NCSX Research Program Plan and Estimates

M.C. Zarnstorff

NCSX Research Preparation

For Princeton Plasma Physics Laboratory

& Oak Ridge National Laboratory

Office of Science Project Review of NCSX

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Overview

5. What is the planning level cost and schedule estimate that will be required for the NCSX project to perform Phase III (which includes implementation of all scope that was removed after CD 2) research activities?

- MIE project will supply core capability to confine plasma with stellarator fields
- As with previous experiments, this core capability will be augmented for fusion research
  - diagnostics
  - heating systems
  - full control system
  - full power supply system
- NCSX Mission and Goals are unchanged since CD-2
- Plan accomplishes High Priority Goals through Phase 3 (3MW heating) by end of FY13.

NCSX Research Mission - Unchanged

Acquire the physics data needed to assess the attractiveness of compact stellarators for fusion energy; advance understanding of 3D fusion science.

(FESAC-99 Goal)

Understand…

- Pressure limits and limiting mechanisms in a low-aspect-ratio optimized stellarator
- Effect of 3D magnetic fields on disruptions
- Reduction of collisional and anomalous 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 and confinement in compact stellarators

Demonstrate…

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

NCSX: Develop Understanding and Basis for ARIES-CS: a Competitive, Attractive Reactor

Reference parameters for baseline:

$\langle R \rangle$ = 7.75 m

$\langle a \rangle$ = 1.72 m

$\langle n \rangle = 4.0 \times 10^{20}$ m^{-3}

$\langle T \rangle$ = 6.6 keV

$\langle B \rangle_{axis}$ = 5.7 T

$\langle \beta \rangle$ = 6.4%

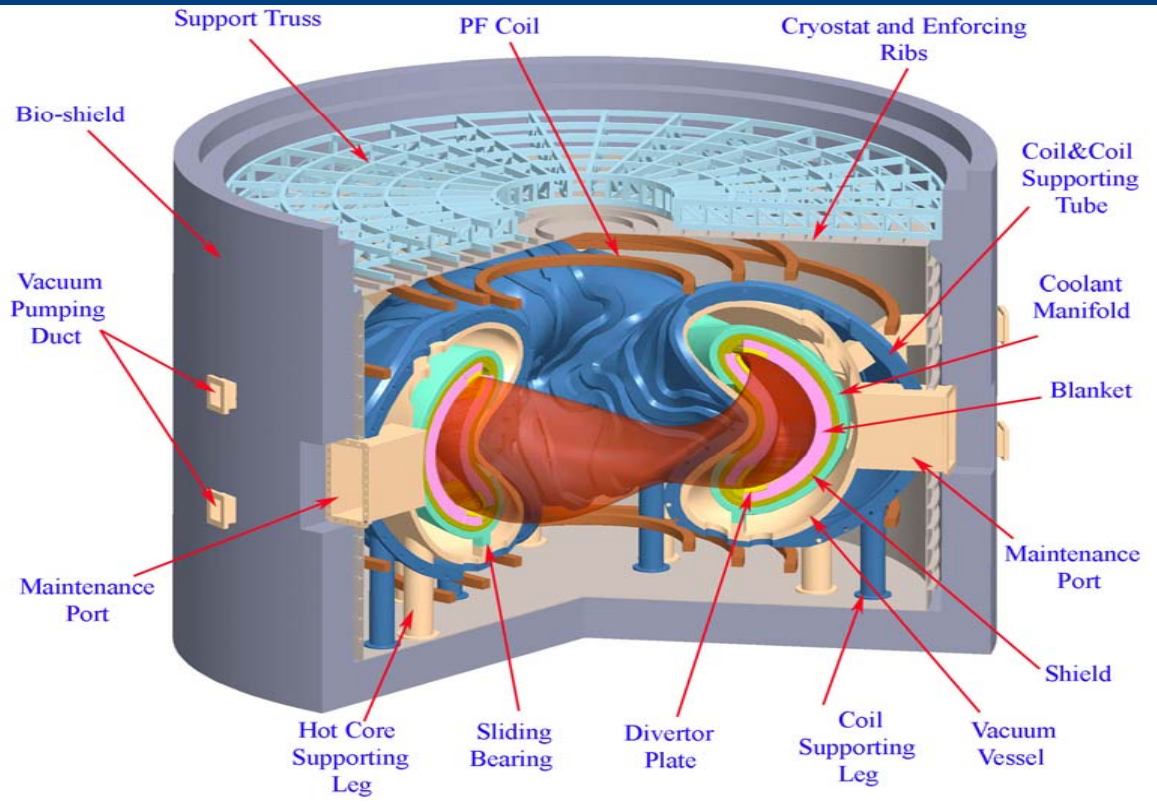
H(ISS95) = 2.0

H(ISS04) = 1.1

I_{plasma} = 3.5 MA (bootstrap)

P(fusion) = 2.364 GW

P(electric) = 1 GW

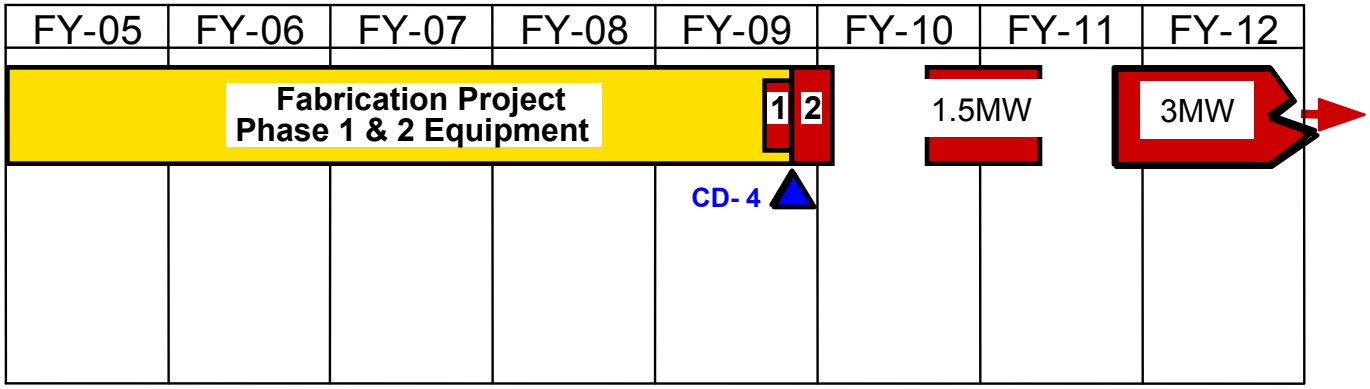


Aries-	-I	-RS	-CS	-AT	-CS
Blanket			LiPb/FS	LiPb/SiC	LiPb/SiC
COE(92)	99.7	75.8	61.3	47.5	48.

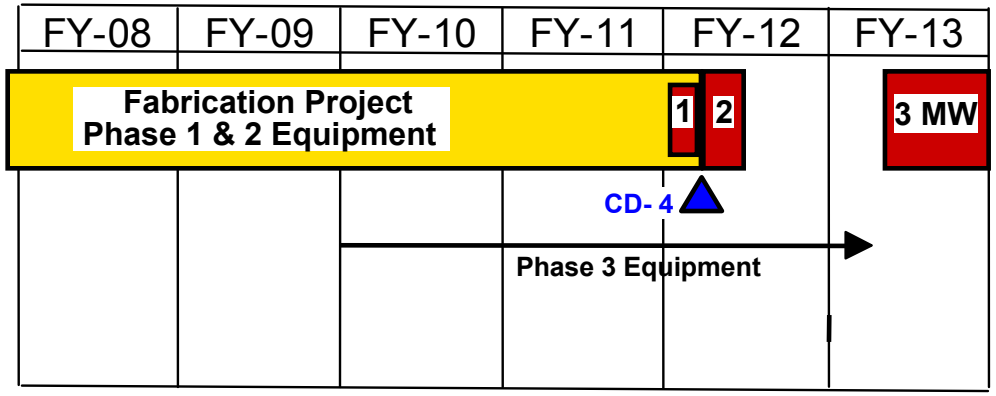
Based on NCSX design

Current Plan Accomplishes Phase 3 in FY-13

2005 Baseline Plan



2007 Plan



Phases:
1. Initial checkout
2. Magnetic configuration studies
3. Initial Heating Experiments (3 MW)

- Change in 2006 : merge 1.5MW and 3MW run in Phase 3

Plan uses FY10 - FY12 Funding to Operate and Prepare for Phase 3 Run in FY13

	FY-10	FY-11	FY-12	FY-13
NCSX Program Total	**19.3**	**19.3**	**19.3**	**45.0**
MIE Project	**17.0**	**6.7**		
Non-MIE	**2.3**	**12.6**	**19.3**	**45.0**
Physics	0.7	1.4	2.6	16.0
Facility Operations	0.5	1.6	2.8	14.7
Facility Upgrades	1.1	8.3	11.3	9.2
Diagnostic Upgrades		1.3	2.6	5.1

National Budgets

As spent $M
assumes inflation:
3.4% on labor
2.5% on non-labor

FY10 - FY12 funding covers

- Operation and Research for Phase 2: Magnetic Configuration studies
- Design and implementation of upgrades (diagnostic and facility) to accomplish phase 3 goals in FY13

FY13 budget assumes constant buying power of NSTX+NCSX, from FY09. Covers

- Completion and commissioning of upgrades
  Total cost of Phase 3 upgrades: $34.4M
- Operation and Research for Phase 3: Initial Heating Studies
- Long-lead preparations of upgrades for FY-15 run ($4.5M for ECH, NB 3&4, diags).

FY13: NSTX is down for maintenance and upgrades. Researchers shift to NCSX.

Upgrades and Research led by PPPL-ORNL partnership. Approximately 1/3 of research conducted by collaborators (as on NSTX).

Phase 2. Magnetic Configuration Mapping Goals for FY12

- Understand vacuum flux surface characteristics
  - Particularly low-order resonant perturbations
  - Look at effects of all coils
- Document control of vacuum field characteristics using coil current
- Understand and model field structure from as-built coils
  - Basis for understanding field equilibrium with plasma

Reviewed at PAC meetings, Research Forum.

Phase 3. Initial Heating Experiments: Scientific Goals for FY13

Prioritized

(1) A. Effect of quasi-axisymmetry on plasma global confinement. Comparison of confinement with stellarator and tokamak scalings.

(1) B. Effect of 3D equilibrium on SOL characteristics and contact footprint

(2) C. Effect of quasi-axisymmetry on flow damping

(2) D. Does pressure-driven MHD activity limit (e.g. disruptions)

(3) E. Magnetic equilibrium reconstruction in NCSX with pressure or current

(3) F. Comparison of measured and calculated MHD stability threshold

(3) G. Does current-driven MHD activity limit pressure (e.g. disruptions)

(3) H. Occurrence of pressure driven flux-surface islands vs iota and shear

Reviewed at PAC meetings, Research Forum.

NCSX Diagnostic Upgrades for FY13 Phase 3

Initial diagnostic upgrades

- In-vessel magnetic diagnostics + instrument external magnetics diags.
- Thomson scattering (n_e, T_e profiles)
- Imaging x-ray crystal spectrometer (v_ϕ, T_i profiles)
- UV spectrometer
- PFC-mounted probes
- Filtered 1D and 2D cameras. Filterscopes.
- IR cameras
- SXR camera
- Interferometer
- Bolometer array

Black: shared w/ NSTX

Collaborations on diagnostics are expected and being discussed.
Diagnostic upgrading will continue throughout the Research Program.

Diagnostic Upgrades Estimates for Phase 3

	Design/ Procure	Fabricate/ Install	Commission	Total
Magnetics	1.32	0.62	0.17	2.11
Thomson scattering	1.97	0.75	0.16	2.89
Imaging x-ray crystal spectr.		0.93	0.06	0.99
UV spectrometer	0.05	0.08	0.02	0.14
PFC-probes	0.02	0.04	0.04	0.10
Filtered cameras, Filterscopes	0.03	0.44	0	0.47
IR cameras	0.03	0.06	0.02	0.11
SXR Camera		0.25	0.03	0.28
Interferometer	0.16	0.21	0.07	0.43
Bolometer	0.06	0.07	0.01	0.14

Phase 3 total: 7.67

National Budgets

As spent $M

Black: shared w/ NSTX

- Pre-CDR estimates, “planning level”. Includes 30% contingency
- Estimates based on actual costs on existing systems (NSTX & others)
- Reviewed by NSTX engineers and planning & control officer

FY10-12: Equipment Upgrades for FY13

Major elements:

Black: shared w/ NSTX

- Data acquisition and control systems
  - acquisition of diagnostics, data infrastructure
  - diagnostic control; initial plasma feedback control

  Plan: PC-based acquisition; MDS+ organized similar to NSTX

- Heating systems
  - 3MW NBI refurbishment and installation (co- & ctr-)

- Plasma facing components and NB armor
  - partial liner inside vacuum vessel (~1/3 coverage)
  - wall conditioning & boronization

- Power systems (supporting 1.2T operation)
  - Modular coils, TF and OH powered from D-site, PF coils from C-site
  - Merged C/D-site interlocks and controls
  - Power for diagnostics

Facility Upgrade Estimates for Phase 3

	Design/ Procure	Fabricate/ Install	Commission	Total
PFCs & NB armor	2.05	1.90		3.95
Port adaptors	0.05	0.85		0.90
Gas fueling systems	0.15	0.21		0.36
Torus pumping system	0.28	0.46		0.74
Glow DC / Boronization	0.04	0.21		0.25
NB#1	0.67	1.00	0.58	2.25
NB#2	0.59	0.85	0.58	2.02
Auxiliary AC Power	0.22	0.22	0.12	0.57
Two trim coils		0.15		0.15
Coil Power systems	0.79	2.29	0.70	3.77
Interlocks	0.47	0.41	0.11	0.98
Cable Runs (D-site to C-site)	0.87	3.47	0.12	4.47
R/T Controls, coil protection	0.73	0.31	0.15	1.20
Ground fault monitor	0.28	0.15	0.01	0.45
Electrical system support & testing	1.03	0.47	0.31	1.81
Central Instrumentation & control		2.11		2.11
Control Room		0.39		0.39
Water cooling systems		0.66		0.66

National Budgets

As spent $M

- Pre-CDR estimates
- Includes 30% contingency

Phase 3 total: 27.0

- Estimates based on actual costs on NSTX, PBX, previous use of equipment.

Status of Upgrade Estimates

- Jobs have varying design maturity
  - Some jobs at CDR level or beyond: Central I&C at CDR level, D to C-site Cabling at PDR level
  - Some jobs refurbish/reconfigure existing equipment (NB, coil power systems, shared diagnostics)
  - Some jobs duplicate existing designs (magnetics, gas injection, trim coils)
  - Many routine jobs (AC power, water, interlocks, pumping, port adaptors)
  - Only PFC & NB-armor job and in-vessel magnetic diagnostics are sensitive to the stellarator geometry.

- 30% contingency on all upgrades
- Ongoing efforts to finalize physics requirements for PFCs and in-vessel magnetic diagnostics
- Plan to develop designs in FY08-FY09, as funding allows, working together with OFES.

FY13 Capability Compared to CD4 Scope in CD2 Plan

	CD2 Plan	Current Plan for FY13	
Neutral beams	One beam refurbished, Not installed	Two beams refurbished and installed	
Magnet power supplies	6 D-site circuits	6 D-site circuits, 2 C-site circuits: all coils powered	
Central solenoid coils	6 coils (PF1-3)	2 longer coils (PF1a),	Sufficient for Ph.3 May be permanent.
Vacuum systems	2 turbo-pumps	2 turbo-pumps	
Gas Injectors	3 locations	3 locations	
Central Instrumentation and Controls	Ready for phase 3	Ready for phase 3	
Magnetic diagnostics	8 instrumented	> 100 instrumented	
Trim coils	18 trim coils	4 trim coils for n=1, 2 modes	Analysis: n=1,2 are the important field errors

Summary

- NCSX Mission and Research Goals (by operating phase) have not changed
  - Plan targets high priority Phase 3 goals in FY13
- MIE project will supply core stellarator confinement facility
- Upgrades are planned and budgeted for FY10 - FY13 to accomplish Phase 3 Research Goals
  - Diagnostics
  - Heating systems
  - Control and data acquisition
  - Plasma facing components
  - Power systems

  Total Cost of upgrades for Phase 3: $34.4M