TRANSP and PTRANSP at PPPL: Status and Plans*

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Abstract

D. McCune, R. Andre, E. Feibush, K. Indireshkumar, C. Ludescher, L. Randerson, PPPL, J-M. Kwon, NFRI Korea – The PPPL TRANSP code suite is a set of tools for time dependent simulation of tokamak plasmas. The entire system consists of over a million lines of fortran-77, fortran-90, C, and C++ code. Although pieces are over 30 years old, the code has been continually upgraded and modernized, now representing over 60 man-years of labor invested. TRANSP now runs as a service on the Fusion Grid, supporting plasma physics research groups around the world. In this poster, status and plans for TRANSP and associated predictive modeling upgrades (PTRANSP) are summarized. Fusion Grid production system results will be shown. Upgrades to physics models (MHD equilibrium reconstruction, ICRF wave interaction with beam injected fast ions, predictive transport), algorithms (MPI-parallelized source models), and client software (web-browser accessible interactive visualization of run results) will be summarized. The relationship of TRANSP/PTRANSP development efforts to SciDAC and FSP will be discussed. Related posters are cross-referenced.

TRANSP: Vision Statement

Provide a comprehensive end-to-end modeling capability for magnetic confinement fusion energy experiments of today and tomorrow.

Traditional TRANSP: Overview

Experiments (Asdex-U, C-Mod, DIII-D, ITER, JET, KSTAR, MAST, NSTX)

Diagnostic Hardware

Preliminary data Analysis and Preparation (largely automated)

MDS+

20-50 signals {f(t), f(x,t)} Plasma position, Shape, Temperatures, Densities Field, Current, RF and Beam Injected Powers.

Pre- and Post-processing at the experimental site…

MDS+

Experiment simulation Output Database ~1000-2000 signals {f(t), f(x,t)}

Visualization

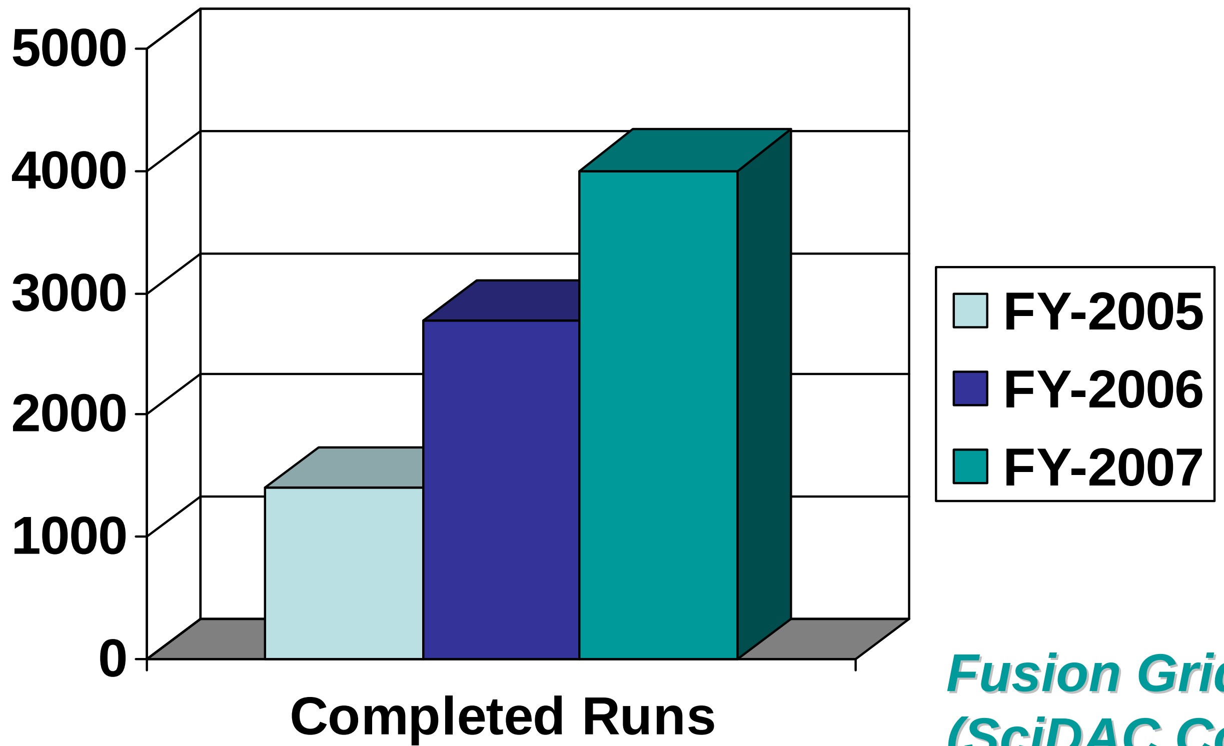
Load Relational Databases

Detailed (3d) time-slice physics simulations: GS2, ORBIT, M3D…

TRANSP Analysis*:
Current diffusion, MHD equilibrium, fast ions, heating, current drive; power, particle and momentum balance.

*FusionGrid TRANSP on PPPL servers

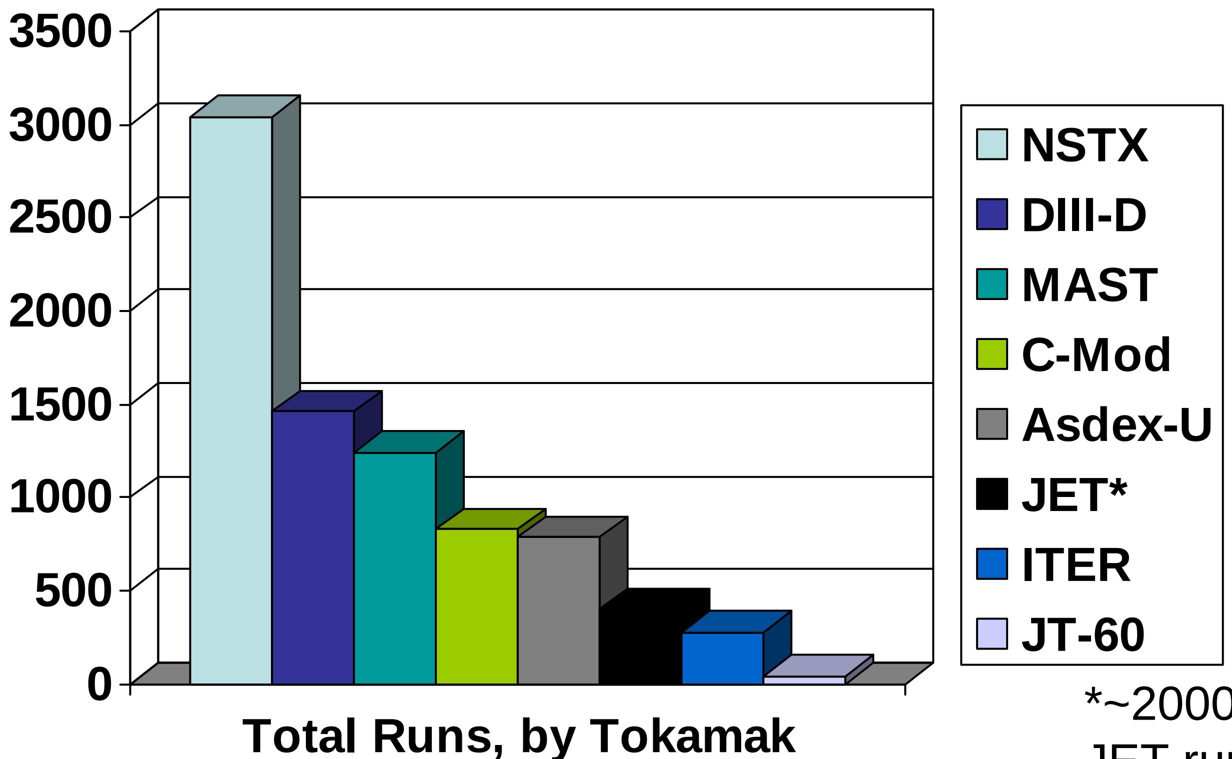
PPPL TRANSP Run Production*



Fusion Grid TRANSP (SciDAC Collaboratory)

*~3x increase in runs; ~6x increase in *crashed* runs– significant labor costs!

PPPL TRANSP SERVICE FY-2005 through FY-2007



8188 Total Runs

*~2000 additional JET runs on JET production server.

FY-2008 PPPL TRANSP Team

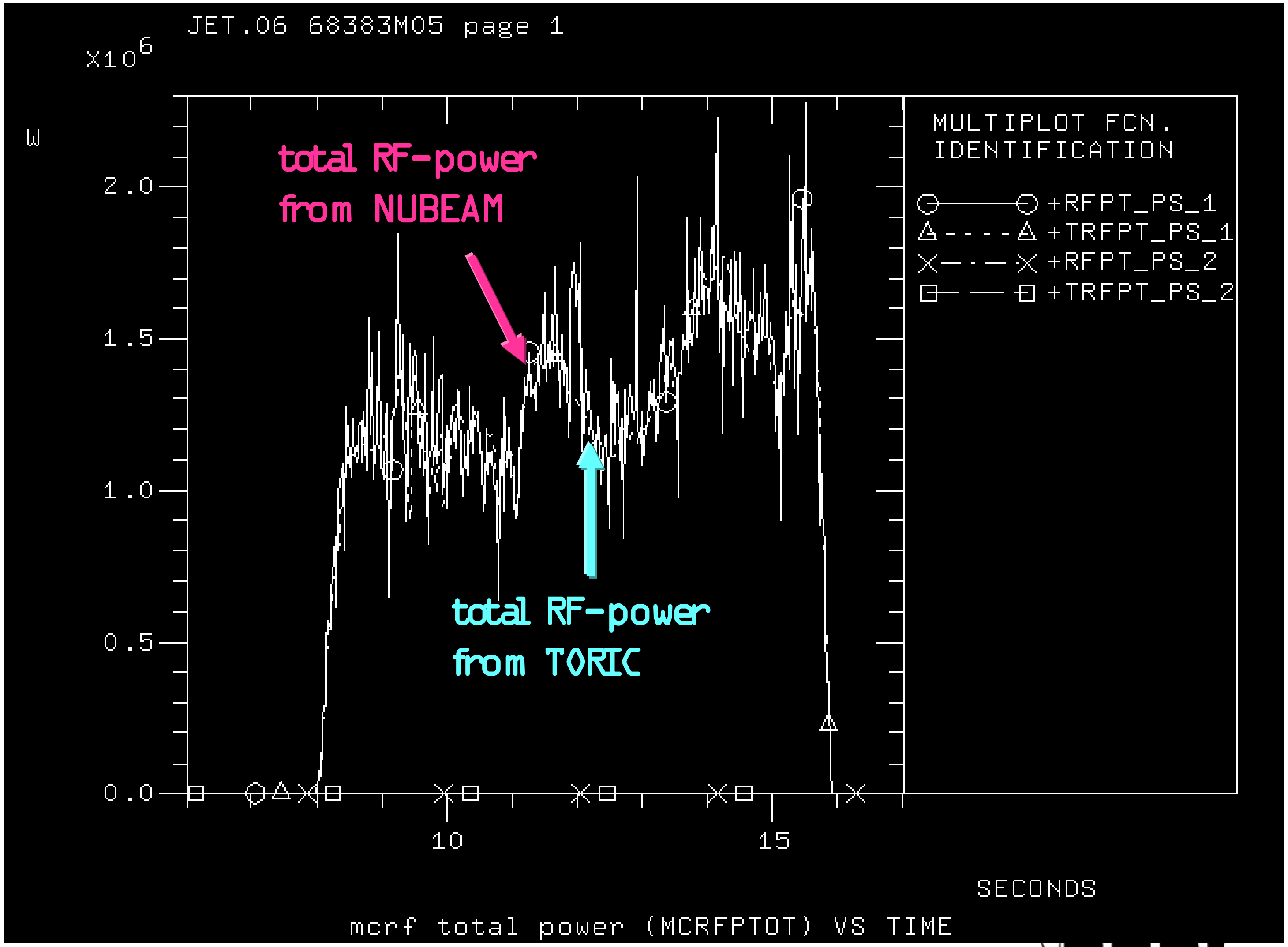
Name	TRANSP	PTRANSP	SciDAC	Other
Andre	80%	20%		
Kumar	50%		50%	
McCune	35%	25%	20%	20%
Feibush	10%		35%	55%
Ludescher	65%	5%	5%	25%
Randerson	30%	10%		60%
Total FTE	2.7	0.6	1.1	1.6

Color code: Physics, Visualization, Engineering/ Operational Support

New TRANSP Features

- Monte Carlo RF Operator (Jae-Min Kwon)
  - TORIC wave field solutions coupled to NUBEAM;
  - Two passes: after first pass orbits are recalculated with E+ renormalized to get power absorption right.
- MPI-parallel TRANSP Server
  - Serial clients share server for 8- or 16-processor NUBEAM calculations.

Beam ion RF-power absorption match between NUBEAM and TORIC5 – see ***UP8.083***



NUBEAM RF Operator Issues

- MPI runs needed for better statistics.
- Wave code needs non-Maxwellian target distribution function.
  - NonMax version of TORIC exists.
  - Need to install and test in TRANSP.
  - Need to learn how to fit “noisy” MC-binned distribution function data in TORIC.
- RF-SciDAC & SWIM SciDAC Research...

NUBEAM Parallel Server

- Operations have commenced.
- Np = 4, 8, 16, or 32 on PPPL cluster.
- Parallel job monitor on TRANSP web page.
- Client server file communications overhead is non-negligible:
  - Only large NPTCLS runs will benefit;
  - We plan to evaluate a more traditional (no client-server) deployment for low-Np runs.
- TORIC parallel server also planned.

Parallel Service Queue Monitor - Windows Internet Explorer provided by PPPL

http://w3.pppl.gov/transp/pfgs_queue_monitor

Parallel Service Monitor

Shows status of parallel server and requests.

User help
Developer help

PPPL Grid Monitor for TRANSP MPI runs

Last check time = Thu Nov 8 11:41:56 2007

Queue server status = Running, available processors = 8
Queue server nodes = kestrel067 kestrel075 kestrel076 kestrel077
Queue server nodes status = All up

Current and queued steps
pshr0005 transp_TFTR.88_37065Y02

Recent steps:

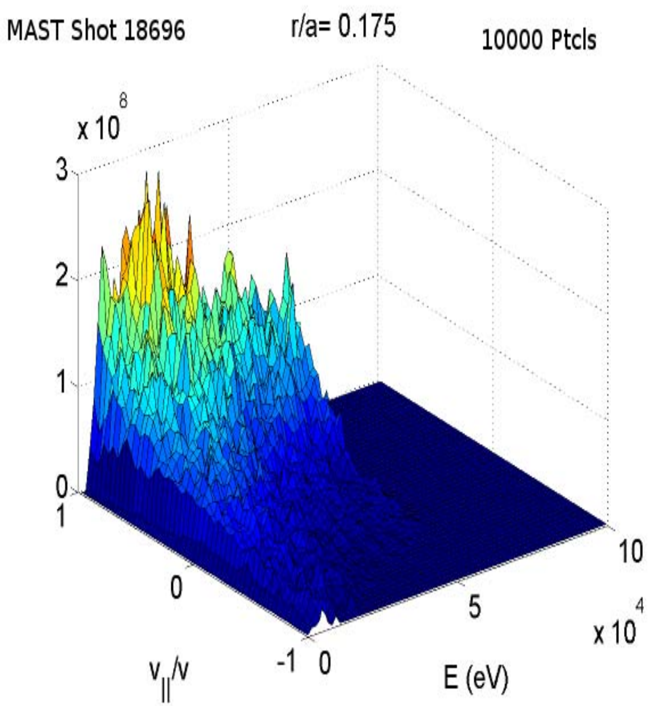
Account	Identification	Start Time	Elapsed Time
pshr0005	transp_TFTR.88_37065Y02	Nov 8 11:41:36	Not finished
pshr0005	transp_WRK.88_37065Y01	Nov 8 11:41:17	19 seconds
pshr0005	transp_TFTR.88_37065Y02	Nov 8 11:40:52	22 seconds
pshr0005	transp_WRK.88_37065Y01	Nov 8 11:39:40	2 seconds
pshr0005	transp_WRK.88_37065Y01	Nov 8 11:39:06	11 seconds
pshr0005	transp_TFTR.88_37065Y02	Nov 8 11:34:56	3 seconds
pshr0005	transp_TFTR.88_37065Y02	Nov 8 11:34:00	2 seconds
pshr0005	transp_TFTR.88_37065Y02	Nov 8 11:33:26	13 seconds
pshr0005	transp_TFTR.88_37065Y01	Nov 8 11:27:35	12 seconds
pshr0040	transp_MAST.04_18696T02	Nov 8 10:29:38	617 seconds

Done — Local intranet — 100%

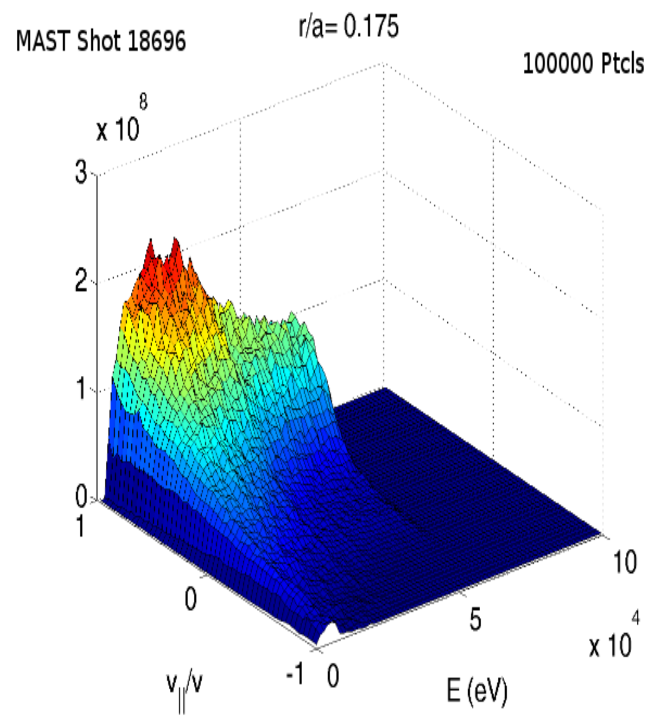
Comparison of wall clock times for 1, 8 and 16 processors

- 3 Identical MAST runs for shot 18696, 100K particles, enhanced FLR model.
- 1 Processor run: 449.2 hours (18.7 days!).
- 8 Processor run: 66.70 hours (6.7x faster).
- 16 Processor run:32.50 hours (13.8x).
- *Acknowledgment:* Matthew Lilley (Imperial College, London); David Keeling, Robert Akers (Culham, UK)-- MAST.

More Particles, Better Statistics



10K particles



100K particles

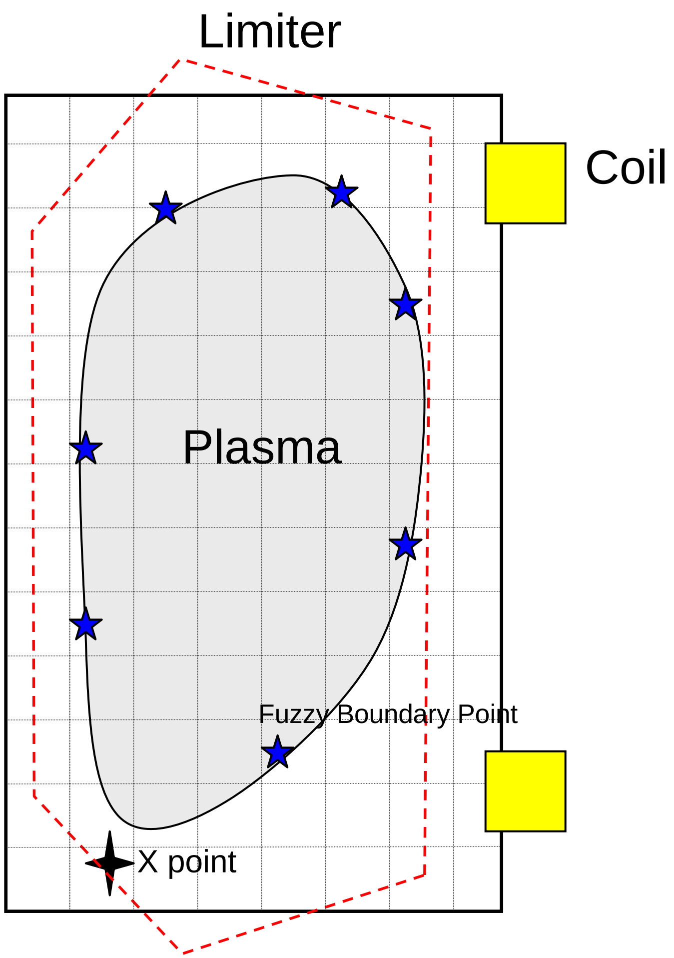
Plots provided by MAST Team

Further TRANSP Improvements

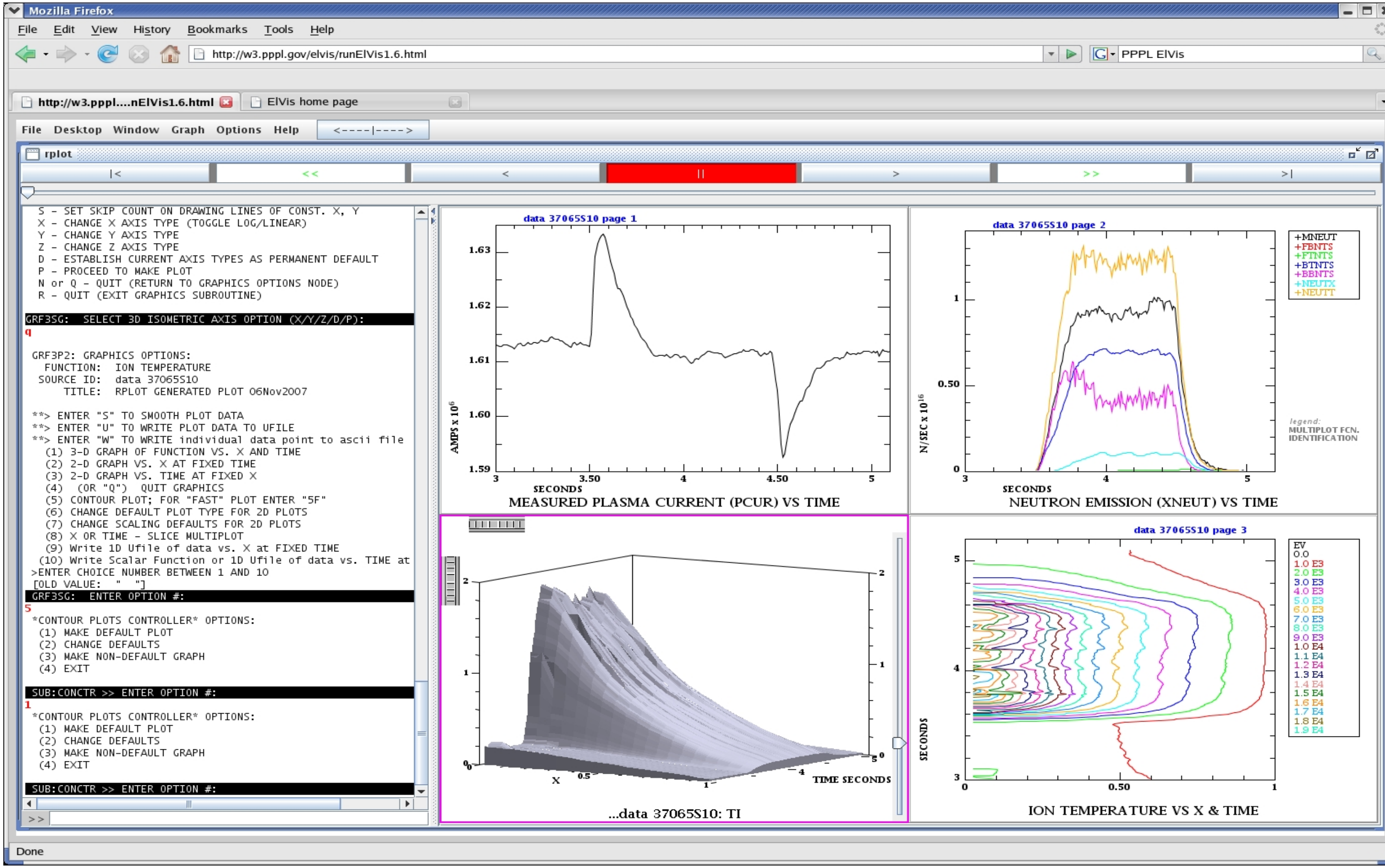
- Improvements to MHD equilibrium:
  - TEQ significantly more reliable for STs.
  - Some cases still fail (sensitive to input data).
  - Method for using TEQ in free boundary mode has been developed and is under test.
- NUBEAM *deposition* distribution function data: set OUTTIM(…) in namelist; use get_fbm ... See poster: **TP8.089**
- ElVis RPLOT runs in web browser…

PTRANSP Implementation of TEQ Free Boundary Solver– see ***UP8.082***

- TRANSP/PTRANSP has successfully been using the TEQ fixed boundary solver for over a year.
  - Reasonably robust and very accurate
  - Has become the preferred fixed boundary solver
- The TEQ free boundary solver is invoked over the fixed solver by a single namelist change.
  - **NTEQ_MODE=102** causes <J.B> to be used in a free boundary solution when TEQ (LEVGEO=11) is being used.
  - The prescribed boundary given as input to PTRANSP is used to select fuzzy boundary points for TEQ. The coil currents are constrained in a least squares manner so that the plasma boundary lies on the fuzzy boundary points.
  - To startup the run an existing free boundary solution of the tokamak is read into TEQ and perturbed through multiple invocations of TEQ to the starting conditions of the shot.
  - A q mode free boundary solution will be made available after further development of the magnetic field diffusion in PTRANSP.
- The $\psi(R,Z)$ poloidal flux solution over the entire grid is available to other modules in PTRANSP through the xplasma fortran 90 interface.



RPLOT in ElVis – Web Access



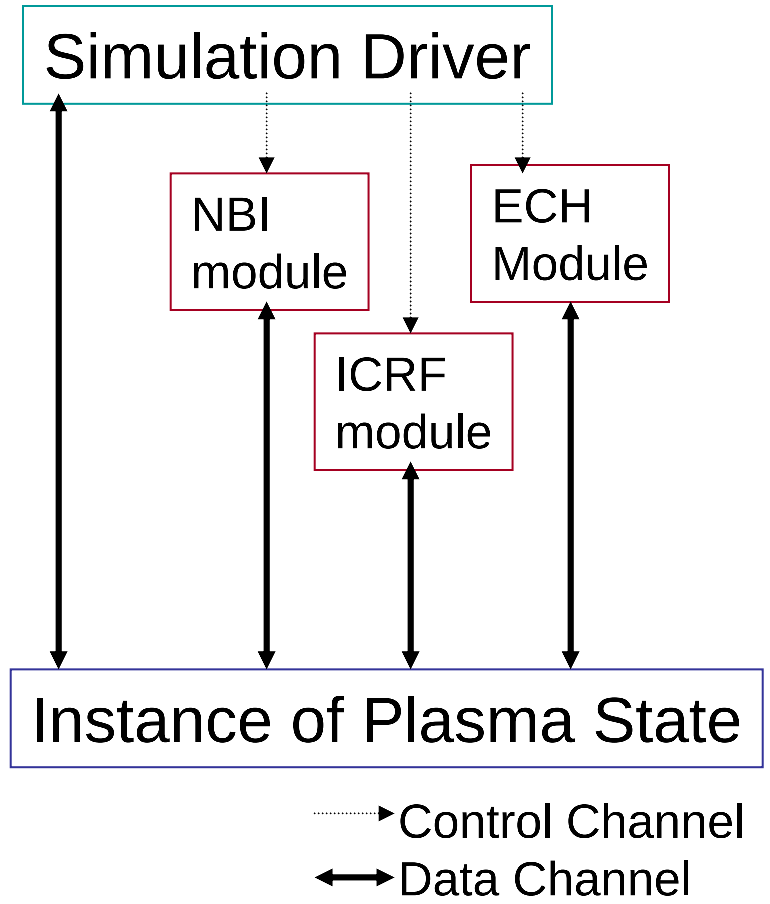
See: http://w3.pppl.gov/Elvis

Future Directions

- More MPI services: TORIC, GENRAY,…
- Improved MHD equilibrium reconstruction
- Continued improvement to Monte Carlo RF operator and wave code coupling.
- Continued MPI development
- Leverage SciDACs; use Plasma State.
- PTRANSP…

SciDAC Plasma State Module

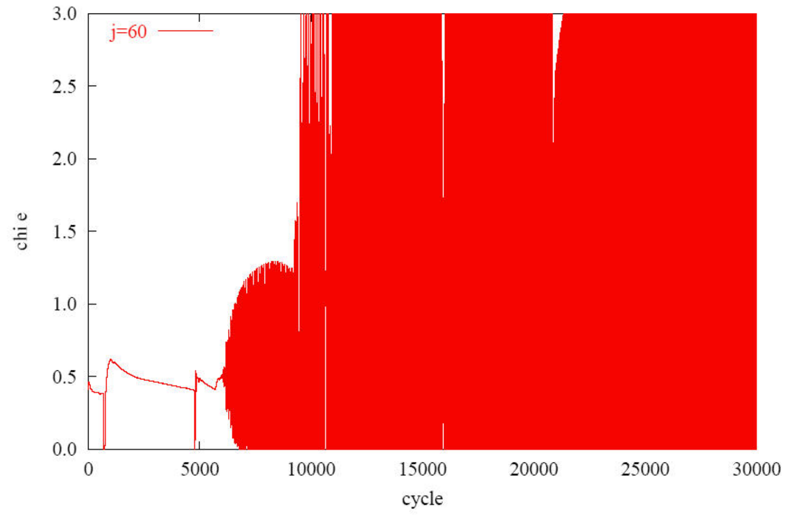
- Repository for live tokamak simulation data:
  - MHD Equilibrium
  - Profiles
  - Species Lists, etc.
- Used in PTRANSP, SWIM; FACETS soon.
- Possibility to couple in CQL3D/GENRAY and other codes.



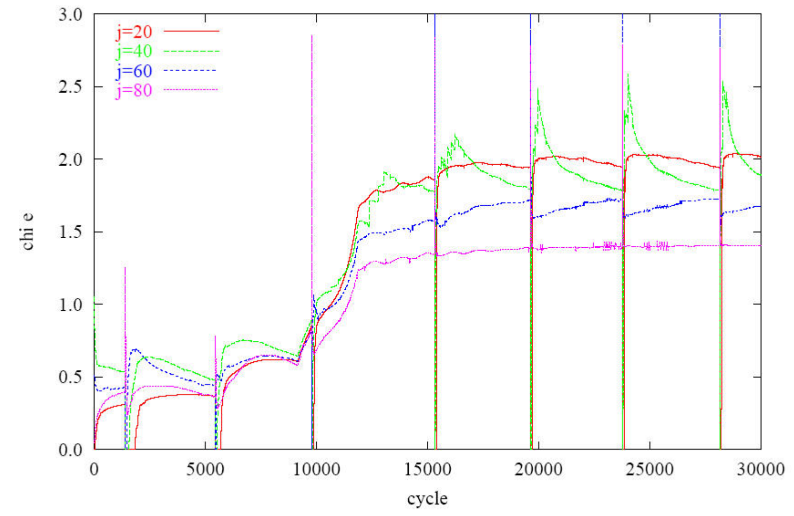
PTRANSP Phase 1 (2004-2006)

- Stiff solver upgrades completed:
  - Free Boundary (TSC): L. P. Ku, et al.
  - Prescribed Boundary: G. Bateman, et al.
- PTRANSP Client-Server Configuration:
  - **TSC** free boundary predictive code client:
    - Compute evolution of equilibrium and profiles;
  - **TRANSP** server:
    - Compute heating and current drive sources;
    - Standard analysis of predictive code results.
  - 2007: used in SWIM SciDAC project.

The PTRANSP Coupled {Te,Ti} Temperature Solver



Without linearization



With linearization

GLF-23

<u>TSC solver method was ported into TRANSP by Lehigh U. Group; Extensive use in TRANSP for ITER Simulations by R. Budny & Lehigh U. team.</u>

Phase 2: PTRANSP is TRANSP

- A project to upgrade TRANSP predictive capability.
- Retained from TRANSP:
  - Code base
  - Production system
  - Connection to experimental data
  - Connection to post-processors
  - Connection to user community.

PTRANSP Phase 2

- "Non-renewable" 3 Year Grant, ~$650k/year
  - Funding approved late in FY-2007
  - General Atomics (25%)
  - Lehigh University (25%)
  - LLNL (25%)
  - PPPL (25%).
- Work scope of grant clearly focused on predictive upgrades to TRANSP itself.

PTRANSP Phase 2 – GA Role

- Add GCNM-P Solver to TRANSP
  - Allow flexible applications:
    - Prescribe electron density (T/F)
    - Prescribe ion densities and impurity levels (T/F)
    - Include depletion by fast species.
    - MHD equilibrium and q(r,t) are input.
- Import TGLF predictive Transport Model into TRANSP via GCNM-P.
- Will use SciDAC Plasma State software.
- Support other uses of TGLF as needed.

PTRANSP Phase 2 – Lehigh U.

- Program of direct improvements to TRANSP internal solvers (with PPPL).
- Predictive Sawtooth and Pedestal models.
- Intensive *use* of PTRANSP for research applications.
- See posters: **UP8.085, UP8.086**

PTRANSP Phase 2 -- LLNL

- Provide Free Boundary TEQ model to PPPL.
- Enhance TEQ to enable concurrent prediction of poloidal field diffusion and MHD equilibrium.
- Additional TEQ enhancements (e.g. hyper-resistivity).

PTRANSP Phase 2 -- PPPL

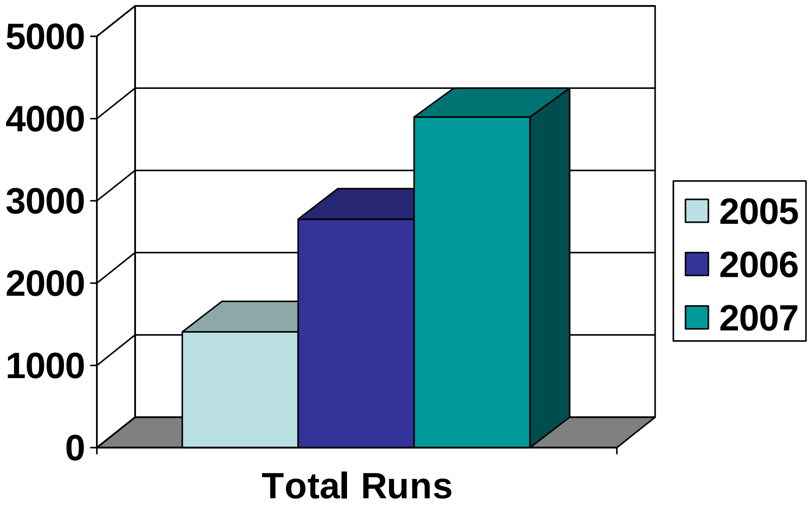
- Provide TRANSP system and development support to all participants.
- Install the TEQ model upgrades provided by LLNL.
- Place PTRANSP capabilities in production and trouble-shoot applications.
- Provide additional TRANSP/PTRANSP upgrades as may be needed.

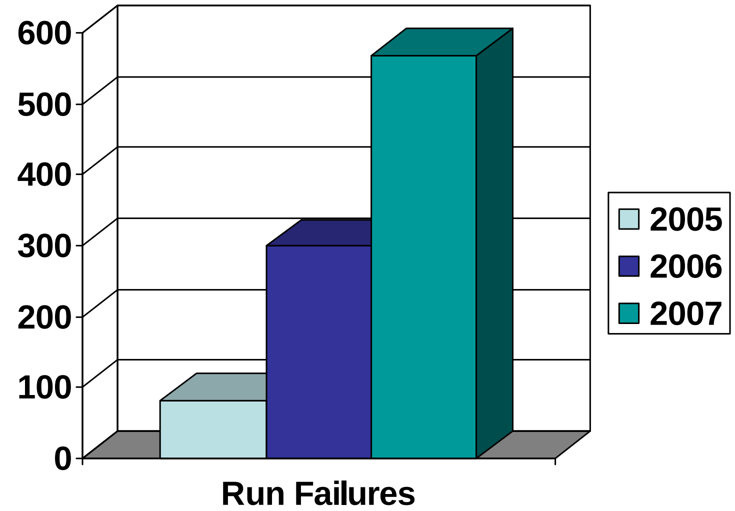
PTRANSP Focus on Plasma Core

- **True** whole device predictive modeling requires validation with close coupling to:
  - Scrape-off Layer (Edge) Plasma Model.
  - Wall Model.
  - Many other things– SOL Atomic Physics, etc.
- Current PTRANSP plans are short term.
  - **Not** high performance super-computing.
  - **No** true **whole device** predictive model.
  - Such capabilities require a much larger effort.
- *Fusion Simulation Project $24M/year…??*

TRANSP Run Production Up

Crashed runs also up…





Runs sorted by Fiscal Year.

Source: ${TRANSP_PATH}/stats … a program that analyzes PPPL TRANSP production system summary log files.

Each crashed run requires manual intervention. PTRANSP & predictive applications a major reason the crash rate is up.

Summary

- Important new capabilities– MPI, Free Boundary, PTRANSP…
- Ambitious development program– more MPI, PTRANSP, access to SciDAC RF codes via Plasma State.
- Labor Constraint:
  - Funding does not allow expansion of team.
  - Operation of production system delivers (P)TRANSP simulations to user community but imposes a heavy labor burden (FSP take note!).