Deployment of NI COTS Hardware and LabVIEW in the C2 FRC Experiment

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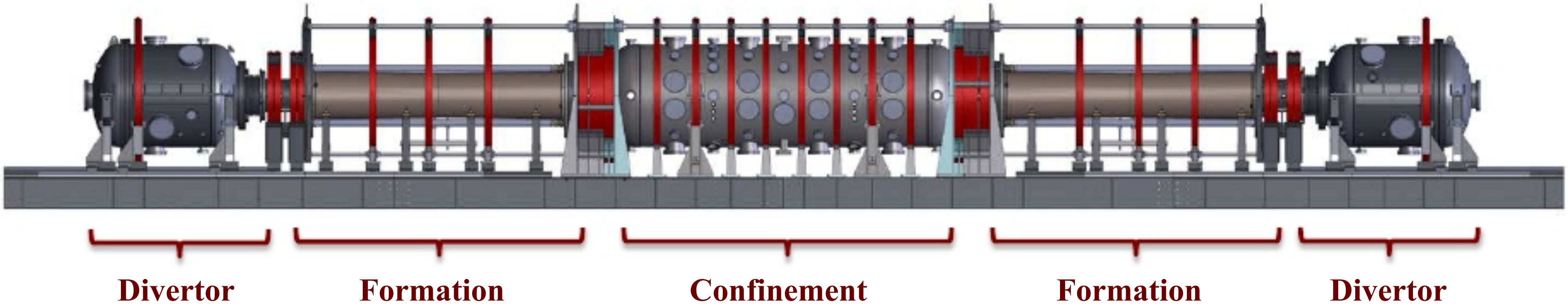
Tri Alpha Energy and C2



Tri Alpha Energy:-

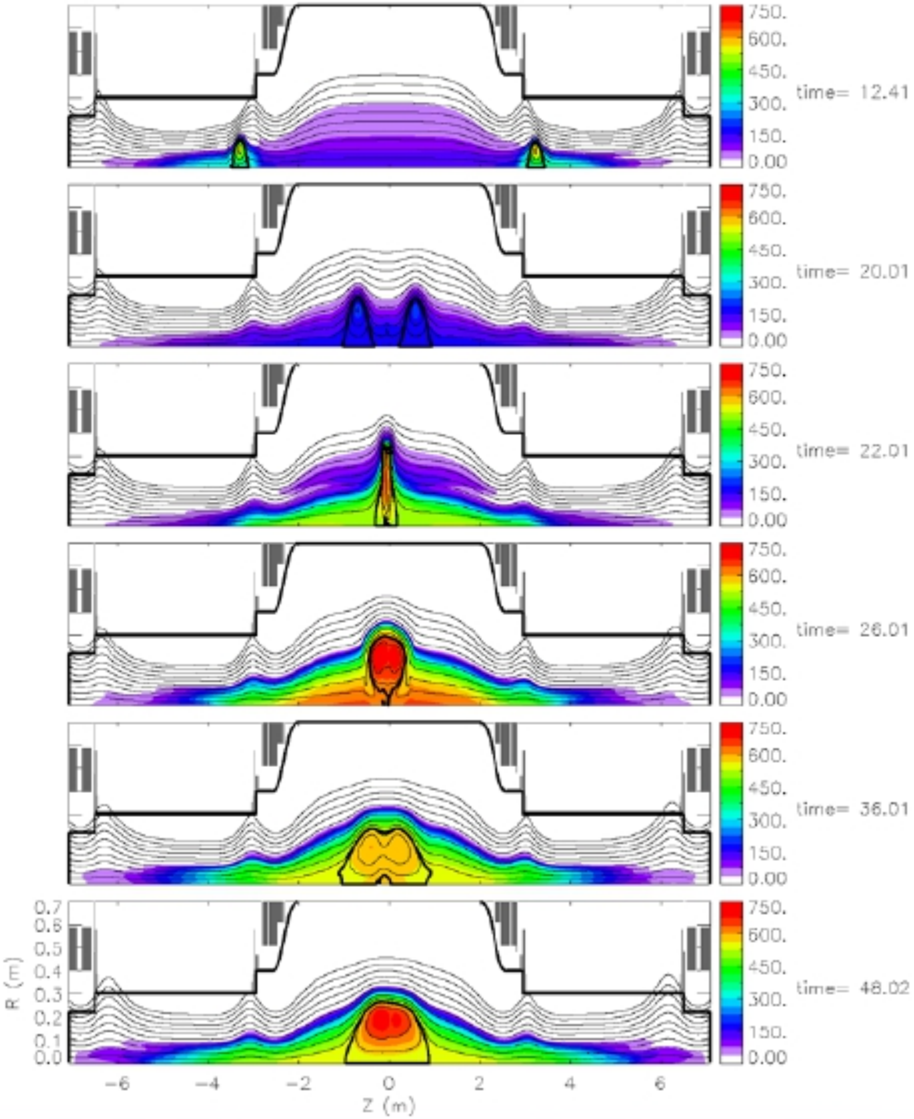
- Is a privately funded technology company founded in 1998
- Is researching plasma Field Reversed Configuration (FRC) techniques for…
- …use in future fusion energy production (p-B_{11} reaction)
- Has built a 120’ device known as C2 for forming, confining and heating plasmas using Neutral Beams

NI Hardware & LabVIEW is used for:-

- Sequencing the experimental subsystems
- Issuing accurate timing and triggering signals (PXI)
- Interfacing with OPC and PLC systems (Allen-Bradley)
- Acquiring data from Diagnostics
- Interfacing data collection with MDSplus (shot based scientific database)

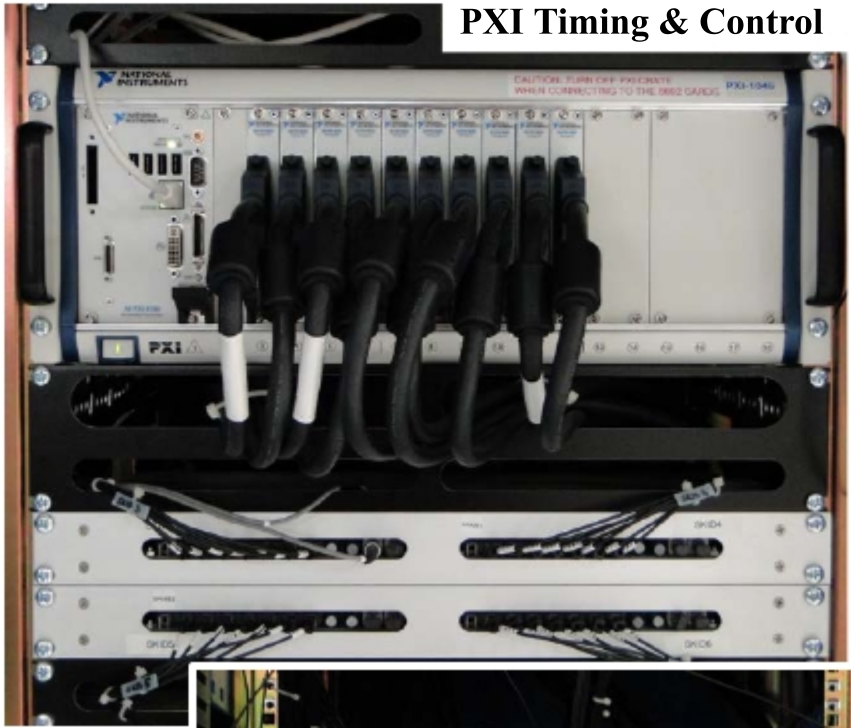
Physics Principles

- Unlike a Tokamak C2 is a linear magnetic confinement device with open field lines at the ends (Divertor section)
- An FRC plasma is a compact toroid with closed field lines along its axis
- The FRC is formed by creating a fast changing axial field by discharging capacitor banks into a number of coil assemblies along the axis (Formation section)
- The two FRCs created at each end of the machine merge by reconnecting field lines in the central Confinement section
- High power Neutral Beam injection then heats the confined FRC driving fast ions in the core



Control Systems

PXI Timing & Control



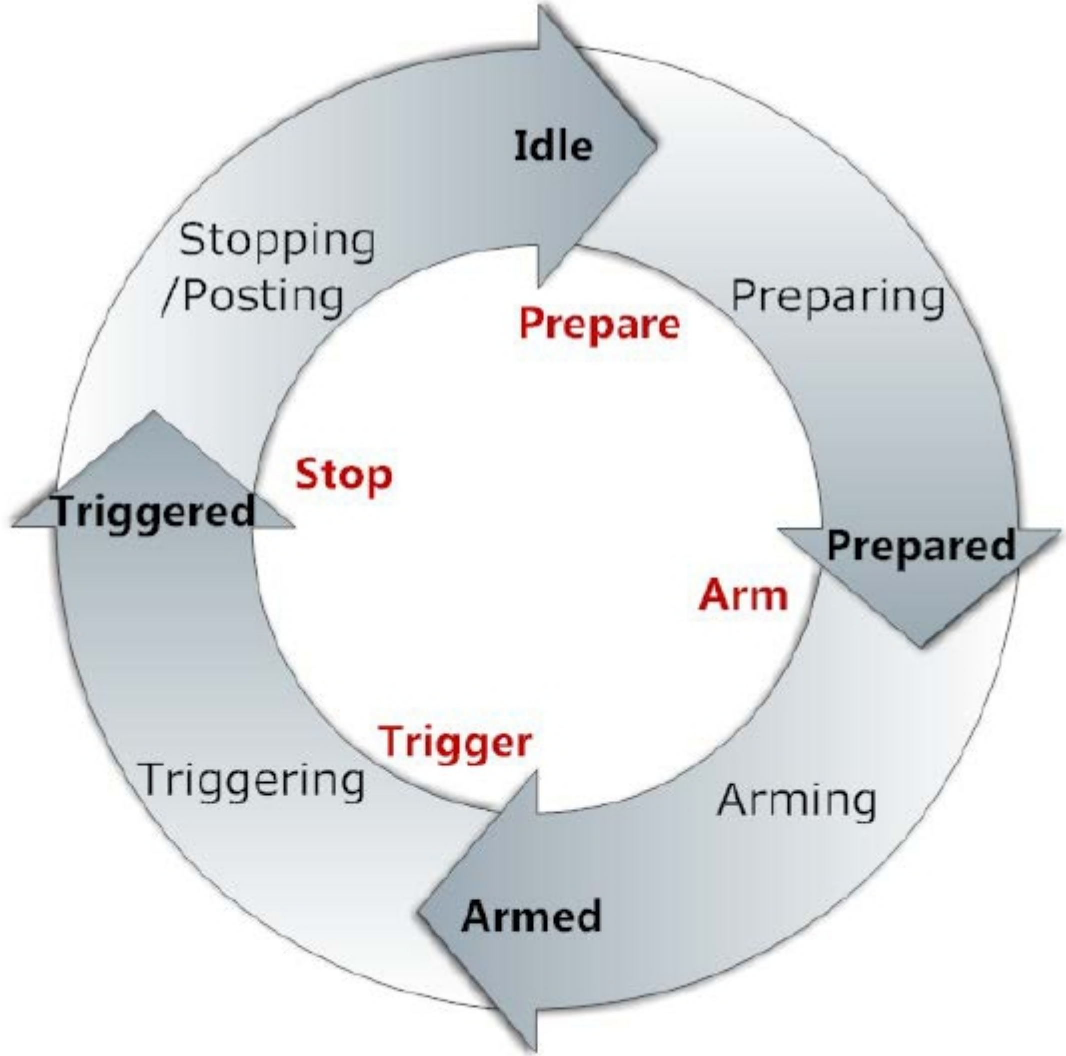
ControlLogix PLC

Short Facts:

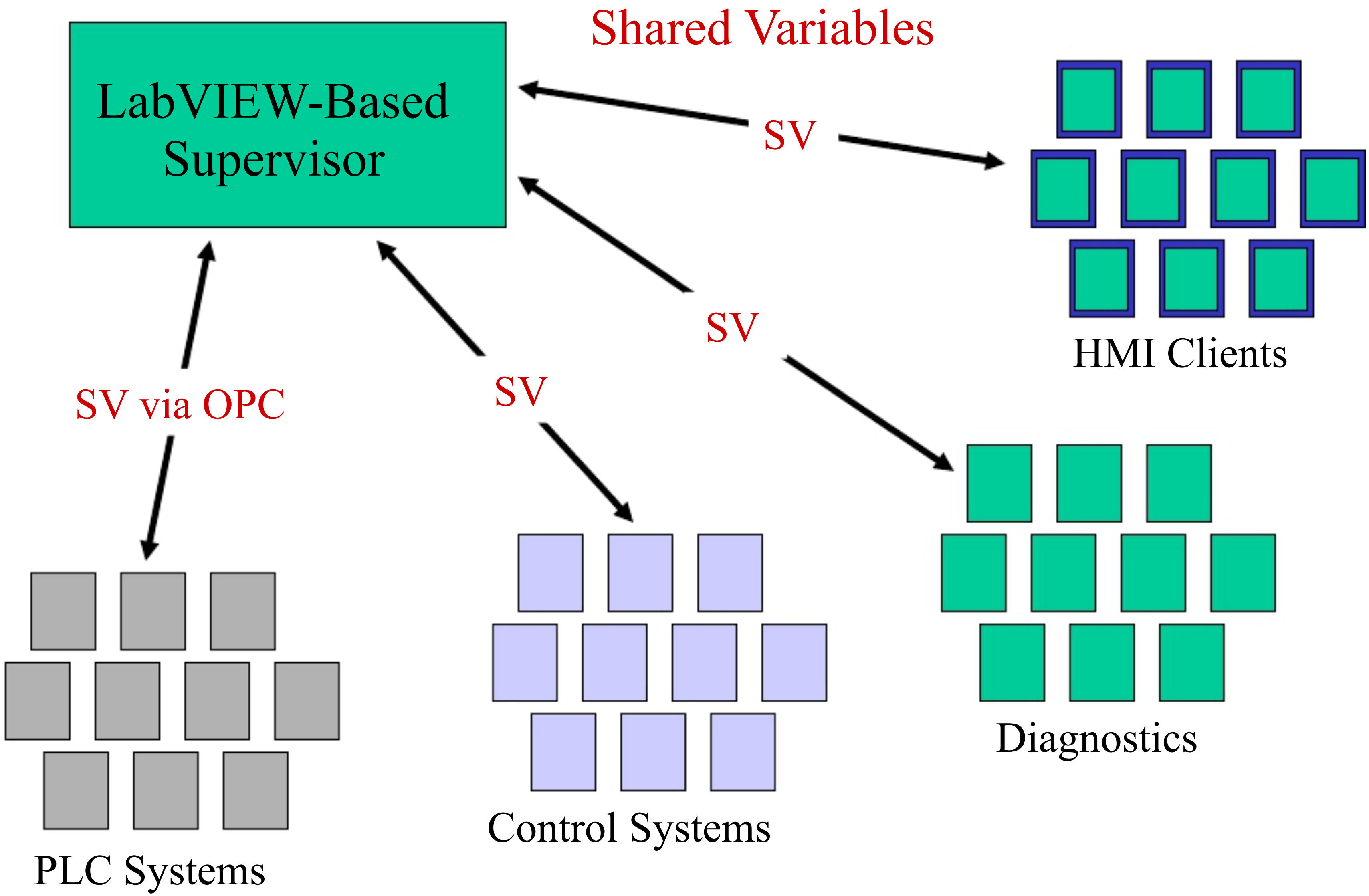
- We use a mix of PXI, cFP and cRIO throughout the experiment
- Over 40 subsystems on C2 require coordinated operation
- Timing signals generated in six PXI crates using PXI-6608/PXI-6602
- LabVIEW used for most control and HMI applications
- Common LabVIEW template interfaces aid development
- D-TACQ systems used for high channel count analog acquisition
- ControlLogix PLCs monitor and control critical vacuum, cooling and safety systems
- Rockwell RSView32 software used for critical system HMIs

LabVIEW Based Supervisory Control

So how do we use LabVIEW to make it work?



Shot Sequence Control



System Hierarchy

Manages Shot Sequence

Supervisor

Translator & Watchdog

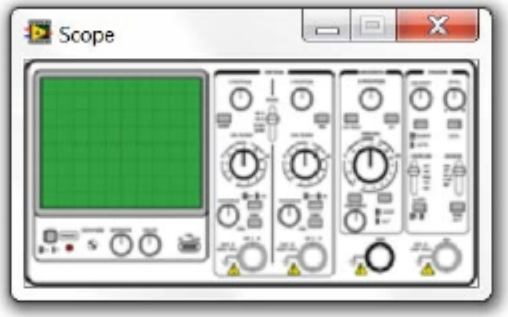
Local Agent

Template-Based

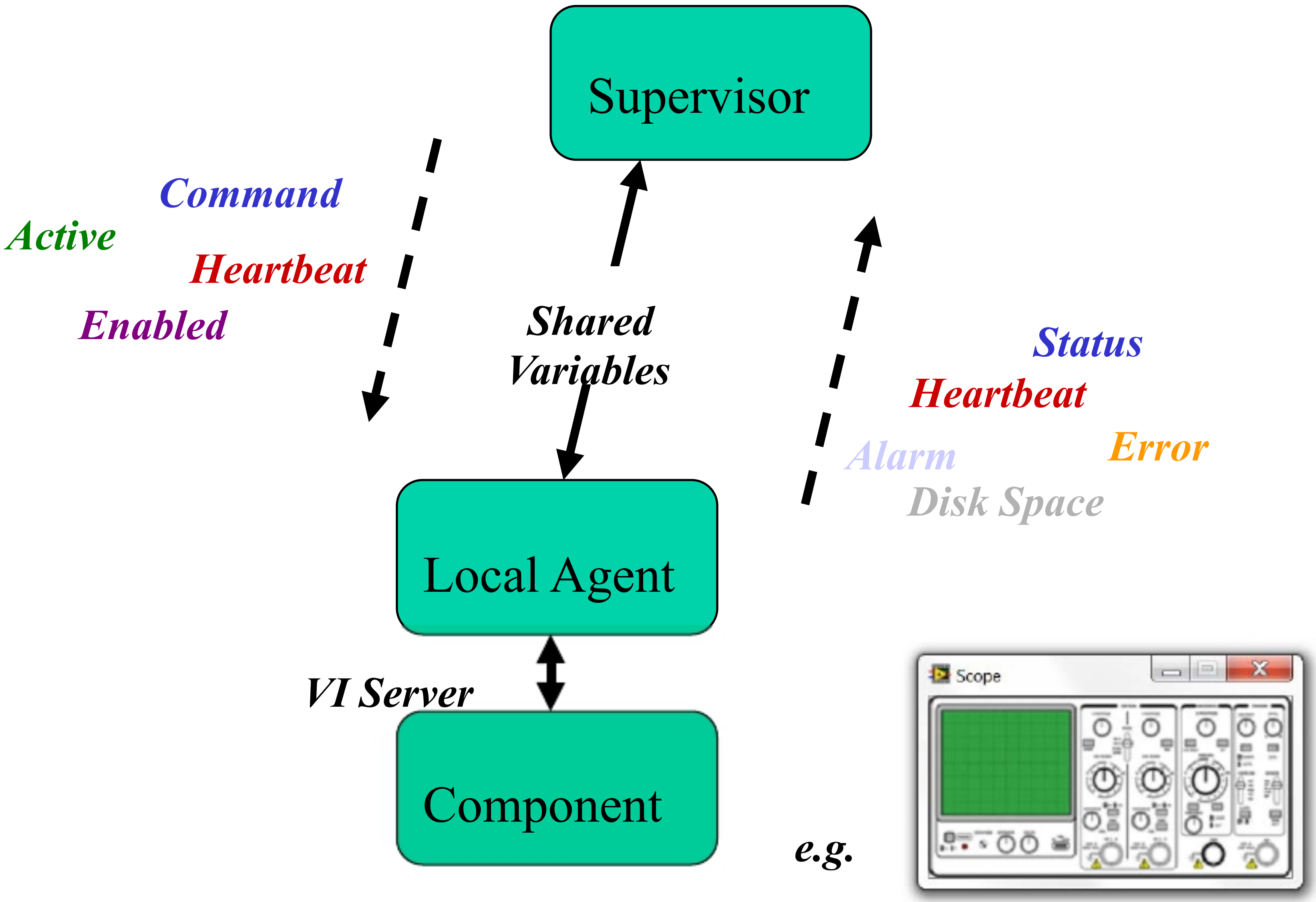
Task Focused

Component

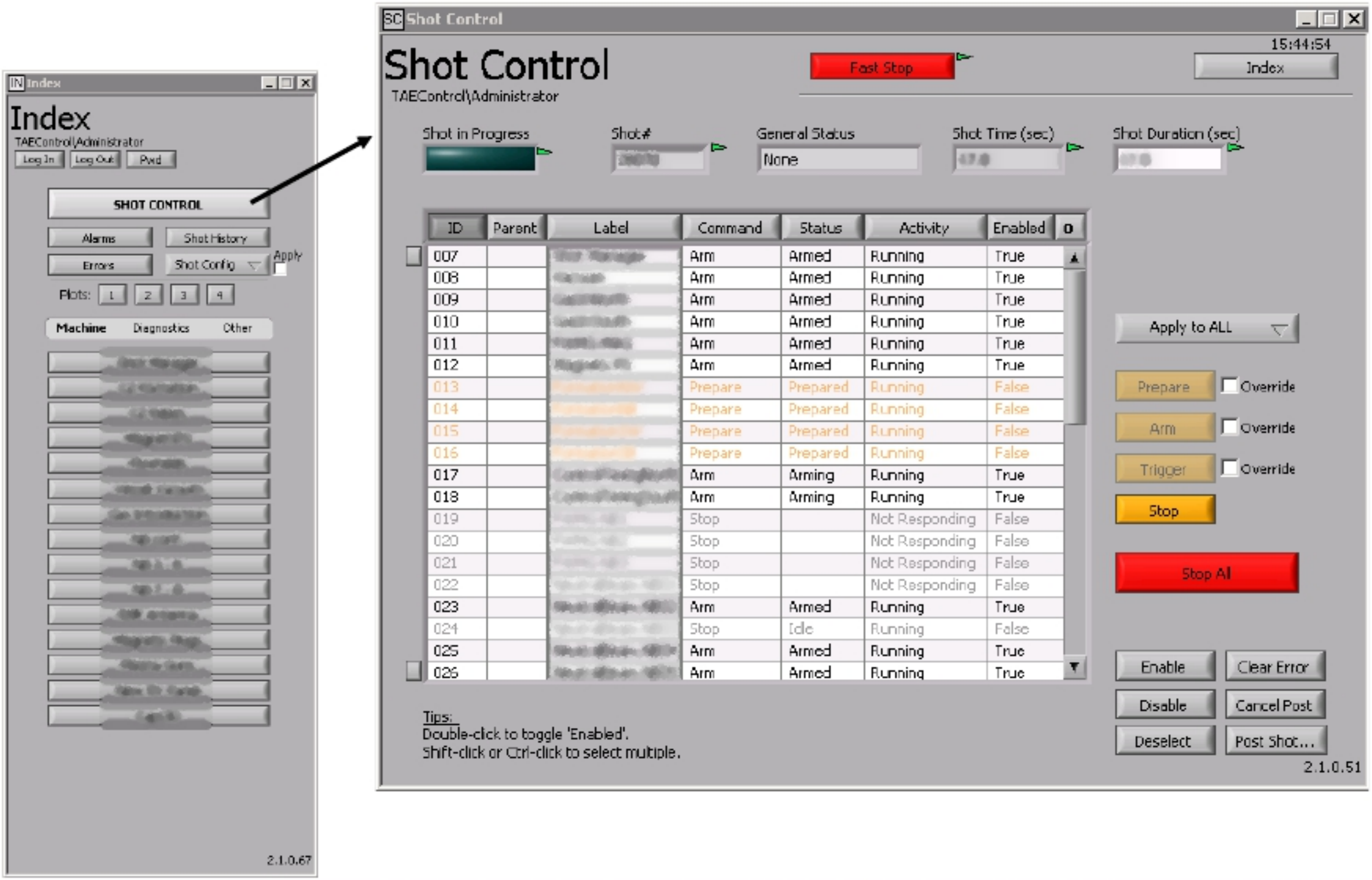
e.g.



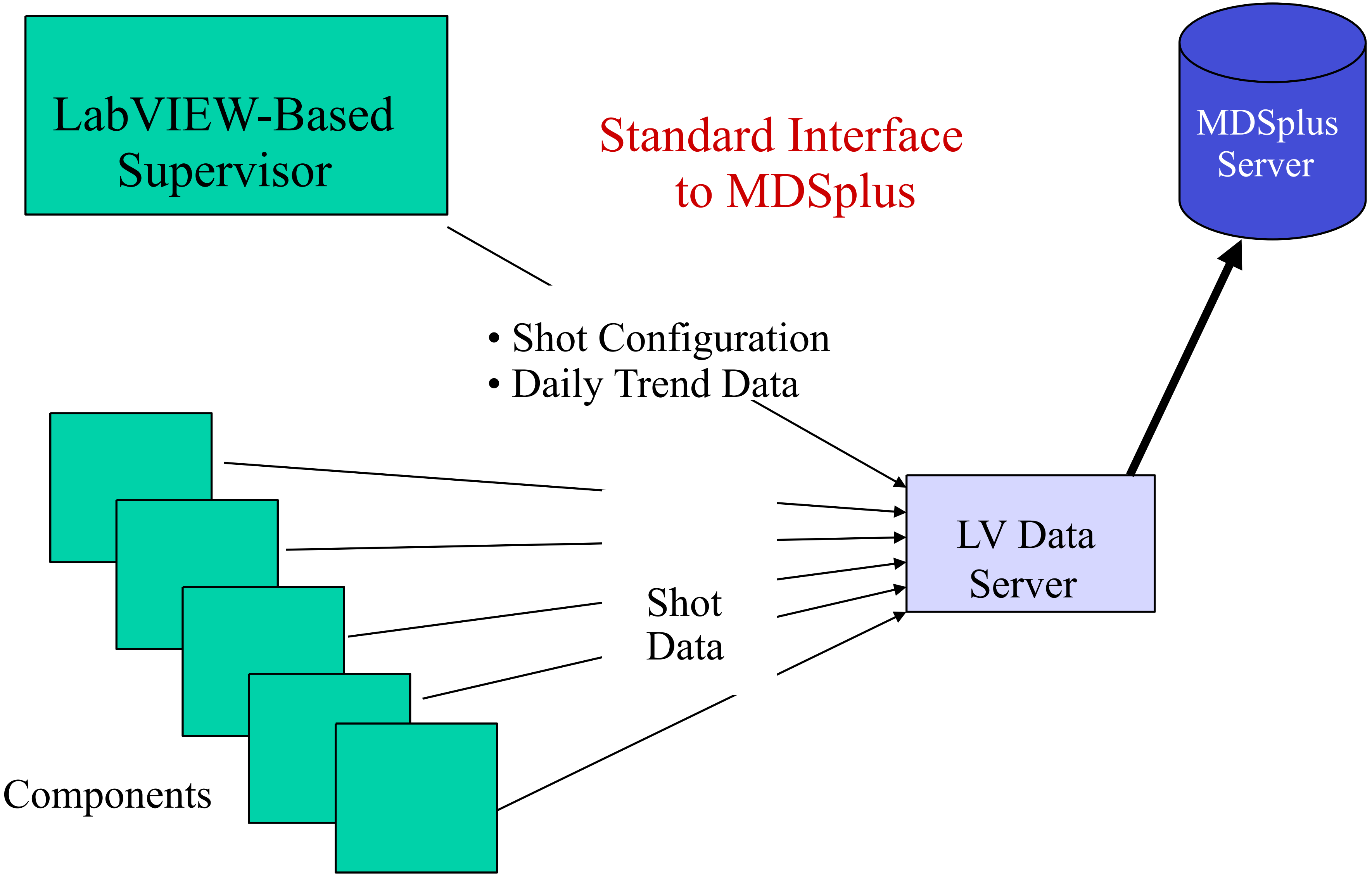
System Hierarchy



Shot Control

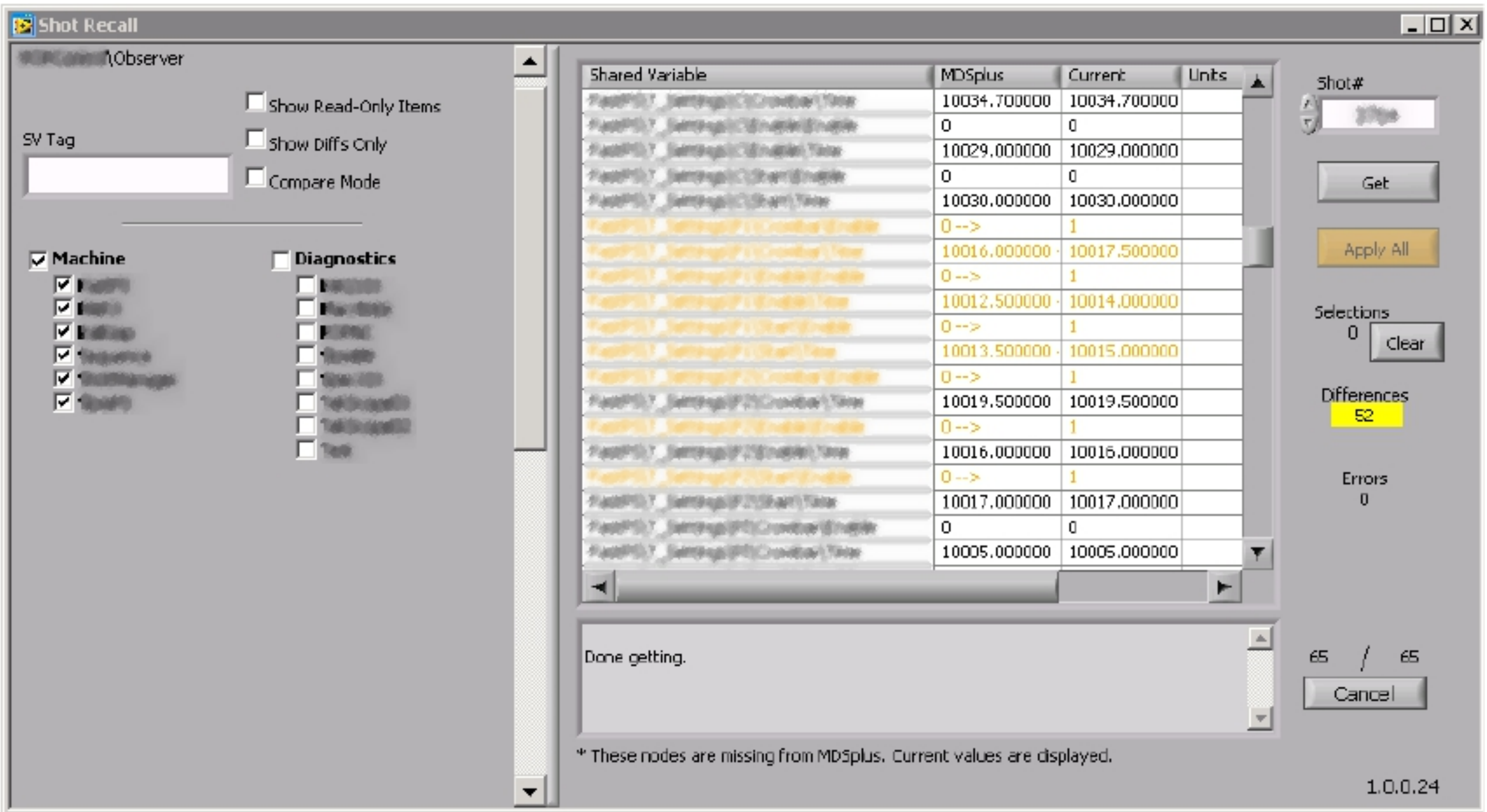


TDMS to MDSplus

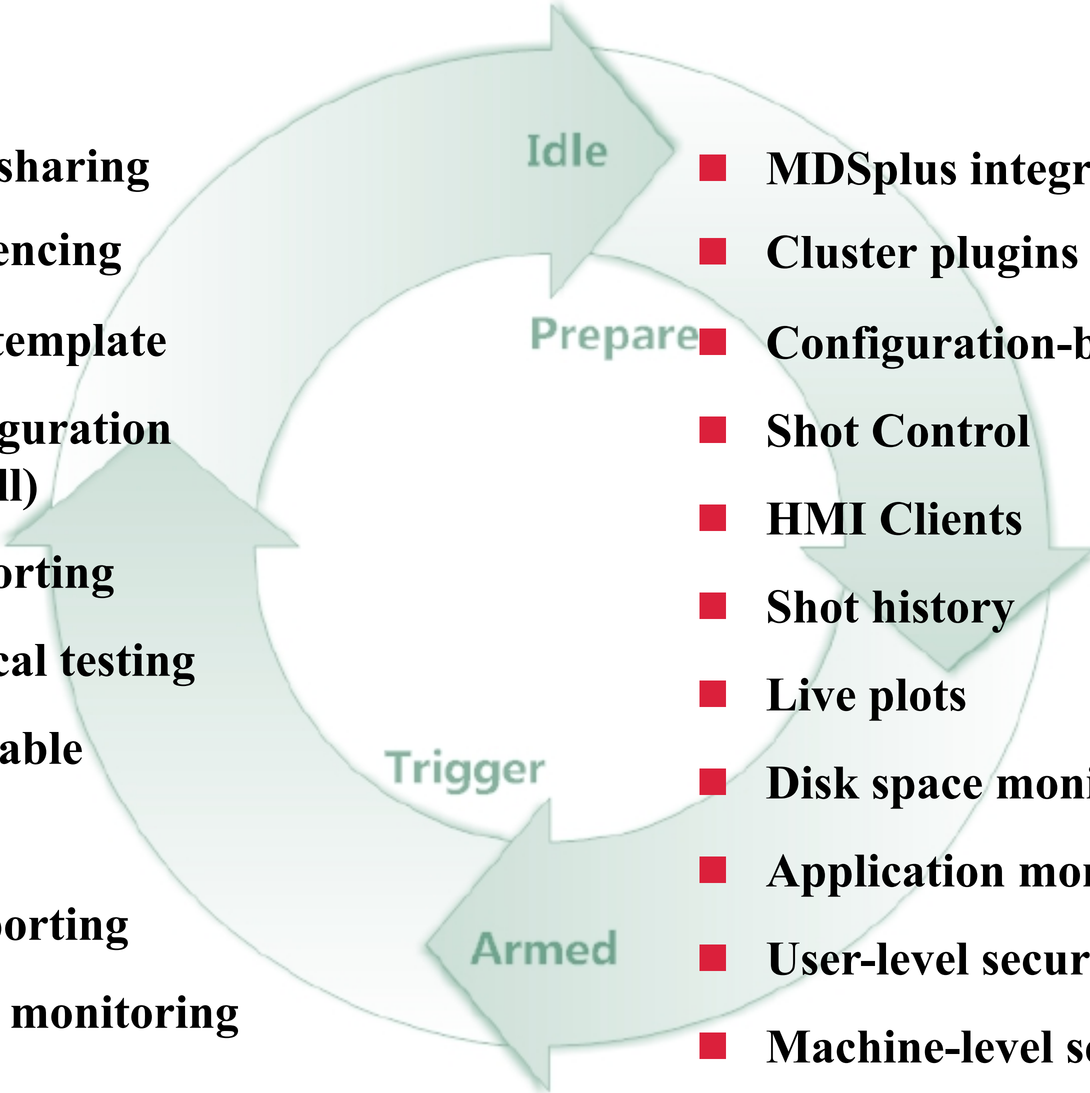


Shot Recall

Settings retrieval from MDSplus



LabVIEW-Based Function Set



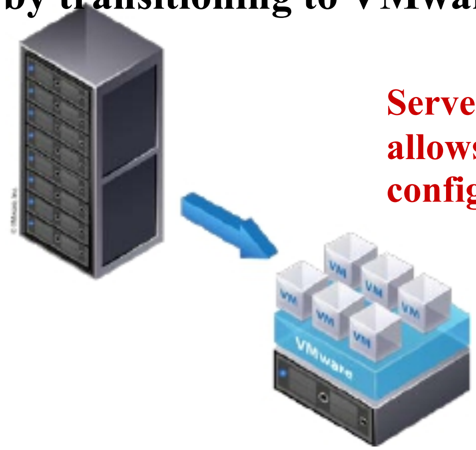
- Live data sharing
- Shot sequencing
- Interface template
- Shot configuration (save/recall)
- Error reporting
- Hierarchical testing
- Re-deployable
- Trending
- Alarm reporting
- Heartbeat monitoring

- MDSplus integration
- Cluster plugins
- Configuration-based
- Shot Control
- HMI Clients
- Shot history
- Live plots
- Disk space monitor
- Application monitor
- User-level security
- Machine-level security

Future Plans

Near Term:

- Upgrade of servers for all experiments by transitioning to VMware



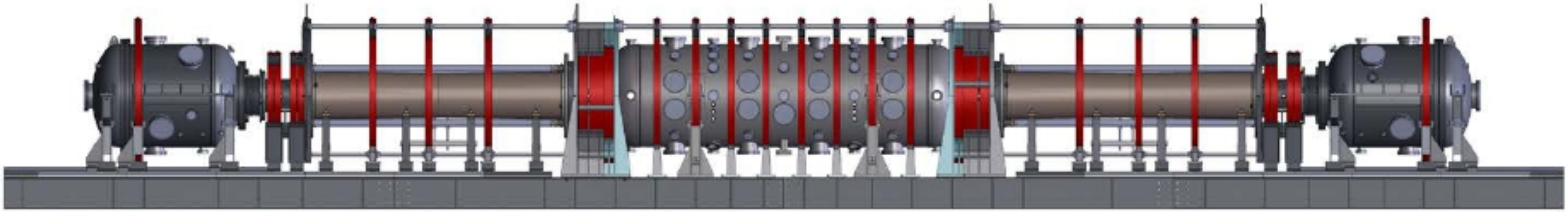
Server consolidation allows High Availability configurations

- New diagnostic and acquisition systems
- More use of cRIO for fast interlocks via FPGA
- Some PLC systems will be configured to be redundant arrangements
- New HMI systems links PLC and NI SV Engine via OPC v2.0

Next Step:

- Future designs will be much larger and more complex (10-20 times)
- Many more subsystems lead to coordination, interlock and safety issues
- Dedicated multicast networks will share data and interlock information between NI and ControlLogix systems
- Other networks for distributed I/O and HMI interfaces
- High Availability (HA) server systems are vital to avoid excessive downtime
- Need reliability at all levels
- Essential to have a LabVIEW Object Oriented Programming methodology to shorten design and programming cycle (need a plug and configure system)

And Finally…



Thanks must go to:

- **Private investors who make it all possible**
- **TAE Management for permitting this presentation**
- **National Instruments for inventing the software and hardware to make it all possible**
- **The TAE Control Team for converting ideas into reality**