NCSX Project Overview and Management

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Office of Science Project Review
Princeton Plasma Physics Laboratory
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The NCSX Project is About 40% Complete

NCSX National Compact Stellarator Experiment

Scope

- Fabricate & install stellarator.
- Adapt to existing technical infrastructure.
- Test system and make first plasma.

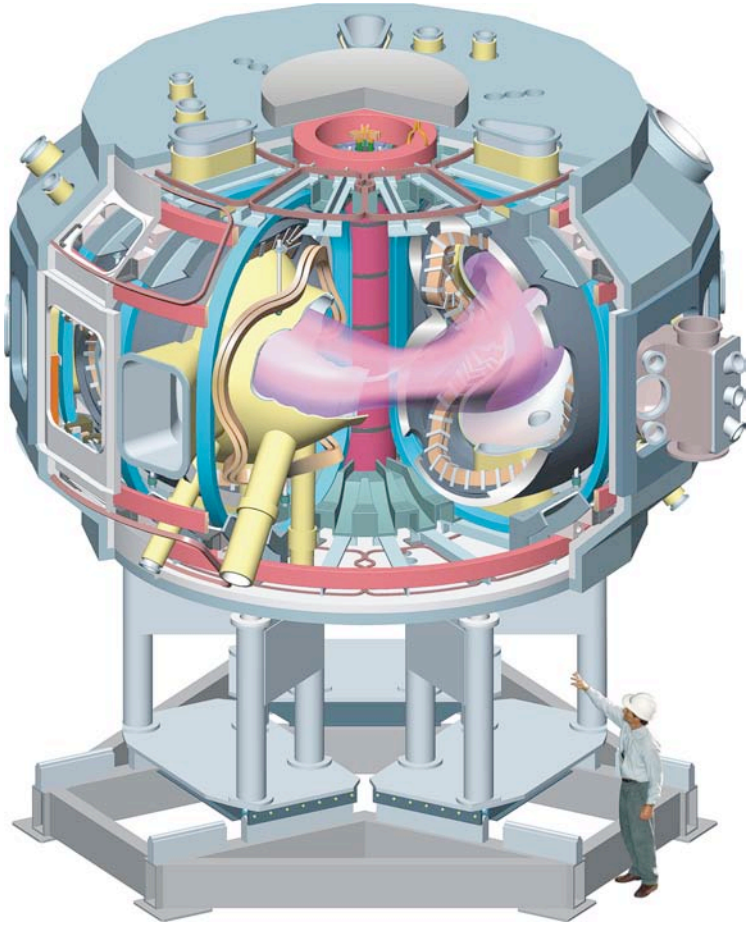
Schedule and cost

- April, 2003 - July, 2009 (76 months)
- CD-3 approved, major contracts placed, 9/04.
- TEC $92.4M

Progress Highlights

- Manufacturing R&D was completed in FY05.
- First major procured component (MCWF) has been delivered.
- On-site coil fabrication has started.

Work performed through 9/05 (30 months)
$37M (40% of TEC).



NCSX Stellarator
Major Radius 1.4 m
Magnetic Field 2.0 T
Pulse length ~1 s

Substantial Risk Reduction Since Last SC Review

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Status at Dec., 2004 SC Review

- MCWF & VVSA contracts off to a good start. Progress in engineering, tooling, materials. Not yet into fabrication.
- PPPL coil manufacturing facility operations had just started. Twisted racetrack winding trials in progress.

Issues & Recommendations. ***Current status.***

- Potential technical difficulties in MCWF and VVSA manufacture. Watch closely.
  Well into production. Risks being managed.
- Test the modular coil chill plate cooling concept.
  Twisted racetrack coil built and tested. Cooling works as predicted.
- Complete R&D on VV field welds and MCWF fracture. ***Done. Positive results.***
- Reduce/mitigate TF coil technical failure risks.
  Made changes in design and fabrication plan.
- Make technician staffing plans more specific. ***Done. Identified by name.***
- Continue to identify and implement cost and schedule efficiencies.
  We have and we will. Examples will be presented.

Outline

- **Major Procurements (MCWF & VVSA)**
- **In-house fabrication.**
- **Project risks- update.**
- **Plans, estimates, and contingencies.**
- **Management update**
  - Organization, risk mgt., and safety.
- **Summary.**

Excellent progress in fabrication and risk reduction.
Sound plans, credible & realistic estimates to complete.
Team staffed and functioning per DOE expectations & project needs.

First Modular Coil Winding Form Has Arrived

Energy Industries of Ohio, Inc.

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18 forms (3 shapes- A, B, C).

Steel casting w/machined surfaces.

Status:

- All 3 casting patterns are fabricated.
- 9 castings are poured (all 6 C's, 3 A's).
- 5 in foundry, 3 in machining, 1 delivered.
- Next two deliveries (EIO forecast): Nov. 14, Dec. 29.

High quality is being maintained.

Manufacture of #1 was more difficult and took longer than expected:

- Missed Level II milestone (deliver first MCWF) by 2 months.
- Missed FY-05 Joule target (wind 1st coil).
  - Expect to complete by Dec. 31.

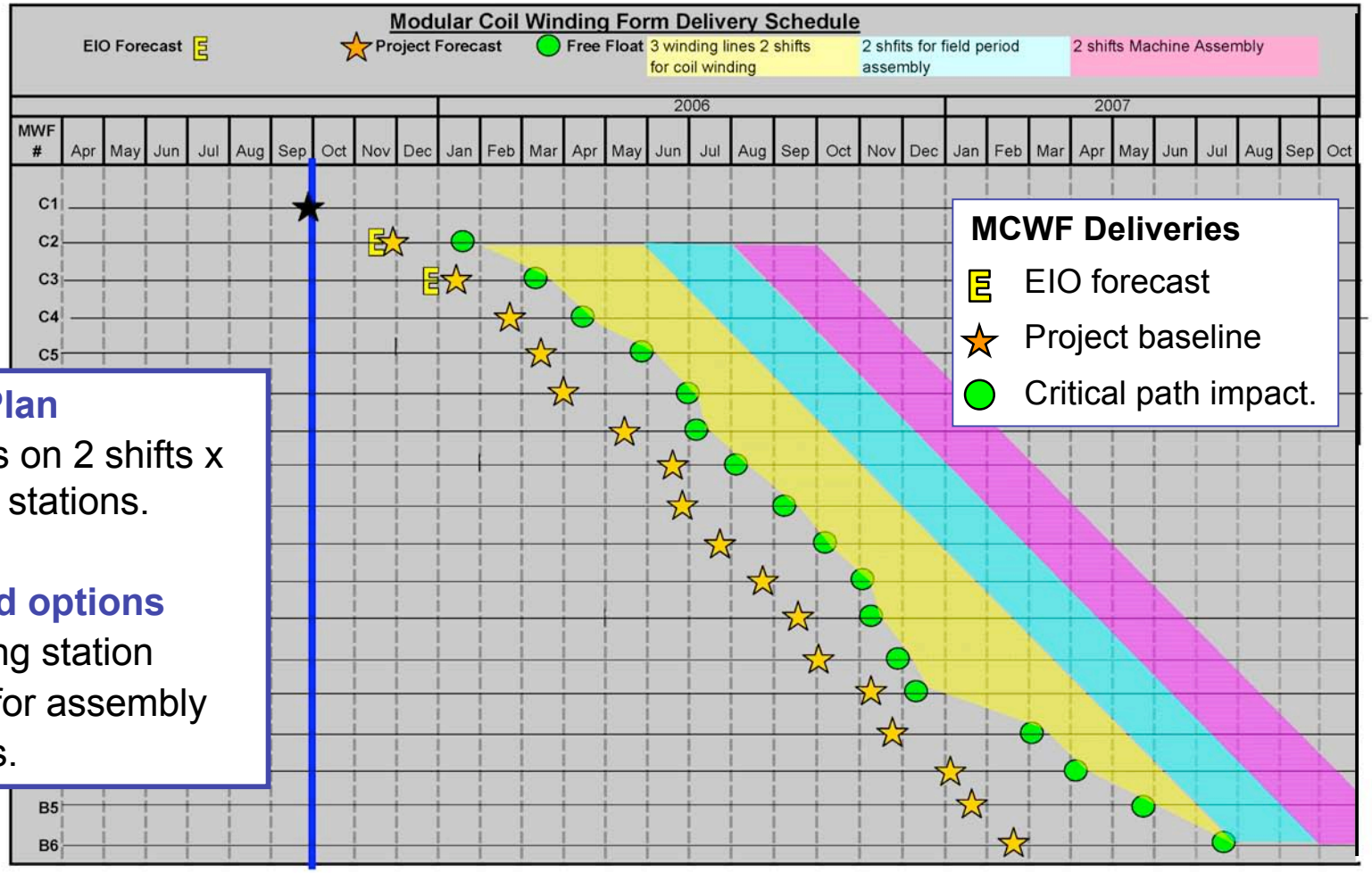
Still supports project baseline (CD-4).

Modular Coil Winding Form (MCWF)

Mounted in Winding Fixture at PPPL

Realistic MCWF Delivery Expectations Support the Project Baseline

- Current plan* accommodates the expected delivery schedule, with float.
  - EIO aiming for last delivery in Sept. 2006. Project plans based on Feb., 2007.
- Reserved options** are available to absorb delays even into shaded areas.



***Current Plan**

- Wind coils on 2 shifts x 2 winding stations.

****Reserved options**

- 3rd winding station
- 2nd shift for assembly
- weekends.

MCWF delivery schedule: P, Heitzenroeder. Coil winding plans: J. Chrzanowski

Vacuum Vessel Manufacture is Progressing Well.

Major Tool and Machine, Inc.

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3 120º shell sectors w/ ports, 3 spacers.

- Shell is fabricated from 60 formed panels, welded together.

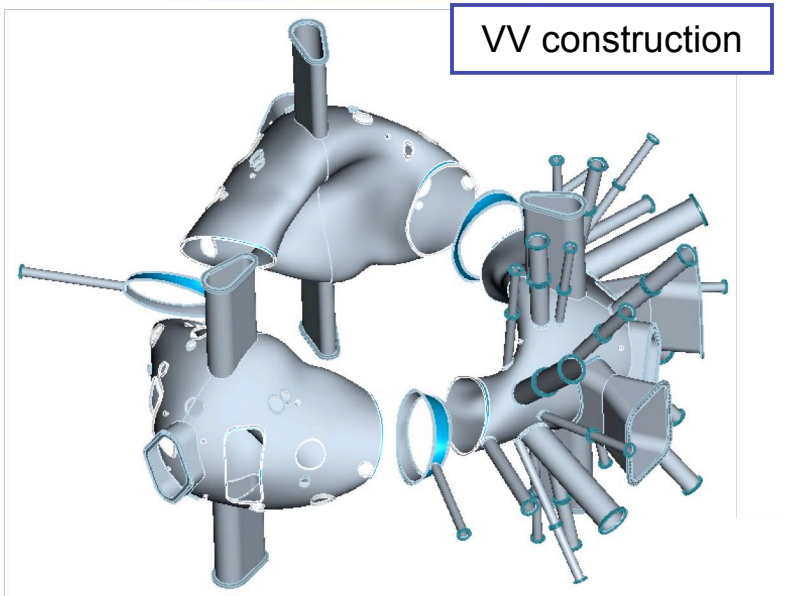
Status:

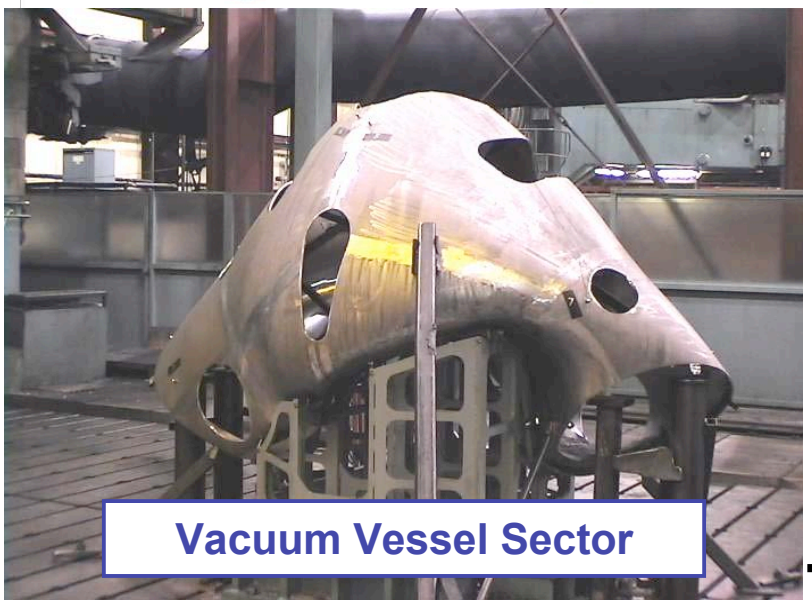
- First two 120° shell sectors are welded.
- Ports are being installed onto first sector.

High quality is being maintained.

Delivery schedule for 3 sub-assemblies:

- Jan., Feb., Mar., 2006
- About 9 months off project's critical path.
- Proposed Level II Milestone reschedule from May to Sept., 2006 leaves ample float and better matches project needs.





M. Viola

MCWF and VVSA Risk Management Mechanisms Are Working Well

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Highlights

- Close project oversight and support of supplier activities.
  - Monthly site visits. Weekly reports. Daily phone calls.
  - Rapid project response to supplier issues and requests.
- Win-Win management: eliminate low-value requirements, accommodate changes to improve manufacturability whenever possible.
- Review in-process QA documentation as it is generated; resolve issues in a timely manner. (Don't wait until part is about to ship!)
  - Weekly conference calls dedicated to quality issues and action items.
  - Effective use of local DCMA representatives for on-site QA support.
- Tight control of requirements and changes.
  - All requests & direction go through contract administrator.
  - No cost claims expected.*

*VVSA price was adjusted after award based on a clarification of the RFP.

P. Heitzenroeder
M. Viola

We Have Hit the Ground Running on Modular Coil Winding.

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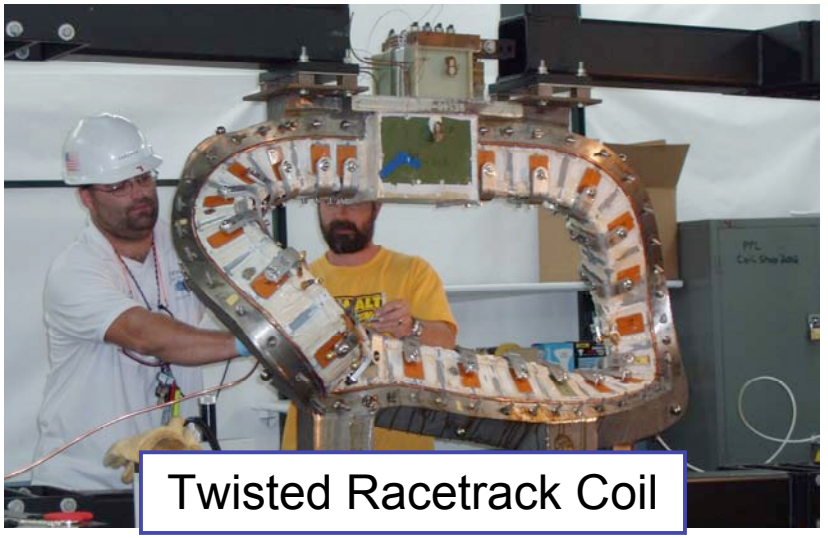
- "Twisted racetrack" R&D coil was successfully fabricated and tested in FY05.
  - Demonstrated all manufacturing operations.
  - Trained the staff. Proved out the equipment.
  - Demonstrated coil operation at temperature, current, and pulse length.

- Completed FDR of Type C coil.
  - Improved the design for manufacturability, based on twisted racetrack. (B. Nelson)

- Winding operations plan is sound.
  - Staff is well qualified and experienced.
  - Procedures are documented & tested.
  - Equipment is proven.
  - Parts are on hand.

Winding operations are off to a good start. (2 shifts)



Twisted Racetrack Coil

First Production Coil

L. Dudek, J. Chrzanowski.

FY-05 Accomplishments Have Reduced Risks.

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We have substantially reduced the key risks identified at the PDR.

- MCWF and VVSA feasibility, cost, and schedule concerns.
  - Fixed-price contracts with capable suppliers.
  - Fabrication of prototypes and first production articles has reduced the uncertainties, and bracketed the remaining schedule risk.
- Modular Coil Winding quality, cost, and schedule concerns.
  - Fabrication by experienced Laboratory staff minimizes quality risks.
  - Design and manufacturing process were developed with extensive R&D input.
  - Twisted racetrack provided a sound basis for fabrication estimates.
- TF coil source availability and quality concerns.
  - Vendor survey found 2 sources with adequate facilities, but did not resolve quality concerns.
  - In-house fabrication minimizes quality risks. (Experienced with planar coils.)
- Field Period Assembly
  - Concerns are interferences, tooling inadequacies, tolerances.
  - FY-05 tooling & process design progress reduced the risks. (T. Brown.)

Future Plans Are Based on Reduced Risks & Updated Estimates to Complete (ETC)

- Risks and uncertainties have been reduced by completing key jobs, e.g.
  - Type C modular coil design (*basis for Type A & B design ETC)*
  - Twisted racetrack *(basis for modular coil fabrication & testing ETCs)*
- Work plans and ETC's have been updated.

$2.4M requested from contingency provides a credible, realistic plan.

Proposed Contingency Draw (ECP-039)	**($k)**	
Variances on completed work	1,593	R. Strykowsky to address.
Estimate changes	1,488	Following slides
Design changes	-724	
Total	**2,357**	

Project Response to Coil Fabrication ETCs

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Modular Coil Winding labor & supervision

- Estimate increased $661k (≈15% of total labor).
- Estimate is based on TRC, w/ no learning curve included.
  - Potential exists for savings via process improvement over 18-coil production run.
- Estimated costs through 3Q of FY06 are fully covered in current budget.
- After 3Q, re-evaluate need for additional budget, based on actual cost of first few coils, actual process improvement gains.

TF Coil Fabrication facility, materials, and operations (requesting $432k)

- Estimate increased $880k based on design maturity (PDR and FDRs) and extensive planar coil experience. Learning curve included.
- Contingency request fully covers estimated costs through FY-06 (1 coil).
- Exploring low-cost fabrication by Chinese fusion laboratory (ASIPP) with impressive in-house fabrication experience (EAST tokamak).
- After FY-06, re-evaluate need for remaining $448k (≈50% of total labor), based on actual costs, any process improvement gains, ASIPP option.

Learning Curve Improvements Are Typical in Repeated Engineering Tasks

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Fusion Examples

- Machining of W7X coil cases: 1200 hrs. on #1, 400 hrs. after 4-5. (4:1 improvement)
- Winding of NSTX PF1a: first coil 11 weeks, second coil 5 weeks (2:1)
- Diamond Wire Cutting in TFTR D&D: first cut 4 weeks, last cut 1 week (4:1).
- Winding of NCSX twisted racetrack coil: 1/2 turn/day at start, 2 turns/day at finish (4:1)

NCSX Plan

- Improve MC & TF coil fab. processes.
  - Use worker input, lessons-learned, time studies.
- Target: reduction in labor hours by ~10% ($530k).

Contingency Requests for Estimate & Design Changes

Estimate Changes	Cost ($k)	Basis
TF Coil fabrication	432	Previous slide
MC and VV Design	793	Type C Actual Costs, Additional VV issues.
Coil-to-coil interface hardware	655	Previously omitted from estimate.
Other	-392	R. Strykowsky presentation
Total	**1,488**	

Design Changes	Cost ($k)	Comment
Use existing coils for solenoid	-466	Install former NSTX PF1a coils. Sufficient for first few years of research. Configuration allows straightforward upgrade later, if needed.
Simplify e-beam mapping equipment	-104	Use existing equipment and experience.
Simplify trim coils	-154	Basic design sufficient for exploratory studies.
Total	**-724**	

Remaining Contingencies are Adequate

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Budget Contingency $9.6M (21.6% of BCWR).

- Adequacy is supported by updated risk assessment. (W. Reiersen)

	BCWR ($k)	Conting. ($k)	Conting (%)
MCWF & VVSA Contracts	6,891	690	10%
Balance of stellarator core systems	19,815	6,058	31%
Ancillary systems & machine assembly	11,326	2,209	20%
Management and integration	6,369	655	10%
	44,401	9,612	22%

- Cost reduction opportunities continue to be explored
  - Coil fabrication process improvement, $530k.
  - Accelerate completion up to 2 months via 2-shift assembly operations? (Reduces carrying costs.) ~$400k
  - Fabricate TF, PF coils or structures at ASIPP (China)? ~$1M

Schedule contingency maintained at 5 months since CD-2.

We Have Organized Ourselves for Fabrication

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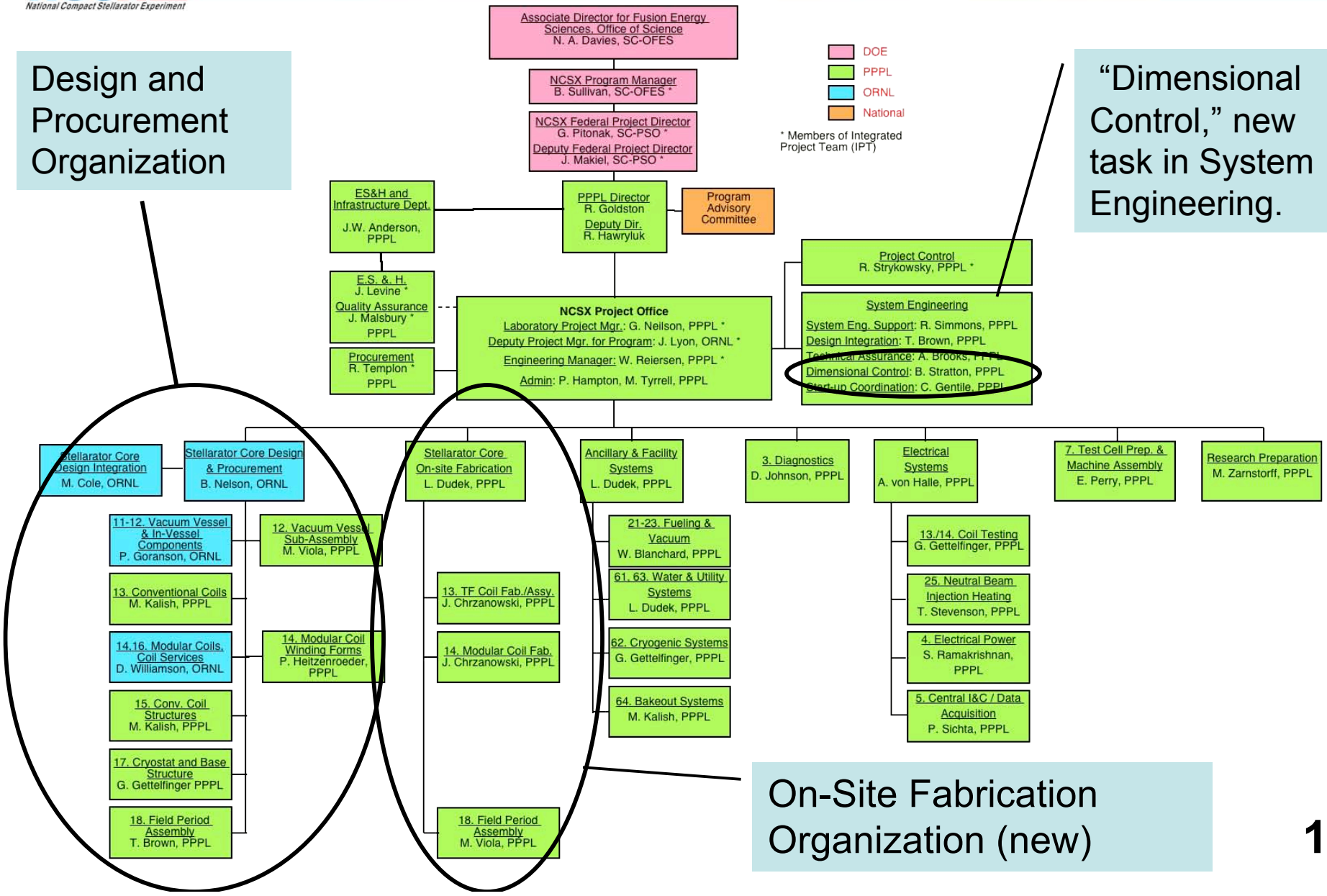
Design and Procurement Organization



"Dimensional Control," new task in System Engineering.

On-Site Fabrication Organization (new)

We Are Staffed and Functioning per Project Needs

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On-Site Fabrication Organization (New)

- Managed by PPPL Fabrication division head, Larry Dudek.
- Ensures safety and efficient resource management for winding and assembly operations in TFTR test cell.
- Technician staff to support FY-06 plans have been identified by name. New hires to support immediate needs have been approved.

Design & Procurement Engineering Organization

- Managed by ORNL fusion engineering group leader, Brad Nelson.
- Staffed by ORNL, PPPL, and contract engineers.
  - Draws on broad range of expertise and provides great flexibility.
- Has led design, R&D, and industry participation since pre-conceptual design.
- Main R&D activities have been successfully completed.

Dimensional Control task (New)

- Led by experienced experimental physicist, Brent Stratton.
- Develops strategies and specific procedures for achieving ±1.5mm accuracy in finished product.
- Tolerance control for modular coils successfully demonstrated.

Safety is Integrated into NCSX Work at All Levels

- All staff taking Hazard Awareness Training (JHA-based) to improve understanding of NCSX hazards.
- Job Hazard Analysis checklist used for all field tasks.
- Lab Activity Certification Committee (ACC) reviews manufacturing facilities and procedures prior to operation. (IPT members participate.)
- Safety is addressed in design process and influences choices, e.g.:
  - thermal insulation dust & flammability hazards
  - hoisting & rigging hazards in assembly operations.
- Safety, cost, and schedule goals are mutually supportive, not in conflict.
  - Work is done according to documented plans and procedures.
  - Project organized for strong safety management, with safety, cost, and schedule responsibilities aligned.

The IPT is Managing Project Risks per O413.3 and the Project Execution Plan

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- Risk mitigation plans, included in the baseline from the beginning, are succeeding.
  - Manufacturing processes have been developed through R&D.
  - System engineering has maintained good control of requirements and design.
  - Value engineering has continued to yield improvements (e.g., pourable VV insulation instead of blankets).

- IPT's risk management approach is working well.
  - Monitor risk mitigation progress at monthly IPT meetings, using dynamic critical issues list as a tool.
  - Monitor MCWF and VVSA procurement risks via weekly IPT briefings.
  - Mitigate cost & schedule risks by offsetting ETC increases with work reductions, design improvements, planning changes, etc.

FY-06 Work Plans Are in Place

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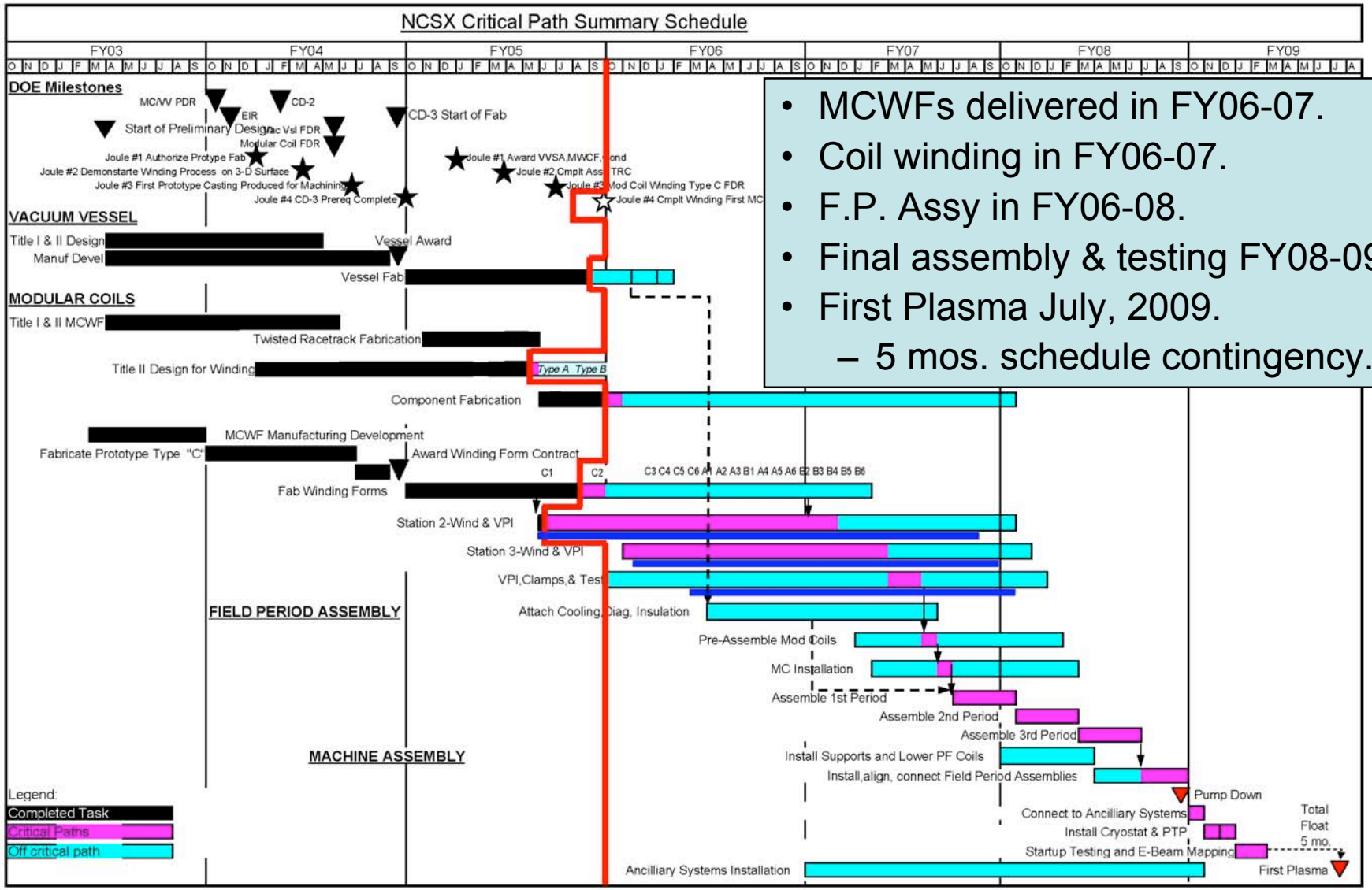
FY06 Budget: $18.9M

Planned Accomplishments

- Stellarator design: Complete Title II for VV & MC. (B. Nelson)
- MCWF: Complete at least 12. (P. Heitzenroeder)
- VVSA: Complete order. (M. Viola)
- Modular Coil Fabrication: wind 7, VPI 6 (J. Chrzanowski)
- TF Coil Fabrication: wind, VPI, and test one (J. Chrzanowski)
- Field Period Assembly: assemble 1 VV sector (T. Brown)

We Will Complete the Project by July, 2009.



- MCWFs delivered in FY06-07.
- Coil winding in FY06-07.
- F.P. Assy in FY06-08.
- Final assembly & testing FY08-09.
- First Plasma July, 2009.
  - 5 mos. schedule contingency.

R. Strykowsky

Summary

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1. MCWF and VVSA procurements support the project baseline.
2. Risk management mechanisms are working in accordance with project needs and DOE expectations.
3. Realistic plans are in place to complete the project.
   - Sound estimates, adequate contingencies supported by risk analysis.
4. In-house fabrication activities provide best value.
   - Minimize risks in highly specialized operations.
5. The Project is staffed and functioning at all levels in accordance with the PEP and DOE requirements (O413.3).