



The NSTX Control System

Presented by David Gates
PPPL, Princeton, NJ
June 25, 2002



Los Alamos
NATIONAL LABORATORY



Outline



- Hardware
- Software development
- Future Plans

Development Philosophy



- Control system complexity should evolve along with machine diagnostic capabilities
- System should allow for expansion
- Use standard off the shelf components - wherever possible
- Distributed acquisition with centralized processing

NSTX Control System Development Plan



- Shape control - Three steps
 - Day 0 - Coil current control (no plasma feedback)
 - Day 1 - R, Z, I_p control (preprogrammed shape)
 - Day 2 - Full shape control based on rtEFIT and isoflux concept
- Gas control - Three steps
 - Preprogrammed valve voltage
 - Preprogrammed gas flow
 - Density feedback
- RF/current profile control
- NBI control

NSTX Hardware Capabilities



- Solaris (UNIX) host computer (Force)
- Sky real time computer
 - FPDP (Front Panel Data Port) DMA(Direct Memory Access)
 - 8 - 333MHz G4 processors - shared memory architecture
- 160 channels of fast real time data acquisition
 - 5 Merlin 9421 FPDP digitizers
 - Systran FiberXtreme FPDP-Fiberchannel data transmission-FPDP
 - Low latency $\sim 5\mu\text{s}$ transmission delay
- Gas injection control
 - 7 data channels, 4 controlled valves
 - Plenum pressure control
 - PLC output

Hardware Development nearly complete

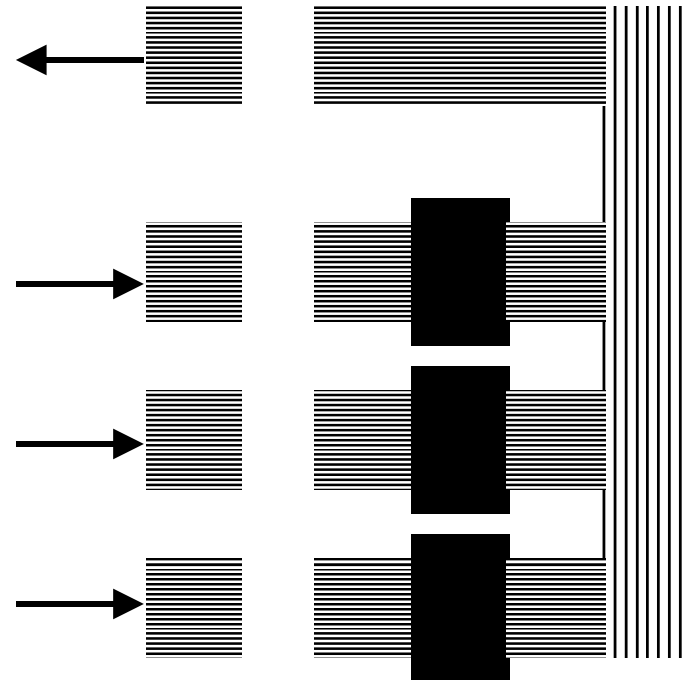


- Off the shelf components
- Very expandable (with FIMM)
- Hardware approach adopted by Culham Laboratory (UK) for MAST
- Inexpensive (~\$200k)/easily maintained (0.2 man-years/year)/ straightforward system development

FIMM to allow data acquisition expansion

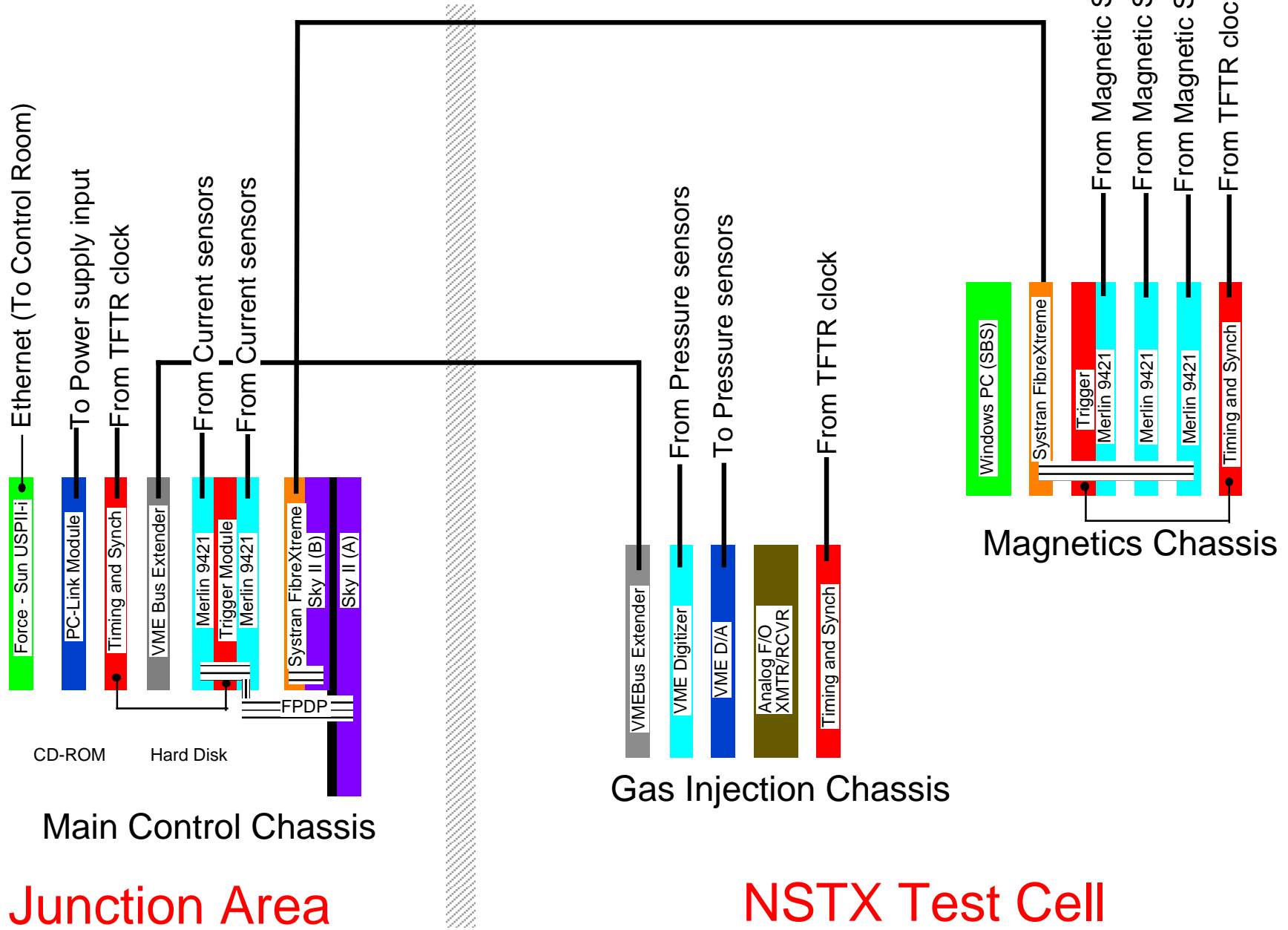
- FIMM \Rightarrow FPDP
(Front Panel Data
Port) Inter
Multiplexing
Module
- Can be daisy
chained to allow
arbitrary number
of data stations
- Prototype being
tested

FPDP Output



FPDP Inputs

Control System Block Diagram



Junction Area

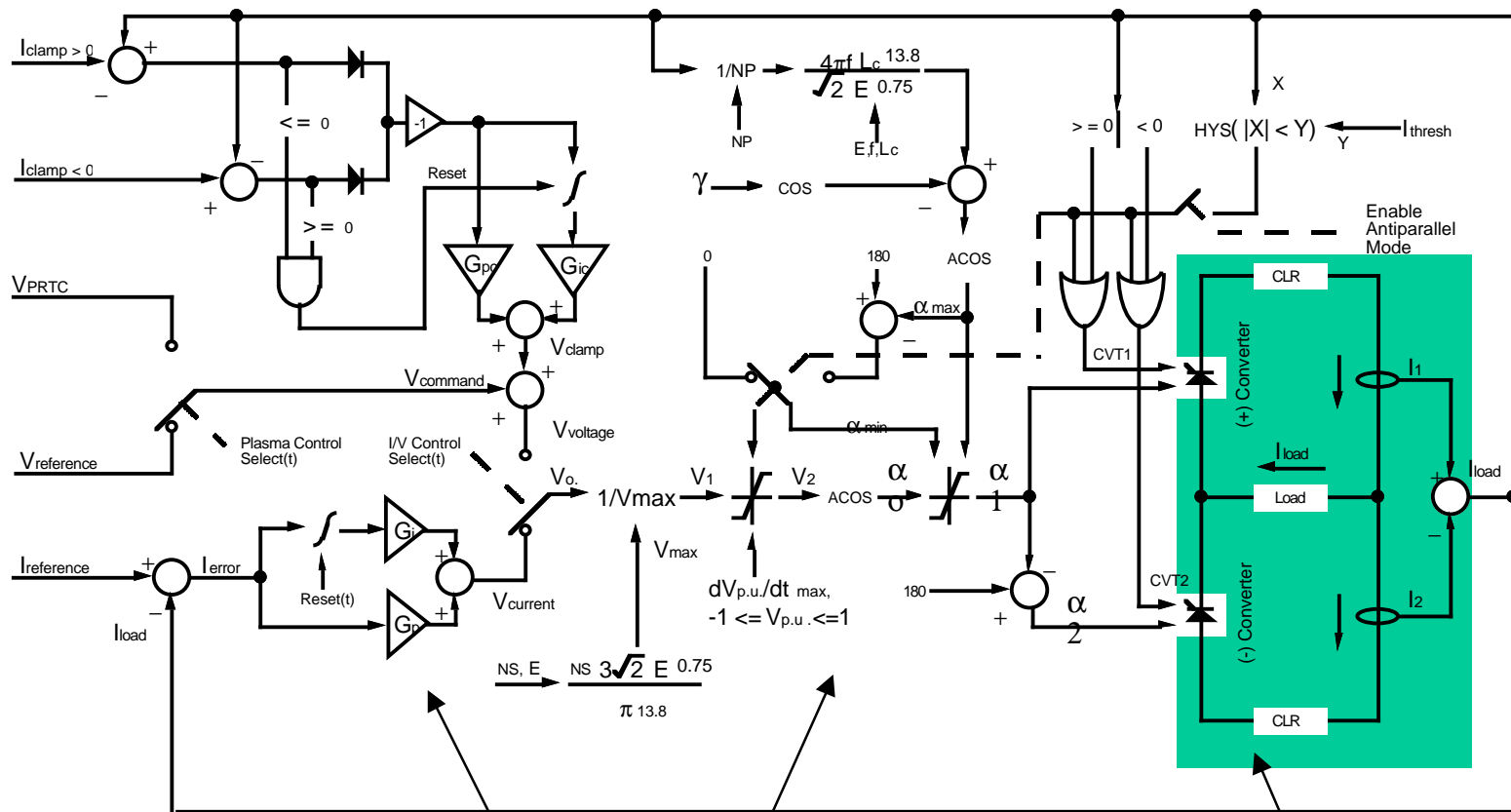
NSTX Test Cell

Software Development



- Integral digital power supply control
- PCS for plasma control
- Algorithms developed locally
 - Easily modified
- rtEFIT/isoflux shape control (w/ J. Ferron)

Flexible software based power supply control

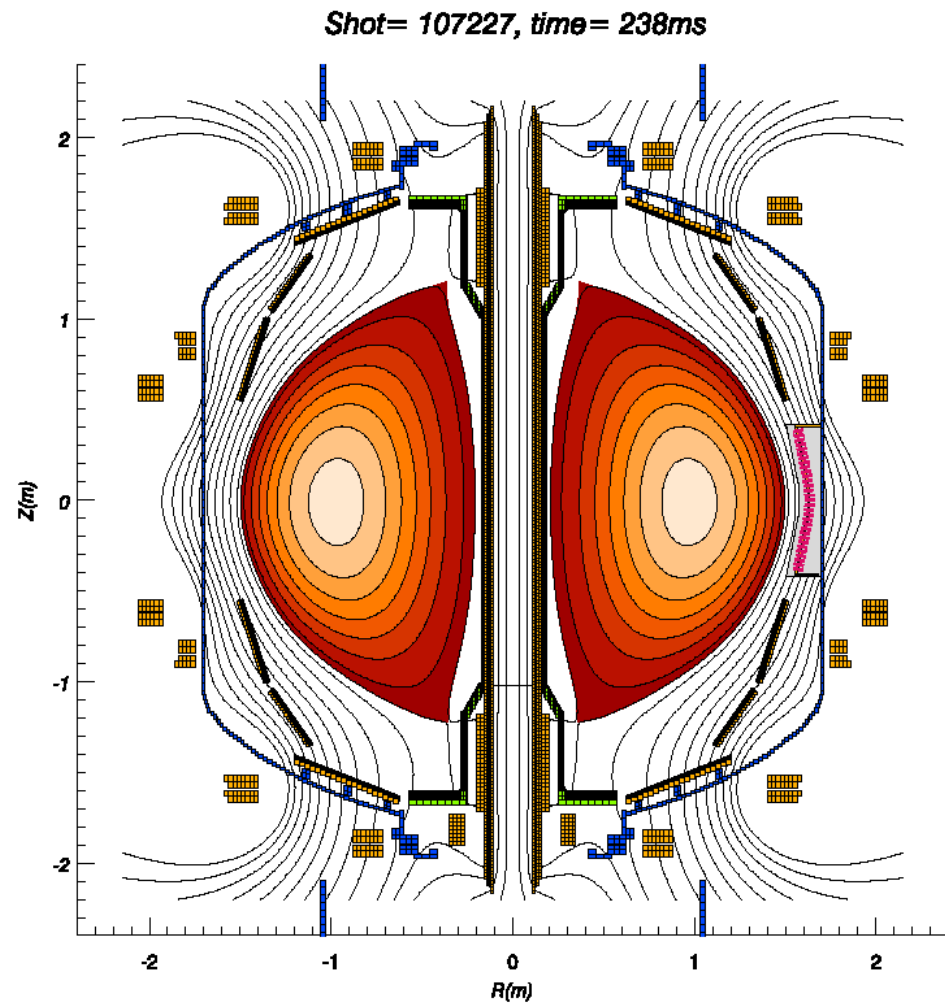


Control Software

Power supply

R, Z, I_p control effective

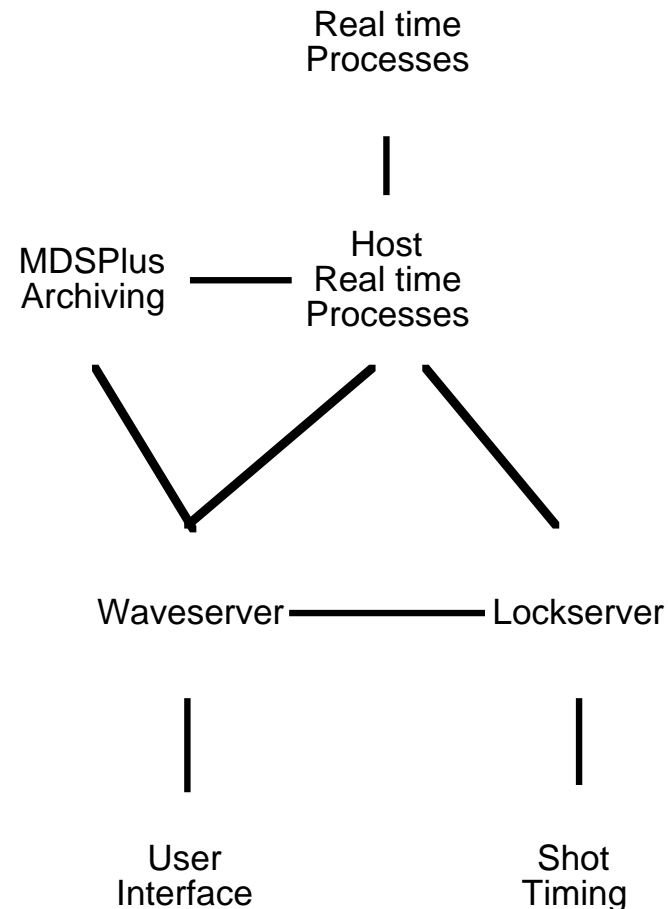
- Adequate for initial research phase
- Achieved desired plasma parameters
 - $\sim 30\% \beta_t$
 - 0.75s pulse
 - 1.5MA plasma current
 - $\kappa \sim 2.5$
 - $\delta \sim 0.8$
- Shape currents preprogrammed
- Discharge development time consuming



PCS architecture



- PCS (developed at GA) is a flexible distributed software system
- Installation and customization for NSTX was (relatively) straightforward
- Is now integrated with MDSplus for data storage/retrieval

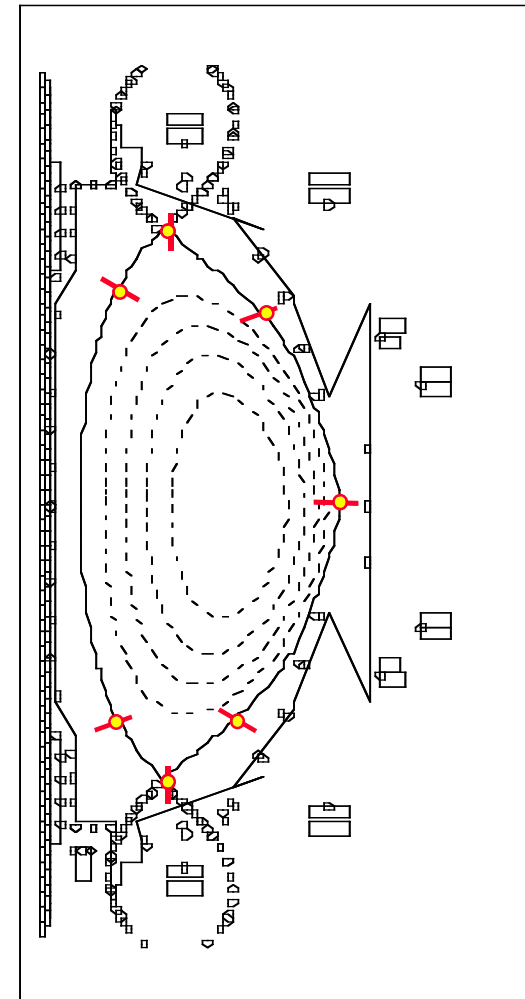
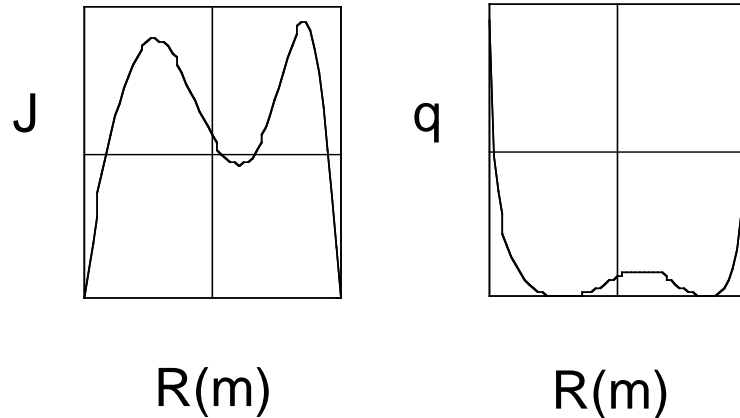


rtEFIT/isoflux control on NSTX



- Code developed for use on DIII-D (J. Ferron)
- Adapted for use on NSTX
- Demonstrated for limiter plasma
- Will be made into a useful tool early in the next run

Isoflux control technique



- n Compute response along "control segments" on grid
- n Prescribe where the boundary should lie along a control segment
- n Compute required change in ψ using RT EFIT calculation
- n Adjust local external shaping coils accordingly

Future Options



- New Measurements (need real-time interpretation)
 - Thomson scattering
 - CHERS
 - MSE
- Full kinetic rtEFIT
- β control with NBI
- RF - real time ray tracing - $J(r)$
 - Current profile control
 - NBI - real time Fokker-Planck / Monte Carlo
- Real time MHD stability calculations

Requested Upgrades



- Extend elongation range
- MHD global mode stabilization
- Add PF4 to coil set
- Density control?
- β control
- Control CHI plasmas

Summary



- NSTX has in place a highly advanced high speed fully digital plasma control system
- Software development in collaboration with General Atomics has been very successful
- Physics based profile control is a promising next step