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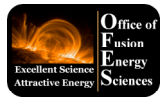

NSTX

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NSTX Facility Operations

Al von Halle
PPPL

For the NSTX National Team

DOE Review of
NSTX Five-Year Research Program Proposal

June 30 – July 2, 2003

Outline

- Overview of Major Subsystems
- Configuration control and engineering procedures
- Machine Availability/ Performance/ Maintenance
- TF Joint Failure
- Environment, Safety & Health/ Quality Assurance

NSTX is Located at PPPL's D-Site

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, recommissioned, 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 45 Sections.

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

TF -	4 PSS
OH -	12 PSS
PF1a/b,U/L -	10 PSS
PF2U/L -	4 PSS
PF3U/L -	8 PSS
PF5 -	3 PSS
CHI -	4 PSS

Plans of 5 more sections for PF4, PF5 Bipolar, RWM, & CHI Absorber Coils

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 5MW 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.

Electron Bernstein Wave (EBW) Heating System to use 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.

Instrumentation and Control

In 2003, NSTX acquired 300MB/Shot, a 50% increase over 2002

On-line storage requirements are expected to increase each year by about 100MB/Shot.

Majority of data travels to the primary control computers via six CAMAC highways:

- Three for Diagnostic Data
- Two for Facility Operations
- One for NBI

Data acquisition utilizing PCI bus architecture has been developed that reproduces the functions of CAMAC.

Instrumentation and Control

MDSplus data presently managed by a VMS operating system:

- Cost of storage of VMS-based data is increasing as compared to LINUX-based systems (now < $10K/TB).
- 1st NSTX LINUX-based system on line this year.

NSTX participating in a multi-processor computing facility at PPPL (purchased 9 dual-processor LINUX-based units for the 140 unit cluster)

- Analysis software for the Thomson Scattering Diagnostic now on that cluster.
- Decreased time to receive electron density /temperature profiles by X3.
- New diagnostic analysis tasks expected to move to the cluster over the next few years.

Configuration Control System is Described in Engineering procedures.

Work Planning (ENG-032)	Web based work planning and approvals. 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 Enables PPPL and Collaborator Staff to 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

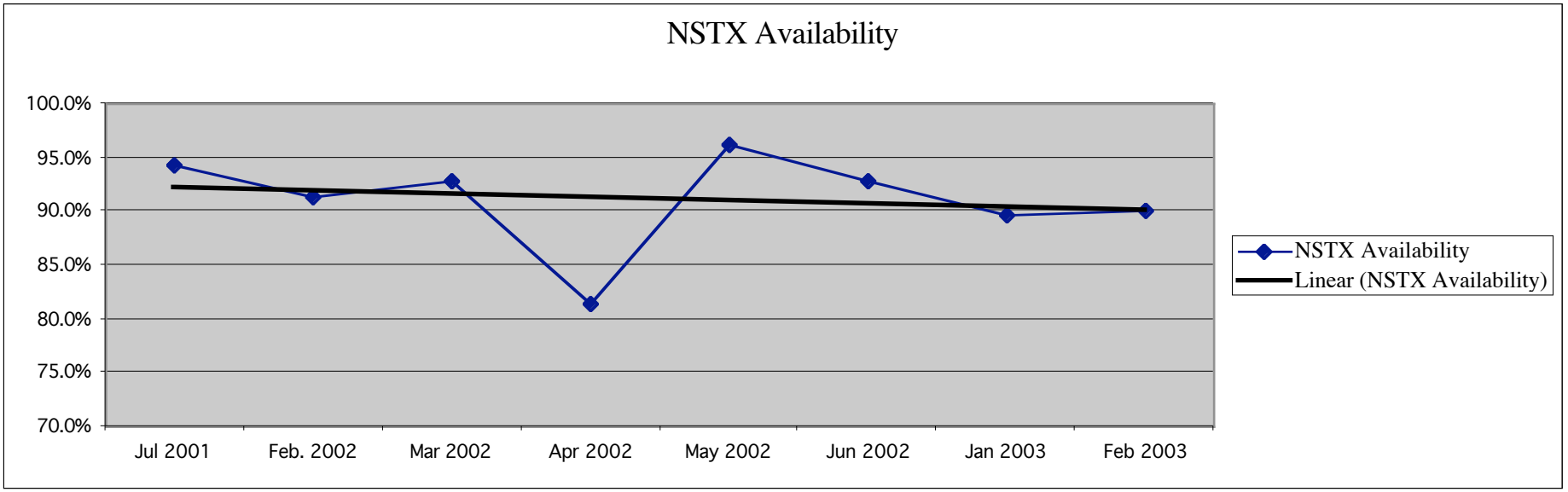
Conduct of Operations	(OP-AD-39)
Chain of Command	(OP-AD-56)
Work Permit System	(OP-AD-09)
Control of Temporary Mods	(OP-AD-03)
Control of Workplace Cleanliness	(OP-AD-24)
NSTX Access Controls	(OP-AD-117)

Formal Training Program for Engineering and Technical 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

NSTX Availability



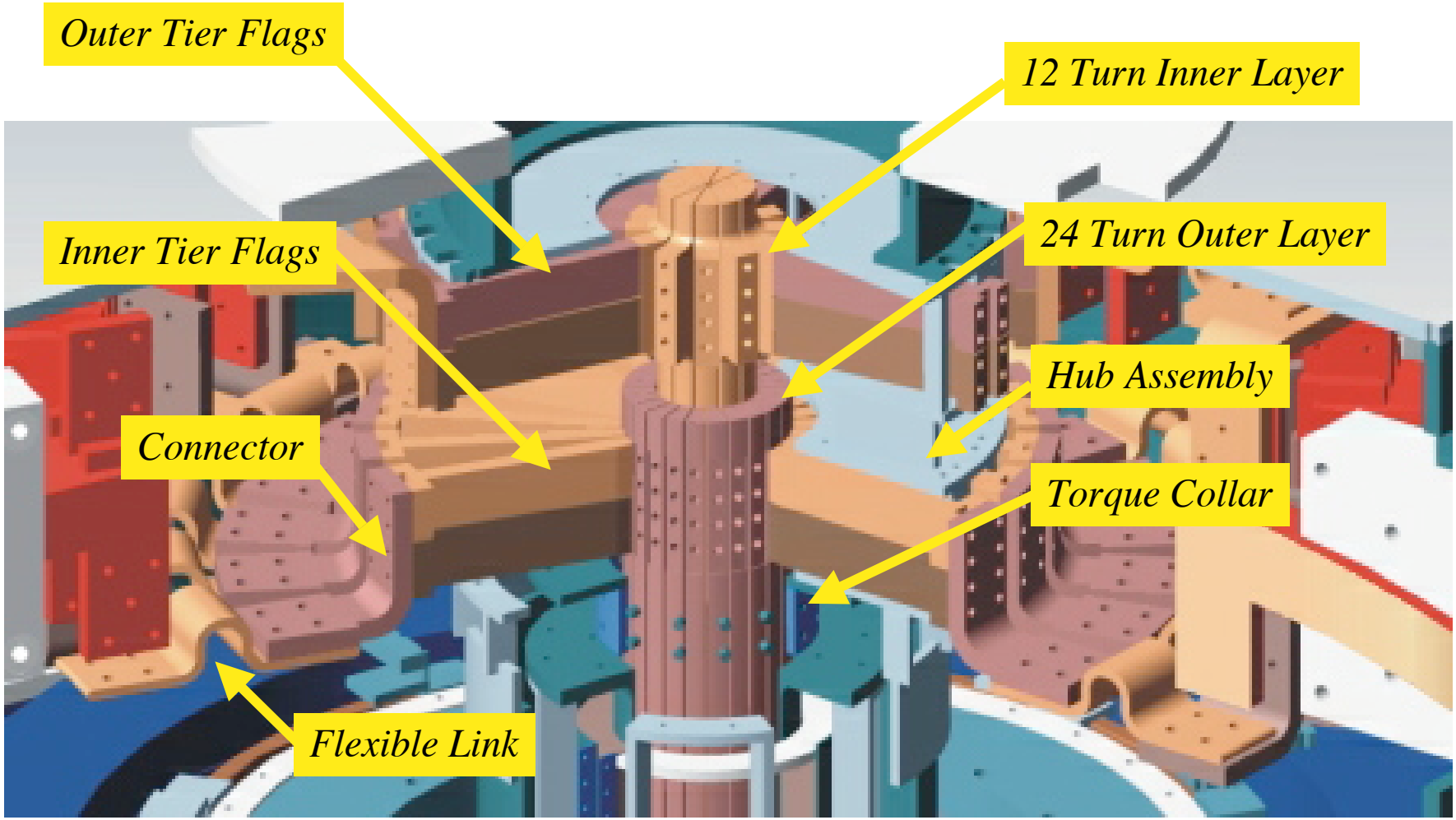
NSTX has typically operated at ~ 90% availability over scheduled run periods. (100% availability would enable 1 plasma attempt every 15 minutes after the morning start-up/tests)

NSTX Availability

Additional run time scheduled to compensate for reductions in lost run days:

- FY'00 - Completed 15 Run weeks (2,504 plasma attempts during this year's run).
- FY'01 - Completed 15 Run weeks (2,137 plasma attempts).
- FY'02 - Completed 13 Run weeks (1,928 plasma attempts).
- FY'03 - 12 Run weeks scheduled. Run ended in 5th week (after 603 plasma attempts/ 22 run days) due to TF coil failure. Redesign/repair in progress.

TF Joint Elements



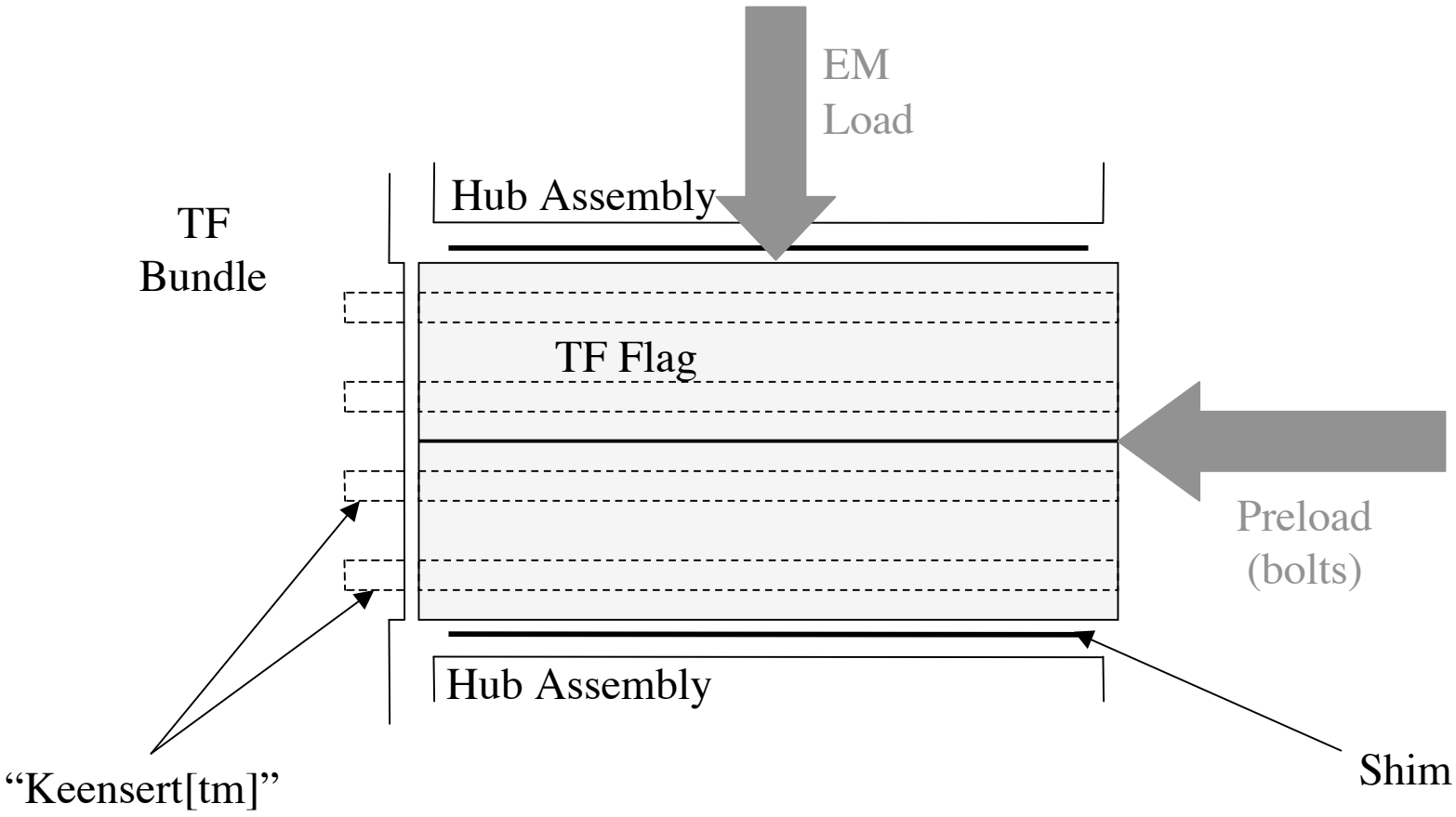
Note: Original Design Shown, Top Portion

TF Joint Failure

View of the lower portion of the TF bundle where the failure occurred at one of the outer layer flags

The flaw in the joint was that the loads on the flag were not adequately transmitted to the hub structure.

TF Flag Joint Load Schematic



Comprehensive Inspection of Joint was Performed During '02 Outage After Operations at 6kG

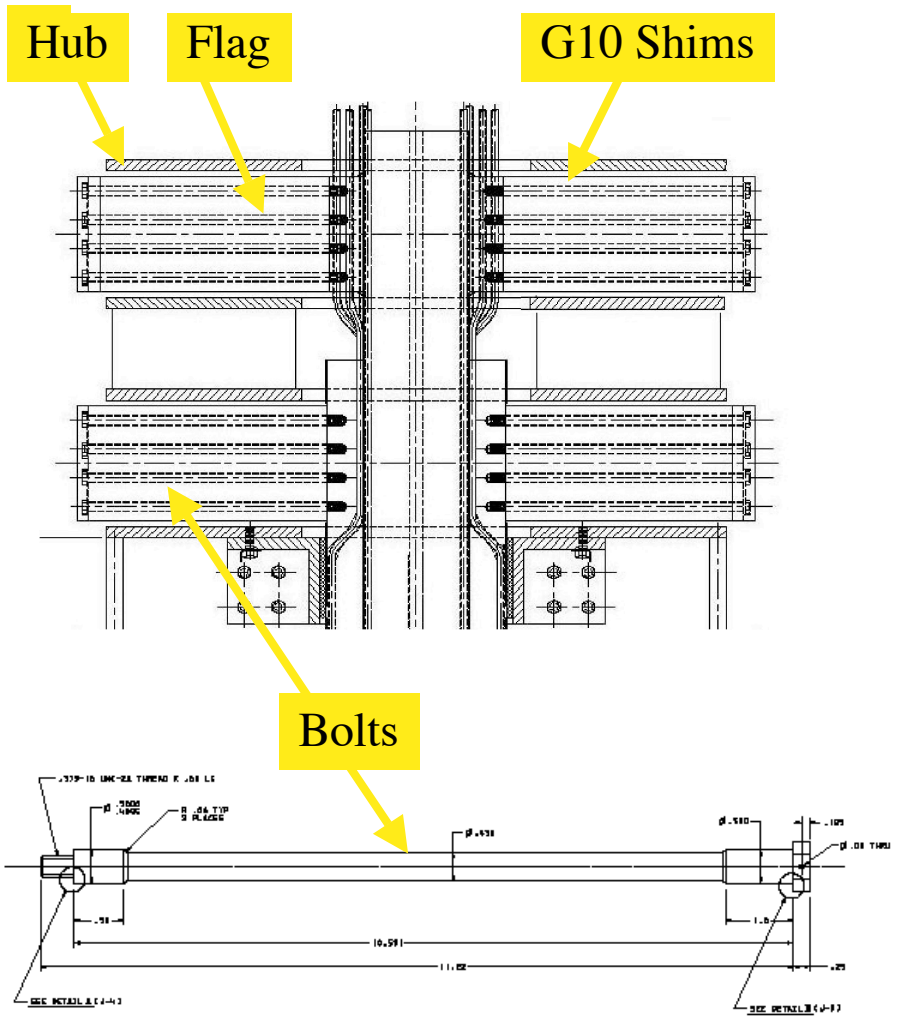
Joint problems identified during maintenance in '02 outage

- Loose Bolts
- Rise of contact resistance
- Marking on joint surfaces
- Copper "mushrooming" around bolt holes

Project initiated a structural analysis of the joint and hub assembly and restricted operations to 4.5kG.

Increased inspection and maintenance routines, and began design activities for a new centerstack.

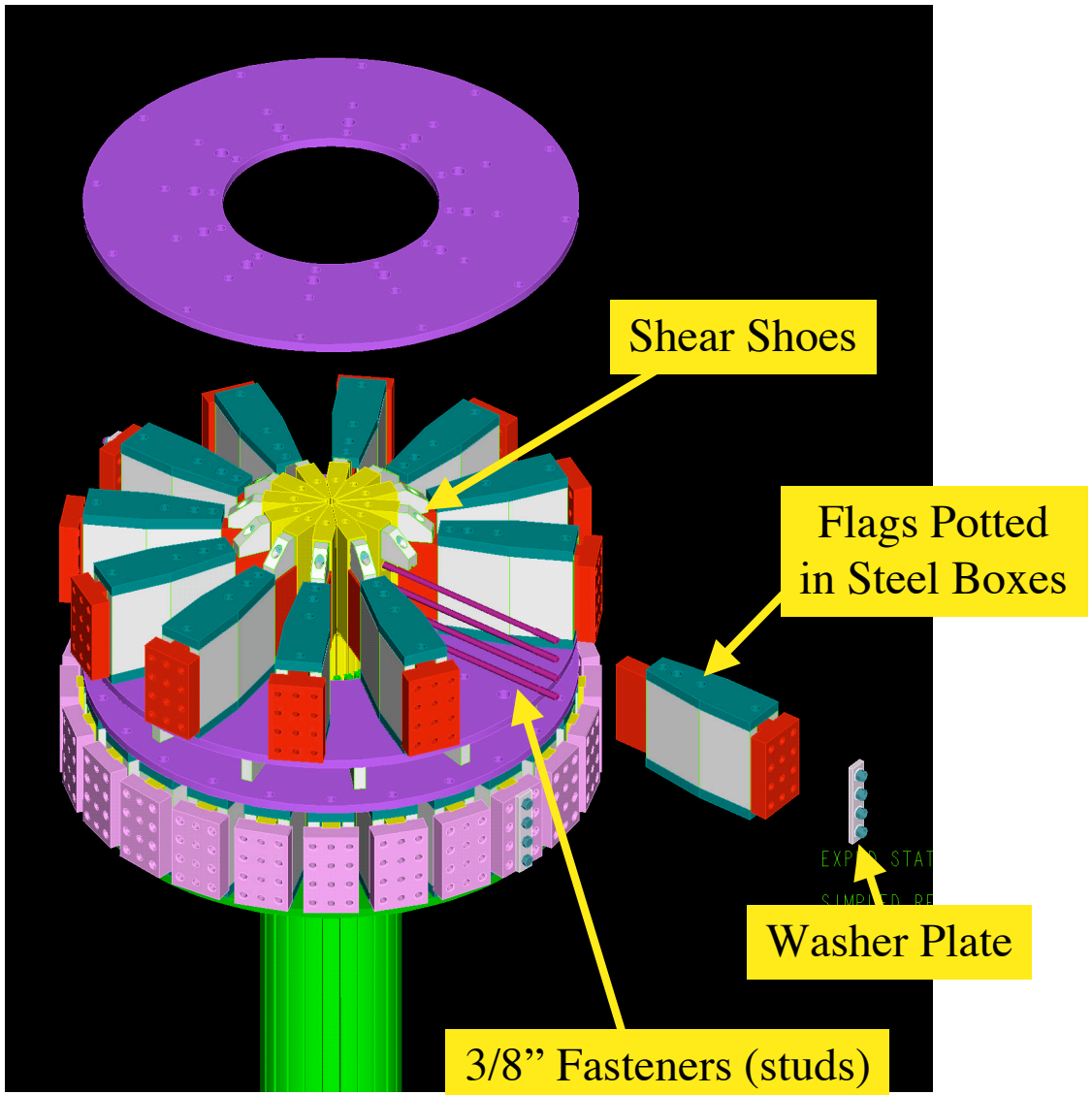
Problems with Original Design Contributing to Failure



Laboratory with PAO conducted a "Lessons Learned Study" and identified issues with:

- Stiffness of hub structure to react moment.
- Transferring loads to hub structure by shims.
- The dual shear/preload function of the bolts.
- Bolt diameter and the engagement of threads.
- Monitoring of joint resistance measurements w/o disassembly.
- Additional review of computational models during engineering design could have identified incorrect assumptions in the finite element analysis.
- Disagreement between field experience and model predictions could have led to questioning model assumptions.

Improved Features of New Design



- 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 w/o disassembly

Increased Testing and Monitoring of TF System Planned

Extensive tests of joint components and prototype are underway.

Integrated system test will be performed in February prior to plasma operation.

- Hub and joint displacements will be compared with finite element analysis.
- Initial Operation will be restricted to 4.5kG while assessing the impact of routine operations.

Voltage taps will enable routine monitoring of joint resistance.

Diamagnetic loop will be used to monitor trends in coil impedance.

Managing the next weakest link

The highly stressed areas in the NSTX design are:

TF Joints and associated support structure

- New TF hub design will dramatically reduce the stresses on the joints.

TF inner bundle insulation shear stress due to OH

- Dissection of the failed TF inner bundle indicates that the TF insulation is unaffected after three years of operation.

OH Solenoid had a minor insulation failure due to issues with vendor quality control

- Planning a spare OH Coil to support 21 weeks per year of operation

CHI Insulators

- Provided an upgraded upper insulator along with additional overvoltage protection and “fast” voltage measurement

Preventive Maintenance

Periodic Preventive Maintenance is performed on:

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 Bake-Out Systems	(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.

NSTX is Committed to Worker Safety

ES&H is a line management responsibility

Central to the way we plan and do work on NSTX

Integrated Safety Management is an effective approach to address safety issues

PPPL's Environment, Safety and Health (ES&H) Division provides the following resources:

Electrical Safety	Radiation Protection
Industrial Hygiene	Industrial Safety
Laser & RF Safety	Environmental Protection
Waste Management	

PPPL ES&H Oversight

ES&H Executive Board

Evaluates the effectiveness of PPPL's ES&H Program and NSTX readiness to operate.

Safety Review Committee

Reviews/approves project Safety Assessment Documents (SAD's).

NSTX Activity Certification Committee (ACC)

Conducts safety reviews of proposed NSTX operations and recommends issuance, revisions and constraints on the NSTX Safety Certificate to the ES&H Executive Board.

- The Safety Certificate defines permissible NSTX operations and constraints.
- ACC appointed by ES&H Executive Board.
- DOE-PAO staff participate as resource members of ACC.

NSTX SAFETY RECORD: 2001-2002

- NSTX received NJ State awards in 2002 & 2003 for working1 and then 2 years without an away from work case.

- Although minor, there were recordable injuries to NSTX workers in CY01 & CY02.
  - 6 cases reported in CY01
  - 5 cases reported in CY02

- Increased attention being given to all recordable injuries at PPPL
  - Safety meetings of all staff have been held and actions taken.
  - For the 1st half on CY03, NSTX has not had a recordable injury.

NSTX Radiological Safety

- Access to NSTX Test Cell and work involving radioactive components are controlled by Radiation Work Permits (RWPs).

- Radiological monitoring (gammas, neutrons, tritium) is performed for NSTX.

- A highly conservative estimate of the maximum annual dose to the public (at Site Boundary) from NSTX operations is <0.02 mrem per year.

Quality Assurance

The Quality Assurance (QA) Division provides the expertise, guidance, and oversight to assure quality.

QA Policies were modeled after Requirements for Nuclear Facility Applications (NQA-1-1997) and tailored to the risks present at PPPL:

P-006	Conduct of Operations
P-013	Use of Procedures
P-052	Special Processes
P-063	Handling, Shipping, and Storage
P-075	Configuration Management
P-079	Identification & Control of Materials
P-086	Calibration of Measurement and Test Equipment
P-037	Software Quality Assurance

Quality Assurance

QA responsibilities include:

- QA Plan, developing quality related policies & procedures
- Inspections - AWS Certified Weld Inspector
- Procurement Quality Assurance
- Audits - Both internal and suppliers
- Tracking open audit/inspection findings

NSTX Has Made Extensive Use of PPPL Infrastructure

TFTR Legacy equipment has facilitated NSTX operations and enabled rapid technical progress.

PPPL supports NSTX by providing engineering, ES&H, QA, and training.

- Good safety record has been demonstrated
- High availability (90%) has been achieved

TF joint failure is understood and a new design is being implemented to address the deficiencies.

- A review of other high stress components on NSTX has been conducted, and actions are being taken in each area to control risks.

NSTX can operate reliably 21 run weeks a year starting in ‘04.