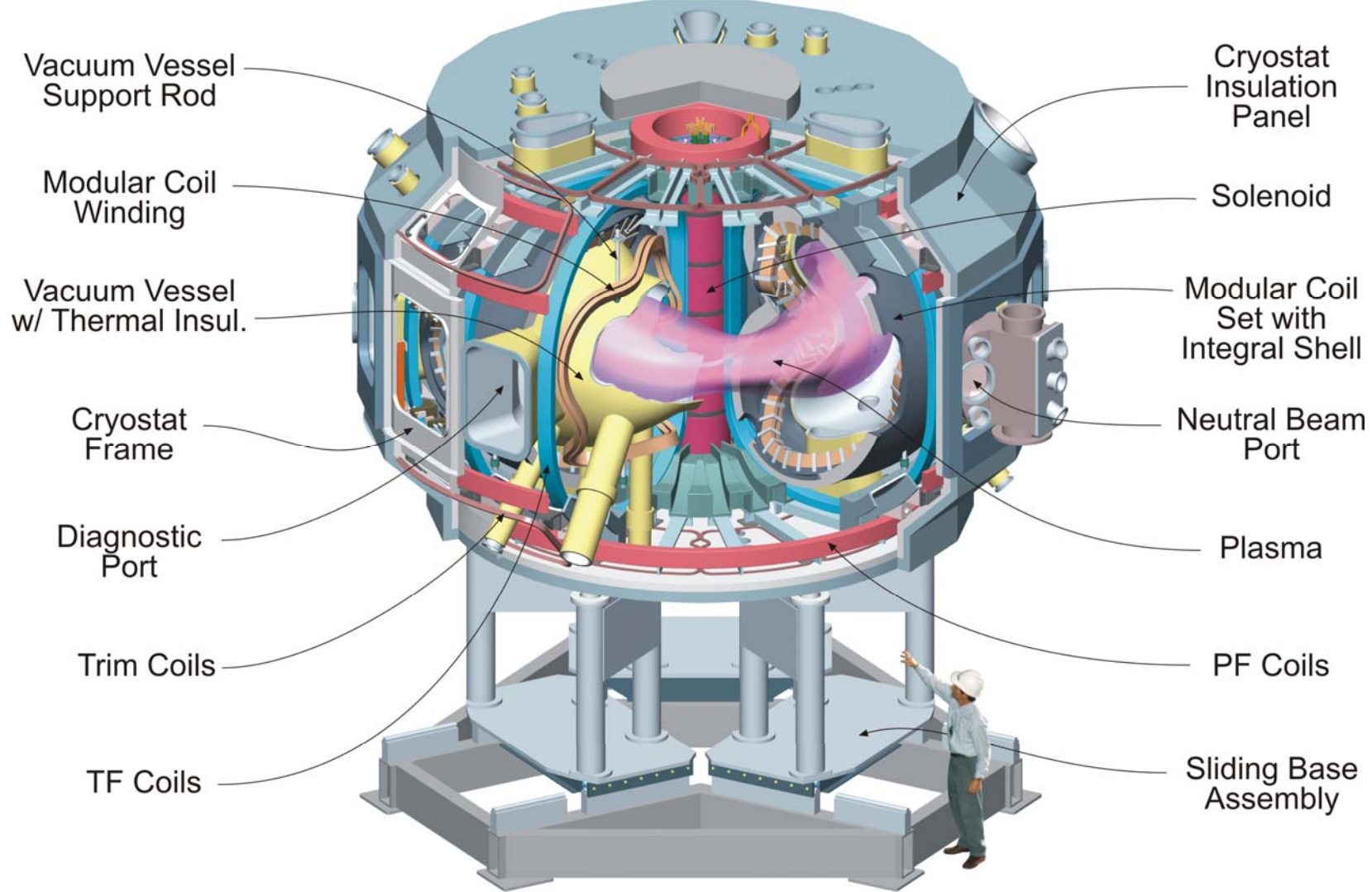
NCSX Project Review  
November 2-3, 2005  
PPPL

# Presentation Outline



- **Overview of the Stellarator Core Design**
- **Status and plans for the major subsystems**
  - Recent accomplishments
  - R&D results and design evolution
  - Design plans – timing, cost estimates
  - Procurement plans
  - Remaining risks
- **Summary**

# Cutaway View of Stellarator Core

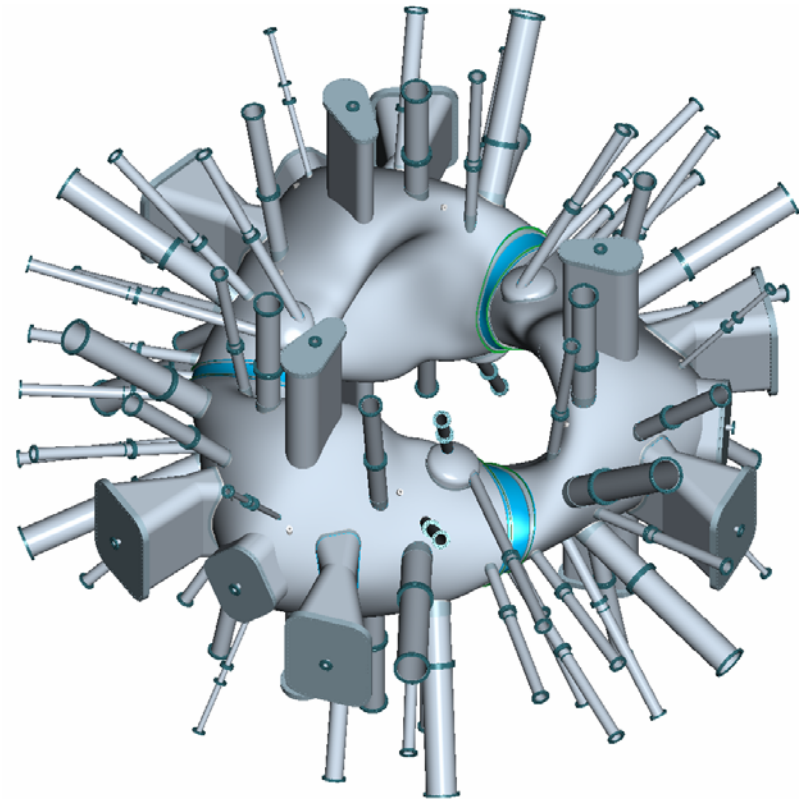


# On track for completion of Vacuum Vessel



- **Recent accomplishments**

- VVSA on track for timely delivery – Viola
- Heating and cooling system design complete, sample tube on order
- Thermal Insulation design nearly complete
- Structural support design complete, in fabrication at PPPL
- I&C design complete

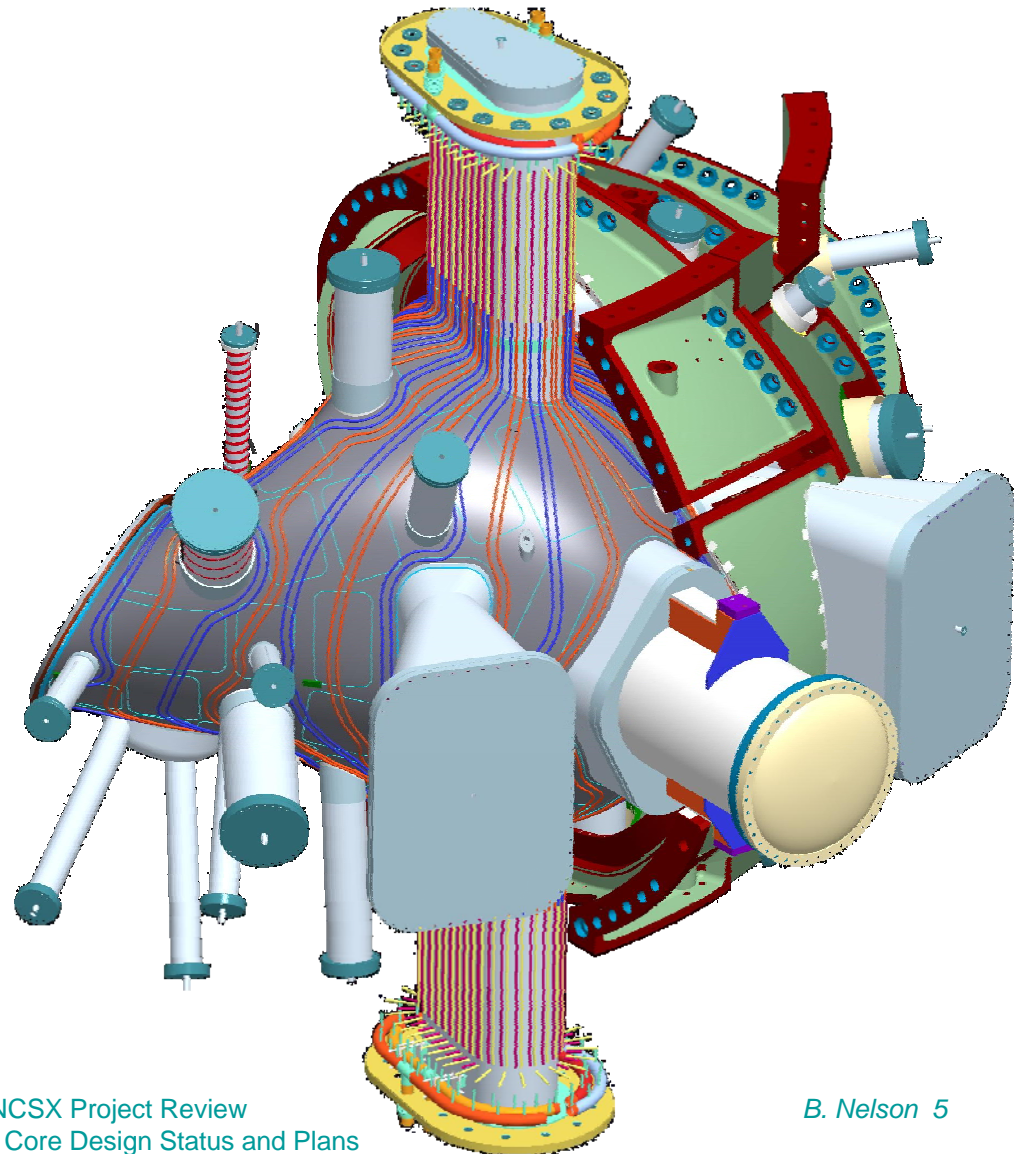


# Vacuum Vessel ancillaries well defined



## VV ancillaries include:

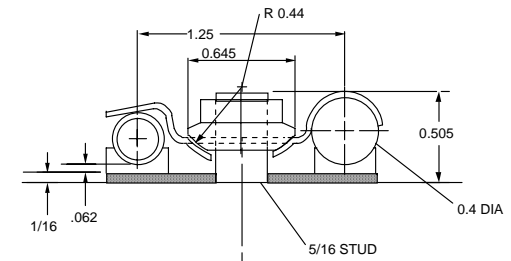
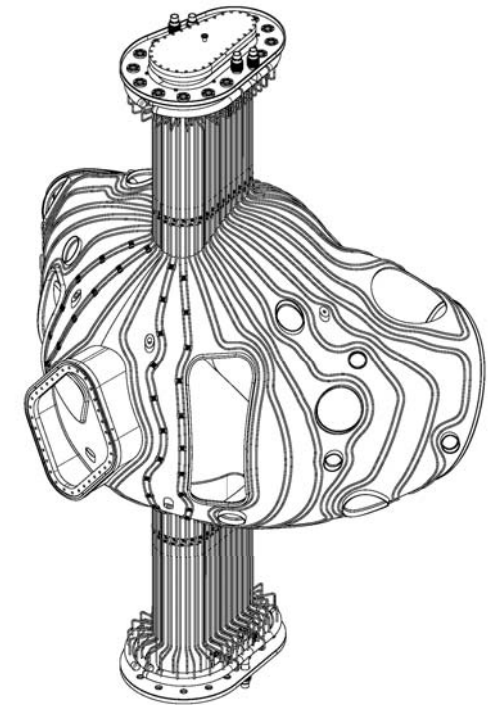
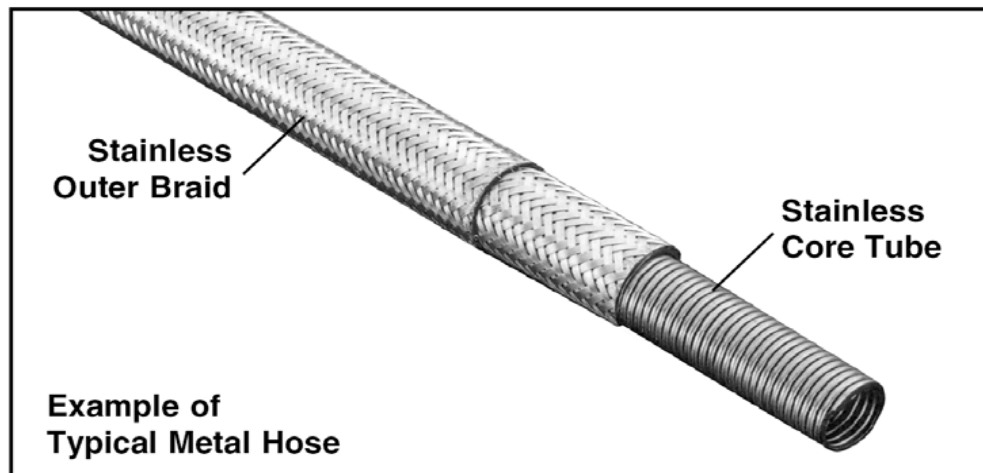
- flux loops
- coolant tubes
- thermocouples
- headers
- diagnostic feed through flanges
- lateral supports
- pumping/personnel access port
- heater tapes



# Cooling tube design modified to aid fabrication



- Original design based on standard 5/16 o.d. stainless steel tubing, formed to CAD-derived geometry data (per vendor input)
- No bids received from vendors
- New design uses corrugated stainless tubing with braided reinforcement
- Standard product, easy to install

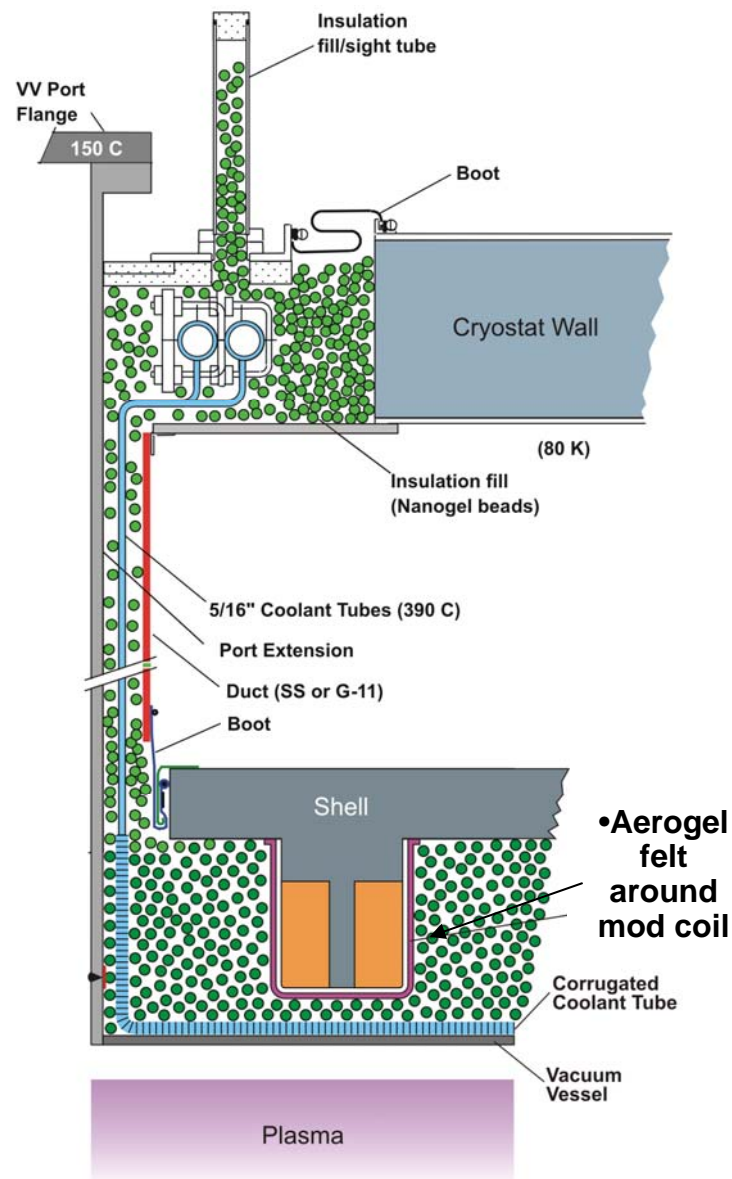


**Cross section at typical clamp**

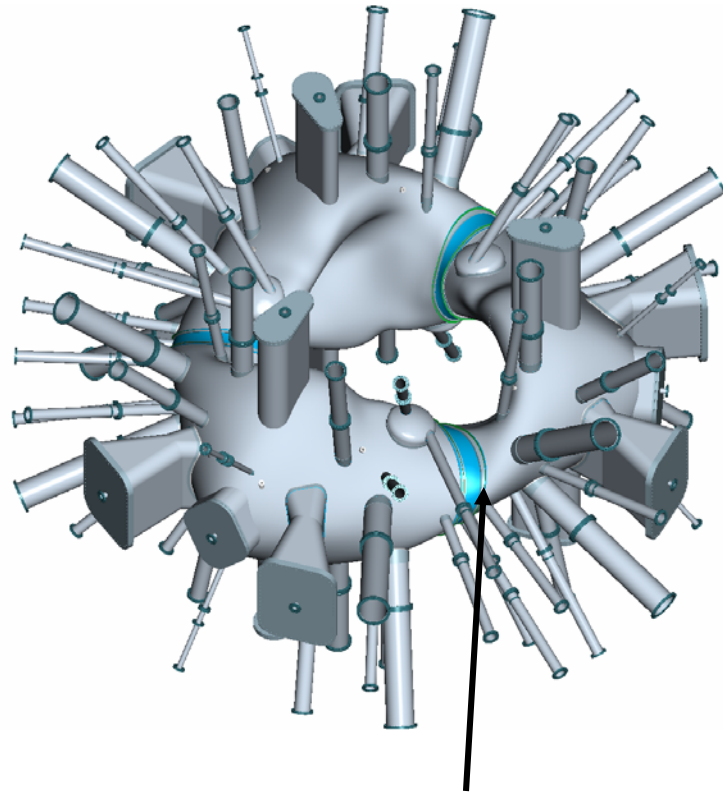
# Loose fill provides better thermal insulation



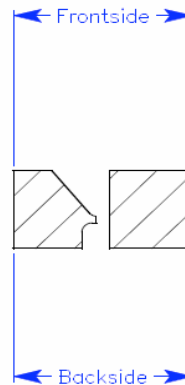
- Original concept used microtherm bats
  - Required custom flat pattern designs for each of 8 layers
  - Thickness limited to 2 inches to provide clearance for field period assy
- New design uses loose fill of nanogel beads
  - Inexpensive
  - Better insulation ( 1/3 heat leak)
  - Current product not rated to 350C, but expect this will be available soon – adequate alternative is perlite



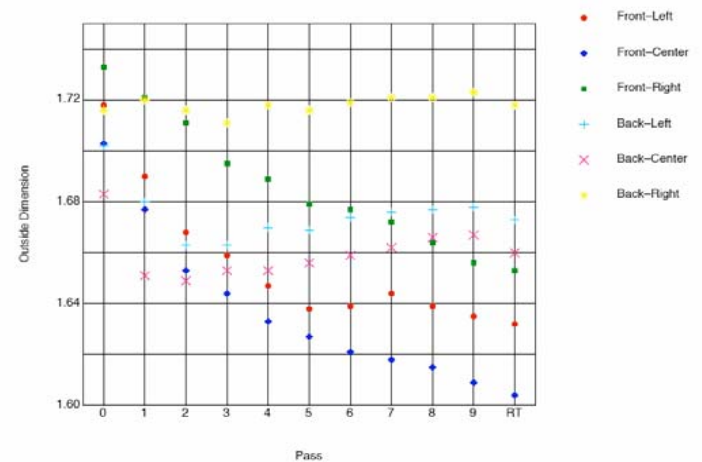
# Welding R&D confirms assembly joint design



**Field joints are welded at custom-machined spacers**



**Final Weld Data**



**Weld shrinkage has been quantified**



# Plan for completing VV design



- Prepare remaining assembly drawings
- Complete mods to heating/cooling tubes, insulation design
- Continue Title III for all component procurements and assembly

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1203-241	Check FMECA Analyses	1-Sep-05	1-Nov-05	32.0	16.0	-
1203-805	Redo CC heating/cooling tube dwgs& analysis	22-Sep-05	1-Nov-05	60.0	-	-
122-012	Heater Tape Design	2-May-05	15-Nov-05	75.0	21.8	-
125-011	Final design WBS 125 local I&C	1-Mar-05	15-Nov-05	18.0	-	-
122-011	Final design WBS 122 Thermal insulation	1-Jun-04	21-Nov-05	129.8	5.0	-
1203-271	Develop Assy Rqmnts spec & process	3-Oct-05	8-Dec-05	180.0	-	-
1203-800	Issue VV FP leak check assy dwg	22-Sep-05	15-Dec-05	32.0	-	-
1203-801	Issue VV FP final assy dwg	3-Oct-05	15-Dec-05	40.0	-	-
1203-802	Issue spacer machining dwgs	3-Oct-05	15-Dec-05	40.0	-	-
1203-803	Issue VV final assy dwg	3-Oct-05	15-Dec-05	40.0	-	-
1203-804	Issue VV assy specification	3-Oct-05	15-Dec-05	40.0	-	-
1203-806	Establish interface reqmnts	3-Oct-05	15-Dec-05	40.0	-	-
1203-810	resolve design pockets for soft x ray arrays	1-Nov-05	15-Dec-05	40.0	-	-
1203-815	Cleanup interfaces cleanup interfaces with other	1-Nov-05	15-Dec-05	20.0	-	-
1203-820	BOM for all VV parts	1-Nov-05	15-Dec-05	30.0	-	-
1203-825	develop acquisition plan for all vv components	1-Nov-05	15-Dec-05	20.0	-	-
1203-830	conduct mini fdr/procurement reviews	1-Nov-05	15-Dec-05	40.0	-	-
1203-901	**WBS 12 FINAL FDR **	(blank)	15-Dec-05	-	-	-
121-035	VVSA Contract oversight FY05 & FY06	1-Mar-05	31-Jan-06	-	446.0	-
121-035.2	ORNL design support during MTM Contract	3-Oct-05	31-Jan-06	107.0	-	4.0
121-038	assist MTM testing of VVSA	15-Nov-05	8-Feb-06	-	-	-
124-031	Title III engr WBS 124	3-Oct-05	6-Mar-06	60.0	2.0	-
125-015	Title III design Local I&C WBS 125	16-Dec-05	20-Mar-06	18.0	-	-
123-031	Title III engr WBS 122	2-Nov-05	19-Sep-06	48.0	8.0	-
121-034.1	VVSA Title III engr	3-Oct-05	22-Nov-06	500.0	-	8.0
122-031	Title III engr WBS 122	1-Oct-07	14-Apr-08	124.0	22.0	-
124-030.0	Release dwg package for fab VV Vertical Supports	30-Sep-05	(blank)	-	-	-

# Plan for completing VV procurement



- Insulation, heaters, cooling tubes and headers procured outside
- VV supports fabricated in-house by PPPL

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
124-037	PPPL Fab VV Vert. Supports WBS 124	17-Oct-05	18-Jan-06	-	800.0	-
124-037L	VV Lateral Supports Fab by PPPL WBS 124	3-Oct-06	4-Jan-07	-	400.0	-
121-036	Ship vac equipt from PPPL to MTM for vac testing	25-Oct-05	14-Nov-05	-	-	2.0
123-030	Issue RFQ & Select Vendor VV H/C Tubing WBS 123	2-Nov-05	1-Dec-05	-	-	-
123-036.9	Award H/C Tubing WBS 123	(blank)	1-Dec-05	-	-	-
124-030L	SPEA VV Lateral Supports WBS 124	17-Oct-05	16-Dec-05	-	-	-
123-037	Fabricate and Deliver H/C Tubing WBS 123	2-Dec-05	6-Jan-06	-	-	45.0
123-130	Issue RFQ & Select Vendor VV H/C Manifold WBS 123	2-Nov-05	6-Jan-06	-	-	-
123-136.9	Award H/C Manifolds WBS 123	(blank)	6-Jan-06	-	-	-
125-037	Procurement Local I&C WBS 125	16-Dec-05	17-Mar-06	-	-	2.4
123-137	Fabricate and Deliver H/C Manifolds WBS 123	9-Jan-06	7-Apr-06	-	-	25.0
124-110	SPEA VV NB port cover	2-Aug-06	29-Sep-06	-	-	-
124-120	Award VV NB port cover	(blank)	29-Sep-06	-	-	-
124-036.9L	Award VV Lateral Supports WBS 124	(blank)	2-Oct-06	-	-	-
123-040	Issue RFQ & Select Vendor insul boots WBS 122	2-Oct-06	5-Dec-06	-	-	-
123-045	Award Insulation Boots & Pyrogel WBS 122	(blank)	5-Dec-06	-	-	-
124-130	VV NB port cover Fabrication	2-Oct-06	10-Jan-07	-	-	53.9
123-050	Fabricate & Deliver Insul Boots & Pyrogel WBS 122	6-Dec-06	14-Jun-07	-	-	55.0
122-030	SPEA VV Thermal Insulation WBS 122	1-Oct-07	28-Nov-07	-	-	-
122-036.9	Award VV Insulation WBS 122	(blank)	28-Nov-07	-	-	-
122-037	VV Insulation Procurement WBS 122	3-Dec-07	14-Apr-08	-	-	45.0

# Vacuum Vessel risks addressed



- Will the vendor supply accurate, vacuum quality components on schedule?

*VVSA on track: Viola*

- Will the vessel leak?

*Intermediate leak checks include thermal cycling,*

*Provisions made for helium leak check of field welds*

- Can we make assembly welds?

*Vendor has cut and re-welded port stubs*

*Field joint weld R&D successful*

- Can we procure and install heating / cooling tubes?

*Flexible tubes readily available and easy to install*

- Will the heating / cooling system work?

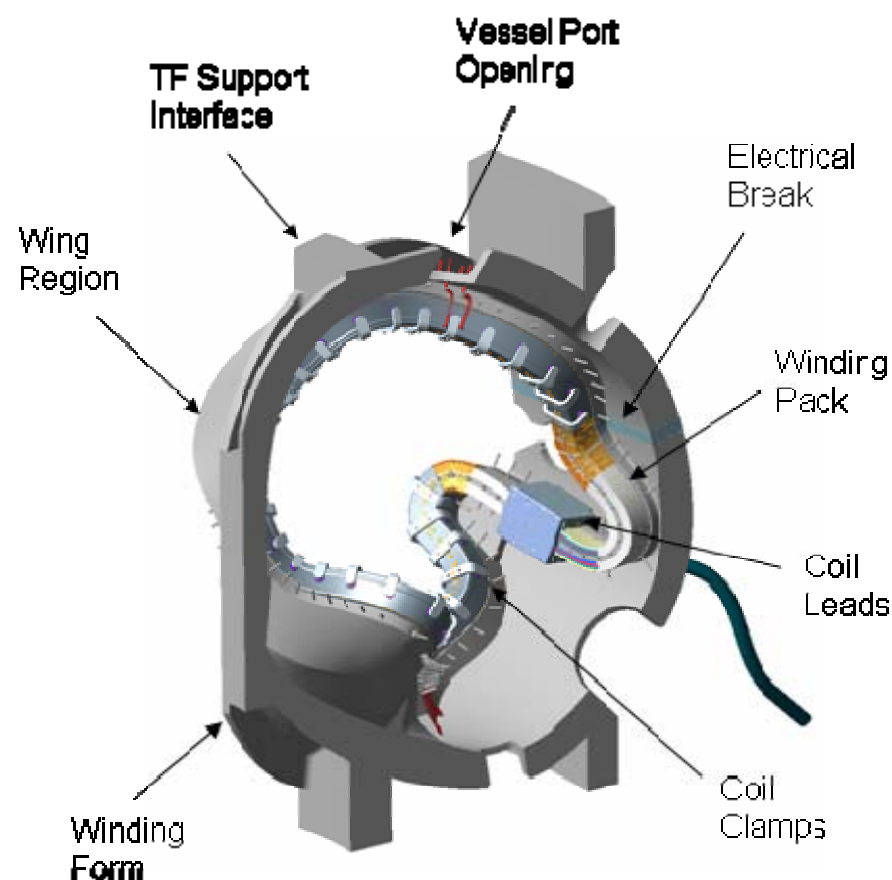
*Analysis says yes, small scale tests planned to confirm*

*Need to finalize loose fill insulation good to 350C*

# Modular Coils



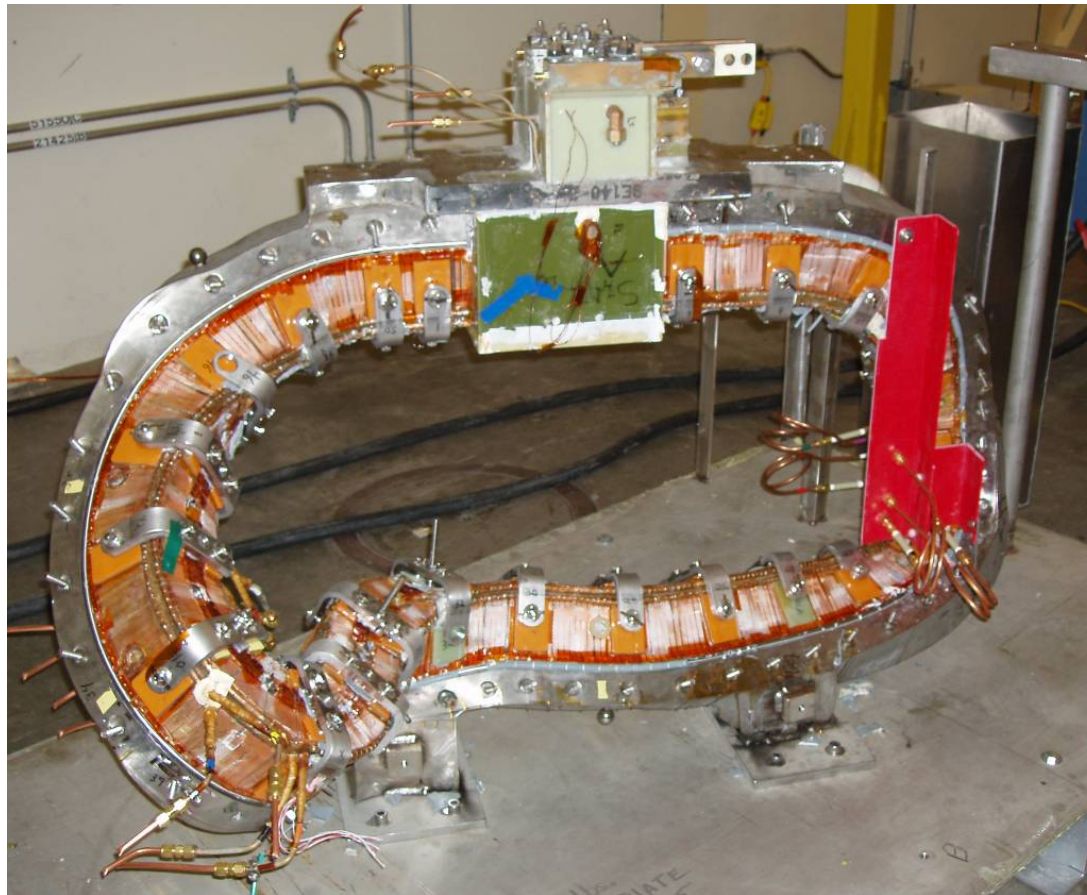
- **Recent accomplishments**
  - Modular coil winding forms on track for timely delivery – Heitzenroeder
  - Winding form design details have been tweaked to optimize fabrication of winding forms and winding of coils
  - Twisted racetrack coil completed, providing significant input for design optimization
  - All type C coil detail part designs and drawings completed
  - Twisted racetrack coil tested



# Twisted Racetrack Coil provided fabrication and performance data



- Full scale, partial prototype of modular coil winding built and tested
- Shape is worst combination of twists and curvature from the three coil types



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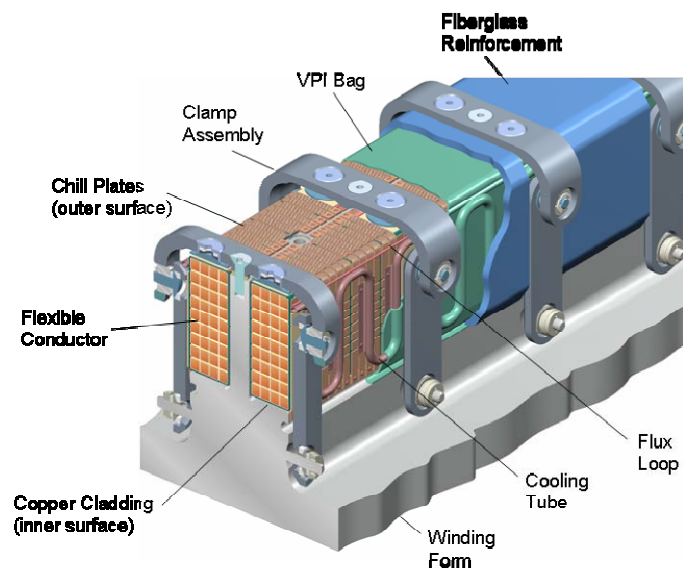
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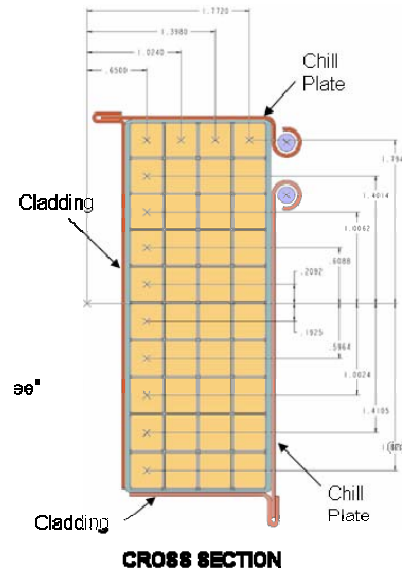
# Modular Coil Cooling has improved



- Cooling system modified for improved fabrication and performance
  - Chill plates and cladding soldered directly to tubing
  - No intermediate layer (“fringe”)



old design

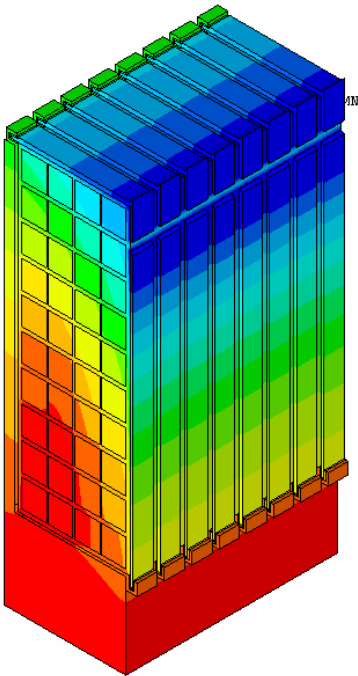


new baseline

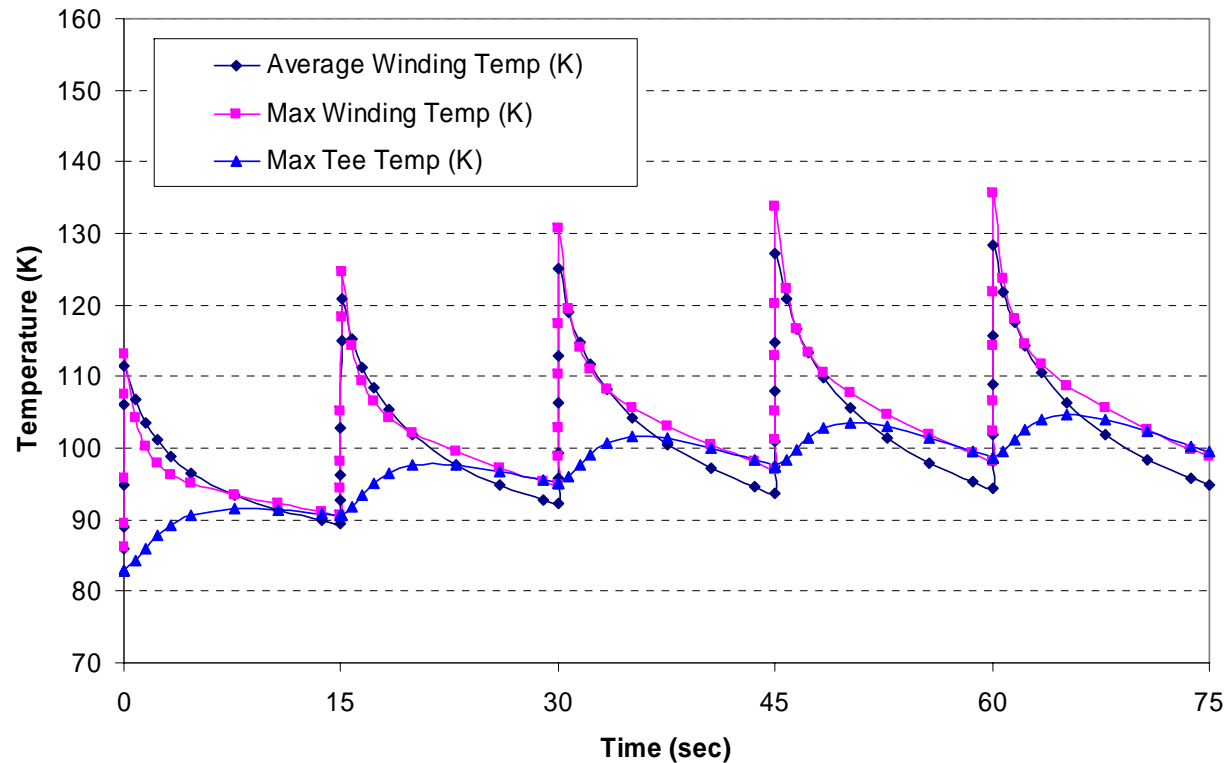


# Modular Coil Cooling acceptable

- Analysis shows some ratcheting for 15 minute rep rate



Typical temp distr.

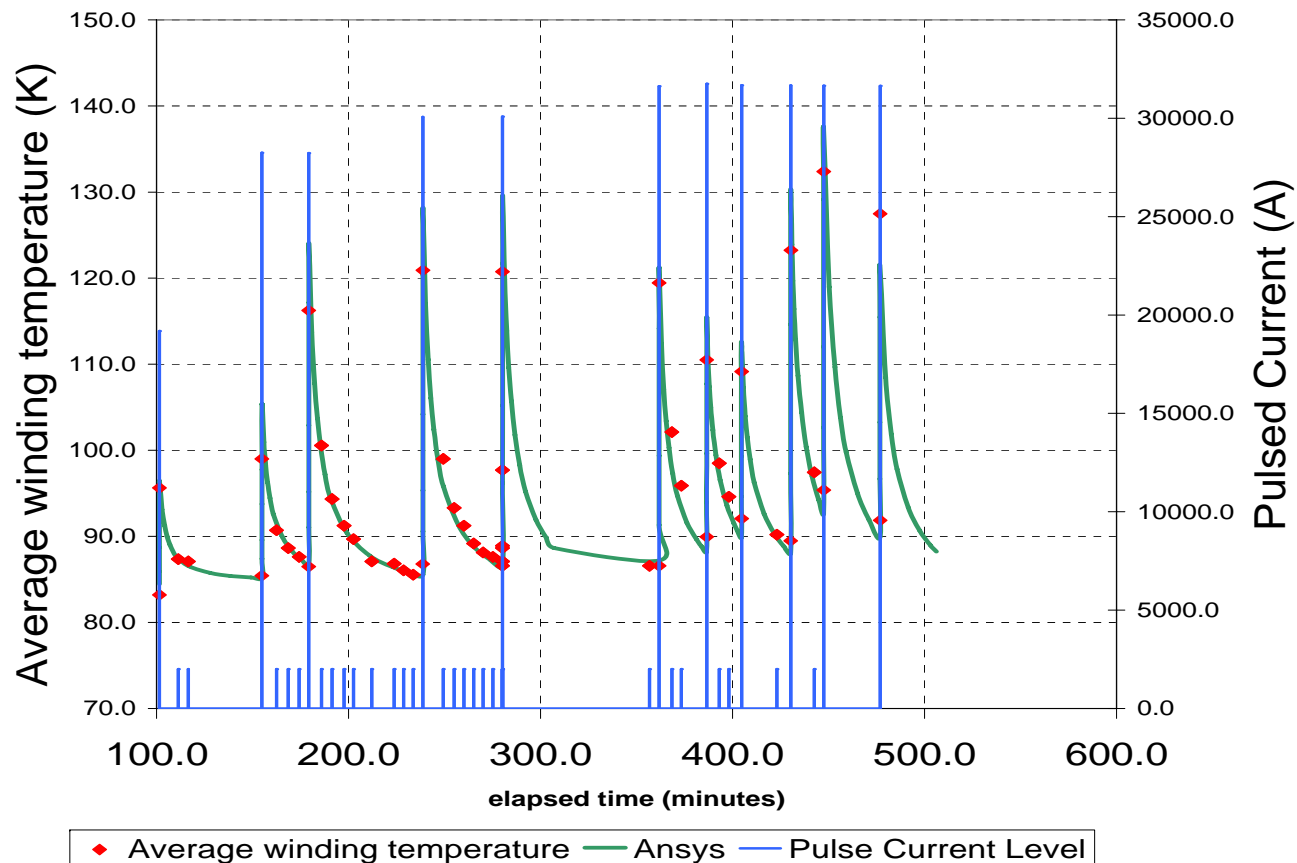


Temperature history for 5 cycles

# TRC testing validates analysis



- Average winding temperature deduced from coil resistance
- ANSYS simulation matches TRC test data

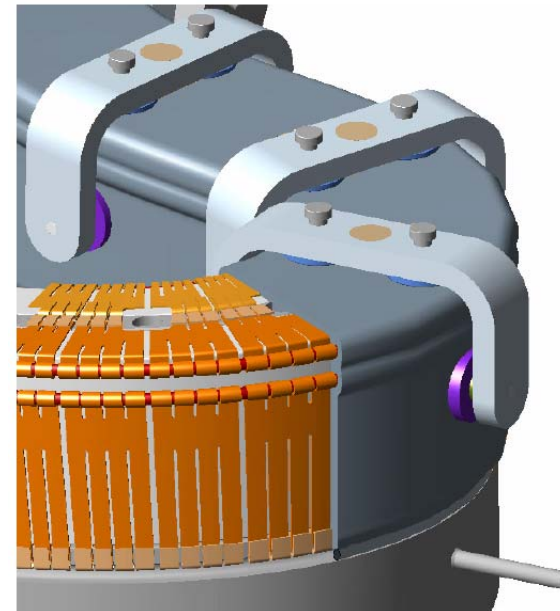
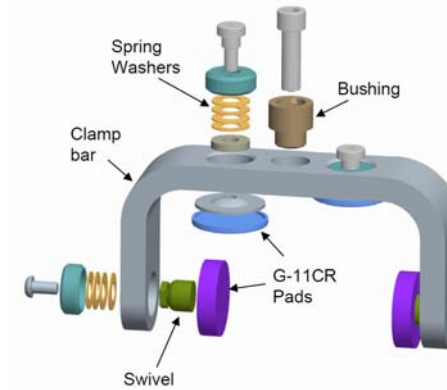
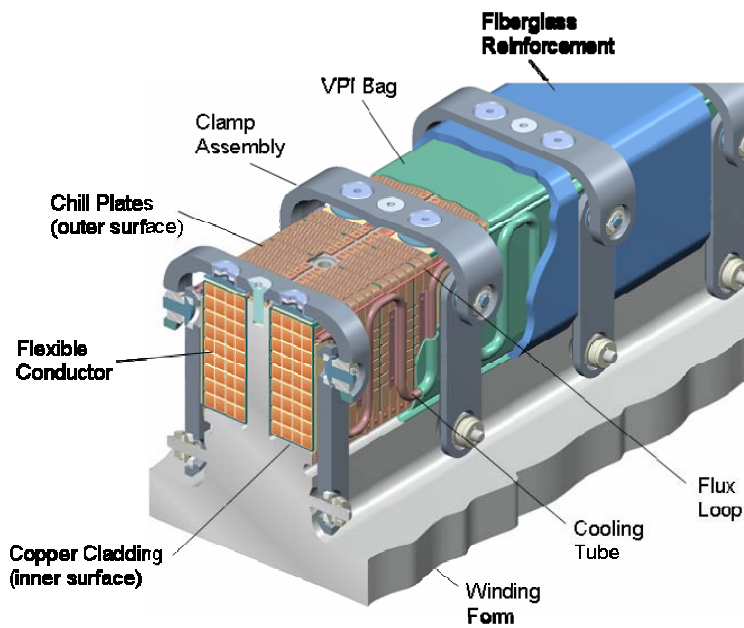




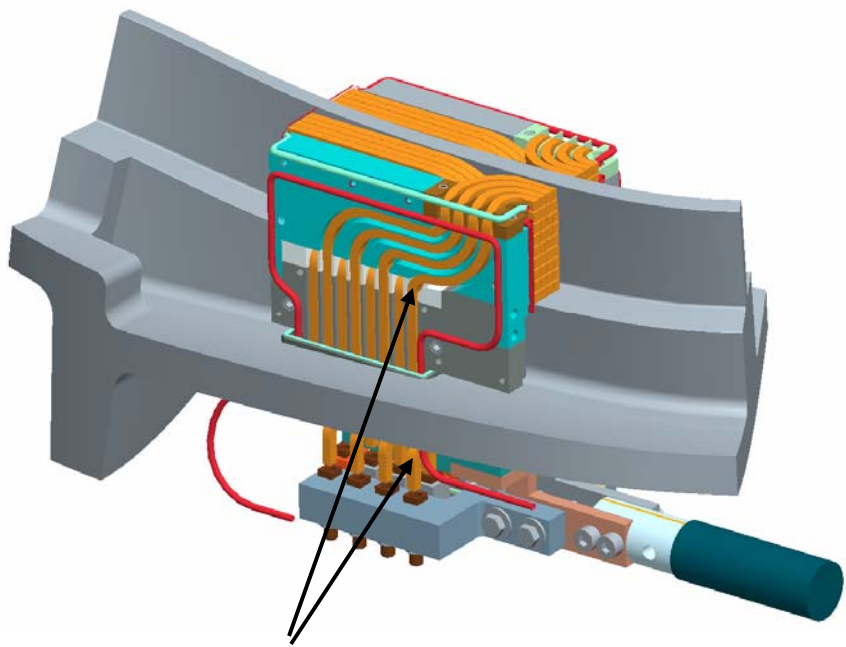
# Modular Coil clamps have improved



- Clamp design simplified
  - Side bars changed to round pads
  - Same clamp design everywhere

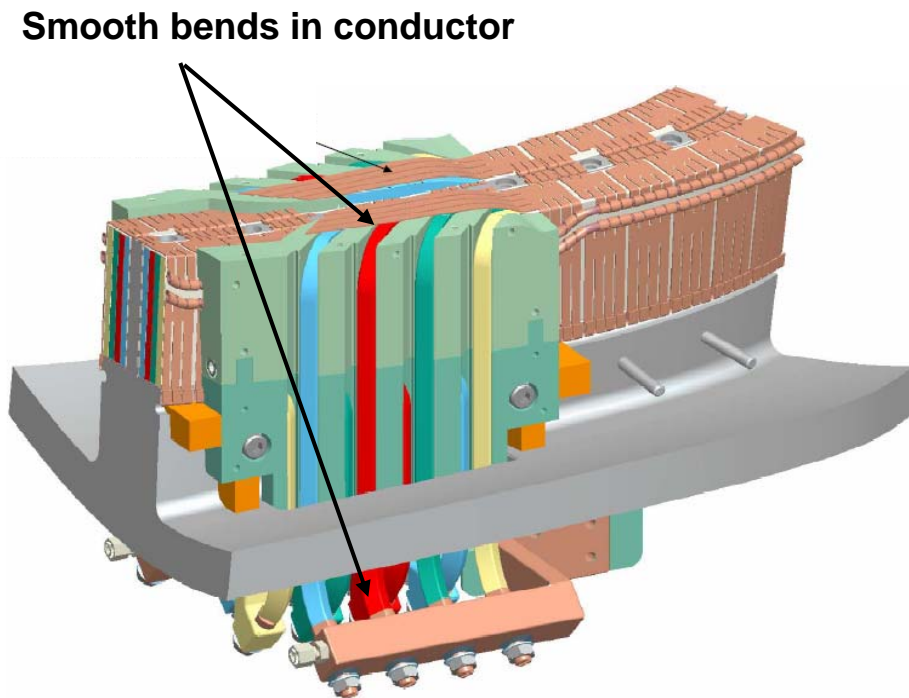


# Leads easier to wind



**Abrupt bends in conductor**

old design



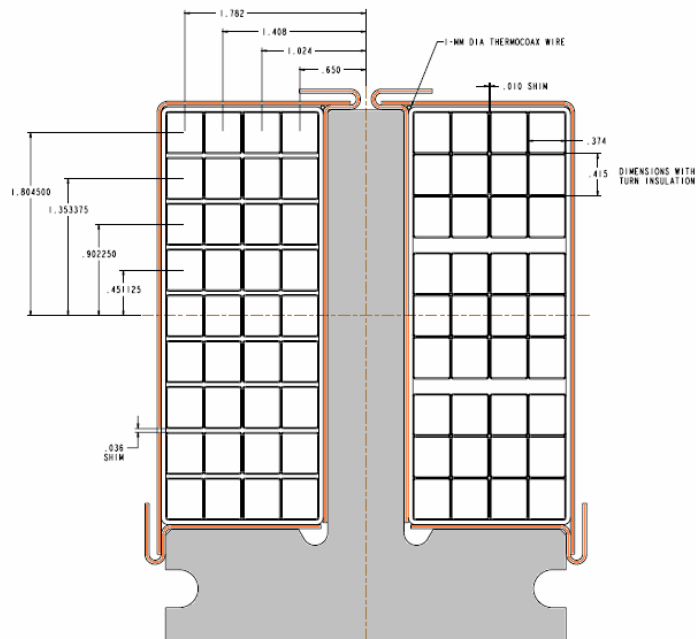
**Smooth bends in conductor**

new baseline

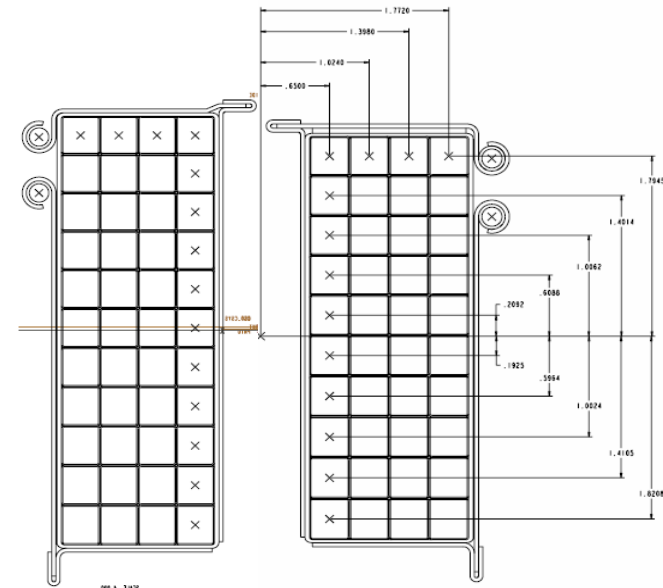
# More turns added in same cross section



- TRC proved “setting” conductor minimizes keystoneing, shims not needed
- “Lacing” technique keeps turns in place during bagging operation
- Extra layer of turns added to each winding pack,
- **current density reduced ~ 10%, heating reduced ~ 20%**



old design

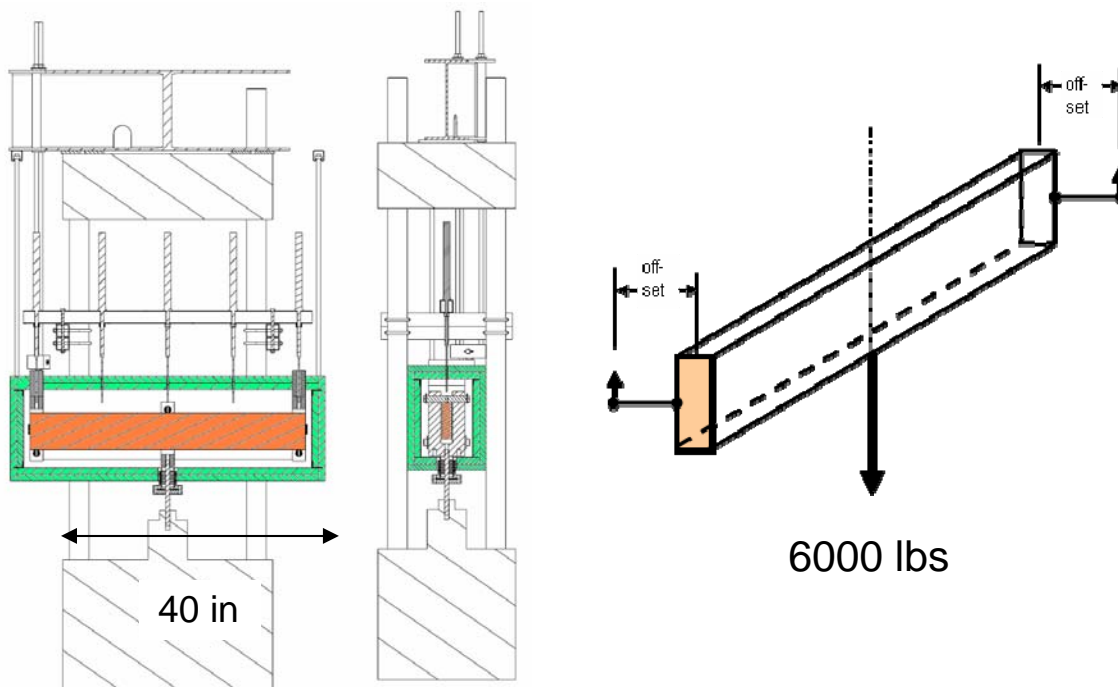


new baseline

# Straight beam tests show robust winding pack



- Prototypical winding pack subjected to bending and torsion, producing ~ 11 ksi bending, ~6 ksi shear
- Deflections consistent with E, G in analysis (8.5, 2.5 Msi)
- Beam testing discontinued after 600,000 cycles (fixture broke)



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# Plans for mod coil procurement



- Winding forms well into procurement phase – Heitzenroeder
- Coil winding getting underway– Chrzanowski
- Test stand modifications done in-house
- Miscellaneous assembly bolts, nuts, shims, etc. procured outside

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1409-136	Valve/pump repairs&safety mods to cryo pp sys	1-Nov-05	1-Dec-05	-	220.0	3.0
1409-135	Production Cryostat Fabr & Install	1-Nov-05	2-Dec-05	-	265.0	10.0
1409-199	Closed Loop Facility Available for Production MC	(blank)	2-Dec-05	-	-	-
1421-100	Submet Requisition for - Assy bolts,nuts,washers	24-Jul-06	4-Aug-06	16.0	-	-
1421-200	Submet Requisition for - Assembly shims	24-Jul-06	4-Aug-06	16.0	-	-
1421-400	Submet Requisition for - Bladders	24-Jul-06	4-Aug-06	16.0	-	-
1421-105	Procurement lead time for-Assy bolts,nuts,washer	7-Aug-06	29-Sep-06	-	-	-
1421-205	Procurement lead time for - Assembly shims	7-Aug-06	29-Sep-06	-	-	-
1421-405	Procurement lead time for - Bladders	7-Aug-06	29-Sep-06	-	-	-
1421-110	Deliver - Assy bolts,nuts,washers	2-Oct-06	3-Jan-07	-	-	449.0
1421-210	Deliver - Assembly shims	2-Oct-06	3-Jan-07	-	-	138.0
1421-410	Deliver - Bladders	2-Oct-06	3-Jan-07	-	-	60.0

# Mod coil risks have been addressed



- Does the composite copper/epoxy winding behave as expected and are the allowable stresses understood?

*Racetrack coil in tension and beam test in torsion and bending shows adequate fatigue life*

- Can the windings be placed accurately on the twisted, curved winding forms?

*Tests on TRC developed robust clamping/measurement procedure*

- Can cooling system components be installed as planned (cladding, chill plates, tubing)?

*Workable design evolved during TRC fabrication*

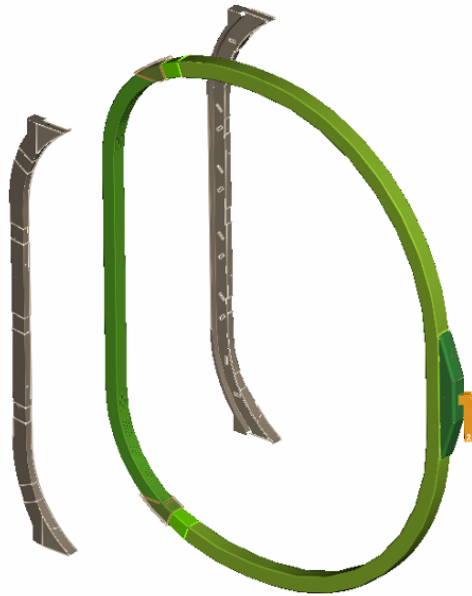
- Does the cooling system work?

*Yes, and results of testing agree with analytical predictions*

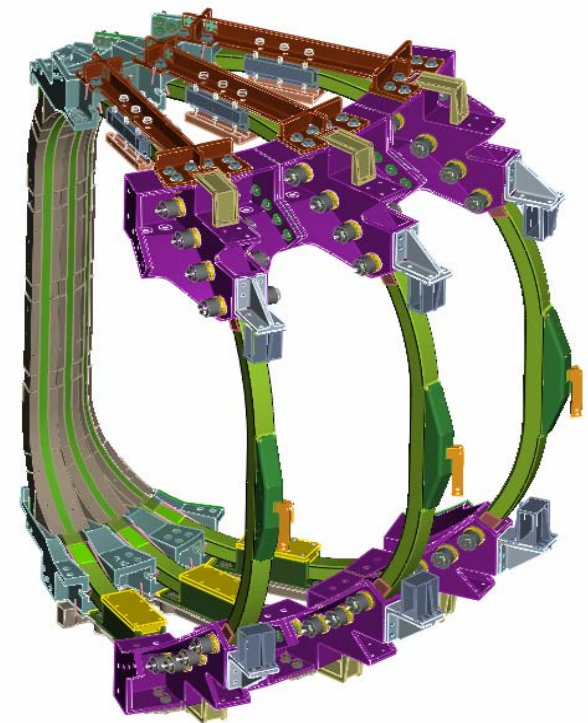
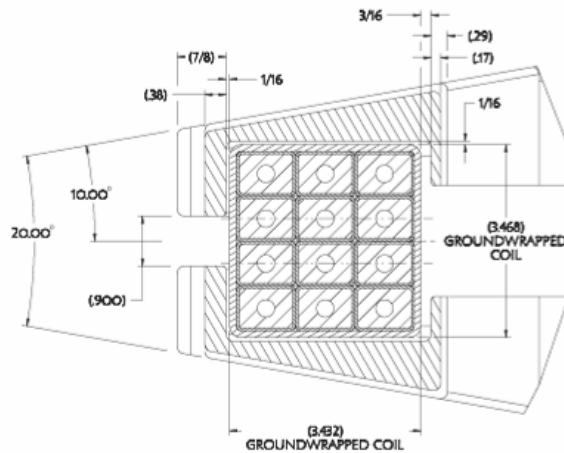
# TF coil design complete through FDR



- Wedge feature added with cast structure, not milled into turns
- Coils will be fabricated at PPPL (Chrzanowski)



Wedge structures and winding



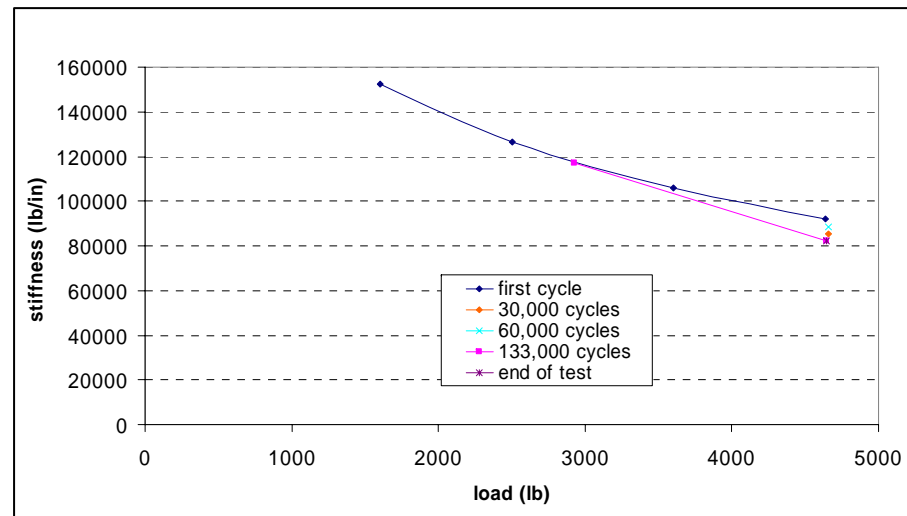
3 coil assembly with external structure



# TF coil winding pack passed fatigue test



- Full scale winding pack tested as beam in bending at RT and 77K
- Survived 2 x Stress for 1 x Life = 8Klbs for 140,000 cycles (representative of all but .5 Tesla scenario)
- Tested at 1xStress for 20 x Life = 4.5Klbs for 260,000 cycles (representative of .5 Tesla scenario)



# Plans for completing TF coil design



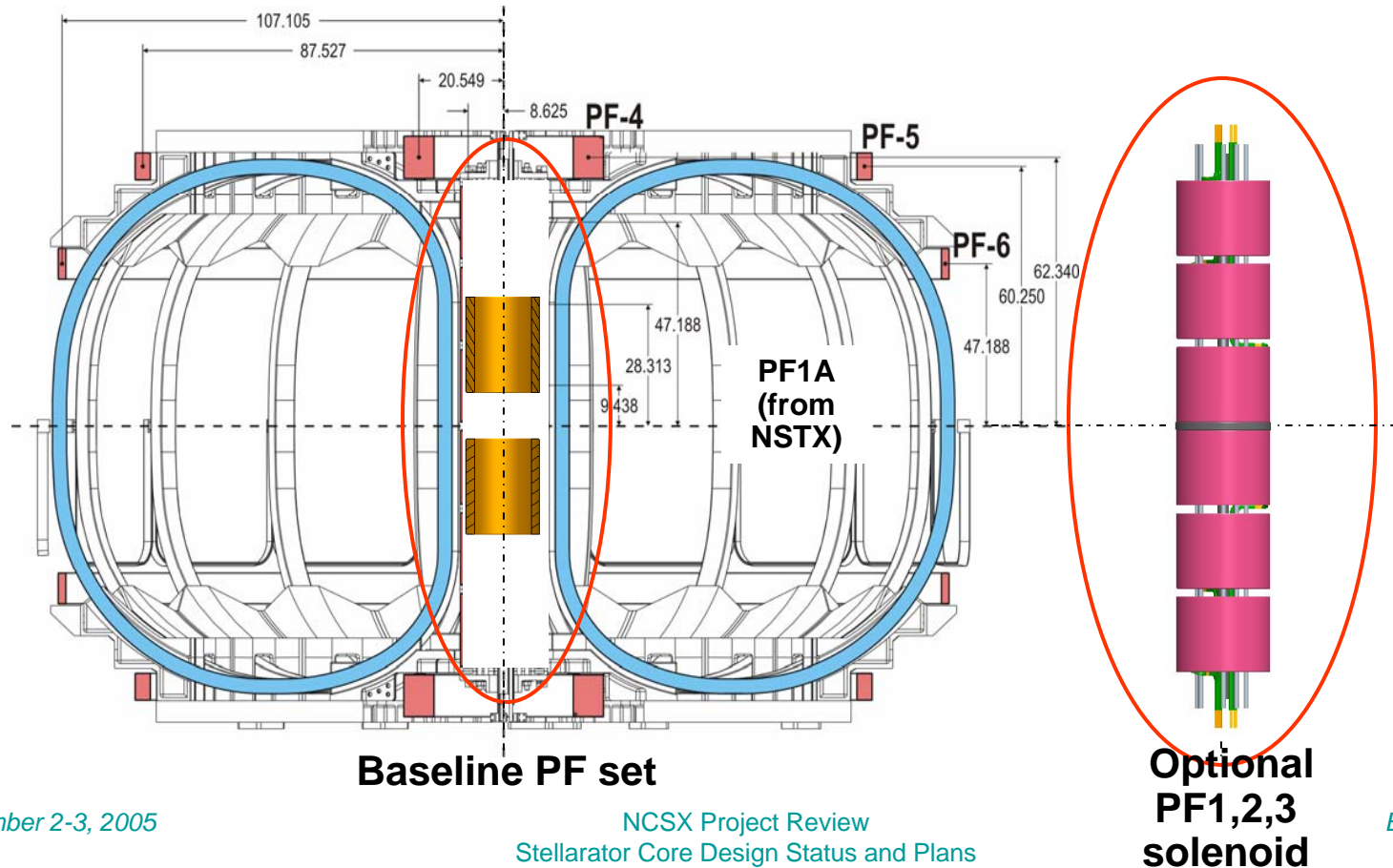
- **Design**
  - Complete analysis and specifications
  - Title III engineering through fabrication
  - No design risks identified

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1301FD-05	Anaylsis Check	1-Mar-05	1-Nov-05	-	16.0	-
1301R-37	Prepare Coil Spec	1-Mar-05	1-Nov-05	-	-	-
1301FD-84	TF Coil Fabrication & assy package approved	2-Nov-05	8-Nov-05	-	-	-
131-031	Title III engr (FDR through 1st coil test 75%)	14-Mar-06	30-Jun-06	-	387.7	-
131-032	Title III engr (completion of coils 10% )	2-Oct-06	19-Nov-07	-	188.1	-

# PF coil design complete through PDR



- Coils are conventional, copper conductor in epoxy glass matrix
- PF1,2,3 will be replaced by existing NSTX coils
- Investigating fabrication of PF-4, PF-5, PF-6 coils in China



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# Plans for completing PF Coil design



- Complete I&C design in FY 06
- Complete PF and CS support FDR in FY 07
- Continue Title III activities through FY 08

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
133-008	Design WBS 134 Conv Coil I&C Peer review	(blank)	12-Oct-05	-	-	-
133-010	Design WBS 134 Conv Coil I&C	1-Mar-05	31-Oct-05	-	72.0	-
133-011	Design WBS 134 Conv Coil I&C FDR	(blank)	31-Oct-05	-	-	-
1302-PF	PF& CS Support Preliminary Design	1-Jun-05	22-Dec-06	-	348.0	-
141-012	PF & CS Sprt PDR	(blank)	22-Dec-06	-	-	-
1301-137	PF & CS Support FDR	(blank)	16-Apr-07	-	-	-
1302-CSS	PF & CS Support Final Design	2-Jan-07	16-Apr-07	-	884.0	-
133-015	Title III WBS 134 Conv Coil I&C	9-Oct-06	18-Apr-07	-	8.0	-
163-015	Title III design CS sprt struc	17-Apr-07	17-Jun-08	-	333.0	-
141-031	Title III engr WBS 132	27-Aug-07	19-Sep-08	-	620.0	-

# Plans for PF coil procurement



- Refurbish PF1A coil pair in-house
- Investigate procurement of PF4,5,6 in China – Need in mid FY 08

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1352-135X	Refurbish NSTX PF1a	3-Oct-05	7-Oct-05	-	16.0	-
133-037	Conv Coil I&C WBS 134 Proc & Install	2-Oct-06	11-Apr-07	-	614.0	9.2
722.010	PF Coil receipt inspect/test (formerly wbs 183)	22-Feb-08	18-Aug-08	-	312.0	-
1355-100	CS and PF 1a Pre-Assy incl coil I&C procurement	19-Aug-08	9-Sep-08	-	240.0	-
163-035	Bid & Award CS Support Struct	17-Apr-07	19-Jun-07	-	-	-
163-036.9	Award CS Support Structure	(blank)	19-Jun-07	-	-	-
141-035	Bid & Award PF Coils	27-Aug-07	29-Oct-07	-	-	-
141-036	PF Coils Awarded	(blank)	29-Oct-07	-	-	-
1352-110	Tooling for PF 4	30-Oct-07	5-Dec-07	-	-	52.5
1352-115	Tooling for PF 5	6-Dec-07	17-Jan-08	-	-	52.5
1352-120	Tooling for PF 6	18-Jan-08	21-Feb-08	-	-	52.5
1352-140	Fabricate/Divr PF 4 lower	22-Feb-08	6-Mar-08	-	-	39.8
1352-145	Fabricate/Divr PF 5 lower	7-Mar-08	27-Mar-08	-	-	39.8
1352-150	Fabricate/Divr PF 6 lower	28-Mar-08	17-Apr-08	-	-	39.8
1352-155	Fabricate/Divr PF 4 upper	18-Apr-08	1-May-08	-	-	39.8
1352-160	Fabricate/Divr PF 5 upper	2-May-08	22-May-08	-	-	39.8
1352-165	Fabricate/Divr PF 6 upper	23-May-08	13-Jun-08	-	-	39.8
163-037	CS Support Structure Procurement/Fab	20-Jun-07	17-Jun-08	-	-	144.8

# Plans for Trim coil design, procurement



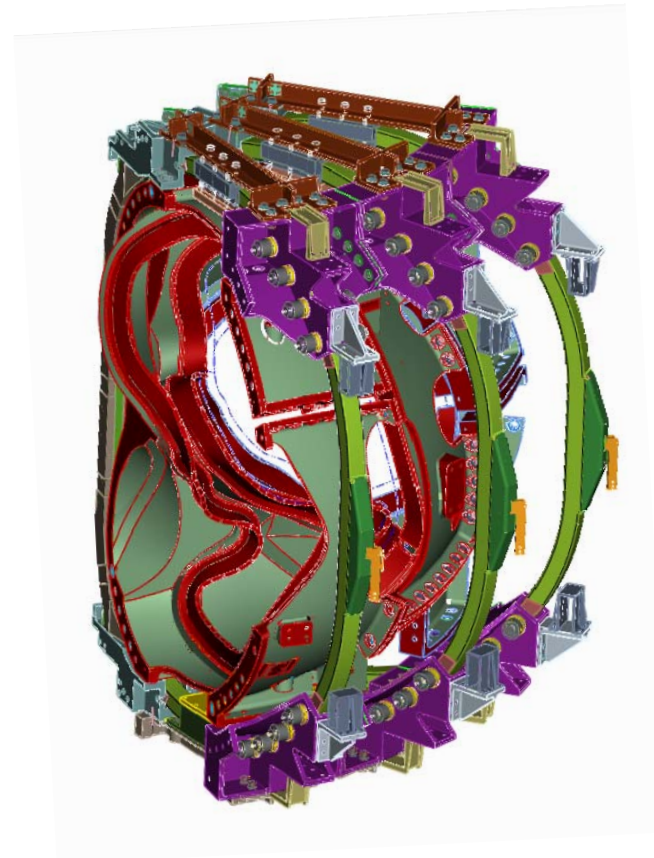
- **Design**
  - Complete design in FY 07
  - Title III engineering through fabrication
  - Trim coils will be identical, simple concept using available conductor
  
- **Procurement**
  - Trim coils built inside in FY 07

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1303-136	Trim Coil PDR	(blank)	10-Nov-06	-	-	-
1303-137	Trim Coil FDR	(blank)	10-Jan-07	-	-	-
1303-TRIM	Trim Coil Design	2-Oct-06	10-Jan-07	-	238.0	-
184-015	Title III WBS 133 Rxt Trim Coils	11-Jan-07	7-Aug-07	-	121.0	-
184-035	Bid & Award Ext Trim Coils	11-Jan-07	14-Mar-07	-	-	-
184-036	Award External Trim Coils	(blank)	14-Mar-07	-	-	-
184-037	External Trim Coil Procurement/Fab*ecp16	15-Mar-07	17-Jul-07	-	-	25.0

# Structure design complete through PDR



- Supports TF, PF coils form mod coil shell
- Baseline concept consists of machined castings bolted together
- Variation with fewer, smaller parts investigated to save cost
- Final design next year



**Structure Design shown assembled with mod coil shell**

# Plans for structure design, procurement



- **Design**
  - Complete analysis, specifications, drawings in FY06
  - Title III engineering through fabrication
  - No design risks identified
  
- **Procurement**
  - Structure slated for outside procurement

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1501-245	Prep Spec, Solicit Bids, and Evaluate Bids	3-Jul-06	2-Oct-06	-	-	-
1501-FD	Final Design Structures	4-Apr-06	30-Jun-06	-	509.0	-
1501-FDR	Structures FDR	(blank)	30-Jun-06	-	-	-
1501-FY05	Prelim Design Structures	1-Jul-05	3-Apr-06	-	241.2	-
1501-PDR	Structures PDR	(blank)	3-Apr-06	-	-	-
153.015	Title III design WBS 153 local I&C	3-Oct-06	1-Oct-07	-	8.0	-
153.037	WBS 153 Support Structure I&C Procurement/Fab	3-Oct-06	1-Oct-07	-	60.0	2.5
162-031	Title III engr WBS 151	3-Oct-06	1-Oct-07	-	938.0	-
162-036.9	Award Coil Support Assy	(blank)	2-Oct-06	-	-	-
162-037	WBS 151 Coil Support Assy Procurement [A/1]	3-Oct-06	1-Oct-07	-	-	814.0



# Coil services design planned for FY 07



- **WBS 161 – LN2 cooling distribution system**
  - Distributes cooling to the coils within the cryostat
  - Preliminary design effort not started, but coil test distribution system is prototypical of design
- **WBS 162 – Coil electrical leads**
  - Distributes power inside cryostat
  - Preliminary design not started, but prototype coaxial cable has been received and ready for cold testing
- **WBS 163 – Coil Protection System**
  - Provides overall coil protection system logic and operating limits for sensor signals, but no hardware
  - Preliminary design effort not started, but TRC tests provided prototypical design

# Plans for Coil services design, procurement



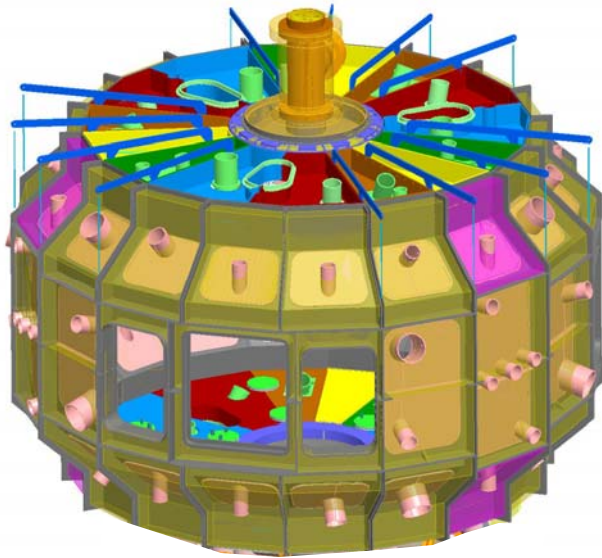
- **Design**
  - Complete analysis and specifications
  - Title III engineering through fabrication
  - No design risks identified
- **Procurement**
  - Piece parts purchased outside for in-house assembly

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
191-001	Title I design WBS 161 LN2 manifolds&pipng	2-Oct-06	10-Jan-07	251.0	80.0	-
191-011	Title II design WBS 161 LN2 manifolds&pipng	11-Jan-07	4-Apr-07	503.0	160.0	-
191-031	Title III engr WBS 161	5-Apr-07	15-May-08	86.0	8.0	-
191-037	Procurement WBS 161	5-Apr-07	8-Oct-07	-	-	53.0
191-038	PDR#17	9-Oct-07	15-Feb-08	-	-	44.4
191-041	LN2 Manifolds & ppg Fab/assy/instl WBS 161	9-Oct-07	14-Jan-08	-	355.0	-
191-042	PDR #17,25,3	9-Oct-07	17-Jan-08	-	113.0	-
132-000	PDR #17 & 25	2-Oct-06	24-Jan-08	220.0	-	-
132-001	Title I design WBS 162 Coil leads	2-Oct-06	11-Apr-07	889.0	-	-
132-011	Title II design WBS 162 Coil leads	12-Apr-07	15-Oct-07	889.0	-	-
132-015	Title III design WBS 162 Coil leads	16-Oct-07	17-Jan-08	98.0	8.0	-
132-037	Coil Leads Procurement WBS 162	16-Oct-07	17-Jan-08	-	-	223.6
163.001	Title I design WBS 163 Coil protection	2-Oct-06	10-Jan-07	162.0	80.0	-
163.011	Title II design WBS 163 Coil protection	11-Jan-07	7-Mar-07	162.0	80.0	-

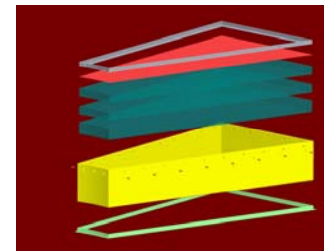
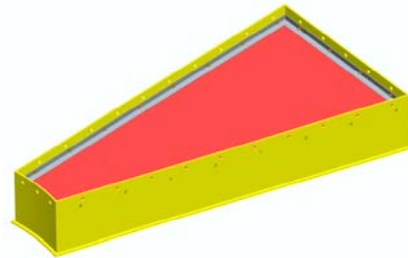
# Cryostat concept consists of insulated panels



- Must accommodate details of all internal components
- Less expensive options being investigated
- Final design next year



**Cryostat Assembly**



**Typical insulated panel**

# Plans for Cryostat design, procurement



- **Design**

- Complete final design and FDR in mid FY 07
- Title III engineering through fabrication

- **Procurement**

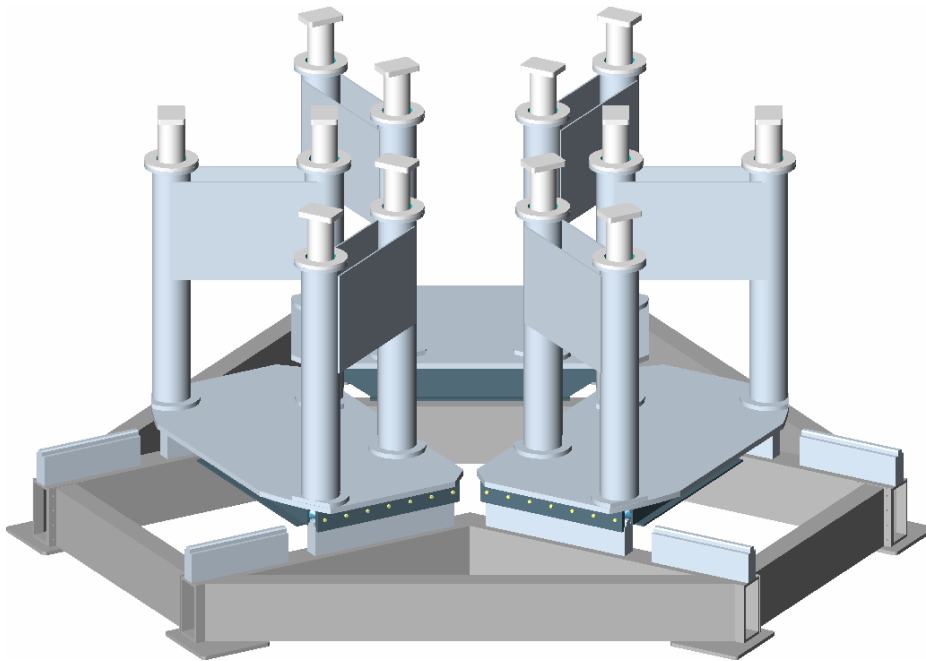
- Cryostat parts purchased outside in FY 08 for in-house assembly

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
151-011	Final Design Cryostat WBS 171	25-Jul-05	22-Jun-07	-	1,537.6	-
171-199	Cryostat FDR	(blank)	22-Jun-07	-	-	-
151-036.8	Prep Spec, Solicit bids, and Select Vendor	25-Jun-07	25-Sep-07	-	-	-
151-036.9	Award Cryostat Procurement	(blank)	1-Oct-07	-	-	-
151-037	Cryostat Procurement [A/1]	2-Oct-07	25-Apr-08	-	-	358.5
151-031	Title III engr	25-Jun-07	28-Jan-09	-	254.0	-

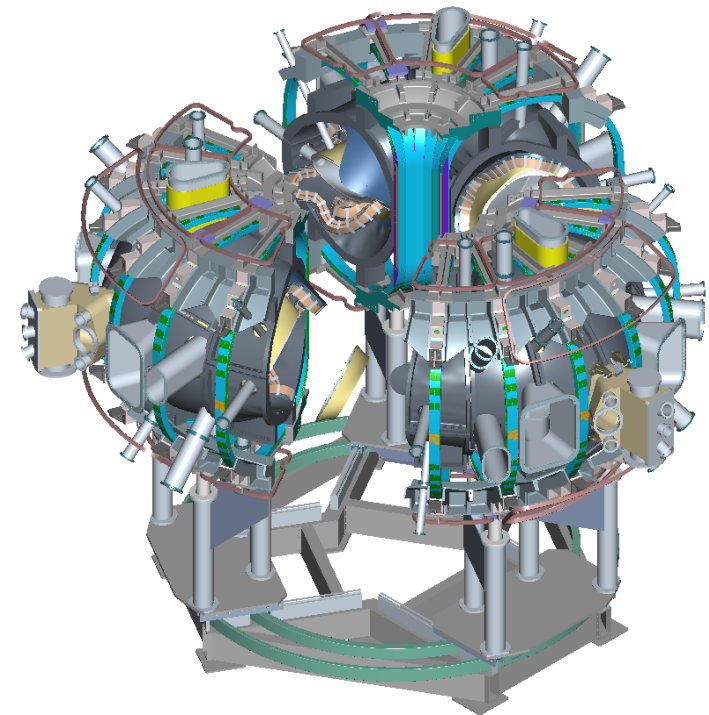
# Base support complete through PDR



- Baseline concept provides sliding supports for final assembly
- New approach will use temporary sliding supports for assembly
- Simplified permanent supports will improve access under core



**Base support concept**



**3 field periods retracted**

# Plans for machine base design, procurement



- **Design**

- Complete FDR in early FY 07
- Title III engineering through fabrication
- Conventional parts for sliding components should simplify design

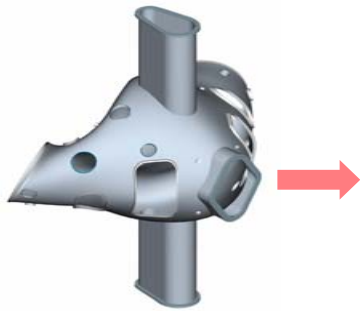
- **Procurement**

- Machine base slated for outside procurement in FY 07

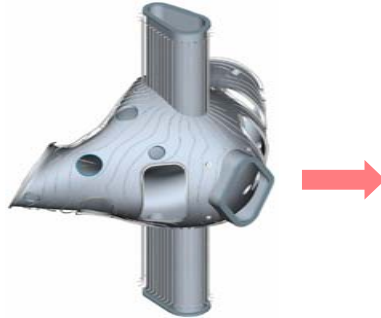
ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
151-003	Base Support Struct PDR	(blank)	26-Oct-05	-	-	-
161-001	Title I design WBS 172 base support struct	1-Apr-04	26-Oct-05	-	37.2	-
161-011	Final Design Base Support Structure WBS 172	2-Oct-06	5-Dec-06	-	372.0	-
172-199	Base Support Structure FDR	(blank)	5-Dec-06	-	-	-
161-036.8	Prep Spec, Solicit bids, and Select Vendor	6-Feb-07	7-May-07	-	-	-
161-036.9	Award Machine Base&supports Procurement	(blank)	7-May-07	-	-	-
161-037	Machine Base&supports Procurement [A/1]	8-May-07	13-Sep-07	-	-	216.7
161-031	Title III engr WBS 172	6-Feb-07	22-Jan-08	-	60.0	-

# Field Period Assembly complete through PDR

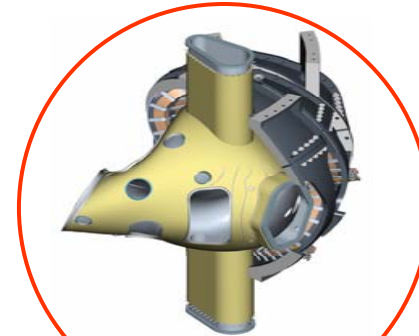
NCSX



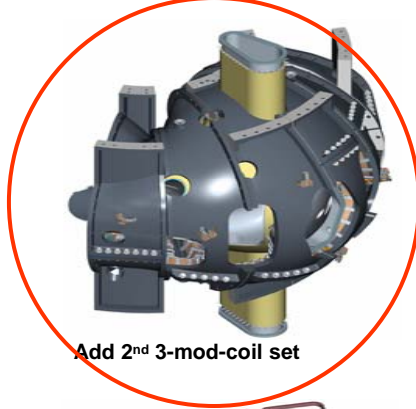
Receive VVSA from vendor



Add coolant tracing



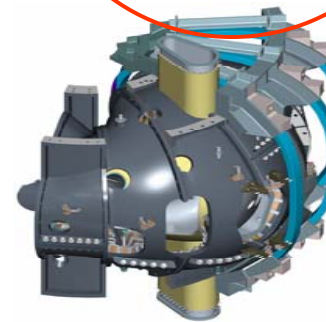
Add first 3-mod-coil set



Add 2<sup>nd</sup> 3-mod-coil set



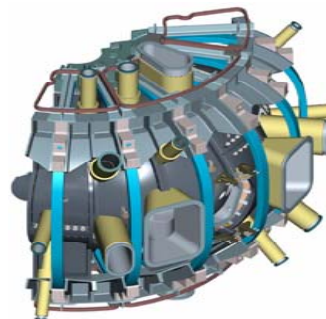
Add VV supports



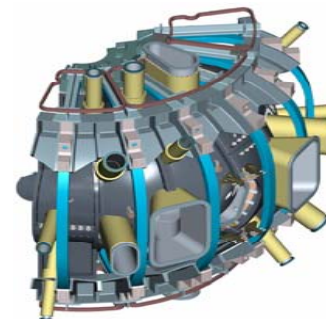
Add first 3-TF-coil set



Add 2<sup>nd</sup> TF-mod-coil set



Add port extensions



Add trim coils

November 2-3, 2005

NCSX Project Review  
Stellarator Core Design Status and Plans

B. Nelson 39

# Plans for field period assembly design



- Complete drawings, analysis and specifications for each fixture, VV fixt. complete
- Prepare field period assembly procedures
- Continue Title III engineering through fabrication and assembly
- Design risks mitigated by simplified concepts

ACT	TITLE	ES	EF	ORNL labor (hours)	PPPL labor (hours)	travel and procurements (\$k)
1803-1.07	Design check and sign-off	20-Sep-05	7-Oct-05	-	2.4	-
1803-1.10	Fab / Design Review - follow-up activities	20-Sep-05	7-Oct-05	-	0.6	-
181.2A	Procedure for VV prep	3-Oct-05	21-Oct-05	-	-	-
1803-1.08	Prep & Issue dwgs.and requisition	10-Oct-05	7-Nov-05	-	-	-
1803-3.15	MC Crane load support sys	10-Oct-05	11-Nov-05	-	-	-
1803-5.02A	Generate as built spherical seat dwg	4-Nov-05	15-Nov-05	-	-	-
1803-2.05	Structural / Seismic Analysis check	24-Oct-05	21-Nov-05	-	80.0	-
1803-2.06	PDR Half Period Assy	7-Dec-05	7-Dec-05	-	-	-
1803-5.05	Run test/metrology measurements	1-Nov-05	8-Dec-05	-	-	-
1803-2.061	FDR Half Period Assy	22-Nov-05	4-Jan-06	-	-	-
1803-2.08A	Prep & Issue Spec,dwgs.and requisition	5-Jan-06	9-Jan-06	-	-	-
1803-3.66	Metrology layout	9-Jan-06	20-Jan-06	-	-	-
1803-3.07	Seismic Analysis check	23-Jan-06	10-Feb-06	-	160.0	-
1803-3.15B	PDR Turning fixture & Base	(blank)	10-Feb-06	-	-	-
1803-4.06	TF Rotation Fixture plus dwgs complete	23-Jan-06	10-Feb-06	-	-	-
1803-4.06A	Metrology layout	13-Feb-06	24-Feb-06	-	-	-
1803-4.08	PDR Final FP Assy	28-Feb-06	28-Feb-06	-	-	-
1803-3.15E	FDR Turning fixture & Base	(blank)	8-Mar-06	-	-	-
1803-4.07	Structural / Seismic Analysis check	13-Feb-06	24-Mar-06	-	80.0	-
1803-4.081	FDR Final FP Assy	11-Apr-06	11-Apr-06	-	-	-
1803-5.200	Metrology layout/support stand dwgs	8-May-06	12-May-06	-	-	-
1803-5.004	Structural Analysis	17-May-06	26-May-06	-	80.0	-
1803-5.005	PDR	30-May-06	5-Jun-06	-	-	-
1803-5.02	TFTR Test Cell FPA arrgmt dwg	5-Jun-06	23-Jun-06	-	-	-
1803-5.006	FDR	5-Jul-06	11-Jul-06	-	-	-
1803-5.007	Pre & Issue Specs and Dwgs	12-Jul-06	18-Jul-06	-	-	-
181.2B	Procedure for MC HP subassy	1-Aug-06	21-Aug-06	-	-	-
181.2C	Procedure for MC insti on VV	1-Sep-06	22-Sep-06	-	-	-
1803-7.10	Tom Brown Engineering	3-Oct-05	29-Sep-06	-	1,088.0	-
1803-7.20	Design Activity	3-Oct-05	29-Sep-06	-	1,295.0	-
181.120	PPPL EM LOE FY06	1-Dec-05	2-Oct-06	-	1,178.0	-
1803-4.10A	Prep & Issue Spec,dwgs.and req-pltfm&sprts	9-Oct-06	20-Oct-06	-	-	-
181.2D	Procedure for TF HP sub assy	2-Oct-06	20-Oct-06	-	-	-
181.2E	Procedure for Final FP assy	2-Jan-07	22-Jan-07	-	-	-
181.121	PPPL EM LOE FY07	2-Oct-06	28-Sep-07	-	1,467.0	-
181.122	PPPL EM LOE FY08	1-Oct-07	30-Jun-08	-	1,100.0	-



# Status summary: 51% complete



WBS	Description		Design	R&D	Procure	In-house fab / assy.	Total
1.2	Vacuum Vessel	<i>spent (\$k)</i>	<u>2,065</u>	<u>1,509</u>	<u>2,617</u>	<u>0</u>	<u>6,191</u>
		<i>total (\$k)</i>	2,474	1,514	5,354	98	9,439
1.3	Conventional Coils	<i>spent (\$k)</i>	<u>1,017</u>	<u>101</u>	<u>201</u>	<u>196</u>	<u>1,515</u>
		<i>total (\$k)</i>	1,496	131	2,024	1,179	4,831
1.4	Modular Coils	<i>spent (\$k)</i>	<u>4,022</u>	<u>7,440</u>	<u>4,631</u>	<u>2,661</u>	<u>18,753</u>
		<i>total (\$k)</i>	5,167	7,456	10,365	8,368	31,356
1.5	Machine Structure	<i>spent (\$k)</i>	<u>75</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>75</u>
		<i>total (\$k)</i>	364	0	1,022	0	1,386
1.6	Coil services	<i>spent (\$k)</i>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
		<i>total (\$k)</i>	714	0	421	0	1,135
1.7	Cryostat and Base	<i>spent (\$k)</i>	<u>372</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>372</u>
		<i>total (\$k)</i>	615	0	918	0	1,533
1.8	Field period assembly	<i>spent (\$k)</i>	<u>756</u>	<u>101</u>	<u>259</u>	<u>220</u>	<u>1,336</u>
		<i>total (\$k)</i>	1,377	101	429	3,374	5,281
1.9	Core Integration and Mgmt	<i>spent (\$k)</i>	<u>1,334</u>	<u>151</u>	<u>0</u>	<u>0</u>	<u>1,485</u>
		<i>total (\$k)</i>	2,609	158	0	0	2,767
	<b>Total</b>	<i>spent (\$k)</i>	<u>9,641</u>	<u>9,301</u>	<u>7,708</u>	<u>3,077</u>	<u>29,727</u>
		<i>total (\$k)</i>	14,817	9,360	20,532	13,019	57,728
		<i>% spent</i>	65%	99%	38%	24%	51%

# Summary



- **Design of the major stellarator core components is nearing completion**
  - Vacuum vessel complete in early FY06
  - Modular coils complete in mid FY06
- **The designs of the major components have been improved based on fabrication and performance tests**
  - Mod coil design modified in response to twisted racetrack coil experience
  - Vacuum vessel details have changed based on value engineering activities
- **Risks have been identified and mitigated through R&D testing**
  - verified performance of the modular coil design
  - verified feasibility of the vacuum vessel field joint design
- **Plans are in place to complete the design and procurement of the stellarator core components**