NSTX

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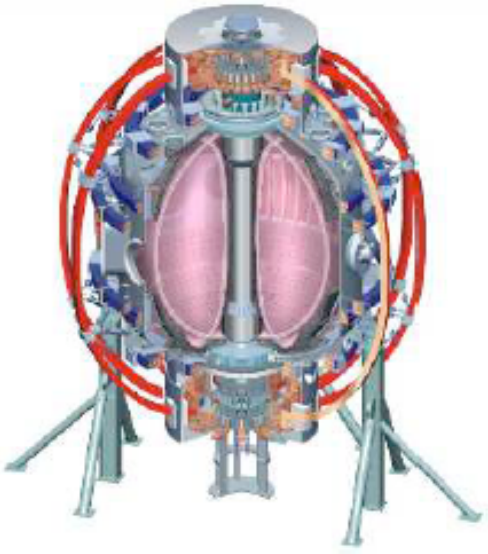
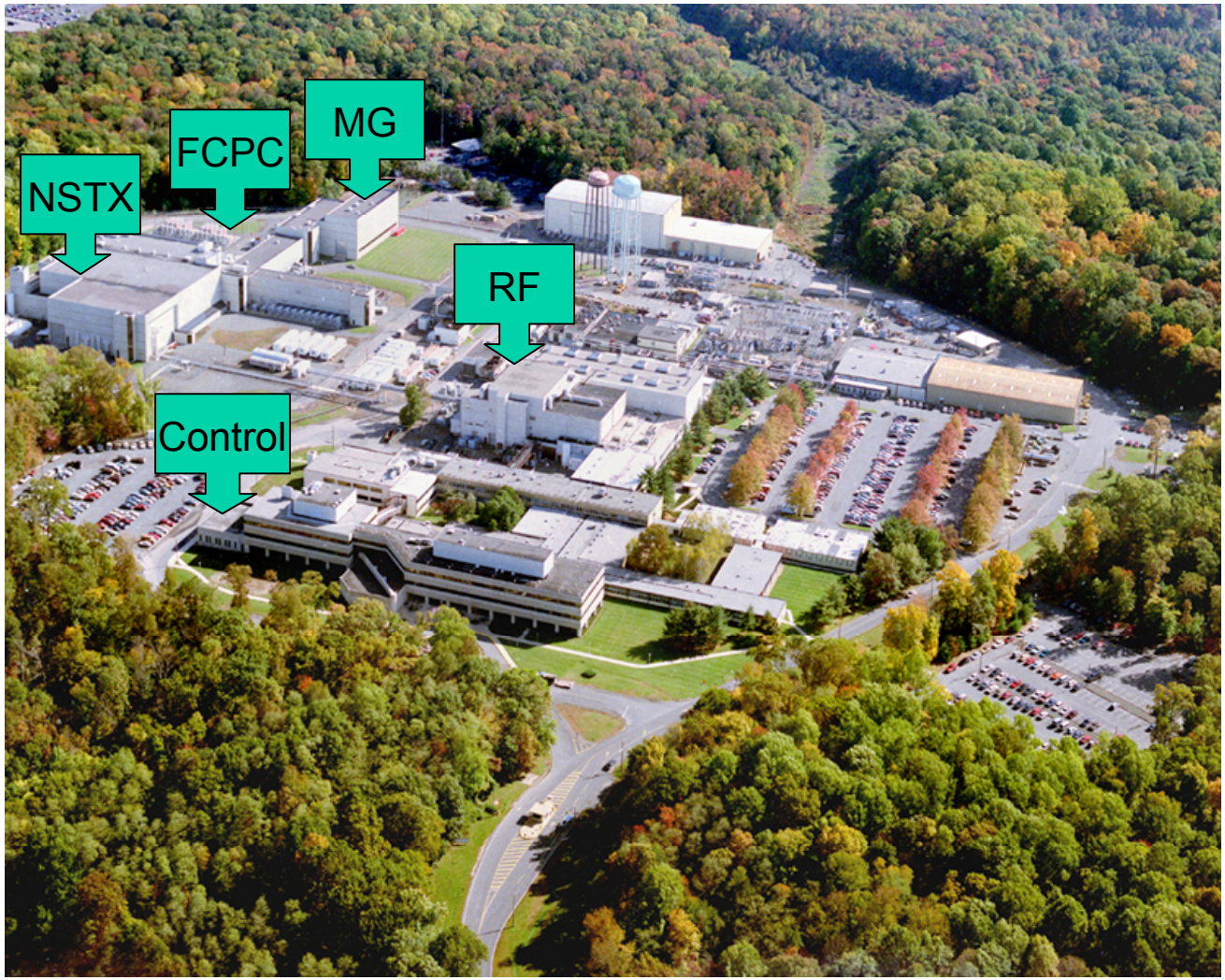
DOE Review of NSTX Facility Operations
Director's Conference Room, PPPL
Julv 30-31. 2008



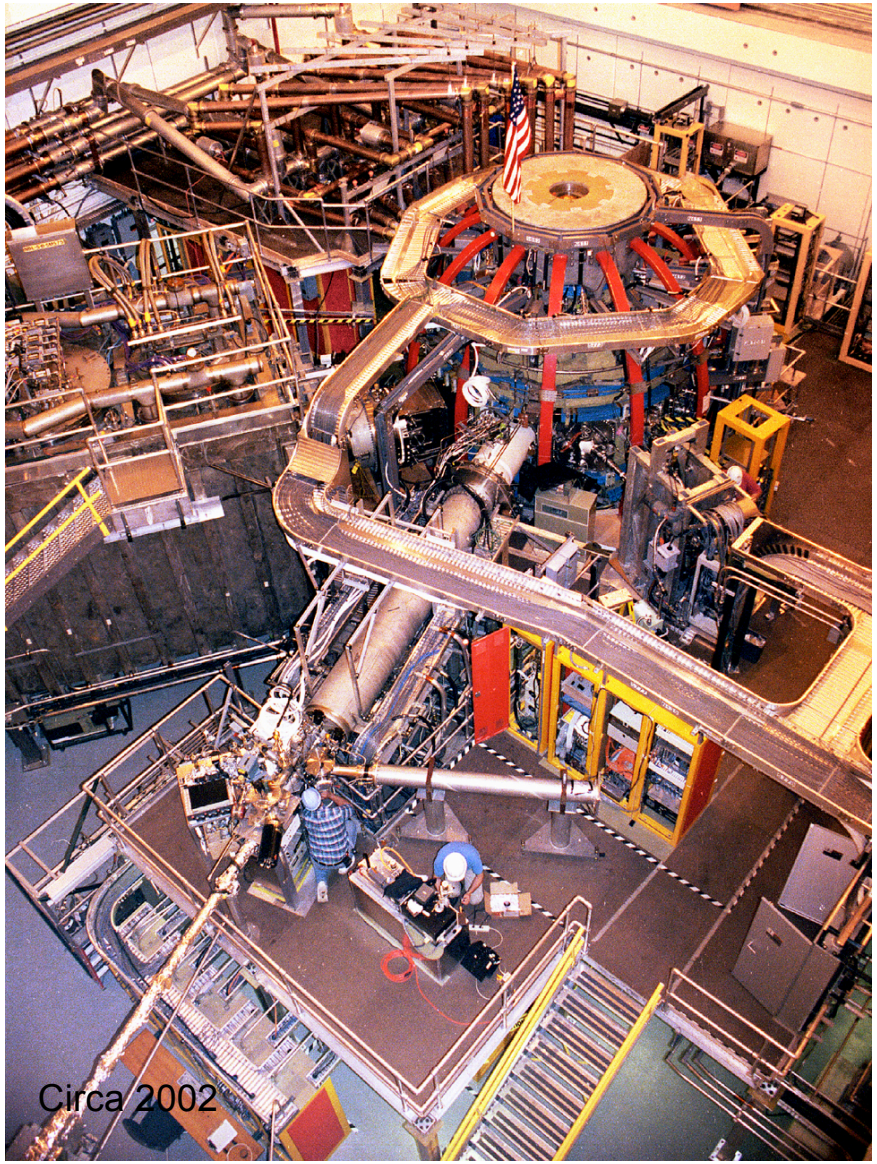
Outline

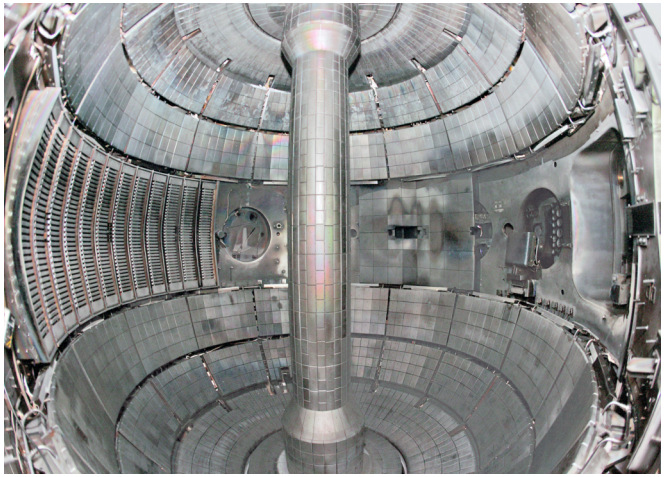
- Overview of Major Subsystems
- Configuration control and engineering procedures
- Machine Availability/ Performance/ Maintenance
- Facility staffing/budgets
- Self Assessments/ Quality Assurance

NSTX is Located at PPPL's D-Site



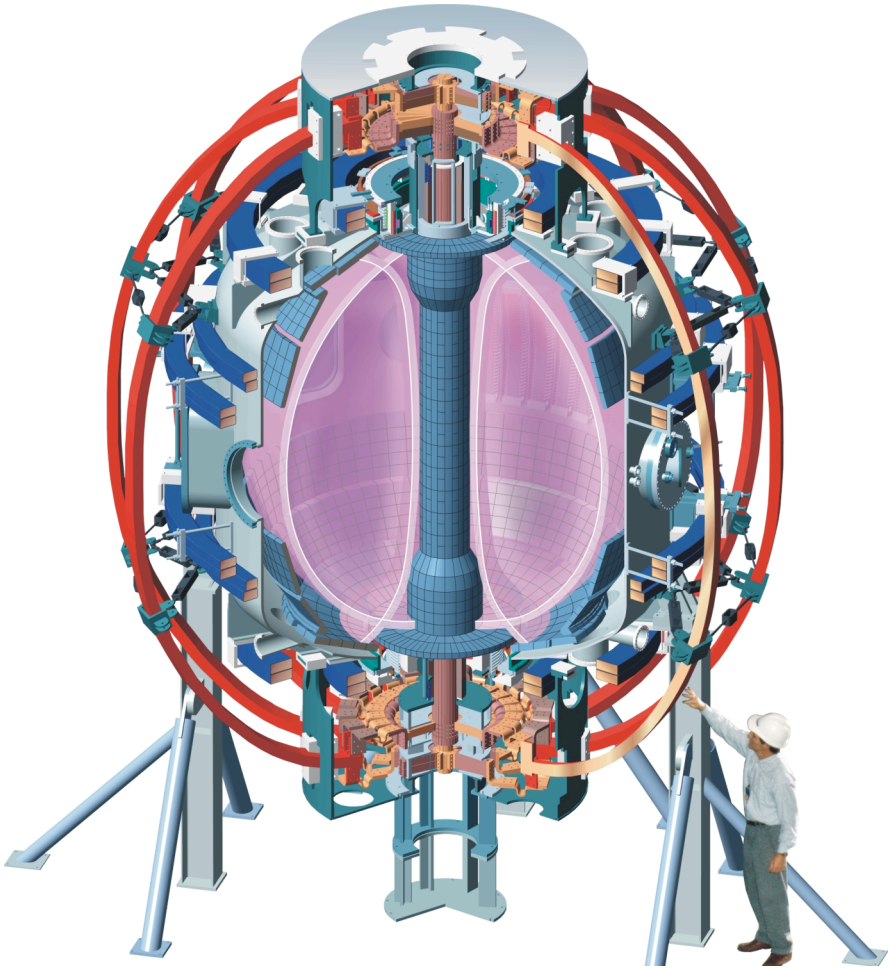
National Spherical Torus Experiment

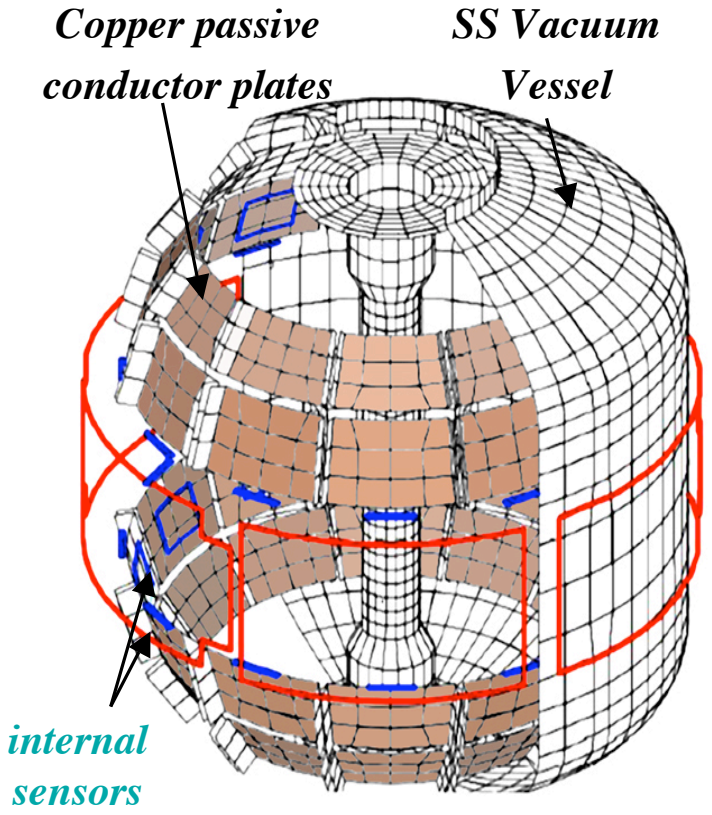




Aspect ratio A	1.27
Major radius R_0	0.85m
Plasma Current I_p	1.4MA
Toroidal Field B_{T0}	0.55T
Auxiliary heating & current drive:	
NBI (95kV)	7 MW
RF (30MHz)	6 MW
CHI	0.2MA
Pulse Length	1-2 sec

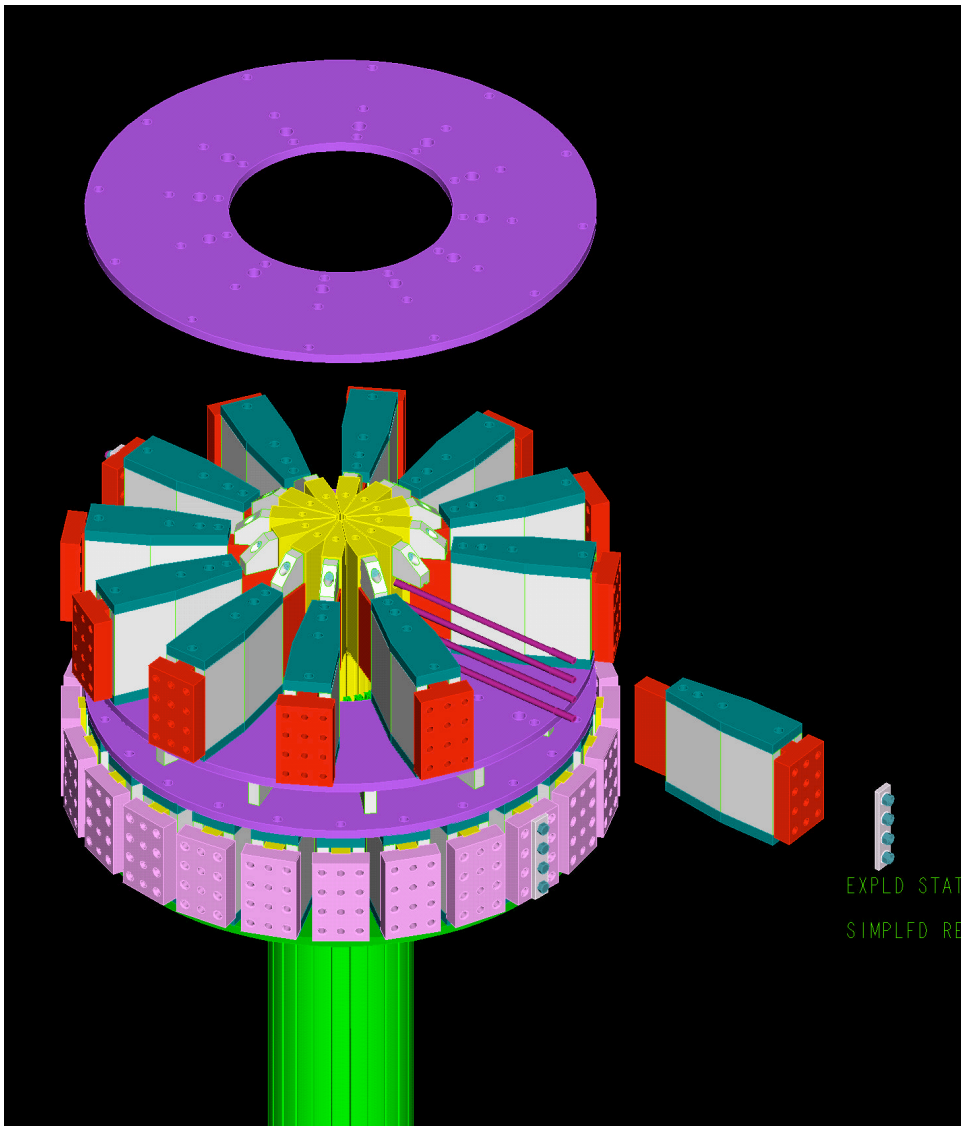
NSTX Coil System





6 ex-vessel midplane control coils

TF Joint 2003 Design Features



- Hub stiffness enhanced via Flag boxes forming web of “I-beam”
- Direct communication of load from flag to hub via potted flags in boxes
- Larger diameter fasteners, 2X preload
- Studs w/nuts instead of thru-bolts
- Belleville washers
- Separated shear/preload functions
- Shear shoes added
- Voltage taps added to facilitate joint resistance measurement

NSTX Torus Vacuum Pumping System

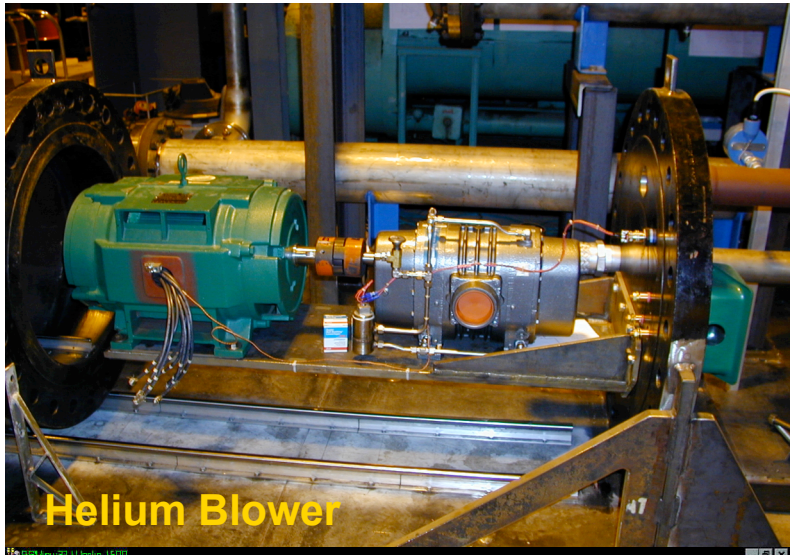
High Vacuum System
- Two 1500 l/s TMPs (Seff ~1600 l/s D2)
- Backed by roots/mechanical pump system

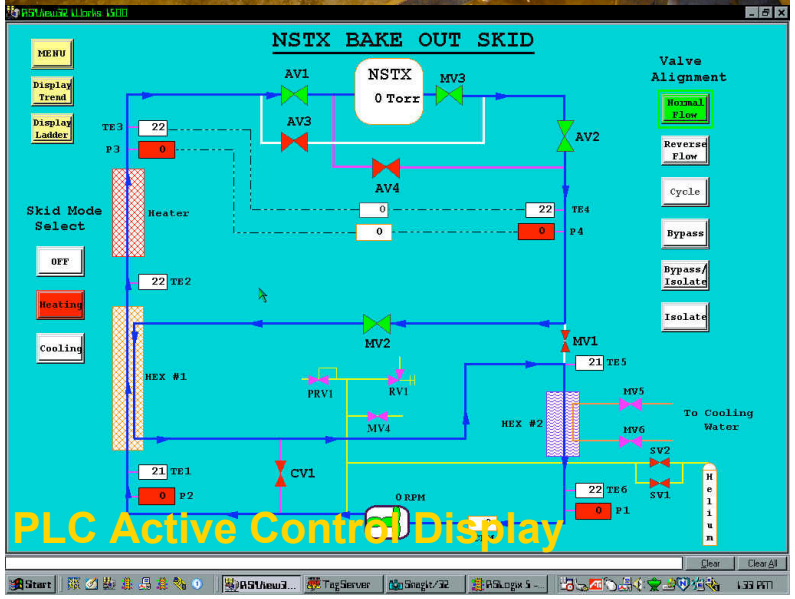
Roughing System
- Roots/mechanical pump system (~2700 and ~300 cfm respectively)
- Roughs down VV to 50 mTorr in ~30 min.

RGA System
- Differentially pumped system
- Orifice valve for measurements at higher pressures (mTorr range)

Control and Monitoring
- All systems remotely controlled and monitored with a PLC
- All systems interlocked against misoperation and to place systems in a safe configuration in the event of power failures or pressure excursions

NSTX Vacuum Vessel Bake-out System





- 420C Helium output heats in vessel tiles to 350C
- Closed Loop 380 psi system achieves required helium density
- VFD Controlled Motor and Blower assembled into pressure vessel
- SCR Controlled Heater inputs 200KW
- Net heat transfer to experiment is 66KW heat or 82KW cooling

NSTX Magnet Power Systems

D-Site Power Conversion and MG Buildings

NSTX utilizes the former TFTR Energy Conversion Systems and Infrastructure.

Site credit for the construction of NSTX in this facility was >$100M

Systems have been refurbished, re-commissioned, and are now maintained by the NSTX project

NSTX Magnet Power Systems

Modular power supplies afford maximum flexibility.

Of the 39 power supplies (78 Sections) originally supplied for TFTR, NSTX is using 48 Sections.

Each section is rated 1kV@24kA for 4 sec every 300 seconds.

TF	71kA
OH	+/-24kA
PF1a/b,U/L	+/-24kA
PF2U/L	20kA
PF3U/L	+/-20kA
PF4	20kA
PF5	20kA
CHI	50kA
RWM (SPA's)	+/-3kA

NSTX Magnet Power Systems

Commutator structure of one of the two D-Site Motor Generator (MG) Sets.

Each set, as supplied with ~600T flywheels, can store 4500MJ with 2250MJ usable from 90-60 Hz. More than enough capability for extended pulse lengths on NSTX.

NSTX Neutral Beam Power Conversion

Neutral Beam Modulator Regulators for the 7MW Neutral Beam Injection (NBI) Heating System

NSTX NBI uses three of the twelve tetrode-based power supplies.

Each supply is rated for 120kV @ 65A and capable of precise regulation.

An Electron Bernstein Wave (EBW) Heating System upgrade would use a spare power supply.

RF Capability

RF Building and coaxial wave-guides to D-Site

Power from six ICRF sources is brought to NSTX to operate the 6MW, 30MHz HHFW system.

These sources are capable of providing 12MW for 3 seconds. 5 second operation would be possible with modest upgrades to the heat extraction systems.

Central Instrumentation & Controls Computing

Central I&C provides data acquisition and control, data storage, analysis and visualization software, timing & synchronization, and integrated control via interfaces with NSTX engineering subsystems and diagnostics.

- I&C is based upon **collaborative software**: **EPICS, MDSplus, PCS.**
  - Most I&C software runs on Linux servers; clients/desktops use Windows, Macintosh, and Linux.
  - Real-time PCS computing hardware and software recently upgraded.

- NSTX **Computing Hardware**: 20 servers, 50 desktops/operator stations, 50 instrumentation PC's, 100/1000 Mbit networks, SAN (Storage Area Network).
  - Exploring Virtual Machine technology and network booting to reduce exposure to hardware failures.

Central Instrumentation & Controls Computing

- NSTX stores approx 2 GB of raw data per shot using **MDSplus.**
  - All MDSplus data, for the life of NSTX, is available from the PPPL SAN.
  - Per-shot data load is always increasing and has historically doubled every 2nd year.

- Some video/image data is not stored in MDSplus due to the (costly) storage needs for large data sets and lack of standard data structures and user software tools.
  - Currently stored on redundant DVD's, but we are exploring commercial video storage subsystems and applications software.

- MDSplus and CAMAC servers will move from **VMS to Linux** for FY09 campaign.

Central Instrumentation & Controls Computing

- Data Acquisition and Control **Fieldbus Technology**:
  - Majority of systems use still use legacy CAMAC.
  - Collaborators (new) diagnostics are using CompactPCI and PC-based systems.
  - Some VME and FPGA (programmable silicon).

- **Cyber security** is a guiding principal in designing and operating NSTX computer systems.
  - Steve Baumgartner, the PPPL Chief Information Officer, will present the details of the PPPL Cyber security systems this afternoon.

Procedures Define Configuration Control

Work Planning (ENG-032)	Web based work planning and approvals to help work follow proper engineering practices. Intended to help staff follow the principles of Integrated Safety Management (ISM) from the earliest part of a project.
Design Verification (ENG-033)	Documentation of design reviews Calculations Chit Resolution
Drawing Control (ENG-010)	Engineering Change Notice Software Change Notice
Installation/Ops (ENG-030)	Procedures and Approval Matrix Record of Training Run Copy Control

Training Required for Work in the NSTX Test Cell

For Unrestricted Access into the NSTX test cell:

- General Employee training (GET)
- Radiation Safety Training
- Lockout/Tagout (Control of Energy Sources)
- Basic Electric Safety
- Knowledge of Administrative Procedures

Conduct of Operations	(OP-AD-39)
Chain of Command	(OP-AD-56)
Work Permit System	(OP-AD-09)
Control of Temporary Mods	(ENG-036)
Control of Workplace Cleanliness	(OP-AD-24)
NSTX Access Controls	(OP-AD-117)

Formal Training Program for all Operating Staff

Operator Training Matrixes (OP-NSTX-12) developed for:

- Chief Operating Engineers (COEs)
- Machine Technicians
- Vacuum Technicians
- Water Technicians
- Field Coil Power Conversion Technicians
- Radio Frequency System Operators
  - High Harmonic Fast-Wave Systems
  - Electron Cyclotron Heating systems
- Neutral Beam Operators
  - Ion Source Systems
  - Cryogenic Systems
  - Beam-line Vacuum ops
  - Operations Shift Supervisor

Managing Work in the Test Cell

Work Permits, approved by the Shift Supervisor, ensure that Test Cell configuration control and proper work practices are maintained.

- Defines location of work, tools required and responsible workers
- Verifies proper procedures are used (Job specific, Lift, etc.)
- Checks permit requirements (RWP's, Line break, Release, etc.)
- Provides record for work for checks before resuming operations

A Job Hazard Analysis (JHA) is performed for each task to help identify existing and potential workplace hazards, and to find ways to control these hazards. The safety controls/equipment needs are defined on the JHA, and reviewed with staff as part of the pre-job brief.

Configuration Control During Operations

Proper system operation is ensured by an approved set of operations procedures:

- Preoperational Test Procedures describe the equipment, methods and steps to bring systems to an operational state.
- Integrated System Test Procedures describe the steps to test and document operation or interactions of multiple systems.
- System Operations Procedures specify the prerequisites, requirements and actions for operating individual systems.
- General Operating Procedures coordinate the operation of multiple systems.

ISTP-001 defines protection system settings and necessary test shots for any changes to the NSTX electromagnetic configuration and/or operating envelope.

Preparing for NSTX operations

Upon Conclusion of Upgrade and Maintenance Activities:

- Remove vessel floor/Clean/Photo/Close and install duct — 1 Week
- Pumpdown/Leakcheck/Prep for Bake-out — 1 Week
- Bake-out — 2 Weeks
- Post-Bake Diag calibrations/Machine Area Scrubs — 2 Weeks
- Integrated System testing/Magnetic Diag Test Shots — 1 Week

These activities have been compressed into a 4 Week period during a mid-run opening.

NSTX Run Day Schedule

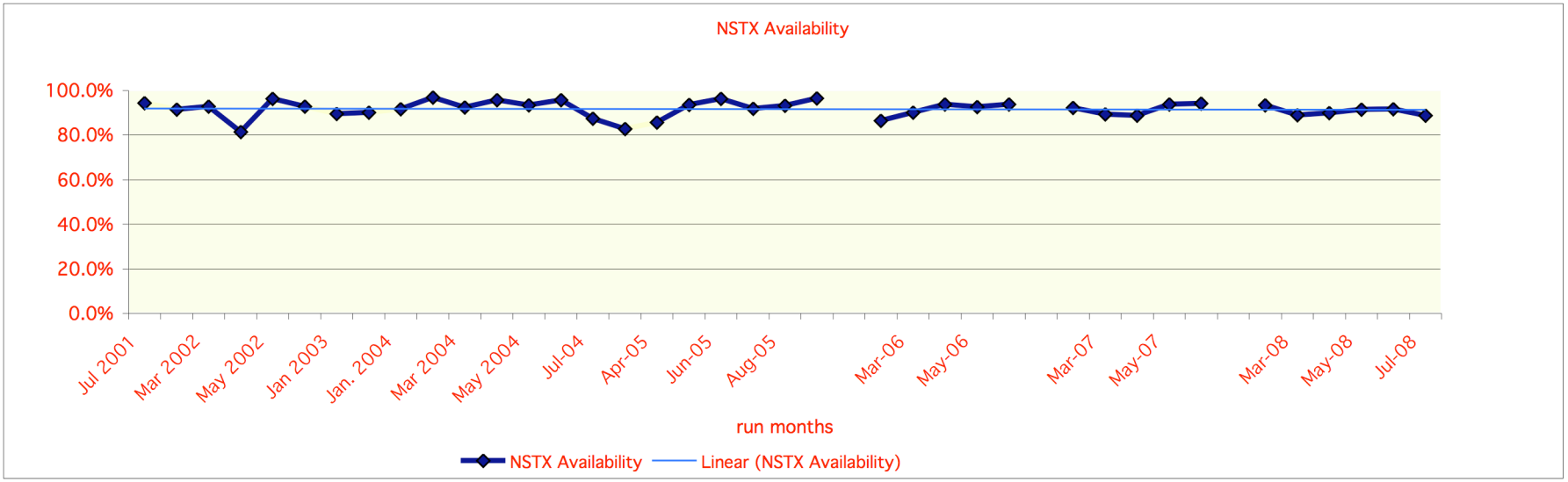
NSTX schedules operations from 7:30AM to 5:00PM, sometimes extending Ops to 7PM on select days.

Machine area scrubs and coil/VV HiPots are performed from 6:30AM to 7:30AM (not counted as run time).

Run Day begins with Experiment (XP) proposed activities such as Glow Discharge Cleaning, Magnetic test shots, shot development, etc.

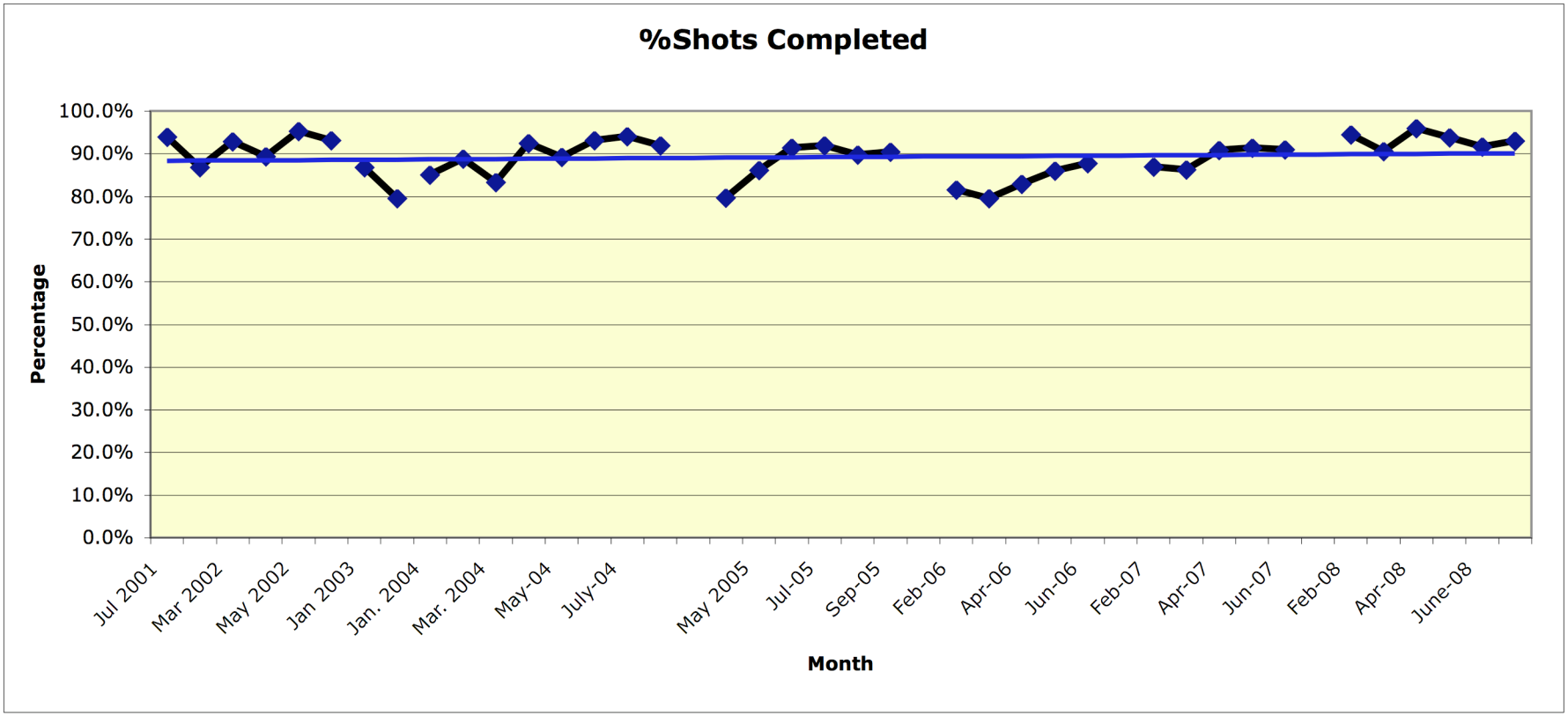
FY	XP Prep (avg)
FY05	:85 Min/Day
FY06	:57 Min/Day
FY07	:50 Min/Day
FY08	:60 Min/Day

NSTX Availability



"Availability" is the % of time NSTX is operating on scheduled run days. Subsystems must be ready to support plasma ops on a 15 minute cycle, or be charged as being unavailable. NSTX has typically operated at ~ 90% availability over scheduled run periods.

Shot-to-Shot Reliability



NSTX successfully produces a plasma in ~90% of its attempts. In FY08, NSTX produced 2571 plasmas in 2760 attempts (93.2%)

NSTX Availability/Reliability Averages

Fiscal Year	Average Availability	Run Weeks	Plasma Attempts	Plasma Discharges	Shot-to-Shot Reliability
FY05	92.9%	18	2476	2221	89.7%
FY06	94.0%	12.7	1932	1617	83.7%
FY07	92.7%	12.6	2078	1879	90.4%
FY08	92.3%	16.6	2760	2571	93.2%

Maintenance & Spare Parts

Major refurbishment of incoming 138kV switchgear recently completed, and an upgrade of the 2600kVA standby generator controls will be completed this summer. Battery back-up systems are routinely maintained.

Motor Generator Sets are on a tight maintenance schedule, and are still supported by GE. Share maintenance data with a similar facility (Northfield Pumping Station)

Power supply components (SCR's, fuses, switchgear, etc.) are commercially available & spares are on hand. Driver boards & fault detectors were designed and built at PPPL & still supported. Currently evaluating new state of the art DC current feedback devices.

Maintenance & Spare Parts

Machine:

- Spare OH coil being fabricated in collaboration with ASIPP
- Spare upper and lower ceramic breaks on hand
- Ability to wind coils, but would need to procure copper/epoxy
- Maintain some spare machine tiles & raw graphite stock

The NB shop has successfully refurbished several ion sources. Spare calorimeter bellows and torus isolation valve on hand.

Spare switch tubes and new switchgear have been procured for the HHFW systems.

The Vacuum Prep Lab maintains spares for Diagnostics and the machines vacuum pumping & Gas Injection systems.

Preventive Maintenance

Periodic Preventive Maintenance is performed per procedures developed and well tested since TFTR:

Safety Interlock Systems	(OP-KK-**, OP-NSTX-**)
Control Systems	(MP-CCD-**)
Energy Conversion Systems	(MP-MG-**, MP-ECS-**)
AC Power Systems	(MP-AC-***)
Heating Systems	(MP-NB-**, MP-RF-**)
Water and He BakeSystems	(MP-WS-**)
Vacuum and Gas Inj Systems	(MP-VAC-**)

An On-Line Preventive Maintenance Management System with automated electronic notifications has been developed and is currently being implemented.

Managing the Next Weakest Link

NSTX is proactive in identifying future problems:

- An OH Coil repair was required early in the life of NSTX. We are building a spare coil in collaboration with ASIPP to maintain the capability of running 25 weeks/year.

- All TF Joint Resistances are measured on every pulse down to the 10's of nano-Ohms. Inspections/maintenance are scheduled for measured upward trends.

- CHI Insulators further protected with additional overvoltage protection and fast voltage measurements.

Trends That Could Impact Facility Ops

Energy Costs:

- Factored in 20% increase in the cost of energy for FY08-FY10 based on Oct 2007 through May 2008, but June 2008 costs are 50% higher than FY05 through FY07.
- To avoid increased cost risk we try to avoid summer months (June-Aug)

World Helium Shortage:

- Due to the shortage, we have seen a 30% surcharge in the cost of helium. Fortunately only a $6K increment this year.

Liquid Nitrogen:

- Expect LN2 costs to track energy cost increases.

NSTX Program Budget by Cost Category

SCIENCE & OPERATIONS by cost category ($000)
FY2006-2010

				5 Yr Plan Base Budget Case	
	FY2006	FY2007	FY2008	FY2009'	FY2010'
NSTX TOTAL	**$32,921**	**$33,801**	**$38,824**	**$46,187**	**$47,083**
SCIENCE	$14,213	$14,548	$16,310	$17,279	$17,625
FACILITY OPERATIONS	$18,708	$19,253	$22,515	$28,908	$29,458
RUN WEEKS	*12.7*	*12.6*	*15*	*15*	*15*
SCIENCE	**$14,213**	**$14,548**	**$16,310**	**$17,279**	**$17,625**
PPPL Science	$9,213	$9,548	$10,410	$11,079	$11,301
Collaborators	$5,000	$5,000	$5,900	$6,200	$6,324
PPPL Science Breakdown					
Labor	$4,448	$4,607	$4,868	$5,053	$5,211
Other Direct Costs	$138	$174	$208	$216	$221
Travel	$154	$147	$161	$176	$180
Indirect Expenses	$4,473	$4,620	$5,173	$5,634	$5,689
PPPL Science Total	$9,213	$9,548	$10,410	$11,079	$11,301
FACILITY OPERATIONS	**$18,708**	**$19,253**	**$22,515**	**$28,908**	**$29,458**
PPPL OPERATING	$17,383	$18,444	$19,845	$20,308	$20,714
CAPITAL Equip	$1,325	$809	$2,669	$8,600	$8,744
PPPL Facilty Ops/CE Breakdown					
Labor	$8,067	$7,895	$8,864	$11,347	$11,704
Other Direct Costs	$1,278	$1,544	$2,261	$3,120	$3,113
Energy	$1,255	$1,204	$1,751	$1,786	$1,821
Travel	$8	$8	$28	$20	$20
Indirect Expenses	$8,100	$8,602	$9,611	$12,635	$12,800
PPPL Facility Ops Total	$18,708	$19,253	$22,515	$28,908	$29,458

'FY2009 & FY2010 reflect NSTX 5 Year Plan Base Budget Case (15% Increment)

NSTX Facility Operations by Subsystem

PPPL COST ($000)/STAFF (FTE)
FY2006-2010

				5 Yr Plan Base Budget Case	
	FY2006	FY2007	FY2008	FY2009'	FY2010'
RUN WEEKS	*12.7*	*12.6*	*15*	*15*	*15*
COST ($000)					
FACILITY OPS	**$18,708**	**$19,253**	**$22,515**	**$28,908**	**$29,458**
Base Operations	$6,607	$6,539	$7,584	$7,648	$7,798
Heating Systems	$3,705	$4,277	$4,631	$4,785	$4,887
Computing	$2,021	$1,990	$1,713	$1,796	$1,897
Power Systems	$2,328	$2,385	$2,541	$2,585	$2,591
Diagnostics	$725	$1,195	$1,348	$1,435	$1,471
Admin & Ops Support	$1,998	$2,059	$2,030	$2,060	$2,070
PPPL Upgrades	$1,325	$809	$2,669	$8,600	$8,744
STAFF FTEs					
FACILITY OPS	**68.5**	**67.9**	**74.5**	**97.5**	**97.7**
Base Operations	22.3	20.8	20.7	21.7	21.7
Heating Systems	17.1	18.2	18.8	19.3	19.3
Computing	7.9	7.8	6.9	7.1	7.1
Power Systems	11.5	11.2	11.1	11.1	11.1
Diagnostics	3.2	5.0	5.3	5.7	5.7
Admin & Ops Support	3.5	3.0	2.8	2.8	2.8
PPPL Upgrades	3.0	1.9	8.9	29.8	30.0

'FY2009 & FY2010 reflect NSTX 5 Year Plan Base Budget Case (15% Increment)

Cost for Incremental Week of Operations

Cost Category	Cost (2008 K$)	Notes
Energy	$45	Experimental Ops & He Refrigerator
Overtime	$28	Technician Support
Gases	$8	LN_2, De, He
Labor/Maintenance	$115	With additional run weeks maintenance, repairs & upgrade support is reduced requiring more staff support
Total	**$196**	

Excludes straight time cost of scientists, engineers & technicians paid whether we run or not

Self Assessments

In addition to research and engineering meetings, an annual all hands Run Assessment is held to discuss opportunities to improve the NSTX program. This year's topics and steps taken:

- Program Coordination - Physics Operators now further participate in proposing shot development in the design of an XP. The Mid-Run Assessment actively measures progress towards publications, and the Run Coordinator tracks longer term XP progress.
- Collaborations - Training notices distributed to all, and more training made available on line. All approved XP's are now posted on line, as well as updated run schedules.
- Run Schedule - Changes made to start earlier, and to automate some diagnostic adjustments. Wider distribution of engineering schedules.
- Run Staffing/Equipment - Shortages of critical spares identified and ordered. Operational improvements to power systems proposed and implemented. Staffing needs identified and some relief provided.

Quality Assurance

The PPPL Quality Assurance Division develops policies and procedures to provide quality related services, and to continuously foster improvements. QA responsibilities include field inspections (AWS Certified Weld Inspector), review of installation procedures, and oversight of procurements. Internal and supplier audits are performed, and open audit/inspections findings are tracked. NSTX has benefited from recent internal audits on:

- NSTX Conduct of Operations (including work permits and JHA's)
- Job specific and access training requirements
- NSTX Support of Collaborations
- The application of the PPPL Hoisting and Rigging Program
- The application of the PPPL Lockout/Tagout Program

NSTX is Committed to Worker Safety

Integrated Safety Management is an effective approach to address safety issues, and is used at PPPL to integrate safety into all work planning and execution.

ES&H is a line management responsibility:

- Central to the way we plan and do work on NSTX
- Safety Topics are discussed at the daily status meeting
- All managers conduct and document safety inspections

Jerry Levine, the Head of the PPPL Environment, Safety and Health (ES&H) Division, will discuss available PPPL ES&H resources and highlight the NSTX safety programs and performance in his presentation later this afternoon.