

NSTX Project Status and Plan

Masayuki Ono
For the NSTX Team



Los Alamos
NATIONAL LABORATORY



ornl



UCLA

UCSD



NSTX Research Forum
Jan. 31 – Feb. 2, 2000

NSTX Project Update Outline



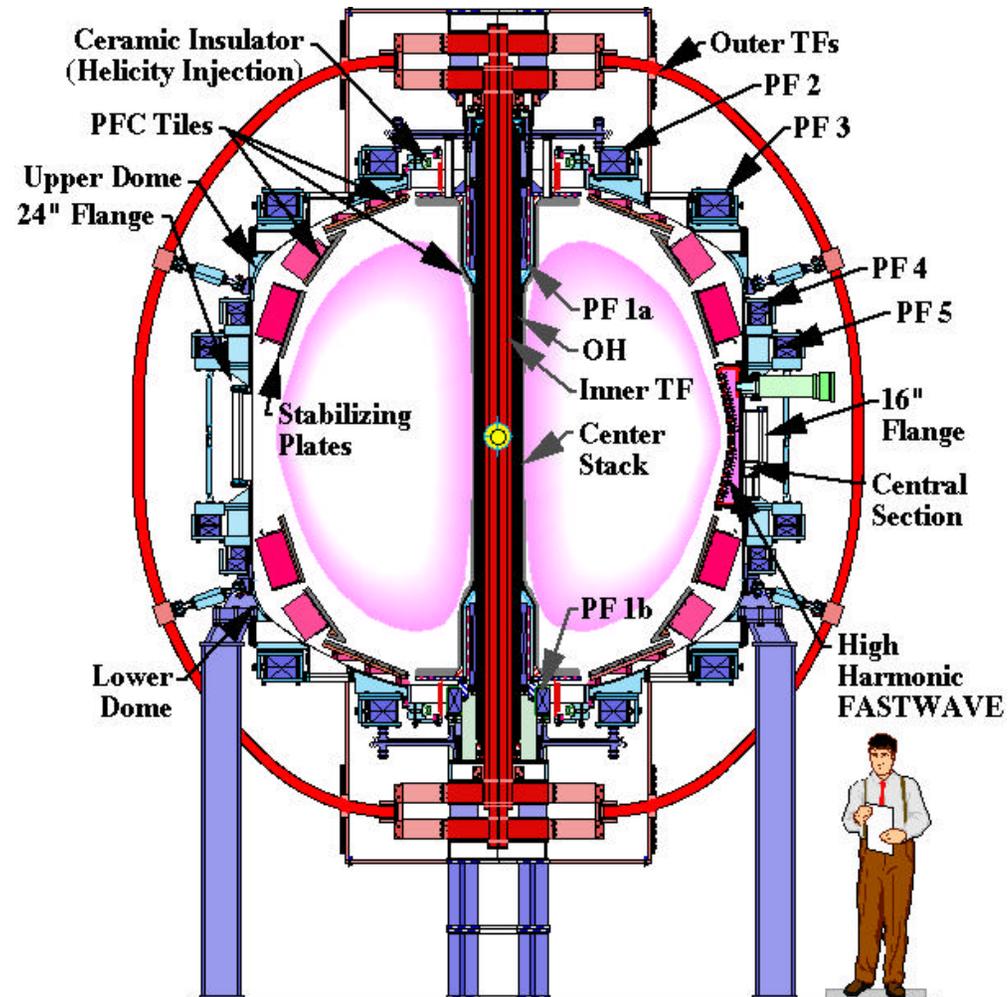
- NSTX Facility Update
- Highlights of Research Operation
- Status of “Tool” Development
 - HHFW
 - CHI
 - Diagnostics
 - NBI Upgrade
- 2000 NBI Outage Schedule
- Draft Operations/Upgrade Plan
- Project Summary

Successful Completion of Construction Project

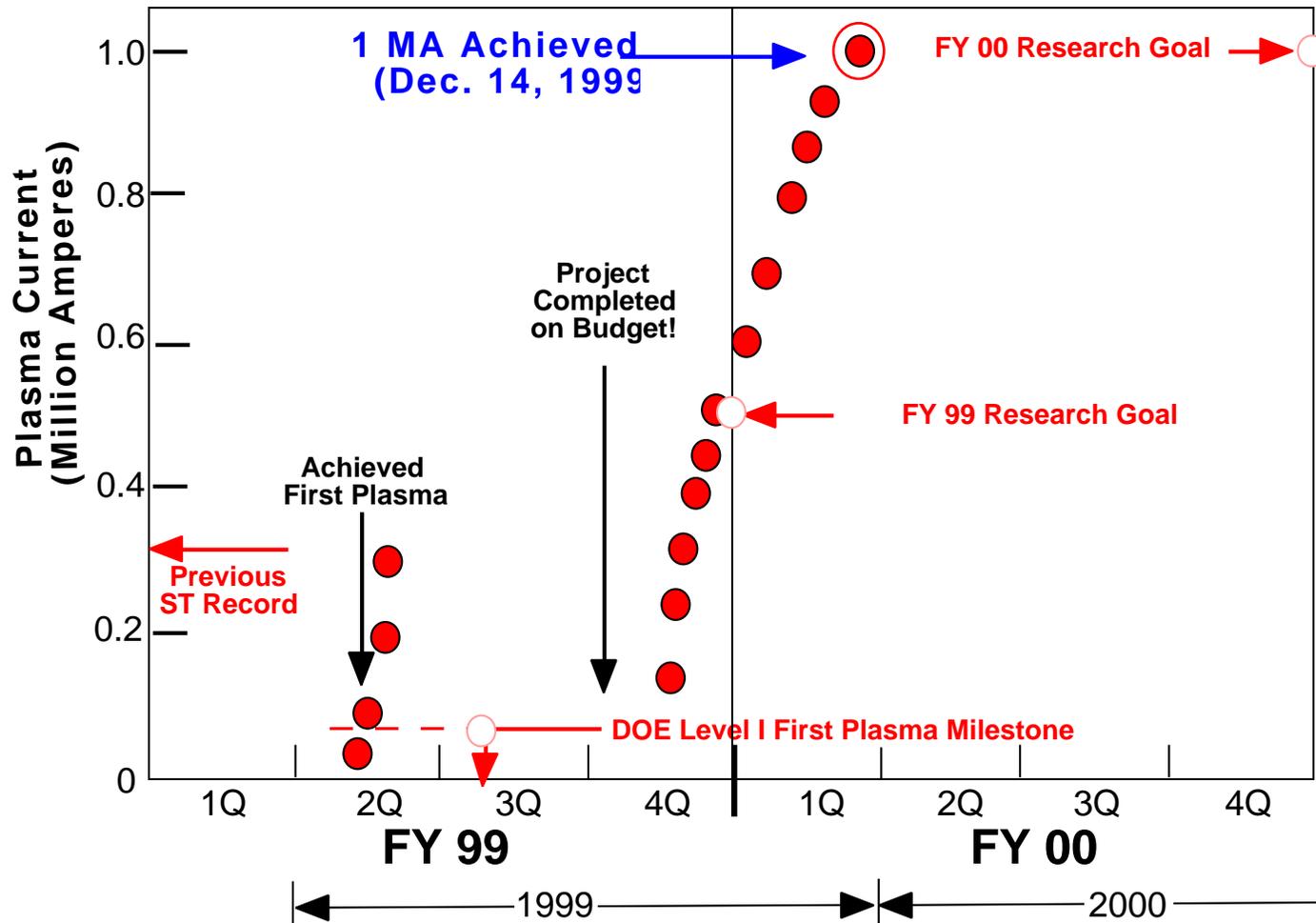


- First Plasma “Flash” Achieved on the last day of PAC 6 (2/12/99)
- **First Plasma Milestone (50 kA) Achieved (2/15/99)**
- 300 kA plasma achieved with about 1/3 OH flux (2/16/99)
- Secretary Richardson dedicated NSTX (2/25/99)
- NSTX received the NJ Governor’s 1998 Safety and Health Award(5/99)
- HHFW antenna installed (7/7)
- **All the TPC tasks completed on budget as defined in MOU (7/8)**
- Center stack reinstalled (7/16)
- Vacuum pump down started and leak checked (7/20)
- Power supply dummy load test completed (7/30)
- Good progress in ET1, 2, & 3 and Diagnostics!

NSTX Device Cross Section



One Million Amperes Achieved on NSTX!

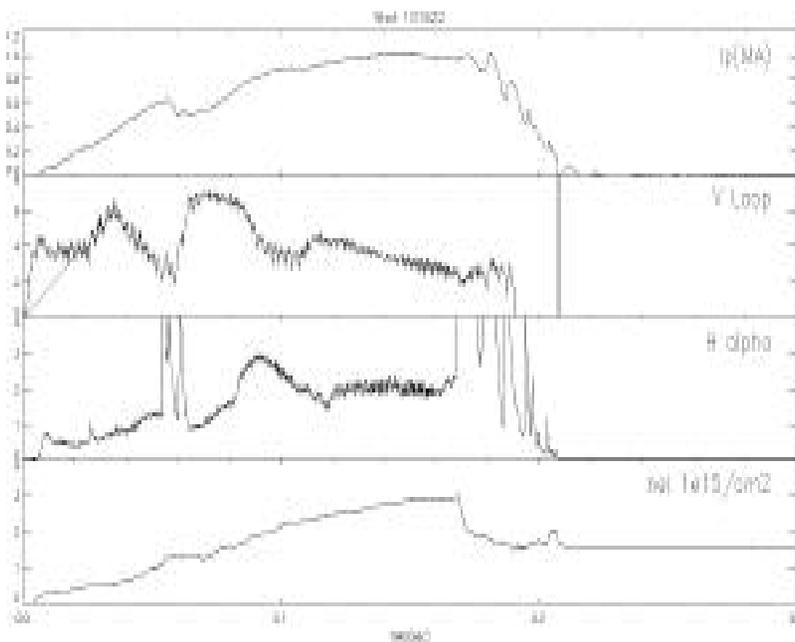


ET1: OH Optimization Status



- Highly successful ET! (R. Bell, S. Sabbagh)
- 500 kA (FY 99 Milestone) discharges obtained in Sept. 1999.
- 1 MA (FY 00 Milestone) discharges obtained on Dec. 14, 1999.
- Ohmic efficiency appears to be good with the Ejima factor of 0.4. (J. Menard)
- Real-Time Plasma Control working for the plasma current and position control. (D. Gates)
- Between-shots EFIT Reconstruction is working well (S. Sabbagh) along with the LANL Fast Camera (R. Maqueda).
- Plasmas with variety of shapes obtained.
 - Elongations up to 2.4, triangularity up to 0.6.
 - Inner limited, double-null, and single-null discharges.
 - Stored energy, plasma beta, and confinement time goes up with plasma density and plasma current. (S. Sabbagh)
 - Density limit thus far consistent with Murakami-Hugill limit. (S. Kaye)
- MHD activities sensitive on the discharge conditions.

ACHIEVED 1 MA MILESTONE



- 1 MA Ohmic Plasma Current reached even with some “hesitation”.
- Position controlled in feedback mode
- Stored energy and plasma beta go up nicely with plasma current.

Facility Availability Improving



	FY 00 Plan	FY 00 To Date
Run Weeks	14	9
Run Days	56	42
# Shots	*	1125

- NSTX Torus Facility is performing close to the original specification
 - TF Coils operated routinely at 3 kG. 6 kG operation will start in the summer of 00.
 - All PF Coils were tested to full rating of 20 kA.
 - OH operated routinely at full rating with +, - 24 kA at 6 kV.
 - GDC worked reliably including the between-shots He GDC. (H. Kugel)
 - Bakeout system brought Center Stack tiles to 300 °C and VV to 150 °C.
 - EPICS Engineering Control System, MDS-PLUS Data Acquisition System and Real-time Plasma Control System are working well.
 -

- Good progress in Research Operations (J. Hosea) and XP Implementations (M. Bell).

ET2: High Harmonic Fast Wave

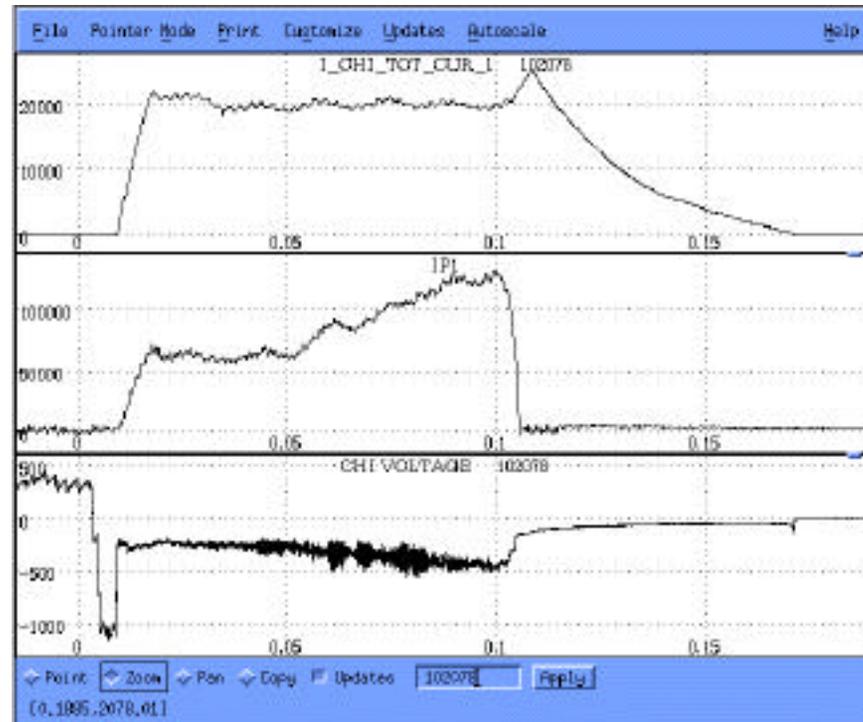
(HHFW: J. R. Wilson, D. Swain)



- Larger than anticipated loading observed – some parasitic loading? (D. Swain/P. Ryan)
- Plasma edge physics is important for good wave excitation.
- Good antenna plasma matching achieved with 8 antennas and two transmitters.
- 2 MW RF power injection milestone achieved. (J. R. Wilson)
- Modulation experiment shows sign of antenna phase dependent electron heating from the Johns Hopkins' soft x-ray diagnostic. (D. Stutman)
- ORNL Edge Reflectometry successfully implemented. (J. Wilgen)
- 12 antenna – 6 transmitter configuration to be implemented during the outage. (J. R. Wilson)

ET3: Coaxial Helicity Injection

(CHI: R Raman, D. Mueller)



- Up to 130 kA plasma discharges obtained with 20 kA CHI injection, current multiplication of 6-7. (R. Raman) Closed flux surfaces appearing? (M. Schaffer)
- The CHI ceramic insulators worked well.
- 50 kA Injection (to achieve 200 kA milestone) for the summer run. (R. Raman)

DIAGNOSTICS STATUS

(R. KAITA)



- Many diagnostics are becoming available:
 - LANL Fast Visible Camera is routinely working. (Diagnostic Work Horse of 1999!)
 - Rogowski Coils worked well (recently calibrated)
 - Flux Loops have been reliable.
 - B Coils worked 60% level (“Failed” coils increased with operation.)
 - 2 mm Interferometer is working. (Fringe skip can be improved?)
 - Slow Visible Camera is operational.
 - Johns Hopkins Ultra-Soft X-ray Diagnostics arrays are operational.
 - Tangential Bolometer Array is operational.
 - PHA Te diagnostic is being commissioned. Some initial results obtained.
 - VIPS is working.
 - SPRED needs a cable repair.
 - Reflectometers (ORNL, UCLA) are beginning to work.
 - IR (Infrared) Cameras need replacement.

UPGRADE DIAGNOSTIC STATUS

(D. JOHNSON)



- Multi-pulse Thomson Scattering System:
 - The laser room is nearly ready.
 - The components are being installed.
 - The system should be available in June before the start of plasma operation.
- EBW emission data recently obtained using ORNL reflectometer system.
- CHERS should be ready with NBI!
- MSE (FP&T) is ramping up, to be available in FY 01.
- Tang. FIR Interfero./Polar. (UCD) to be available in FY 01.
- Diagnostic shutters will be installed during this outage for key diagnostics.
- Neutral Particle Analyzer (NPA) is delayed due to tight budget.
- Fluctuation/transport diagnostics are future opportunities.

NBI Upgrade Status

(S. Stevenson)



- All FDRs successfully completed except FDR on Control System (Apr. 00)
- Contracts on major procurement items signed. Accepted bids in line with the original estimate.
- The NSTX installation-work-ramp-up has started with the outage.
- Tight schedule but making satisfactory progress toward completion.
- NBI Operation to start in Oct. 2000.

NSTX National Research Team is working well!



- **Columbia University, 3-D Wall Currents Modeling** made a significant impact and **EFIT/MHD** effort coming together nicely.
- **LANL Fast Camera** has been the workhorse of the plasma operations.
- **ORNL ECH Preionization** system has been working reliably for OH and CHI.
- **ORNL HHFW** collaboration is a shining example of enabling technology collaboration. **Edge Reflectometry** is measuring the edge density profiles.
- **GA Real Time Control System** collaboration has been invaluable.
- **University of Washington** is leading the **CHI** research very nicely. Excellent synergy with HIT-II! **GA** is developing a nice analysis tool for **CHI**.
- **Johns Hopkins University Ultra-Soft X-ray system** is working well and yielding important results (e.g. electron heating during HHFW).
- **UCLA Core Reflectometry** is yielding data.
- **RF Collaboration effort (MIT, GA and UCSD)** are preparing important tools.
- **SNL's Diagnostic Tiles** have been installed.
- **LLNL, UCD, and FP&T** are addressing the longer-term needs.



Los Alamos
NATIONAL LABORATORY



ornl



UCLA

UCSD



FY00 NBI Outage Schedule (L. Dudek)



- Outage started (1/17)
- Vacuum vented (1/19)
- Vacuum vessel entry (1/26) (No visible damages – H. Kugel)
- Remove Center Stack (2/7)
- Measure in-vessel hardware locations (2/25 – 3/9)
- Install NBI Armor (2/17 – 4/25)
- Remove/Modify Pump Duct Section (3/2 – 5/31)
- Install Diagnostic Sensors (3/24 – 4/28)
- Reinstall Center Stack (4/13)
- NBI Duct Installation (4/30 – 5/26)
- Vacuum pump down (6/1)
- Start of Plasma Operation (7/7)

FY00 INCREMENTAL BUDGET ALLOCATION



- Operations

- Additional 2 run weeks (completed)
- High Temperature Bakeout Enhancement (Hot Air instead of Dowtherm)
- Diagnostic Data Network in NTC (Collaborator diagnostic support)
- CHI Fast Gas Injection System (completed)
- Real Time Plasma Control Upgrade
- Spares
- High Power ECH/EBW Upgrade Design Support

- Science

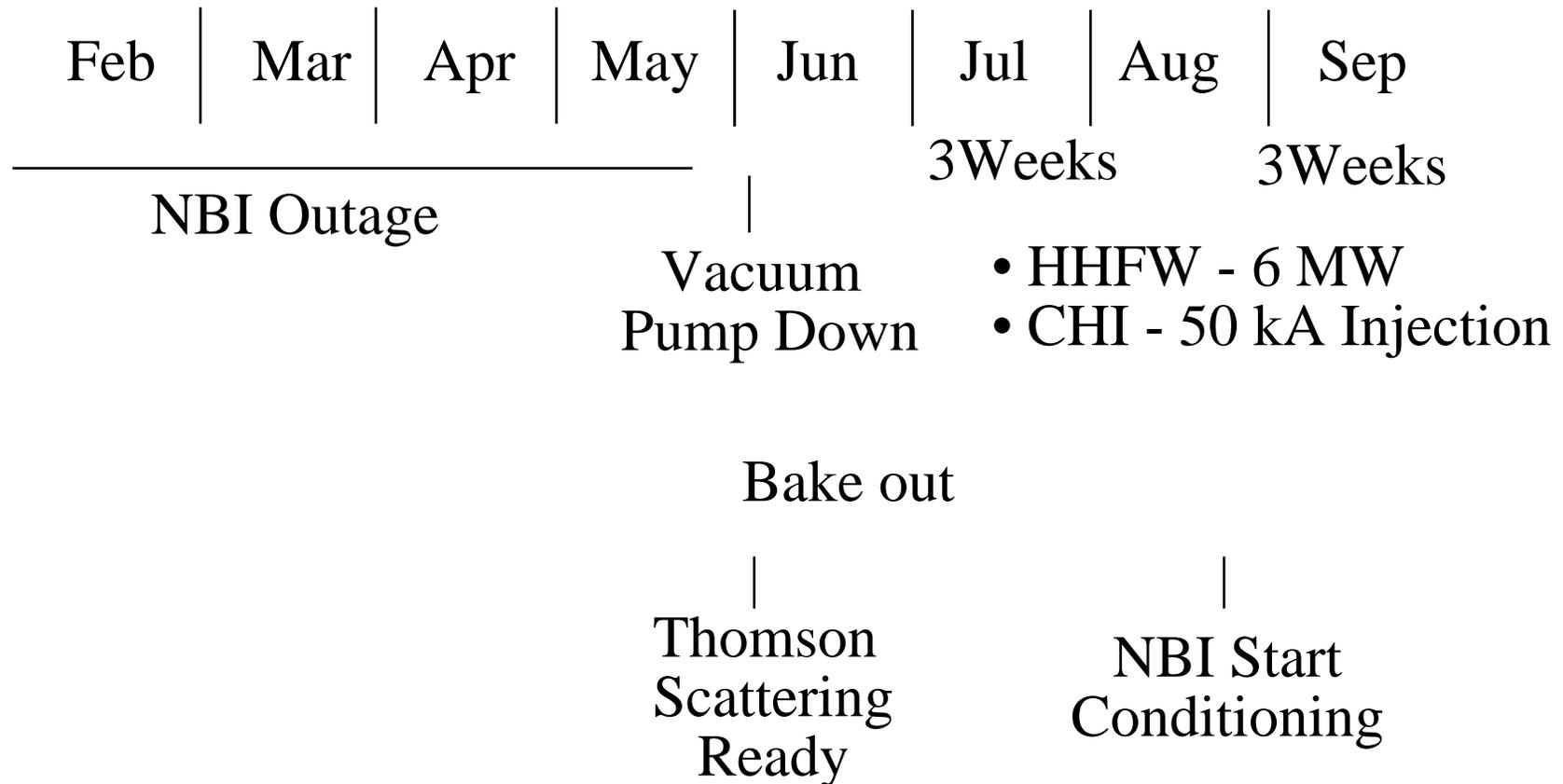
- Enhanced magnetic sensors including locked mode coils
- Automated Shutters
- International ST Collaborations
- Reciprocating Probe Support
- Diag. Mezzanine Support (MSE)

Key Facility Milestones in FY 00



- Complete Hookups for CHI Fast Gas Injection System Nov. 99 (Done)
- HHFW Commissioning Nov. 99 (Done)
- Vent VV for NBI Upgrade Jan. 00 (Done)
- NBI Armor Installed Mar. 00
- Complete NBI Source Refurbishing June 00
- Complete in-vessel installation June 00
- Install Locked-Mode Coils June 00
- Machine Start-up and Testing July 00
- NBI Vacuum System Operational July 00
- 3 NBI Sources Tested July 00
- Complete CHERS Design July 00
- Complete Multi-time, Multi-point TS System Installation July 00
- Begin NBI Conditioning Aug.00

FY 00 Draft Operations Plan



FY 01 Draft Operation Plan



Phase II Research

# of run weeks	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	2	2	2			2	3	3	3	2		

	Start of NBI Operations	MSE proto-type Channel						MSE 8 - 10 Channels				
	Start of CHERS											
	2 channel FIR Intef/Polar. MSE Stark Spectrum					Diborane NPA Wall Mode Sensors						Tang. X-ray 7-Ch FIR Passive Plates Mod.

Note: FY 01 Operations assumes 19 weeks (15 base + 4 incremental)
 The run schedule is relatively flexible due to no large installation tasks.

Very High Stable Has Been Identified Crucial for Attractive Power Plant



- **CS Upgrade to investigate simultaneous:**

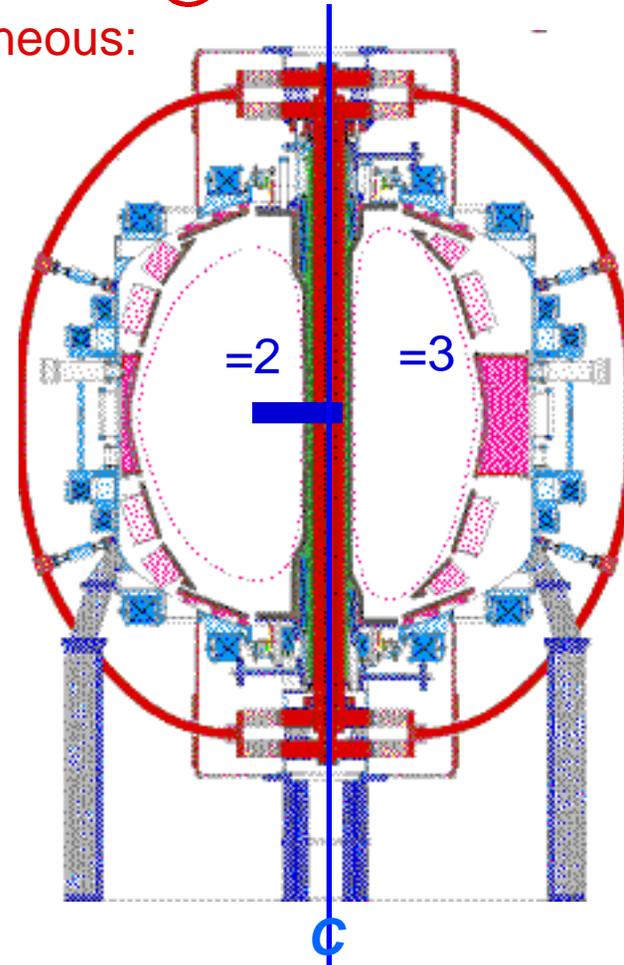
- Very high β = 50 %
- Very high f_{boots} = 90%.

- **Proposed hardware upgrade:**

- $n = 3$, $R/a = 1.4$, $B_T = 1T$
- Double OH flux
- $I_p = 1 MA$
- Interchangeability
- NBI (7 MW, 5 sec, 90 keV)
- HHFW (8 MW, 5 sec)
- Adv. PFC/Stabilizing Plates
- Adv. HHFW Antenna
- Other advanced features?

- **Cost & Schedule: (\$2M/year)**

- Design (FY 01 inc.)
- Fabrication (FY02-03)
- Installation and Test (FY 04)



Center Stack Upgrade



Specification

- Interchangeable Center Stack
- 1 T Capable (3 times more copper)
- 1V-S OH Coil (twice the present)
- Straight inboard profile higher and higher

Benefits

- Explore ARIES-ST-like configuration (very high and f-bt)
- Higher toroidal field for physics exploration
- Larger OH flux for higher inductive current operation (e.g., 2 MA)
- 1 MA discharges with half-swing
- Greater operational flexibility and reliability

Proposed Plan

- Engineering design in FY 01
- Fabrication in FY 02-03
- Ready for installation in FY 03-04

Longer Range Facility Plan



Phase I		Phase II		Phase III
FY 00		FY 01		FY 02 FY 03

Plasma
Operations

Wall Stabilization:

|
Wall Sensor
Installation

|
Passive Plates
Reconfiguration

|
Active Mode
Control?

New Center Stack: Physics Req. Engineering Design

Fabrication

|
Ready for installation

Fueling:

|
Gas Fueling

|
NBI Fueling

|
Adv. Fueling

Heating & CD:

NBI (5 MW, 5 sec)
HHFW (6 MW, 5 sec)

NBI (7 MW, 5 sec)
HHFW (8 MW, 5 sec), Adv. Launcher
ECH/EBW (400 kW, 100 msec)

Wall Conditioning: High Temp Bake, Solid Target Boronization

Diborane Boronization

Lithium glow

Liquid Lithium

Diagnostics: Magnetics Plasma Profiles Current Profile E-field Profile Plasma Energy/Particle Transport

Plasma Velocity Profiles Plasma Fluctuations (density, temperatures, potential, magnetic fields)

SUMMARY OF NSTX PROJECT ACTIVITY



- NSTX achieved the first plasma milestone in Feb. 1999, ten weeks ahead of schedule.
- NSTX Construction Project was completed within TPC with excellent safety record.
- Plasma operations resumed with additional hardware and capabilities.
- All indications are good thus far! Achieved 1 MA “ST world record” discharges. Good performance trend with current and plasma density.
- HHFW and CHI are starting to work!
- Diagnostics are ramping up rapidly.
- Strong National Research Team is working together very well!
- Exciting time is ahead with us with NBI and many new capabilities!
- Center Stack Upgrade is planned for FY 03-04 time scale.