

Technical Status and Remaining Work

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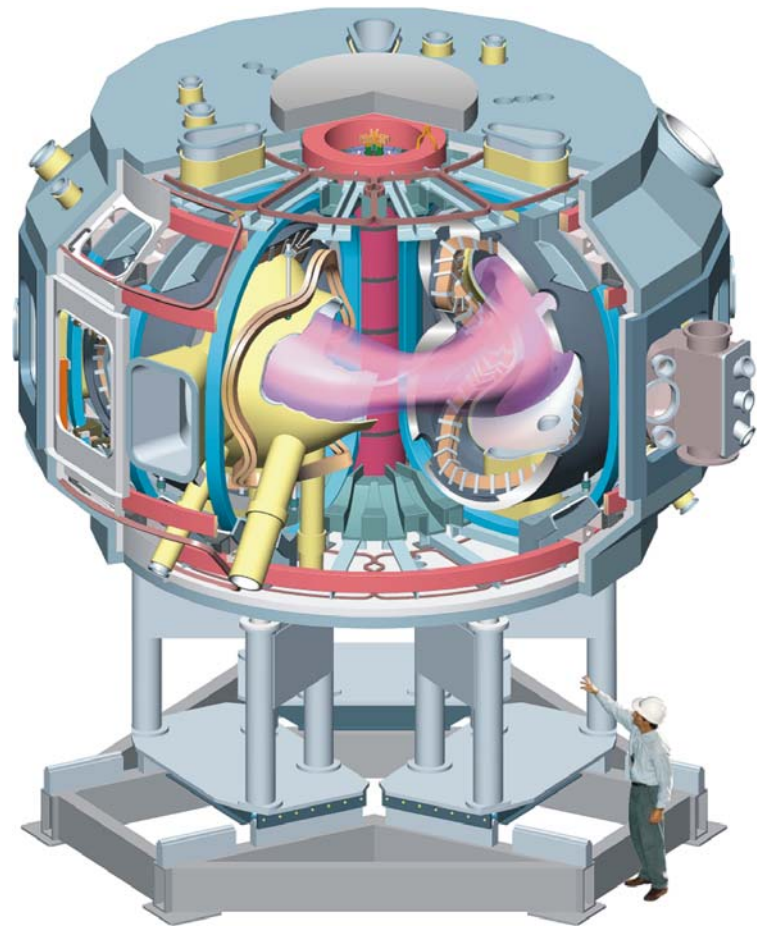
Outline



- Status of Components
- Progress since August, 2007
- Remaining Work
- Design Maturity and Risk
- CD-4 Scope and Performance

Talk Organization

- **Inner Core:** Stellarator Core Out to MC Shell and VV Port Flanges
- **Outer Core:** Stellarator Core Beyond MC Shell and VV Port Flanges
- **Ancillary Systems:** Facility Beyond Stellarator Core



NCSX Stellarator

Major Radius 1.4 m

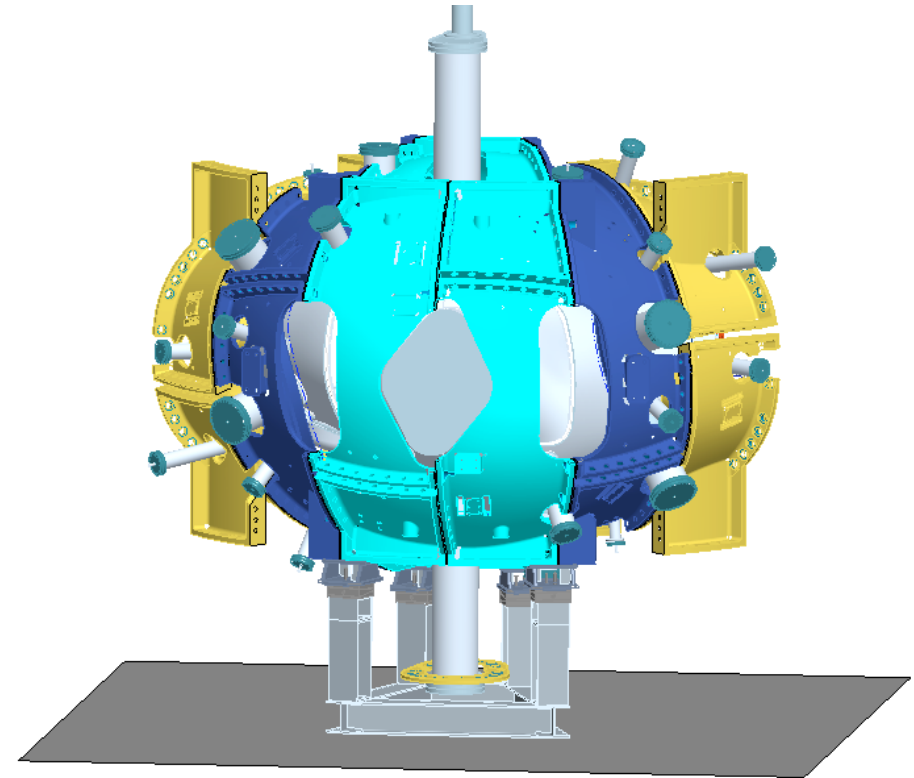
Magnetic Field 2.0 T

Pulse length ~1 s

Inner Core: Stellarator Core Out to MC Shell and VV Port Flanges



Assembling modular coils
into half-period assemblies
(Assembly Station 2)



1/3 of the Inner Core
(after Assembly Station 3)

Our Riskiest Procurements Are Behind Us



Vacuum Vessel Sub-Assys. (\$5M)
September, 2006.



Modular Coil Winding Forms (\$9M)
completed June, 2007

- Challenging technical requirements (geometries, tolerances) stretched PPPL, ORNL, and supplier capabilities. Drove cost and schedule growth.
- Remaining procurements are smaller ($\leq \$1\text{M}$) and simpler.
 - PF and Trim Coils are ≥ 10 months off critical path.

Vacuum Vessel Assemblies Are Nearly Complete

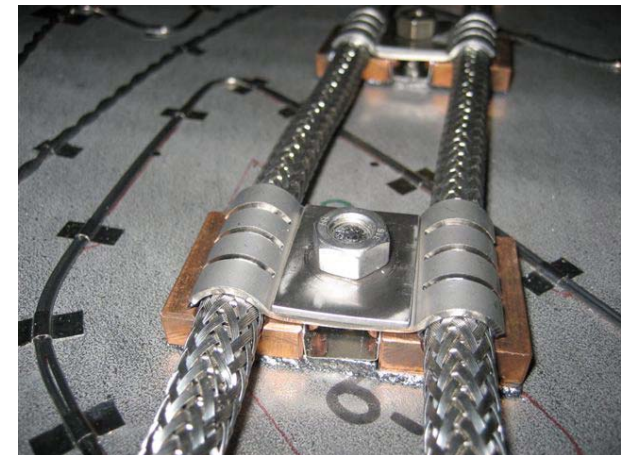


Components installed on vacuum vessel sub-assemblies

- Cryostat interface flanges
- Diagnostic flux loops.
- Heating & cooling hoses.
- Heater tapes.
- Thermocouples

All 3 complete except for lead termination and final testing.

8 months off critical path.



Modular Coil Production is Progressing Well



16 coils (of 18) have been wound and VPI'd.

Production operation has been smooth, with no major issues for over 1.5 years.

- Tolerance on current center position (± 0.5 mm) is being met.
- Technical risks have been retired.

**Last coil will be VPI'd in July
(6 months off critical path)**



Modular Coil Interfaces

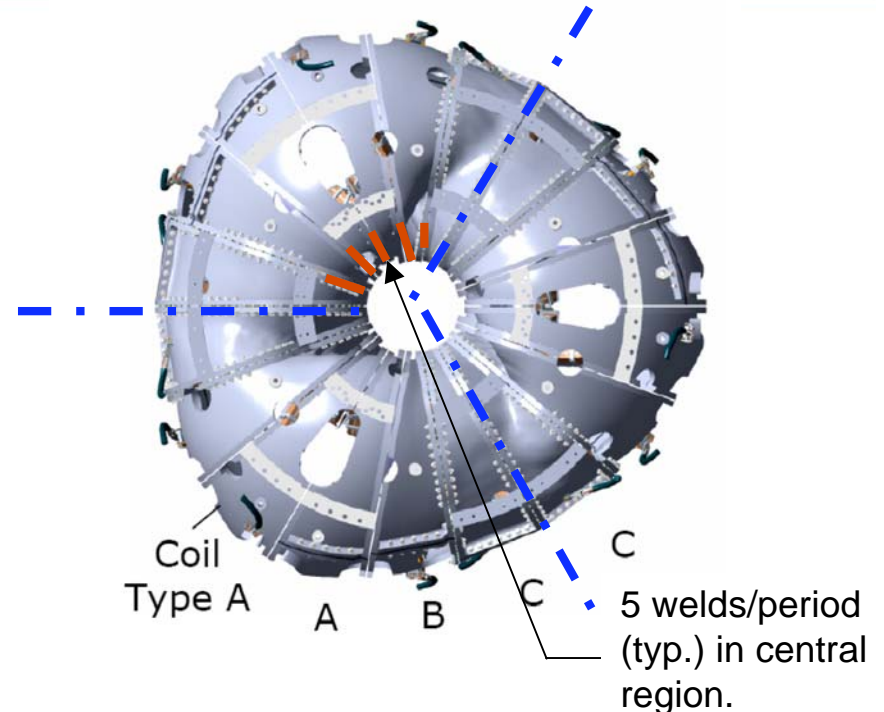


Hardware

- Bolts, nuts, washers, bushings, etc.
- Moderate-friction shims (A-A, A-B, B-C)
- High-friction shims (C-C)
- Shear plates (C-C)
- Compression pucks (C-C)
- Inflatable shims

Assembly Processes

- Metrology (± 0.2 mm inter-coil tolerance)
- Welding (low distortion)
- Handling and accurate positioning of components.



Status

- **Design was completed Nov., 2007**
- Many critical operations prototyped.
- Parts and procedures for half-period assembly (A-B-C) are in hand.

Half-period assembly has started

Inner Core Design Maturity



WBS	Scope	Job Mgr.	CDR	PDR	FDR
Inner Core (Stellarator Core out to MC Shell & VV port flanges)					
12	Vacuum Vessel	Goranson			
14	Modular Coil Assemblies	Williamson			
14	MC AA, AB, BC Interface	Williamson / Cole		X	X
14	MC CC Interface	Williamson / Cole			X
18	FPA Tooling:				
18	Station 3 stands and lift fixtures	Brown			X
18	Station 3 module alignment system	Brown			X
82	Assembly Sequence Plan Maturity		Assessment	Envisioned future changes	
82	Station 2	Brown	99%	probably none	
82	Station 3	Brown	90%	module alignment system	

Legend	
	Completed before August 2007 Lehman Review
X	Completed since August 2007 Lehman Review
xx/xx/xx	Current forecast

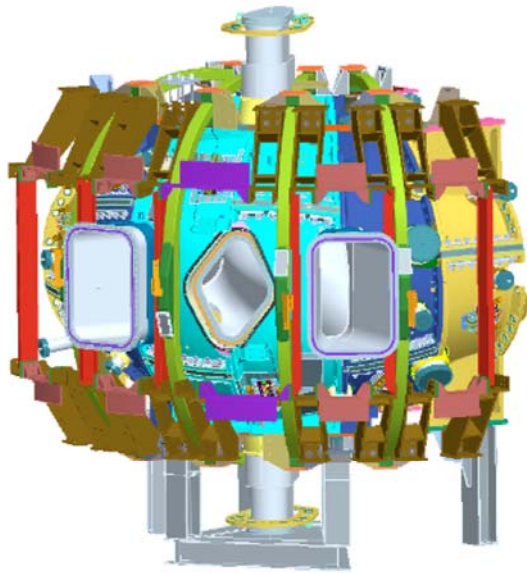
Design has matured since August Lehman Review

- Equipment design is now complete.
- Component fabrication is nearly complete. Mature activity.
- Assembly tooling and sequence plans (basis for assembly estimates) are very mature.
- Risk of further design-driven cost & schedule growth is reduced, though not eliminated.

Risks now are mostly process-related, for example

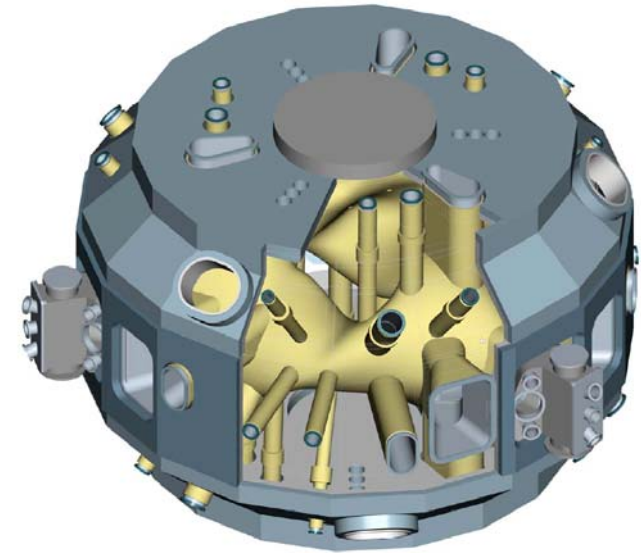
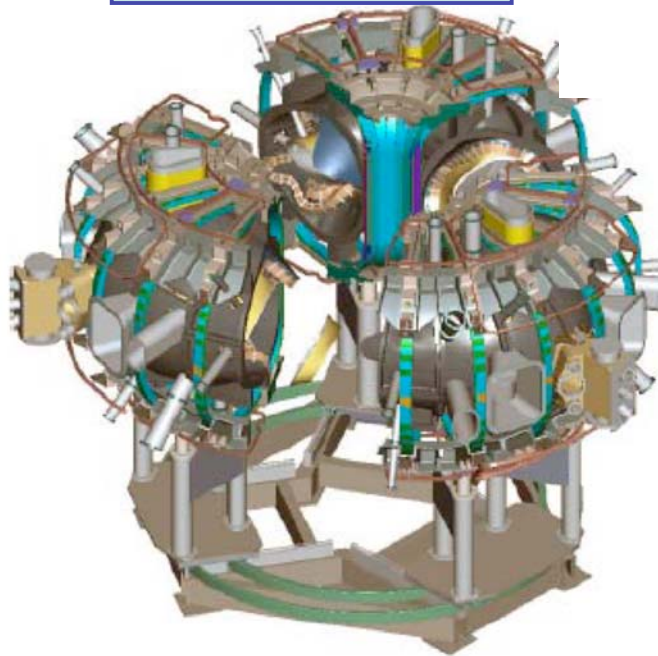
- Part deflection during assembly: mitigated by design, rigid fixturing, low-heat weld process, process development, careful monitoring with metrology.
- Parts interfering or not matching up: mitigated by design, pre-assembly fit-up trials, CAD modeling with as-built dimensions.

Outer Core: Stellarator Core Outside MC Shell and VV Port Flanges



Completed
Field Period
(after Station 5)

Final Machine
Assembly
(Station 6)



Cryostat
completes the
Outer Core
(Station 6)

Toroidal Field Coil Production is Progressing Well

Everson Tesla, Inc., Nazareth, PA



9 coils (of 18) have been completed.

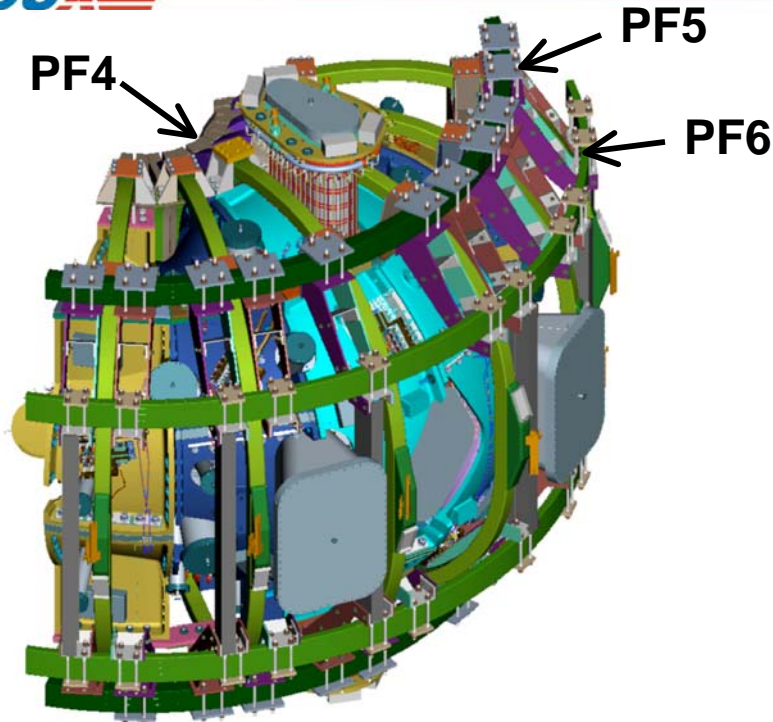
Smooth production operation has been established.

- Producing 1 every 3-4 weeks.
- Technical risks have been retired.
- ± 3 mm tolerance is being met.

**Last coil to be shipped in October
(>1 year off critical path)**



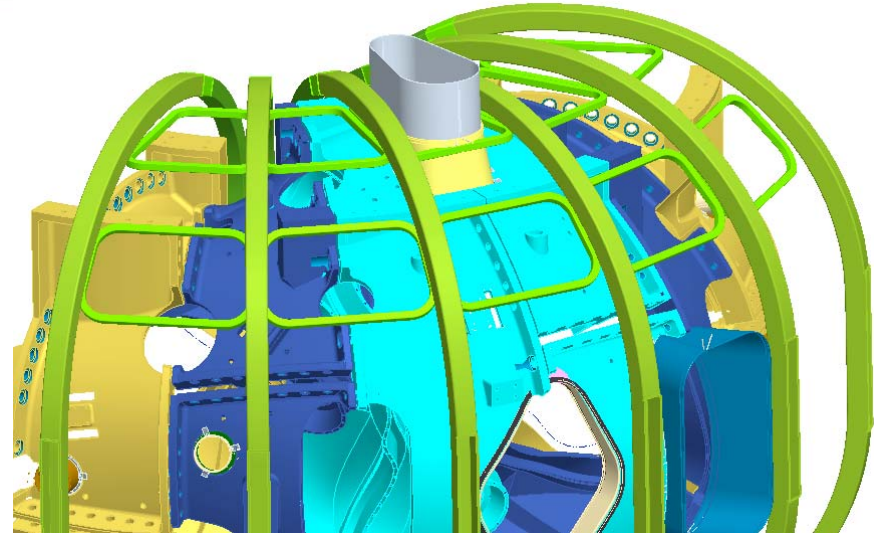
Poloidal Field Coils and Trim Coils



Poloidal Field Coils

RFP has been issued.

- Proposals due 4/2; Award 5/6.
- Multiple offerers expected.
- PF 5L and 6L due Feb. '09.
(~1 year off critical path)
- Balance due Sept. '09.



**Field Error Compensation Coils
(Trim Coils)**

- 48-coil array controls magnetic islands due to field errors.
- Compensates for fabrication errors with margin ($\geq 100\%$) to cover non-conformances if necessary.
- In preliminary design; ~10 months off critical path.

Outer Core Design Maturity



WBS	Scope	Job Mgr.	CDR	PDR	FDR	Free Float (days)	Start fab. / Award
Outer Core (Stellarator Core Beyond MC Shell & VV port flanges)							
12	NB Transition Ducts	Goranson		6/26/08	9/25/08	400	3/10/09
13	PF Coils	Chrzanowski		X	X	280	5/6/08
13	Trim Coils	Kalish	X	3/18/08	5/7/08	210	6/27/08
15	Coil Structures	Dahlgren			6/15/08	175	7/15/08
16	LN2 Manifolds	Goranson		4/2/08	7/7/08	240	10/6/08
16	Electrical Leads	Goranson		8/21/08	3/29/09	445	5/1/09
17	Base Structure	Dahlgren		X	4/21/08	270	6/30/08
17	Cryostat	Raftopoulos	10/1/08	4/14/09	7/23/09	346	7/1/10
18	Assembly Tooling:						
18	Station 5 base	Brown		X	4/3/08	205	7/28/08
18	Station 5 lift fixture	Brown		X	4/22/08	317	8/22/08
18	Station 6 module supports ("sled")	Brown		6/11/08	7/9/08	274	1/5/09
18	Station 6 spool piece support	Brown		6/11/08	8/6/08	439	2/5/09
82	Assembly Sequence Plan Maturity		Assessment	Envisioned future changes			
82	Station 5	Brown	90%	coil support details, cryostat supports, lifting features			
82	Station 6	Brown	75%	cryostat details, carts-base integration, racks, cable trays, unknowns			

Legend	
	Completed before August 2007 Lehman Review
X	Completed since August 2007 Lehman Review
xx/xx/xx	Current forecast

FY-08 priorities: Push design. Order remaining coils and structures.

- Design work has been accelerated, but still maturing.
- Interfaces are critical. Being addressed by a strengthened design integration team.

Risks

- Further growth in assembly estimates as component designs and assembly sequence plans mature. Mitigated by pushing design, emphasizing integration.
- Parts interfering or not matching up: mitigated by design, pre-assembly fit-up trials, CAD modeling with as-built dimensions.
- Assembly schedule delays due to unavailability of parts. Mitigated by pushing design and procurements, and having free float (≥ 8 months) in the schedule.

Ancillary Systems

WBS	Scope	Job Mgr.	CDR	PDR
Ancillary Systems (Facility Beyond Stellarator Core)				
12	Heater control sys	Gernhardt		4/24/09
2	Fueling	Blanchard		4/29/09
2	Fueling and vacuum	Blanchard		1/7/09
3	Diagnostics:			
3	VV spacer flux loops	Stratton		N/A
3	Visible camera system	Stratton		10/1/09
3	Electron beam mapping sys.	Stratton		4/27/09
4	Coil Protection System	Ramakrishnan	X	9/15/08
4	Power Systems	Ramakrishnan		9/15/08
5	Central I&C	Sichta		Jan-Dec. '09
62	Cryogenic Systems	Raftopoulos	2/12/09	10/2/09
63	Utility Systems	Dudek		10/29/10
64	VV heating and cooling system	Kalish		2/4/10
85	Startup	Gentile	Starting safety docs. & ISTPs in FY-08	

Legend	
	Completed before August 2007 Lehman Review
X	Completed since August 2007 Lehman Review
xx/xx/xx	Current forecast

FY-08 priority: Push power systems design.

- Systems are conventional and very similar to past projects, e.g. NSTX.
- Consulting with outside experts on cryo. system.
- Most of the design work will start in FY10.

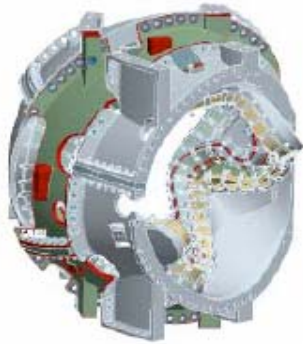
Overview of Remaining Work



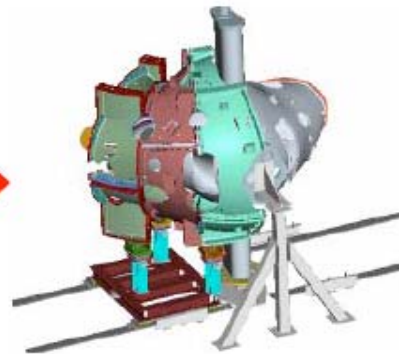
	EAC (\$M)	To-Go (\$M)	To-Go (%)
Component Fabrication	65.0	12.2	19%
12 Vacuum Vessel	11.1	1.4	12%
13 Conventional Coils	8.3	4.5	54%
14 Modular Coils	40.8	2.6	6%
15 Coil Structures	2.1	1.6	74%
16 Coil Services	1.1	1.1	100%
17 Cryostat & Base Structure	1.6	1.1	69%
Assembly	29.4	23.2	79%
18 Field Period Assembly	20.1	14.6	72%
7 Test Cell Prep & Machine Assy.	9.3	8.6	92%
Ancillary Systems	11.2	9.0	81%
2 Fueling & Pumping	1.2	0.8	70%
3 Diagnostics	1.9	0.8	42%
4 Electrical Power Systems	3.3	2.7	81%
5 Central I&C/Data Acq.	2.1	2.1	98%
6 Facility Systems	1.9	1.8	99%
85 Integrated System Testing	0.8	0.8	100%
Engineering Mgt. & Integration	19.2	9.9	52%
Management	13.3	7.4	56%
Total Work	138.1	61.7	45%

- Largest, riskiest systems (VV, MC) are nearing completion.
- Assembly is the largest to-go activity. High risk. Just starting.
- Management and Engineering have been strengthened to improve risk management.

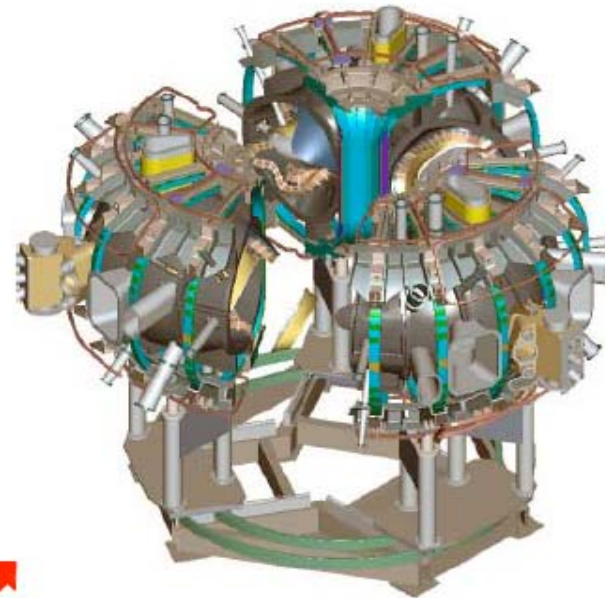
Assembly is the Largest Remaining Activity



Assemble 3 coils
for half field period
Now Underway!



Install 3-coil set
over vacuum
vessel sector



Connect 3 field periods



Connect 2nd 3-coil
set over vacuum
vessel sector

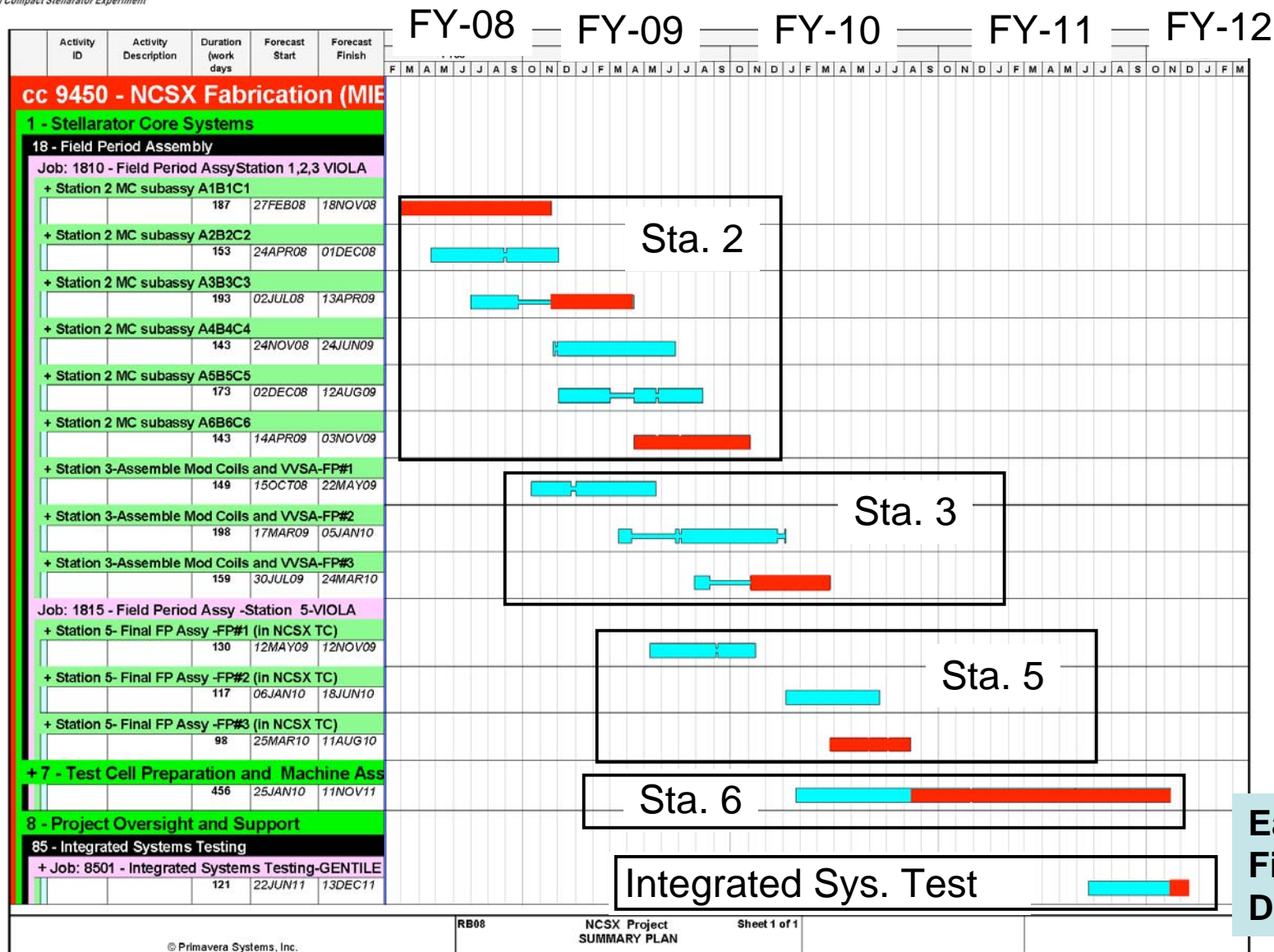


Add ports & TF
coils to complete
a field period



Require coil current center
accurate to ± 1.5 mm

Critical Path: Assembly & System Testing



CD-4 Performance & Scope Objectives



- The project is addressing all CD-4 Project Objectives as documented in the Project Execution Plan (PEP).
 - Detailed reconciliation of project plans with CD-4 objectives was documented and presented at the August Lehman review.
- Following a Lehman review recommendation, DOE directed the project to restore machine capabilities to ensure consistency with the baseline approved by Dep. Sec. in 2005.
- In response, scope was added and is included in the current BCP.
 - Full set of trim coils.
 - Vacuum pumping system (permanent), incl. NB transition duct, utilities.
 - Vacuum vessel port heater control system.
 - Gas injectors (restore total to 3)
 - Magnetic diagnostic sensors (restore instrumented total to 8)
 - Central I&C (restore to 2005-equivalent performance)

Summary



- The Vacuum Vessel and Modular Coils are nearing completion.
 - Design is complete (retired risk).
 - Procurements are complete (retired risk).
 - Assembly is starting.
- Stellarator components outside the MC shell are in design and procurement.
 - Design is being pushed but still maturing- a risk.
 - Activities are at least 8 months off the critical path.
- Power systems design work has started.
 - Most other ancillary systems design work will start next year.
- Assembly is the largest remaining activity and is the critical path.