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NSTX Facility/Diagnostics/Budget Update and Plans for FY 06 - 08

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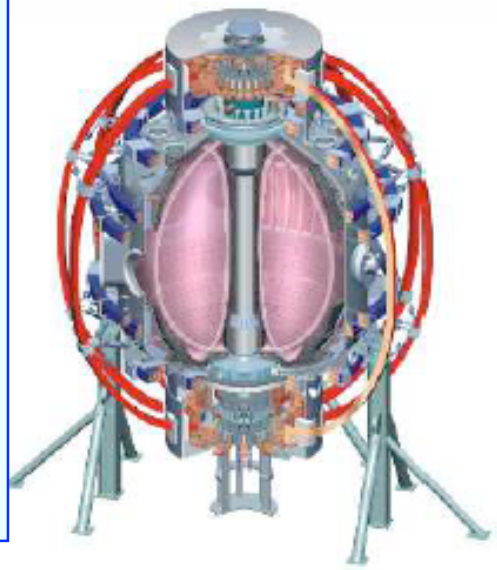
FY 2008 Budget Planning Meeting

March 14 - 15, 2006



NSTX Facility and Diagnostic Capabilities

Device Parameters

R = 85 cm

a = 65 cm

κ = 1.7 - 2.7

δ = 0.3 - 0.8

B_T = 5.5 kG

τ_{TF} (3.5 kG)~ 3 sec
~ 6 τ_{skin}

I_p = 1.5 MA

V_p = 14 m^3

E_p ~ 430 kJ

P_{NBI} = 7.4 MW

P_{HHFW} = 6 MW

350°C bakeout

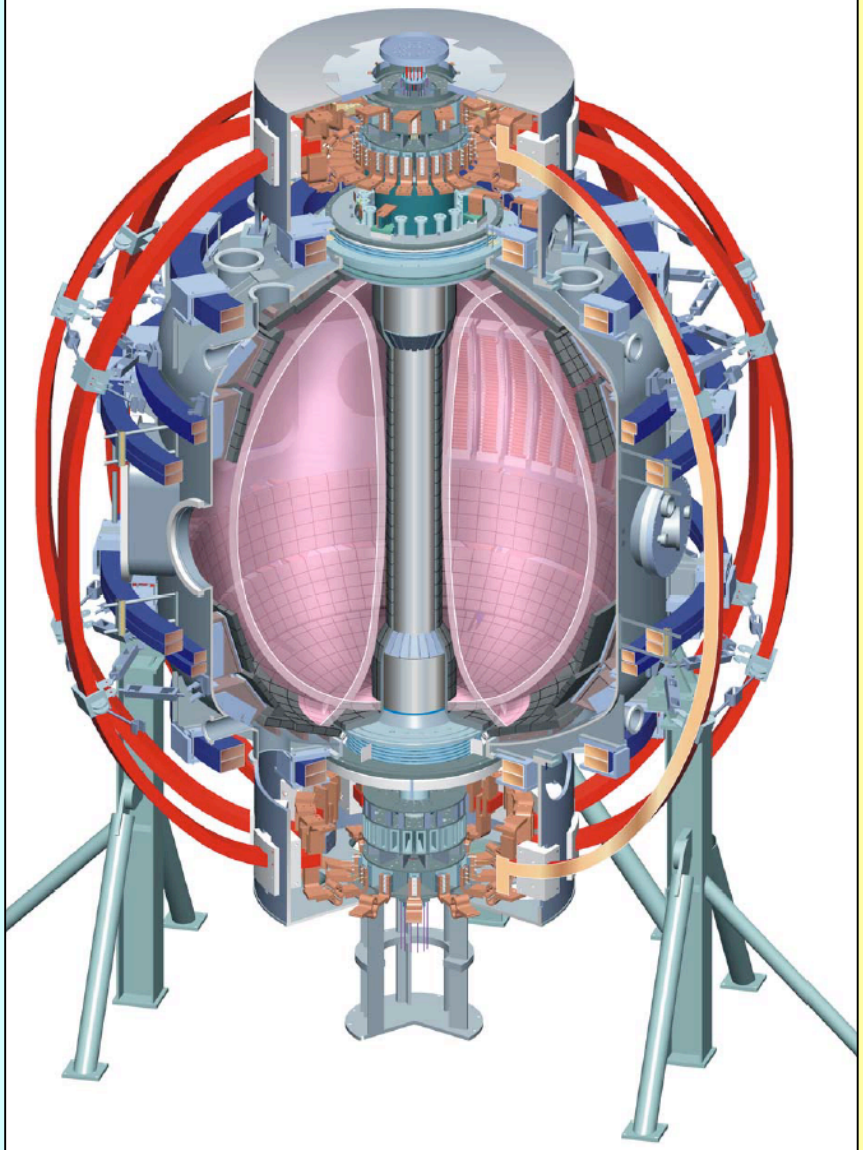
Passive Plates

EF/RWM Coils

I_{CHI} ~ 400 kA

60 cm dia. ports

Wide tang. access



In red - collaboration

Major Diagnostic Systems

Confinement Studies

- Magnetics for equilibrium reconstruction
- Diamagnetic flux measurement
- Multi-pulse Thomson scattering (30 ch)
- CHERS: $T_i(R)$ and $V_\phi(r)$ (51 ch)
- Neutal particle analyzer (2D scanning)
- FIReTIP interferometer (119mm, 6 ch)
- Density Interferometer (1 mm, 1ch)
- Visible bremsstrahlung radiometer (1 ch)
- Midplane tangential bolometer array
- X-ray crystal spectrometer: $T_i(0)$, $T_e(0)$
- MSE-CIF (8ch)

MHD/Fluctuation/Waves

- High-n and high-frequency Mirnov arrays
- Ultra-soft x-ray arrays – tomography (4)
- Fast X-ray tangential camera (2μs)
- Wave reflectometers
- FIReTIP polarimeter (6 ch, 600 kHz)
- Tangential microwave scattering
- Electron Bernstein wave radiometer
- Fast lost-ion probe (energy/pitch resolving)
- Fast neutron measurement
- Locked-mode detectors
- RWM sensors (n = 1, 2, and 3)

Edge/divertor studies

- Reciprocating Langmuir probe
- Gas-puff Imaging (2μsec)
- Fixed Langmuir probes (24)
- Edge Rotation Diagnostics (T_i, V_ϕ, V_{pol})
- 1-D CCD H_α cameras (divertor, midplane)
- 2-D divertor fast visible camera
- Divertor bolometer (4 ch)
- IR cameras (30Hz) (3)
- Tile temperature thermocouple array
- Scrape-off layer reflectometer
- Edge neutral pressure gauges

Plasma Monitoring

- Fast visible cameras
- Visible survey spectrometer
- VUV survey spectrometer
- X-ray transmission grating spectrometer
- Fission chamber neutron measurement
- Visible filterscopes
- Wall coupon analysis
- X-ray crystal spectrometer (astrophysics)

FY 05 Plasma Operations Completed Successfully

- FY2005 Joule milestone: 17 run weeks

  Achieved: 18 run weeks producing 2221 plasmas.

- All facility and diagnostic milestones completed on or ahead of schedule.
- Excellent safety record in 2005.
  - Maintaining our tradition and goal!
- New Research Capabilities introduced in FY 05 yielded exciting results:
  - New PF 1A divertor coils for strong shape control - $\kappa \sim 2.7$, $\delta \sim 0.8$;
  - Error Field / Resistive Wall Mode (EF/RWM) coils powered by Switching Power Amplifier for plasma rotation and stability control;
  - 8 channel Motional Stark Effect (MSE) diagnostic for the first current profile measurement in high beta plasmas;
  - 30 ch MPTS for detailed profile particularly in the pedestal region;
  - 1.5 kV CHI capacitor bank and direct gas/ECH feed into injector for efficient current generation with closed flux surfaces;
  - Tangential high-k scattering system for electron transport study;
- Toroidal field coil joints operated very reliably at 4.5 kG.

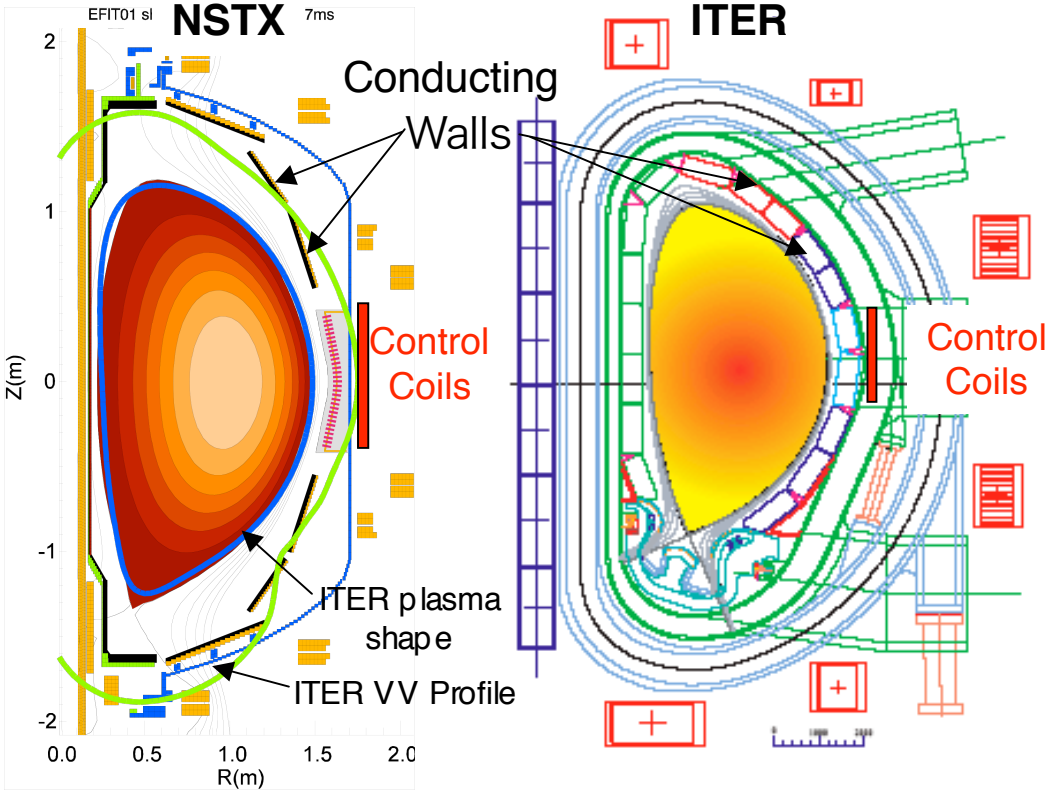
New Research Capabilities for FY 06 Run

- **FY2006 Joule milestone: 11 run weeks**
- Plasma operations resumed in February 2006 and end in May.
- New Research Capabilities for FY 06 experiments
  - Lithium Evaporator for improved particle recycling control for high performance long pulse discharges (March);
  - Feedback capability for EF/RWM coils powered by Switching Power Amplifier to improve and extend high performance plasmas (March);
  - 12 channels for MSE diagnostic to improve current profile determination, particularly in the outer region (March);
  - 2 kV operation of CHI capacitor bank to extend closed flux surface formation to higher current (April);
  - Dual remotely steerable, obliquely viewing radiometers for EBW emission covering extended frequency range 8 - 40 GHz (March);
  - TF qualified to 5.5 kG;
  - TF pulse length can be extended by ~20% if needed.

MHD

NSTX Well Positioned for Cutting Edge EF/RWM Research

	FY 06	FY 07		FY 08	
Run Weeks Base / Request	11	12	8	10	10
EF/RWM	● EF/RWM Feedback (Columbia)				
		● PCS Processor Upgrade (GA)			
Disruptions	● Fast X-ray Camera (PSI)				
	● Fast Multi-Color-Te(r)(0.1ms, JHU)				



Capabilities and Plan

- EF/RWM coils powered by SPAs operated well in pre-programmed mode in FY 05
- Feedback control software written, compiled, and tested in simulation mode.
- Ready to test feedback control early in FY 06 run.
- PCS Processor Upgrade will provide faster feedback control x 3-10.

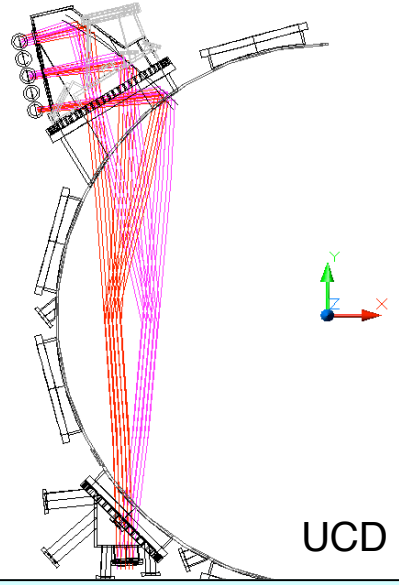
Transport and Turbulence

World leading diagnostics to address key transport physics

	FY 06	FY 07	FY 08
Run Weeks **Base / Request**	11	12 / 8	10 / 10
	● MPTS 30 ch	● Interim P-CHERS	● Full P-CHERS
	● Multi-Color-T_e(r)(JHU)	○ Full P-CHERS	○ 3rd MPTS Laser
	● MSE/CIF 12 ch	● MSE/CIF 16 ch (Nova)	
	● Corr. Reflect. (UCLA)	■ Next-step Fluctn diag	
	● High k Scattering (UCD)		

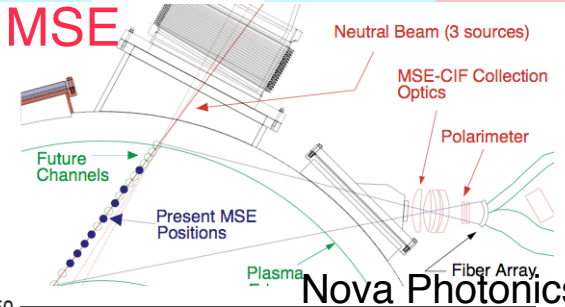
● - Base
○ - Increment
■ - Decision Pt

Tangential High-k Scattering

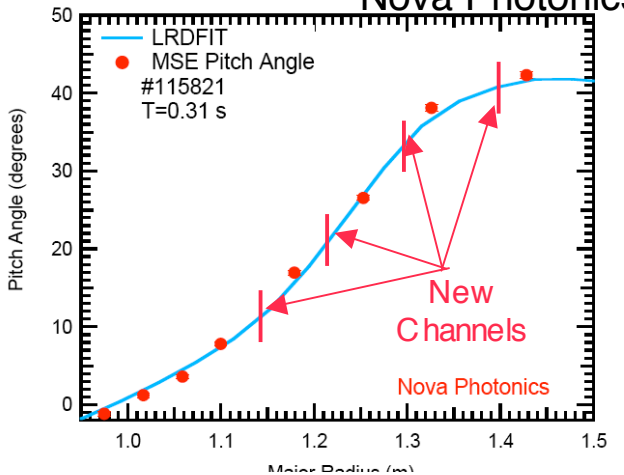


Unprecedented spatial resolution at high k

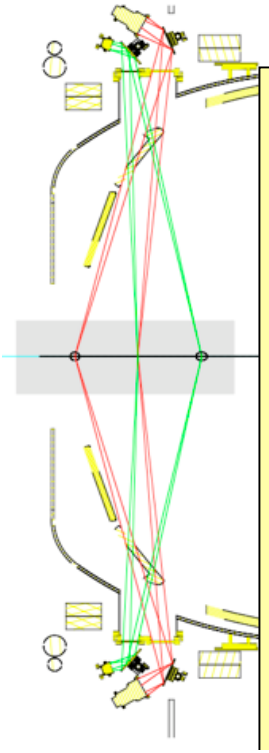
MSE



Nova Photonics



P-CHERS



- **Unique** up/down symmetric ports along NB for optimal view
- Interim system - covers outer half of the plasma
- Full system - covers whole radius with resolution ~ 51 Ch T-CHERS

Boundary
Extend high-performance discharges

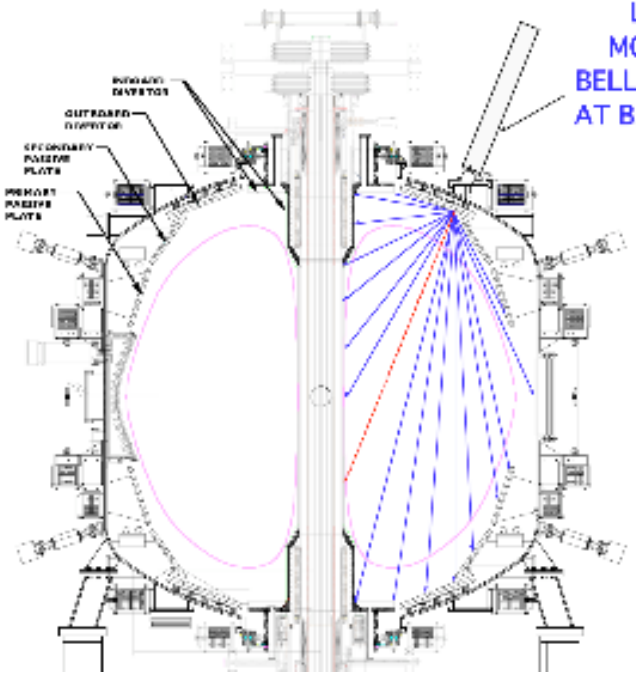
NSTX

FY 06	FY 07	FY 08

● - Base
○ - Increment
■ - Decision Pt

Run Weeks
Base / Request

FY 06	FY 07		FY 08	
11	12	8	10	10
● Lithium Evaporator	● 2nd Li Evap		○ Pellet Injector (ORNL)	
● Lithium Pellets	■ Core Fueling DP			
	■ Adv. Particle Exhaust DP			
	● Fast IR Camera (ORNL)		○ Divertor Diagnostics (ORNL)	



Li evaporator coat the lower region including divertor plates

Achieving low particle recycling regime

- FY 05: ~ 25 mg of lithium from multiple pellets reduced recycling
- FY 06: Utilize lithium evaporator LITER-1 with supersonic gas injector
- After FY 06 run, assess needs for
  - core fueling: pellets or CT injector;
  - additional particle control: second lithium evaporator, liquid lithium tray, or divertor cryo-panel.

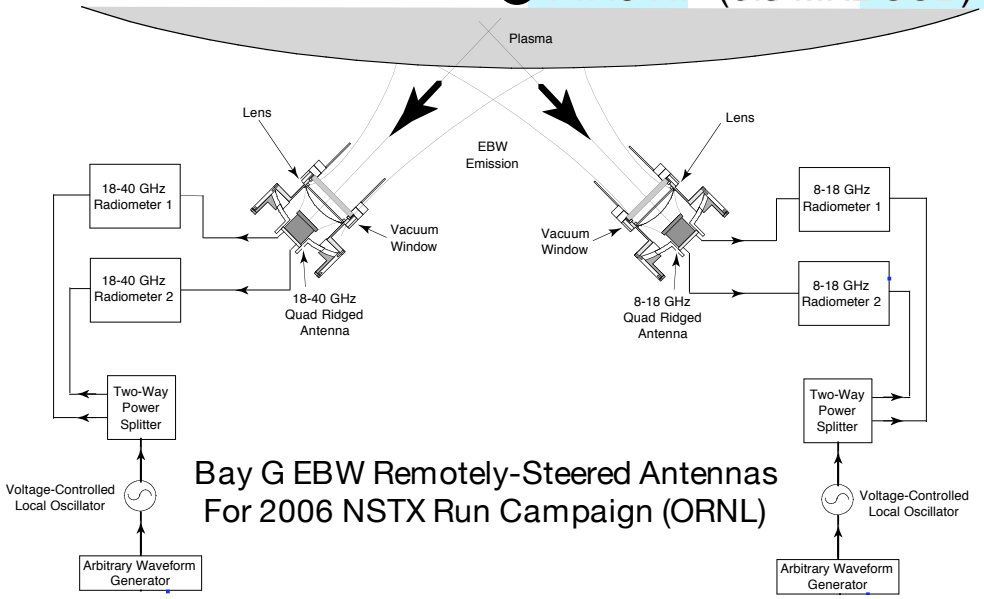
Waves and Energetic Particles

Current and Pressure Profile Control for Advanced Regimes

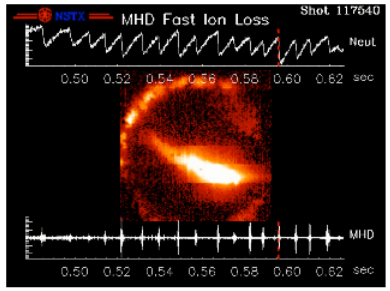
NSTX

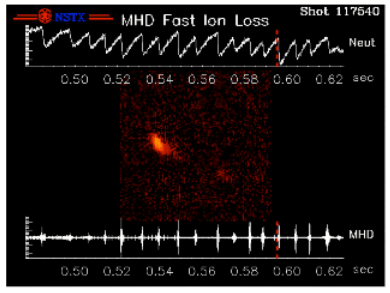
	FY 06	FY 07	FY 08
Run Weeks Base / Request	11	12	8 / 10 / 10
HHFW	● Edge Wave Reflectometer (ORNL)		○ HHFW Antenna Upgrade
		● Core Wave Reflectometer (UCLA)	
EBW emission		● Dual EBW Radiometer (8-40GHz, ORNL)	
1 MW EBWCD		■ Decision Point	○ Complete FDR
			● Complete FDR Complete Site Prep Antenna Design
Energetic Particles	● Fast Lost Particle (JAEA) ● Core Reflectometer (UCLA) ● FIReTIP (0.5 MHz UCD)		● Fast-ion D-alpha camera(UCI) ● FIReTIP (2.5 MHz UCD)

● - Base
○ - Increment
■ - Decision Pt



Bay G EBW Remotely-Steered Antennas For 2006 NSTX Run Campaign (ORNL)





The fast camera based lost ion probe was able to measure MHD induced rapid fast-ion-loss events in sub-msec time scale (JAEA)

Solenoid-Free Start-Up

Enables ST-CTF and Attractive Tokamak Reactors

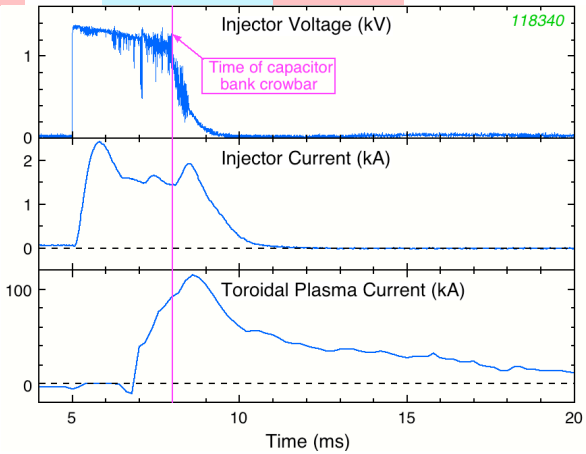
NSTX

	FY 06	FY 07	FY 08
Run Weeks **Base / Request**	11	12 / 8	10 / 10
Coaxial Helicity Injection	● 2 kV CHI Bank Capability	● Dynamo edge probe (UCSD)	
PF-only Start-up		■ Pre-ionization DP	○ Improved pre-ionization

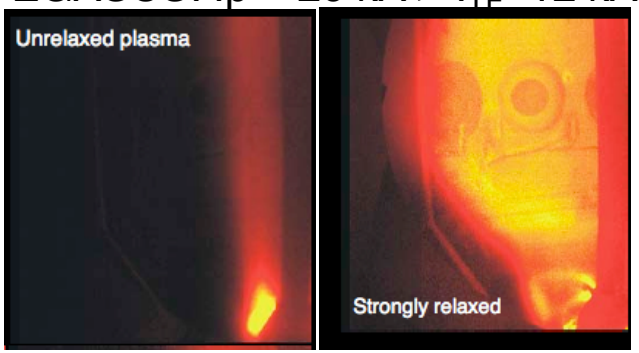
● - Base
○ - Increment
■ - Decision Pt

- Coaxial Helicity Injection (U. Washington)
  - In 2005, CHI bank operated at 1.5 kV, achieved very high current multiplication with closed flux surface plasma
  - For 2006, upgrade for 2kV operation to extend toward higher current

- PF-only Start-up / Iron Core
  - In 2005, needs for high power pre-ioinization (e.g., ECH/EBW) determined
  - EBW, high-$k_{||}$ HHFW antennas, Plasma Gun (PEGASUS), and/or CT-Injection may provide efficient pre-ionization
  - Investigate optimum utilization of modest iron core for start-up and ramp-up



PEGASUS: Ip = 26 kA > I_{TF}=12 kA



NSTX Budget Summary ($M)

	FY 06	FY 07		FY 08	
Budget level	Actual	Base	Incremental	Base	Incremental
Run Weeks	11	12	20	10	20
Facility Operation	17.7	18.2	1.0	18.4	1.4
Facility Upgrades	0.5	0.5	1.8	0.4	2.1
Facility Total	**18.2**	**18.7**	**2.8**	**18.8**	**3.5**
PPPL Research	9.7	9.8	0.2	9.9	0.5
Diag Upgrades	0.6	0.8	0.5	0.6	0.5
Coll. Diag. Interf	0.5	0.6	0.1	0.6	0.1
Collaborations	5.0	5.2	0.3	5.2	0.3
Science Total	**15.8**	**16.4**	**1.1**	**16.3**	**1.4**
NSTX Total	**34.0**	**35.1**	**3.9**	**35.1**	**4.9**

- 12 and 10 run week cases in FY 07 and 08 include minimal upgrades.
- Incremental budget allows drastic increase in facility utilization, implementation of the 1 MW EBW system and other high priority upgrades.

Requested Case will Greatly Enhance NSTX Science Output

- Significantly increase Facility Utilization:
  - 20 run weeks in FY 07 and FY08 (~ 100% increase from Base Case)
- Improve Facility/Diagnostic Capabilities:
  - Construction of 1MW EBW system (FY 07 - 09)
  - Core fueling (FY 08)
  - Outer PF start-up pre-ionization (FY 08)
  - Full P-CHERS (FY 07)
  - Critical Boundary Physics diagnostics (FY 08)
  - Third laser for MPTS to improve time resolution (FY 08)
- Improve Facility Reliability and Availability
  - Better Preventive Maintenance and
  - Critical spare parts

Consequences of 10% Budget Cut (FY08)

- Significant reduction in runtime (from 10 to 5 weeks)
- NSTX staff reduction of ~ 15 FTE relative to the base case
  - 12 further staff reduction if severance not funded additionally
- Non-labor reduction of ~ 20%
  - Diagnostic components, spare parts, energy, travel, *etc.*
  - Only corrective maintenance and replacement of failed components
- Significantly reduce facility and diagnostic upgrades procuremnet ~ 60%
  - Delay upgrade of p-CHERS diagnostic
- Similar impact on all collaborations
- Research slows by 50%

Facility, Diagnostic and Budget Summary

- Very successful FY05 run:
  - 18 run weeks with all milestones completed on or ahead of schedule
  - Facility upgrades: New PF 1A coils; EF/RWM coils powered by 3 ch. SPA; 1.5 kV CHI with improved ECH/gas; Movable GDC probe
  - Diagnostic upgrades; High-k Scattering, 30 ch. MPTS, 8 ch. MSE-CIF, Edge Reflectometer, EBW Radiometer (18-40 GHz), Fast-sFLIP
- Exciting FY06 run with new capabilities started:
  - 11 run weeks started in February, end in May with June as contingency
  - Facility upgrades: Lithium Evaporator; EF/RWM coil feedback; 2 kV CHI
  - Diagnostic upgrades: 12 ch MSE-CIF; Dual remotely-steered radiometer (8 - 40 GHz) for EBW emission; Dynamo probe for CHI; 0.1ms Multi-color $T_e(r)$
- Two cases presented for FY07 and FY08
  - NSTX addresses issues important for ST as well as ITER through ITPA and USBPO
  - Incremental Budget would allow NSTX to contribute significantly more to those important goals