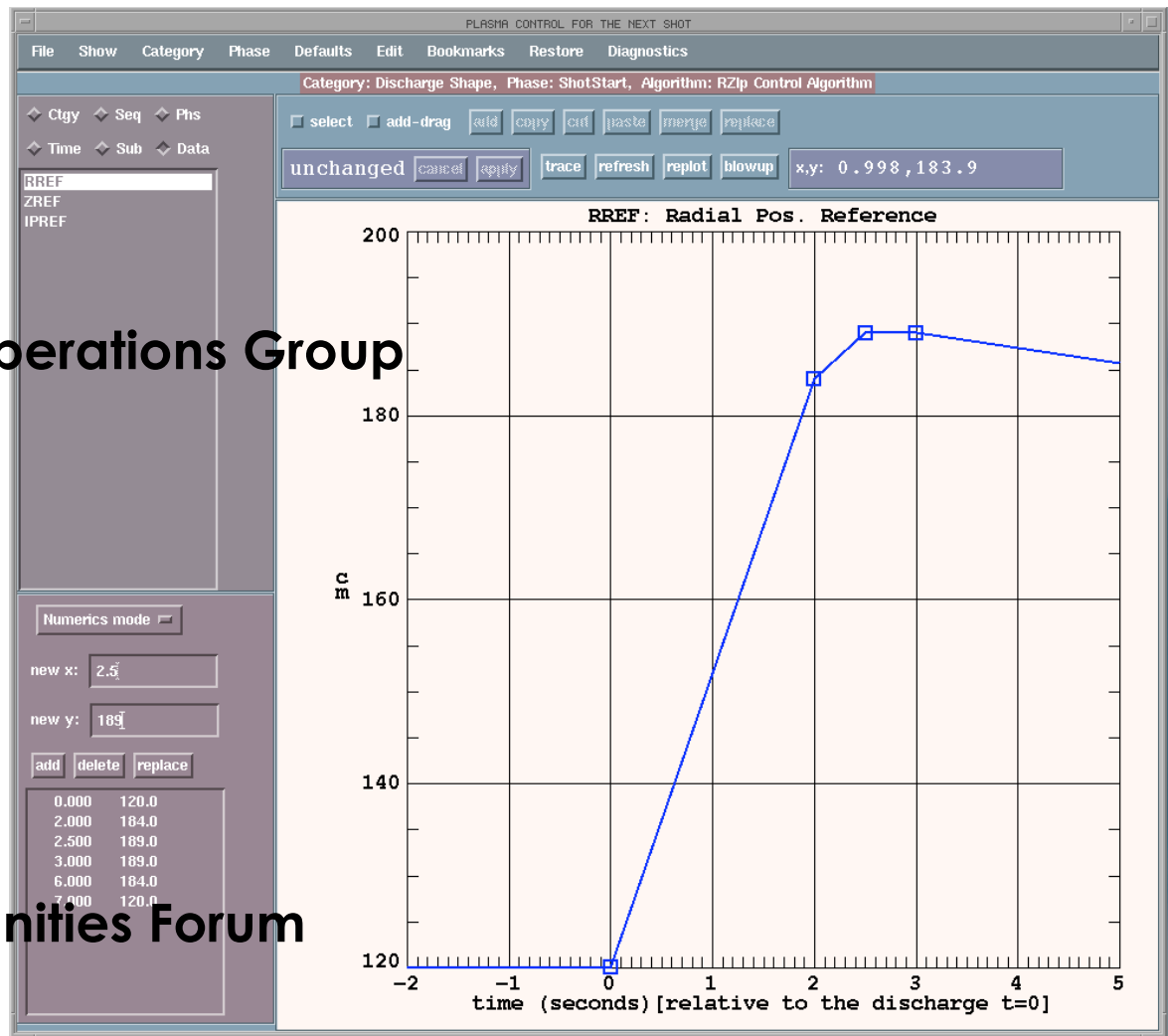# DIII–D Plasma Control System and NCSX

Dave Humphreys
DIII-D Plasma Control/Operations Group

NCSX Research Opportunities Forum
December 7-8, 2006

DIII-D PCS is a Highly Flexible Plasma Control Platform Readily Adaptable for Stellarator Control Needs

- **General infrastructure for waveform programming, algorithm execution, realtime multi-cpu parallel computation and inter-process communication, analog or digital I/O, …**

- **Hardware solution is highly scalable:**
  - Cpu's can be added arbitrarily to expand power
  - Realtime network, digitizer and D/A channels expandable as needed

- **Software solution allows arbitrarily complex algorithms:**
  - Realtime linux OS
  - Realtime code in C
  - IDL-based gui

- **Extensive infrastructure for PID-based or state space multivariable control algorithms, many useful numerical subroutines**

- **Large number of general toroidal MFE algorithms may be readily adaptable to stellarator operational and physics needs**

DIII-D
NATIONAL FUSION FACILITY

DIII-D PCS is a Flexible, Scalable Multi-cpu Control System Supporting Arbitrarily Complex Algorithms

DIII–D plasma control system hardware structure

•**Commercial Off-The-Shelf components**

DIII–D Tokamak

IDL-based GUI

• **Linux-based OS and C-code allows complex algorithms, rapid modification and development**

32 & 96 channel PCI format 250 kHz D-TACQ digitizers

Intel VME cpu/digital and analog output converters

2.4 GB/sec Myrinet network

Myricom **SWITCH**
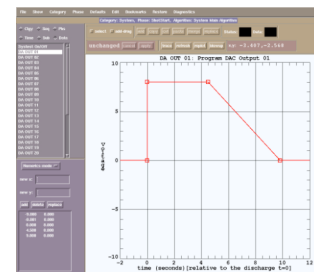
•**Multiple CPUs run in parallel;**
•**10 μs -10 ms cycle times**

•**PCS real-time Network Gateway computer and user interface host**

3.1 GHz Real-time Intel computer array (13 in 2005)

Remotely located real-time computers

Integrated PCS and Modeling/Simulation Environment is a Complete Plasma Control Package

Plasma Control System
Multi CPU's

Hardware

Tokamak

Control Development Tools
– Multiverable robust design
– Anti-windup
– Validated using DIII–D
– Implemented in PCS

PCS Simulator
– Software simulation of multi-cpu hardware
– Contains functionality of hardware & PCS control software: RtEfit, IsoFlux
– Same Graphical user Interface as normal PCS

Tokamak Simulator
"Simserver"

Software

Real-time workshop™

Models
– Power supplies, actuators diagnostics, filters, D/A
– Linear plasma model
– Other plasma models: DINA
– MHD stability, Disruption . . .

Simulink Simulation
Actuator inputs
Tokamak model
Diagnostic output
(A) → D/A → Power supplies → → → D/A → (B)
Diagnostic processing

THE DIII-D PCS IS BEING USED AT TOKAMAKS WORLDWIDE

(PEGASUS PCS in early stages of operational implementation)
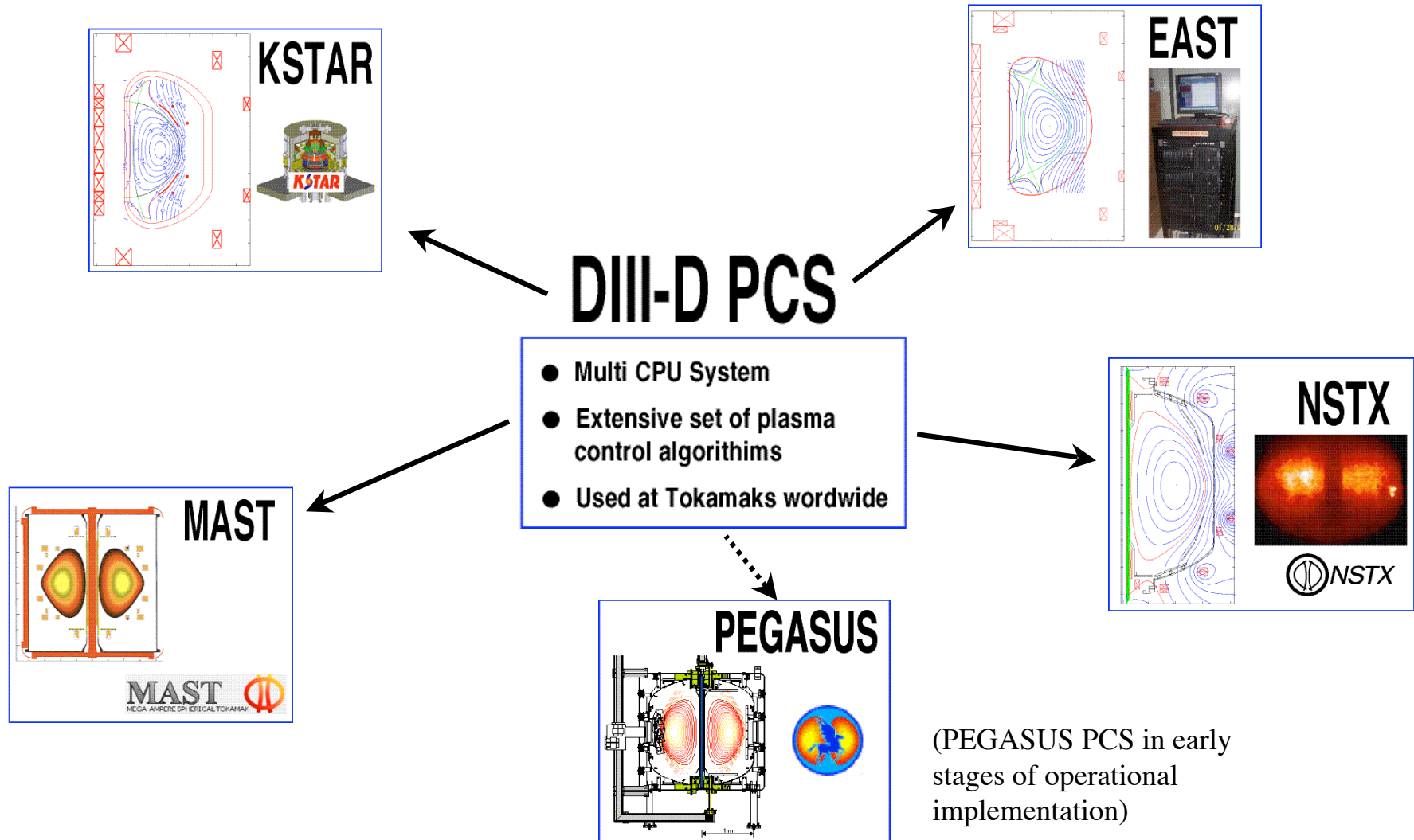
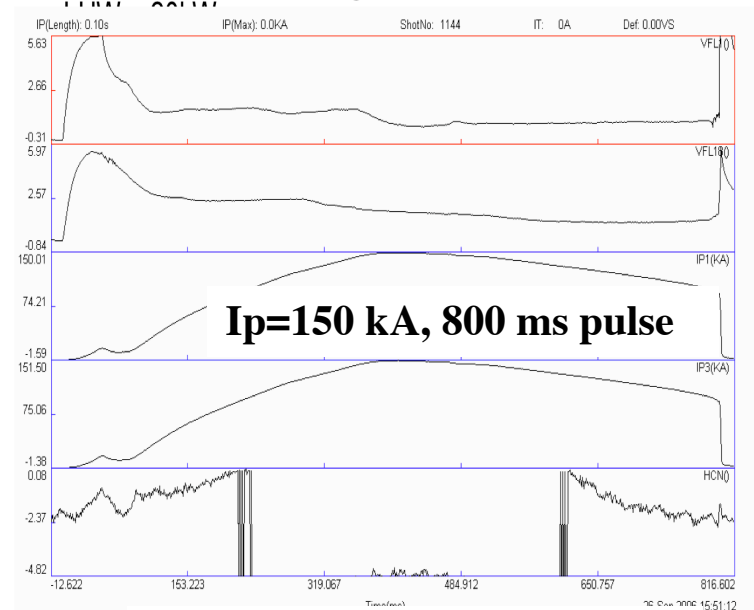# PCS Instrumental in Recent Successful Startup of EAST Tokamak at ASIPP Hefei, China

GA, June 2005

ASIPP, March 2006

Shot 1144: EAST First Plasma

@15:51, 26/09/2006
- Bt: 2 T, Breakdown Voltage: ~ 5.6, IP: 150 kA,

Ip=150 kA, 800 ms pulse

ASIPP, September 26, 2006

Time is Right to Begin Discussion of NCSX Control Needs and Potential of DIII-D PCS to Fulfill

- **Interface/infrastructure software requirements?**

- **Hardware requirements and solutions?**
  - Processing power (number of cpu's, speed)
  - Interprocess communication? Realtime network, reflective memory?

- **General control requirements?**
  - Acquired channels: number, sample rates, …
  - Actuator outputs: number, latencies, analog/digital signals, etc…

- **Specific control algorithms?**
  - Algorithm execution speeds?
  - Operating point regulation
  - High performance algorithms: mitigate effects of noise, disturbances
  - Physics/mission-specific algorithms

- **Control modeling, design, simulation tools?**