NCSX Overview & Assembling the NCSX Team

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Outline

- NCSX goals, design, and mission
- Preparation of the NCSX Research Team
- Progress on fabrication

National Compact Stellarator Experiment (NCSX): Combine Best Features of Stellarators & Tokamaks

Use flexibility of 3D plasma shaping to combine best features of stellarators and tokamaks, synergistically, to advance our understanding of both

—Stellarators: *Externally-generated helical fields; steady-state compatible; robust stability, generally disruption free.*

—Tokamaks: *Excellent confinement; low aspect ratio – affordable; self-generated bootstrap current and flows*

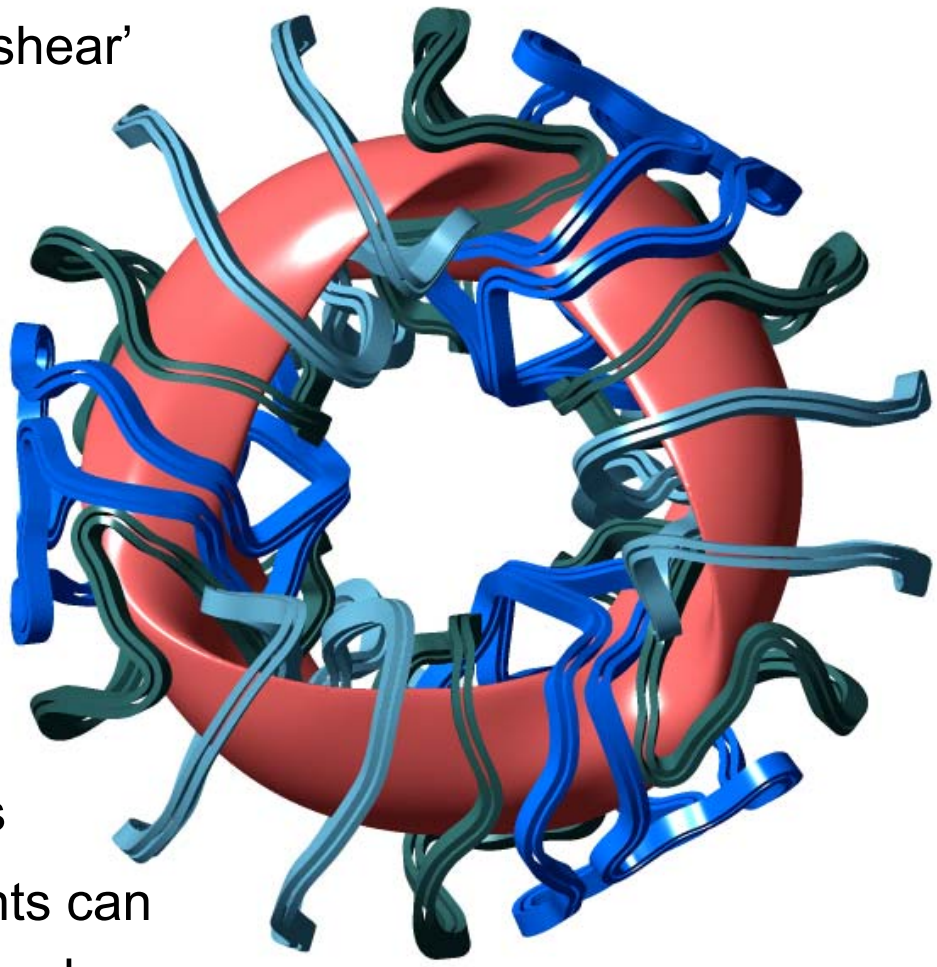
Transport Optimization: Quasi-axisymmetry

- (Boozer,1983) Orbits & collisional transport depends on variation of |B| within flux surface, not the vector components of B !
- (Nührenberg) If |B| is symmetric in flux coordinates, get confined orbits like tokamak

$\Rightarrow$ transport very similar to tokamaks, undamped rotation

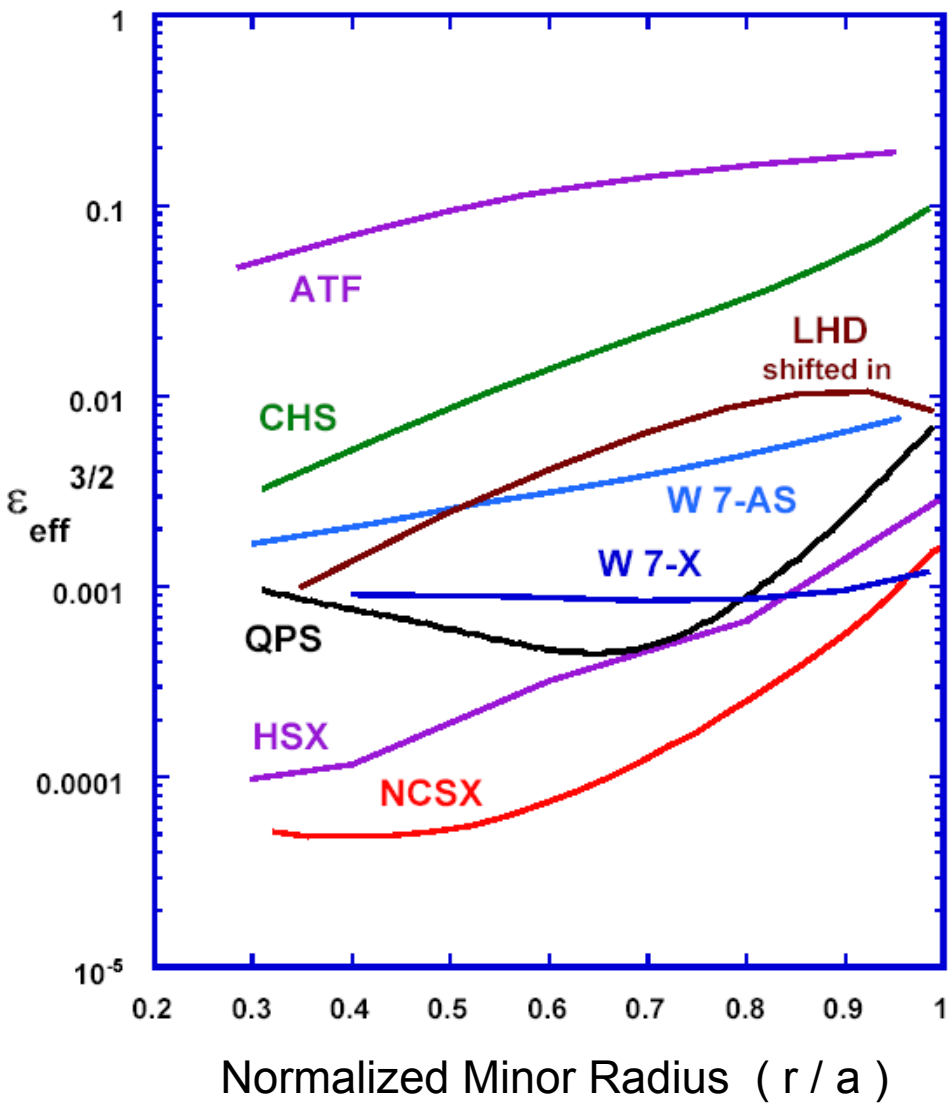
NCSX Design Has Attractive Properties

- 3 periods, $R/\langle a\rangle=4.4$, $\langle\kappa\rangle\sim1.8$, $\langle\delta\rangle\sim1$
  ¾ of transform from coils, 'reversed shear'
  no need for external current drive
- Passively stable at $\beta=4.1\%$ to kink, ballooning, vertical, Mercier, neoclassical-tearing modes
- Stable for $\beta \geq 6\%$
  by adjusting coil currents
- 18 modular-coils (3 shapes)
  Full coil set includes PF coils,
  weak TF coil for flexibility & trim coils
- Coils are flexible: by adjusting currents can control stability, transport shape: iota, shear
- Designed to have good flux surfaces at high- β



Quasi-Axisymmetric: Very Low effective ripple

- Very low effective helical ripple
  ε_{eff} ~ 1.4% at edge
  ~ 0.1% in core
- Gives low flow-damping
  allow manipulation of flows for flow-shear stabilization, control of E_r
- Allows balanced-NBI
  24% loss at 1.2T, drops as B↑
- Reversed shear helps stabilize turbulent transport, via drift precession reversal



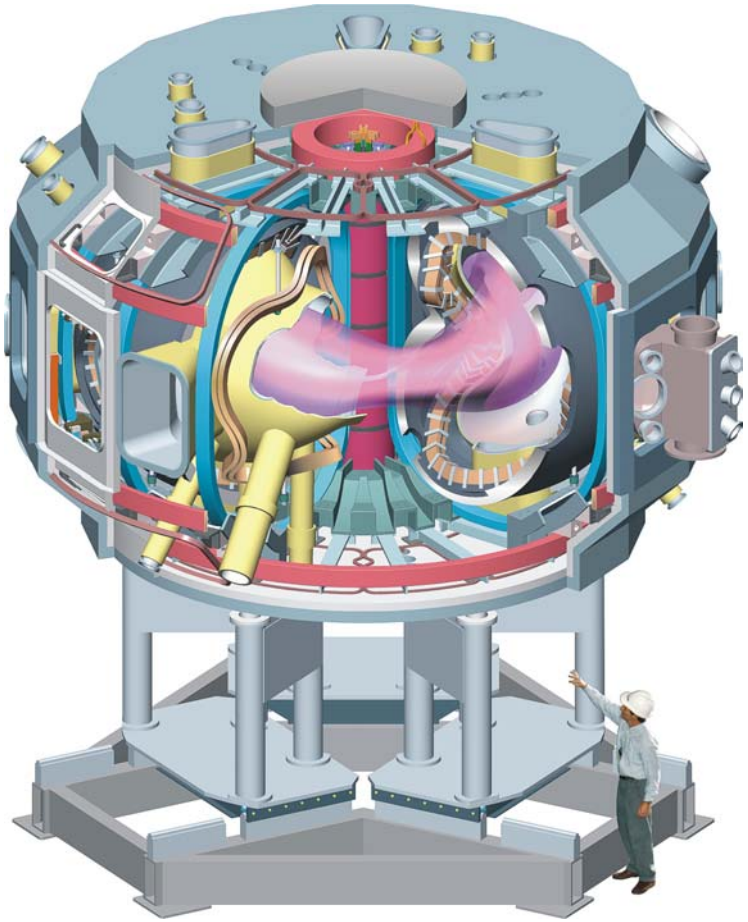
NCSX will be a Flexible Experiment

- Wide range of 3D shaping flexibility, for control of physics properties
- B $\leq$ 2 T

- NBI power up to 6MW (1.5MW initial)
- ICRF power up to 6MW
- ECH power up to 3MW

- Full set of diagnostics planned

- Robust divertor configuration, using flux expansion in elongated cross-section



NCSX Research Mission

Acquire the physics data needed to assess the attractiveness of compact stellarators; advance understanding of 3D fusion science.
(FESAC-99 Goal)

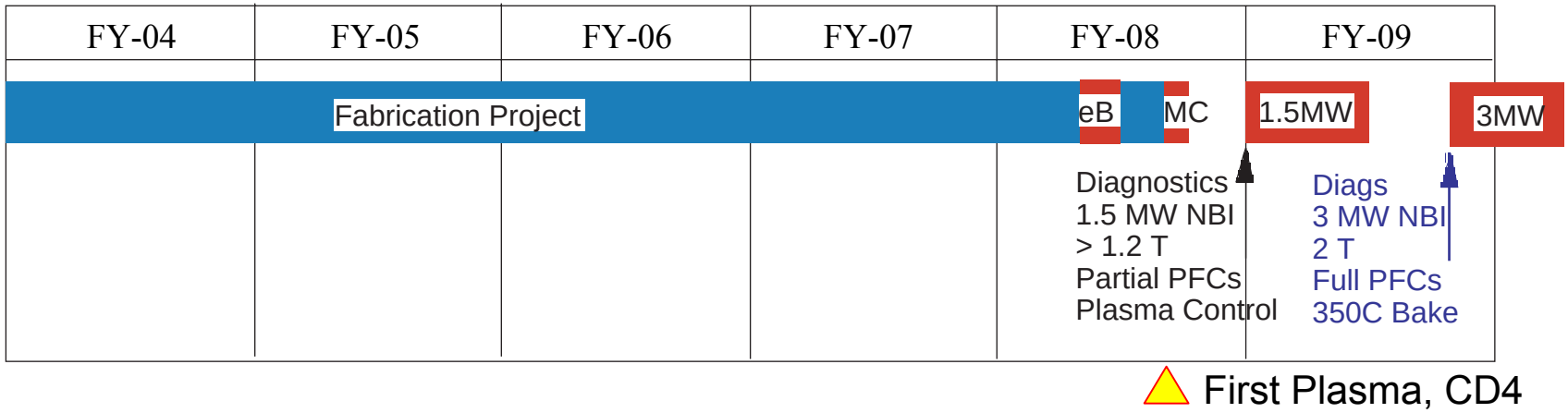
Understand…

- Pressure limits and limiting mechanisms in a low-A current carrying stellarator
- Effect of 3D magnetic fields on disruptions
- Reduction of neoclassical transport by quasi-axisymmetric design.
- Confinement scaling; reduction of turbulent transport by flow shear control.
- Equilibrium islands and tearing-mode stabilization by design of magnetic shear.
- Compatibility between power and particle exhaust methods and good core performance in a compact stellarator.
- Energetic-ion stability in compact stellarators

Demonstrate…

- Conditions for high-β disruption-free operation
- High pressure, good confinement, compatible with steady state

NCSX Research will proceed in Phases



- Initial Plasma and field mapping
  - Engineering measurements and tests.
- Magnetic Configuration mapping
  - Characterize magnetic field for research.
- 1.5MW Initial Experiments
  - Global confinement scaling, with and without current; Density limits; Plasma evolution
  - Effect of low-order rational surfaces; vertical and current-driven mode stability
  - Initial plasma-wall interaction
- 3MW Heating
  - Control of shape during evolution
  - Moderate pressure tests of stability; effect of 3D fields on disruptions
  - Confinement scaling; local transport; rot. damping; effects of trim coils; enhanced conf.
  - Effect of plasma on surface quality; neoclassical tearing
  - Wall coatings; characterization of wall interaction; attempts to control influx

Preparation of NCSX Research Team

NCSX will be operated as a National Collaboration, including members from many institutions

Plan to start Research Forums in FY2005/06 to

- Identify groups interested in developing needed diagnostics
- Nucleate the research team
- Develop detailed research plans and responsibilities
- Similar to NSTX

Expect call for first round of diagnostic proposals in FY06

- For funding starting in FY06/07
- Additional calls for diagnostic and participation proposals in FY07 and FY08

For more details see:

- B. Stratton: Diagnostic Opportunities on NCSX
- D. Johnson: Poster G08, Thursday morning

NCSX Project Has Started

- ✓ NCSX Fabrication Project Approved and Started in 2003
- ✓ Contracts for prototype coil-forms and vessel segments begun
- ✓ Preliminary Design Review – Oct. 2003
- ✓ Preliminary Baseline and External Independent Reviews – Nov.2003
- Final Design Review – May 2004
- First Coil – 2005
- First Plasma – 2008
- NB-heating – 2008

Other Preparation Activities:

Diagnostic planning

Discharge evolution simulation

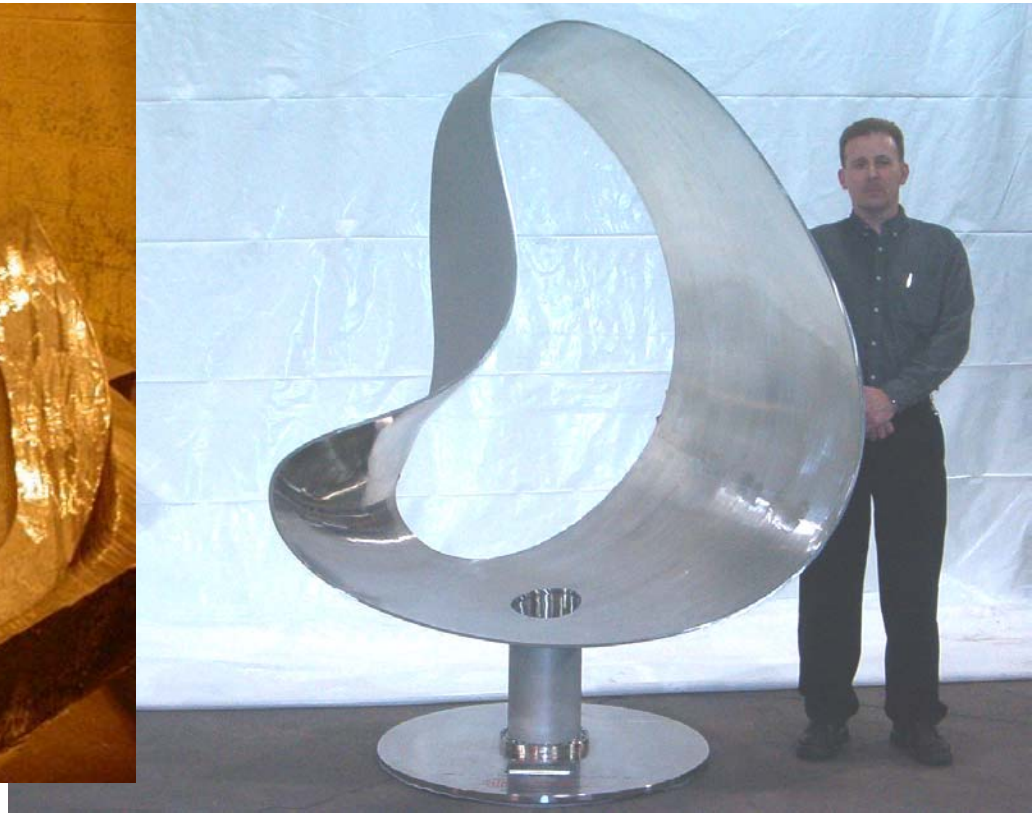
Equilibrium reconstruction

Edge modeling – PFC design

Prototypes are Being Constructed

Casting for Full-size coil winding form and support structure

Energy Industries of Ohio



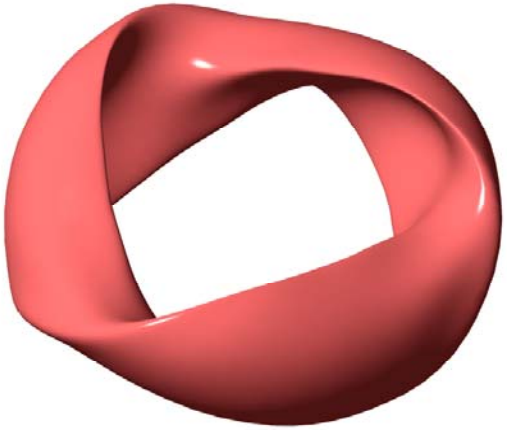
Full-size vacuum vessel segment

Major Tool, Indianapolis

- 2nd vendor for each
- Prototypes will be delivered this spring for testing and assembly studies
- Production contracts late this summer

Conclusions

- NCSX is an exciting opportunity for unique fusion-science research.
  - Stabilize high-β instabilities with 3D shaping with $\beta > 4\%$
  - High no-wall β-limit without driven currents
  - Tokamak-like transport using quasi-axisymmetry.
  - Low ripple-transport, low rotation damping
  - Flexible coil system

- NCSX provides opportunities for new diagnostics and collaborations.
  - First research forum in FY05 to start forming collaborative Research Team
  - First call for diagnostic proposals in FY06.

- NCSX Fabrication Project has started!
  - Prototyping underway
  - Final design reviews, May 2004
  - First plasma: 2008