NCSX and QPS

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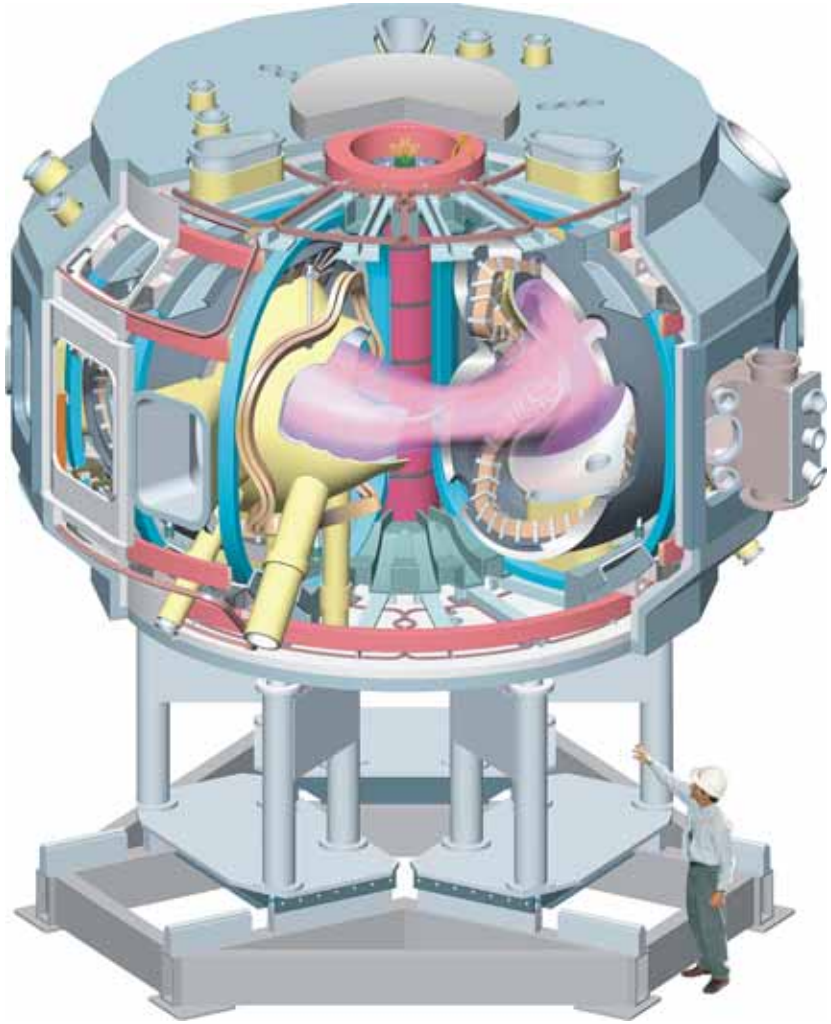
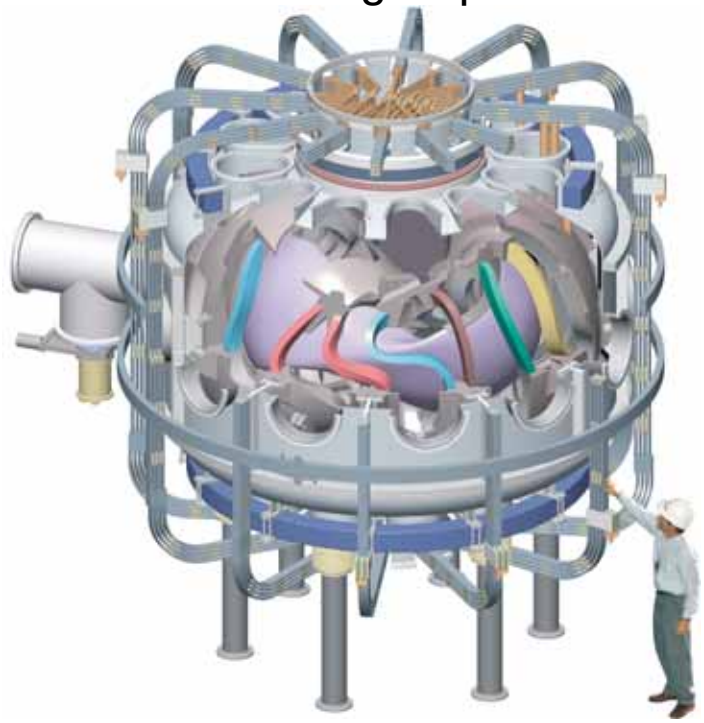
Office of Fusion Energy Sciences
FY-06 Budget Planning Meeting
March 17, 2004



Outline

- Contributions to FES program goals.
- Progress highlights
- Plans and funding requirements



NCSX (PoP)

Fabricate Components in 05-06

Begin Sub-Assembly in 06

QPS (CE)

Design and R&D in 05-06

NCSX and QPS Are Advancing OFES Configuration Optimization Goals (IPPA Goal 2)

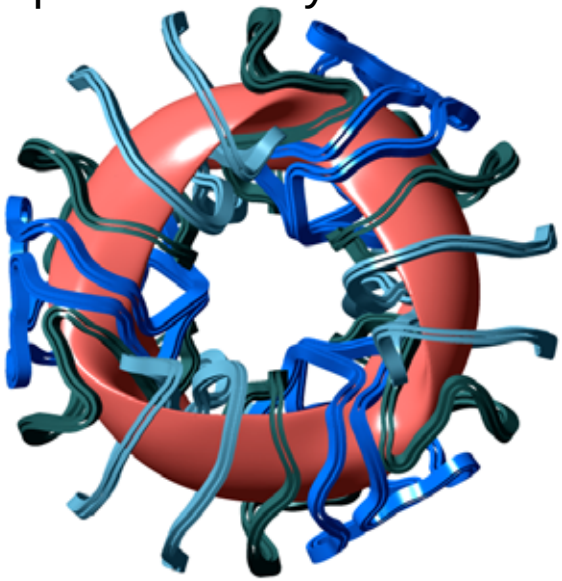
Solutions for practical MFE systems.

- Steady state with no re-circulating power for current or rotation drive.
- Passively stable without active feedback; no disruptions.
- Low aspect ratio (≤ 4.4) and high beta (≥ 4%) ⇒ high power density.

Stellarator physics benefits derive from their 3D geometry.

- More design freedom lets us design for desired plasma properties.
- Cost: more complex coil geometry.

Research: test physics, quantify benefits *vs* costs, assess overall merit.



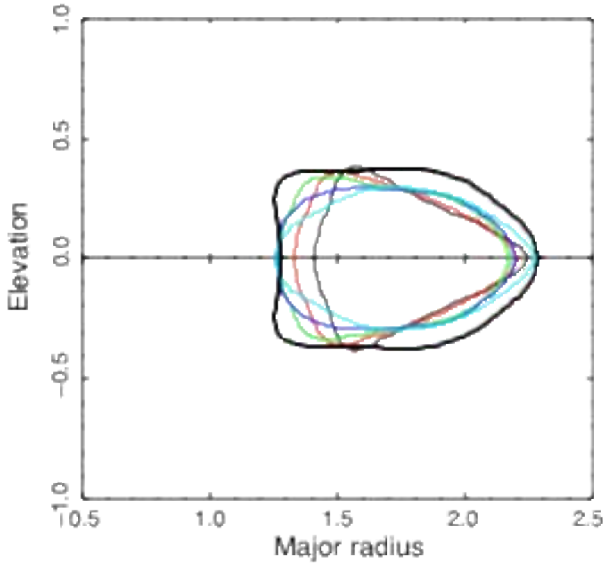
NCSX Plasma and Coils

PoP Program Goal: Determine the attractiveness of the compact stellarator as an MFE confinement concept

Compact Stellarators are Designed to Test 3D Physics

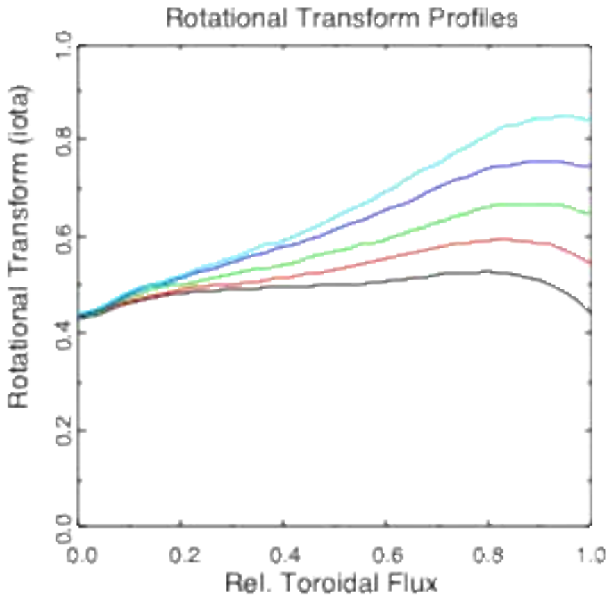
Physics-optimized magnetic configurations. For NCSX:

- Low effective ripple
- Low aspect ratio (< 4.4)
- Stellarator (or “reversed”) shear
- Kink and ballooning stable at β = 4%
- Tearing mode stable.



Flexibility to vary key configuration properties

- Ripple
- Stability β limits
- Rotational transform
- Shear (*shown at right)*
- Accommodates wide range of profiles.



NCSX and QPS Are Advancing Our Fundamental Science Goals (IPPA Goal 1)

Stellarators advance 3D plasma physics understanding important to MFE science generally, including burning plasmas.

- Rotational transform sources (int., ext.): effect on stability, disruptions?
- 3D plasma shaping: stabilize without conducting walls or feedback?
- Magnetic quasi-symmetry: tokamak-like fundamental transport properties?
- Effects of 3-D fast ion resonant modes & Alfvénic modes in 3-D?
- 3D divertors: effects on boundary plasma, plasma-material interactions?

NCSX quasi-axisymmetric design provides physics link between stellarators and axisymmetric devices: tokamaks, STs, and RFPs.

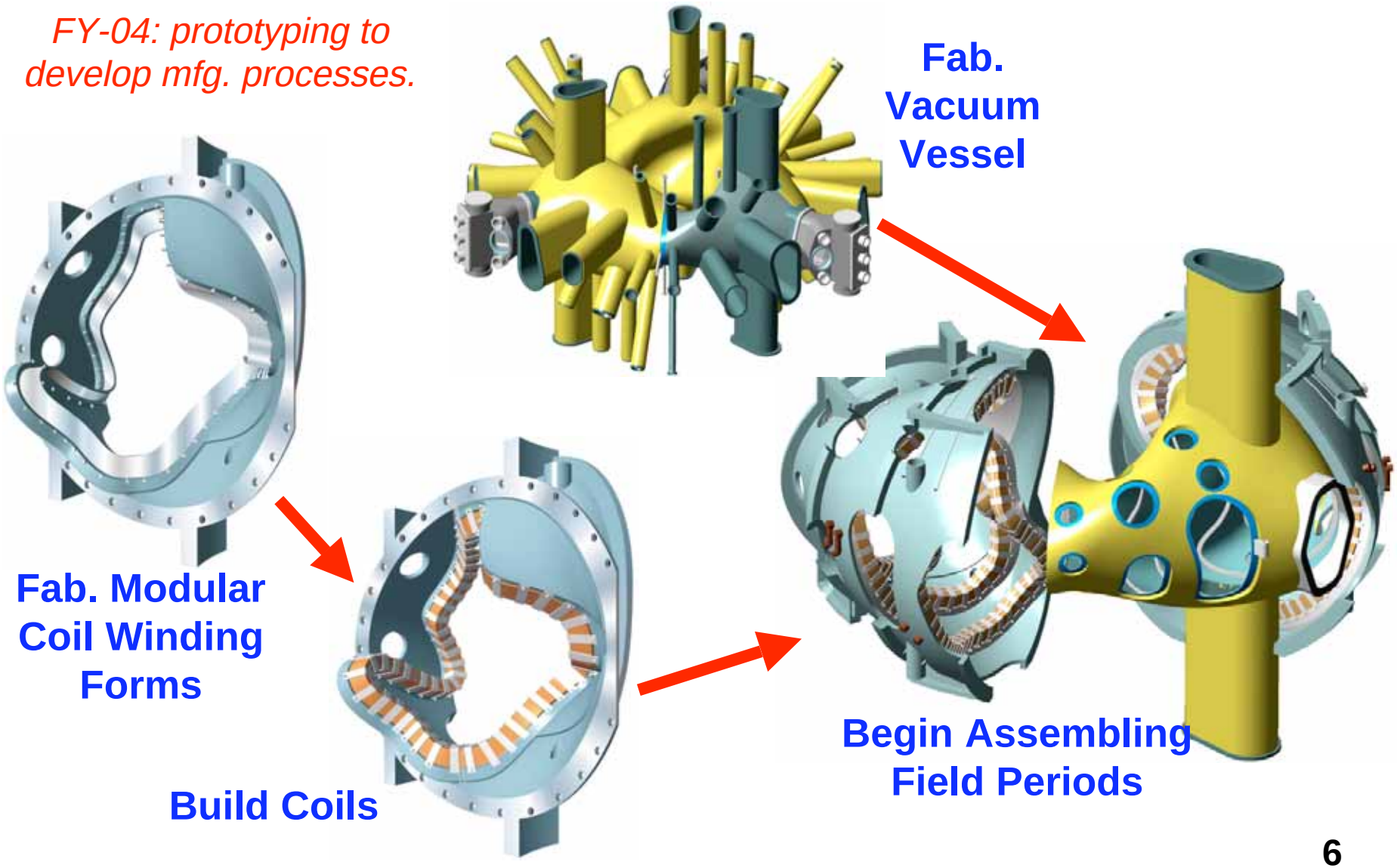
- Builds on tokamak advances, including ITER burning plasma R&D.
- Compact stellarator advances will benefit other configurations.

QPS explores quasi-poloidal optimization with some features of W-7X but at much lower aspect ratio (<3).

Timely construction of new U.S. stellarator experiments is important to minimize costs and deliver the science.

NCSX FY05-06 Plans: Fabricate Main Components, Begin Field-Period Assembly

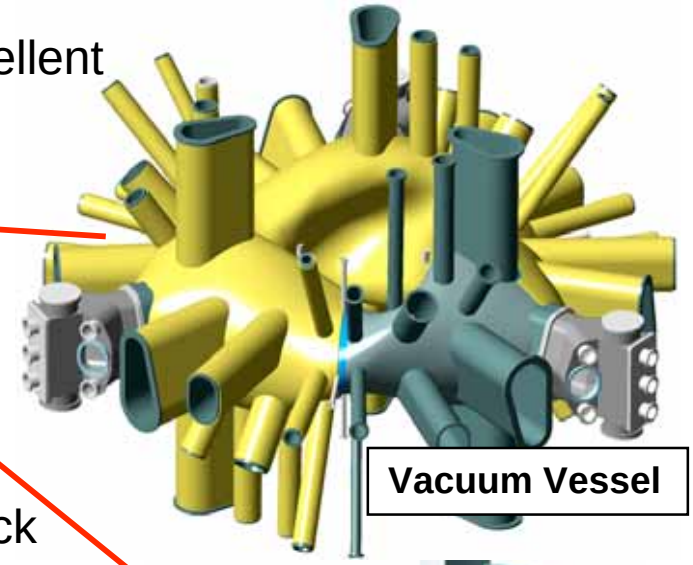
FY-04: prototyping to develop mfg. processes.



Prototyping of NCSX Components Is Going Well

- Since last BPM, contracts were awarded to excellent manufacturer teams.
  - Major Tool and Machine, Indianapolis, IN.
  - Rohwedder, Inc., Orlando, FL.
  - Energy Industries of Ohio, Cleveland, OH.
  - J.P. Pattern, Milwaukee, WI.
- Dual suppliers maintains competition and fallback options.
- They provided estimates to support project baseline.
- They are now fabricating full-scale prototypes.

Prototypes will be received and evaluated prior to awarding contracts to the successful teams.

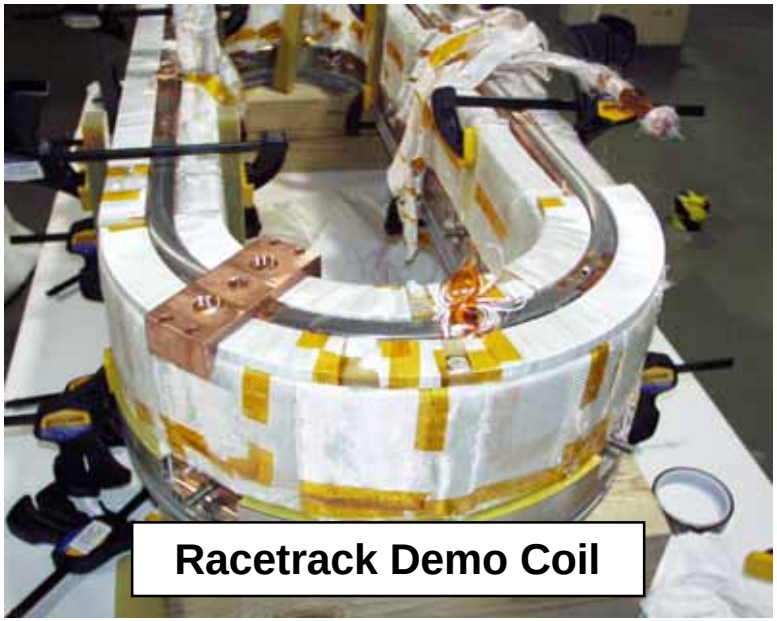


Prototyping Results to Date Are Very Positive

Winding Form Prototype
(before cleanup and machining)
MetalTek International, EIO Team

Vacuum Vessel Prototype
Major Tool and Machine, Inc.

We Are Preparing To Wind the NCSX Modular Coils at PPPL


Racetrack Demo Coil

Winding Trials on a 3D Form

Autoclave - (Vacuum Oven)

- Fabrication methods, design details, and staff capabilities are being developed with a series of increasingly difficult coils.
- Tools and fixtures are being built.
- **Full scale prototype will be wound later this year to demonstrate the entire process.**

NCSX Had Three Successful Reviews Last Fall: Design, Cost, Schedule, and Management OK!

Preliminary Design Review, Lehman Review, OECM Ext. Independent Review

All found: Project ready to be baselined.

- Plans and estimates based on mature design, sound technical basis.
- Adequate contingencies and risk mitigation plans included in budget.
- All review recommendations were addressed and incorporated in baseline.

Project baseline approved at CD-2 (February, 2004) has a good foundation.

Cost estimate increased beyond the CD-1 range ($69 - 83M) to $86.3M.

- Better understanding as a result of design and R&D, incl. manufacturer input.
- Lessons learned from past projects:
  - analysis, engineering oversight, construction support, system integration.
- Review recommendations:
  - add'l R&D & testing, 2nd winding line, VV bake to 350C, field-mapping now part of project.
- Funding stretchout.

Value improvement reductions partially offset the increases.

Annual funding is below CD-1 profile in 05; slightly higher peak in future.

Cost increase was handled by schedule stretchout. First Plasma now May, 2008.

Plan for the Rest of FY04: Begin Fabrication

Complete prototype fabrication and evaluations

- Vacuum vessel due March & April; Winding forms due in June.

Complete coil winding preparations

- Set up fabrication and test facilities in TFTR test cell.
- Build and test “twisted racetrack” sub-scale demo coil.
- Start winding full-scale prototype coil on prototype winding form.

Complete Final Design of the Winding Forms and Vacuum Vessel

- Final Design Review: May 19-20.

Begin production of Vacuum Vessel and Winding Forms

- Lehman Independent Project Review, June 8-9.
- Fixed-price proposals received by June 30.
- CD-3 approval in July.
- Award production contracts in August and September.

NCSX Plans for FY-05 and -06

Coils

- Modular coils: fabricate all 18 winding forms **(8/06)** and finish 15 coils
- Award TF contract **(4/05)** and complete 13 of 18 coils. Award PF contract **(6/06)**.

Vacuum Vessel

- Fabricate vessel and ports **(2/06)**.
- Install external attachments, e.g. magnetic loops, heating/cooling services.

Field Period Assembly

- Prepare tooling and metrology. Start building coil sub-assemblies **(9/06)**.

Power Systems

- Install support towers **(FY05)** and run new DC service from TFTR rectifiers to NCSX test cell **(FY06)**.

Ancillary Equipment

- Refurbish equipment for neutral beams, vacuum pumping, gas injection.

Test Cell Preparations

- Ready to begin machine assembly **(end of FY06)**.

Research Preparations: FY-05 and -06

Long-lead development to prepare for operation

- Assembly of NCSX research team starting in FY06.
  - NCSX research will be a National Collaboration, like NSTX
  - First research forum: mid-FY05.
- Design and begin fabrication of diagnostic upgrades
  - Start discussions at High-Temp. Diagnostics Workshop this April.
- Edge modeling; Design and begin fabrication of PFCs
- Development of discharge control strategy, analysis capabilities.
- Exploration of RF upgrades.

Plans will be discussed with NCSX PAC at next meeting (June, 2004).

NCSX Program Funding Follows CD-2 Plan

(flat in FY05)

$M	FY:	2004	2005		2006
			Base	Incr.	Base
NCSX Fabrication					
	PPPL	13.815	14.415	4.900	20.500
	ORNL	2.106	1.506	0.500	1.600
Total		15.921	15.921	5.400	22.100
NCSX Research Prep					
	PPPL	0.472	0.472		1.155*
	ORNL	0.218	0.227		0.425
	LLNL	0.080	0.080		0.120
Total		0.770	0.779		1.700
NCSX Program Total					
	PPPL	14.287	14.887	4.900	21.655*
	ORNL	2.324	1.733	0.500	2.025
	LLNL	0.080	0.080		0.120
Total		16.691	16.700	5.400	23.800

* Includes $200k for other institutions via subcontract.

$5.4M increment would restore 05 budget to the CD-1 profile.

Funding Stretchout Has Adverse Impacts

10% cut in FY-05 and -06, with respect to CD-2 plan:

- Additional 5-month delay, $1.3M cost increase *vs* CD-2 baseline.
- Prolongs critical FY05-06 fabrication tasks, increasing costs and risks.

Continued flat funding through the end of construction would cause serious problems:

- 10-month delay, $2.7M cost increase *vs* CD-2 baseline.
  TEC increases to $89M, First Plasma delayed to March, 2009.
- Severe task stretchout leads to inefficiencies and discontinuities in tasks and project personnel, increased cost and schedule risk.
- Staffing impacts at PPPL.
- **Significant delay in NCSX science results.**
  - Impacts MFE Science program, including burning plasma contributions.

QPS Since Last BPM: Advanced Conceptual Design

Lehman Conceptual Design Review (CDR) in June 2003 was positive.

- All action items and near-term recommendations have been completed.

Advanced Conceptual Design continuing.

- QPS designs and estimates have incorporated all NCSX developments.
- R&D modular coil winding form design finished; award contract by June.
  - Focus on features that differ from NCSX.
- Modifications to UT building for coil winding facility being reviewed.
- New building that will house QPS facility under construction.

All documentation for CD-1 has been submitted to DOE.

- Acquisition Strategy, Preliminary Project Execution Plan, etc.
- DOE CD-1 approval meeting scheduled for March 25.

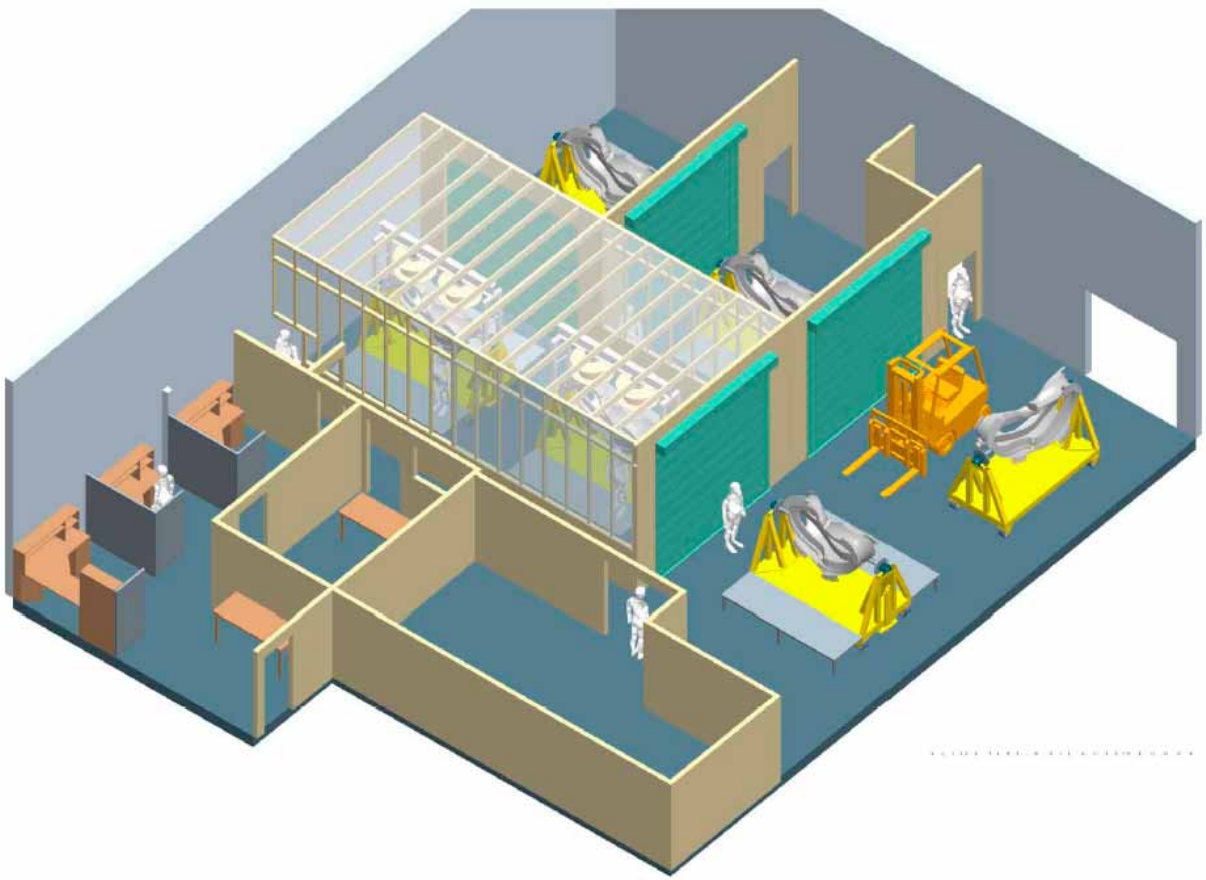
QPS Plans for FY 2005

Complete design of tooling for R&D coil fabrication -- 1/05.

Machine R&D modular coil winding form -- 6/05

- Casting to be obtained in FY 2004.

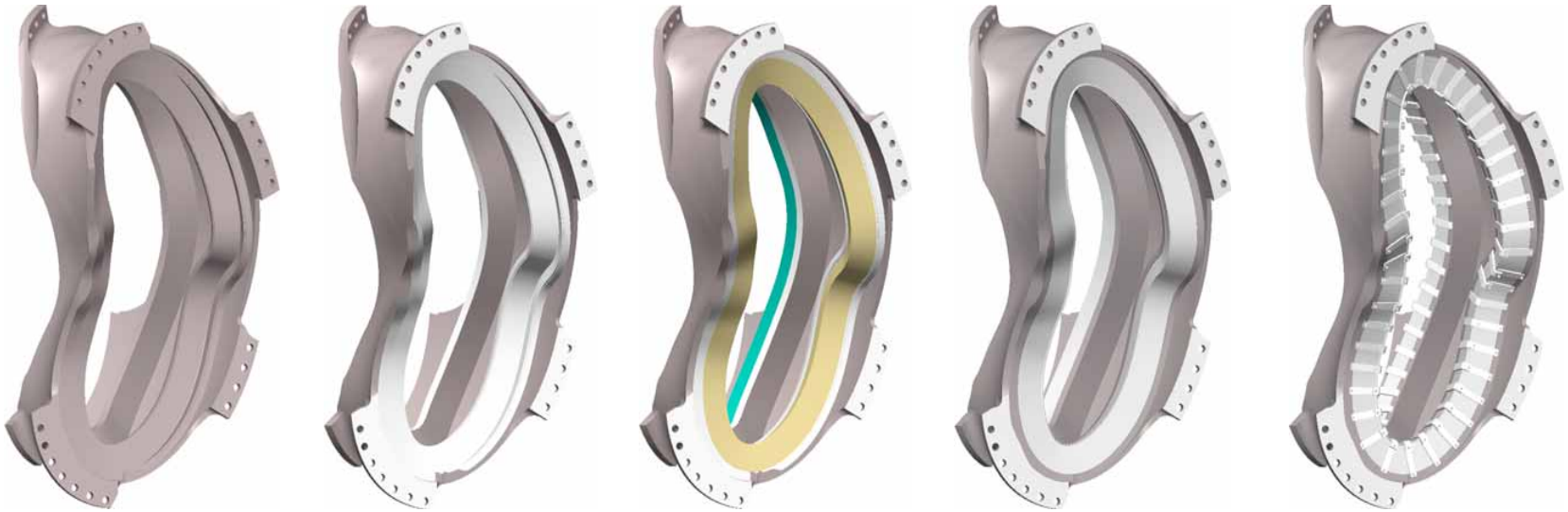
Set up facility for winding R&D coil at UT-Knoxville -- 9/05.



QPS Plans for FY 2006 Base Budget

Complete winding R&D coil -- 5/06.

Vacuum can R&D coil and impregnate with epoxy -- 9/06



Rough casting

M5

Machine winding form & flanges

Conductor wound directly into structure

"Cans" welded to structure

Clamps attached to structure

Incremental Budget in FY 2006 Allows QPS Project Start

- DOE Preliminary Design and Baseline Review and External Independent Review -- 2/06.
- Baseline approval (CD-2) -- 3/06.
- Final Design Reviews for modular coil winding forms and vacuum vessel -- 6/06.
- Complete prerequisites for CD-3 milestone -- 7/06.
- Award production contract for modular coil winding forms -- 9/06.
- First Plasma, January, 2010.

QPS Budget Scenarios

$M	FY:	2004	2005	2006	
			Base	Base	Base+ Incr.
QPS Conceptual Design, R&D, and Research					
	ORNL	0.643	0.643	0.643	0.225
	PPPL	0.300	0.300	0.300	0.075
Total		0.943	0.943	0.943	0.300
QPS MIE Project					
	ORNL				2.650
	PPPL				2.400
Total					5.050
QPS Program Total					
	ORNL	0.643	0.643	0.643	2.875
	PPPL	0.300	0.300	0.300	2.475
Total		0.943	0.943	0.943	5.350

Incremental budget required in FY 2006 to proceed with QPS project.

New Compact Stellarator Projects Are Succeeding

Technical reviews and DOE decisions have been positive.

- **NCSX: 3 successful baseline reviews, CD-2 approved.**
- **QPS: successful CDR, CD-1 board meeting scheduled for 3/25.**

NCSX is building prototypes and preparing to begin producing the main components this fiscal year.

In FY05-06, NCSX component fabrication will be largely completed and field period assembly will start.

- On track for FY-2008 First Plasma.

NCSX requests FY-05 increment to recover schedule.
QPS requests FY06 increment to start the project.

Compact stellarator program strongly supports U.S. goals and makes important contributions to world stellarator research.