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Data Acquisition and Instrument Control at the Lujan Center: An Update

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NOBUGS 2010

New Opportunities for User Group Software

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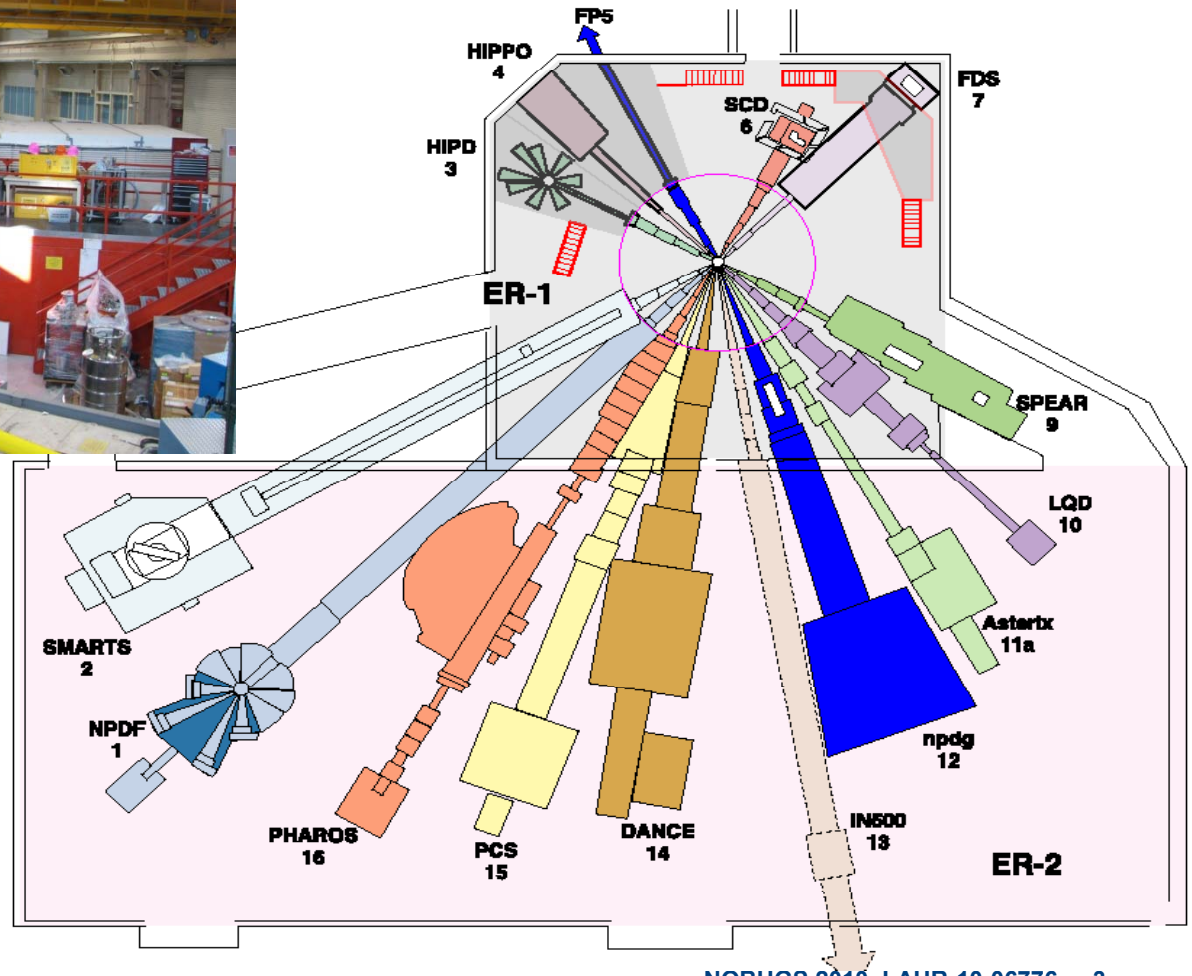
Abstract

The Lujan Center at the Los Alamos National Laboratory's Neutron Science Center (LANSCE) is a spallation neutron source where research in materials and biological sciences is conducted on time-of-flight neutron scattering spectrometers on eleven beam lines. Execution of an experiment on a Lujan Center neutron spectrometer involves 1) operation of the beam line components, 2) control of the sample environment equipment, 3) measurement of the neutrons scattered from the sample, and 4) presentation of the data in a form suitable for analysis. Automation and coordination of these functions is essential to effective conduct of experiments. As reported at the 2008 NOBUGS conference, we have been implementing a major upgrade and overhaul of both our data acquisition software and associated run time control environment.

Our recent focus has been the roll out of our new Linux-based data acquisition software (LDAQ) and its refinement, customization, and adaptation to the individualized requirements of our spectrometers. The software was used on three spectrometers in 2008, five in 2009, and is presently (2010) used on seven. The rest of our spectrometers are scheduled for conversion in 2011.

Our main focus has now shifted to three areas, one technical design, one support, and one compliance. In the technical design area we are working to define and develop a more uniform and integrated EPICS-based framework for the control of beam line components and sample environments. In ways this is more challenging than our data acquisition software upgrade because 1) there is significantly more variability among spectrometers on the components and sample environments to be controlled, and 2) previous standardization was weak. In the support realm we are working to move the LDAQ software from development to production mode and put together the necessary infrastructure to do so. Lastly, on the compliance front, we are wrestling with the impact of computer and network security issues and rules and their impact on our data acquisition and control systems.

Lujan Center is a US National User Facility for Neutron Scattering



- 100 kW spallation source
- Tungsten target w/ LH and water moderators
- 17 beam lines
- DOE-BES User Program ~600 users per year

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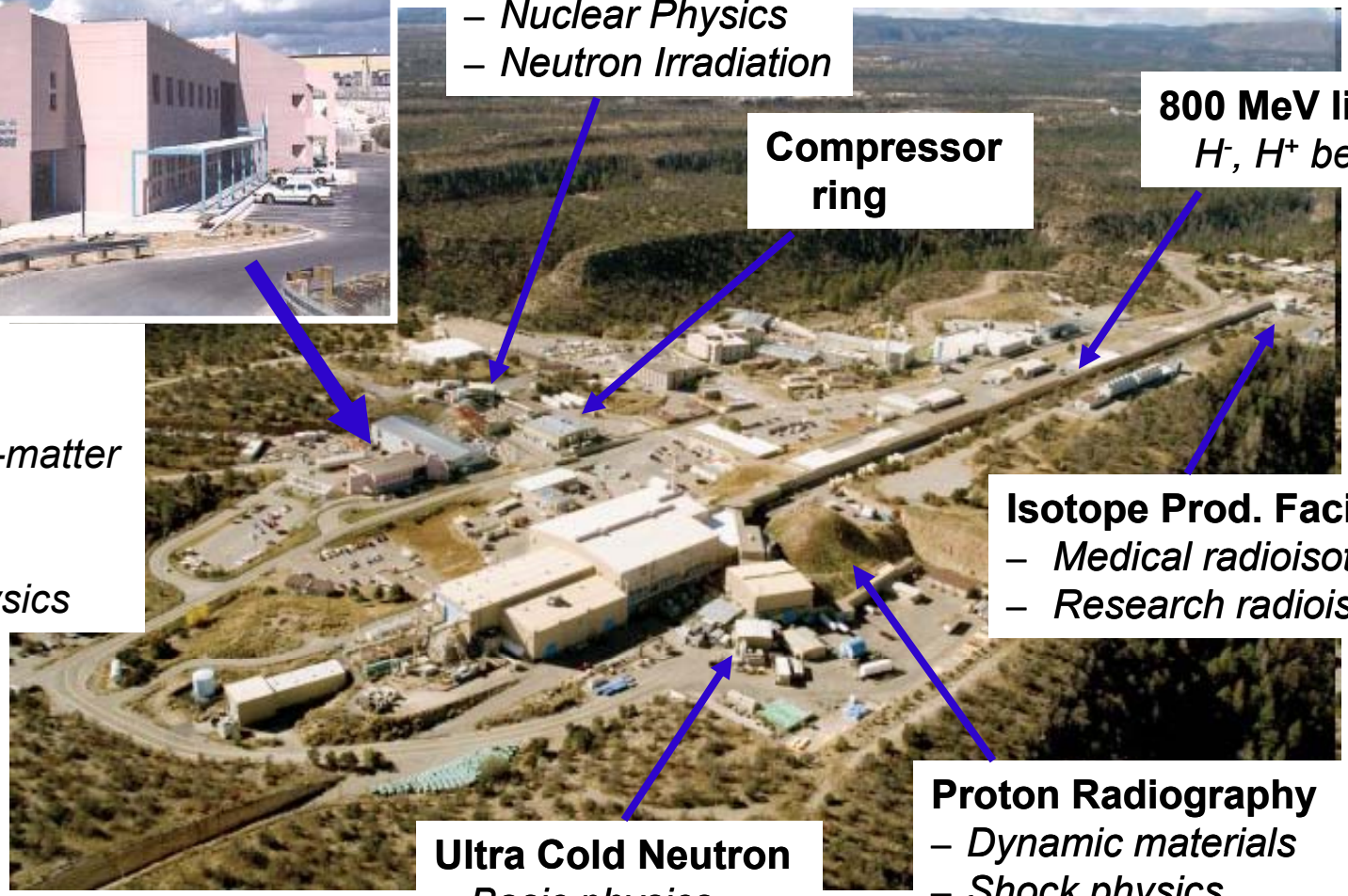
Lujan Center is the largest experimental area at the LANSCE accelerator facility.



WNR
- *Nuclear Physics*
- *Neutron Irradiation*

Compressor ring

800 MeV linac
H^-, H^+ beams

Lujan Center
- *Materials*
- *Condensed-matter*
- *Bio-science*
- *Geophysics*
- *Nuclear physics*

Isotope Prod. Facility
- *Medical radioisotopes*
- *Research radioisotopes*

Proton Radiography
- *Dynamic materials*
- *Shock physics*

Ultra Cold Neutron
- *Basic physics*

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Neutron scattering experiments

Neutron scattering is used to look at material structure

- Neutron "wave" interactions with atomic lattice
- Can probe more deeply than x-rays

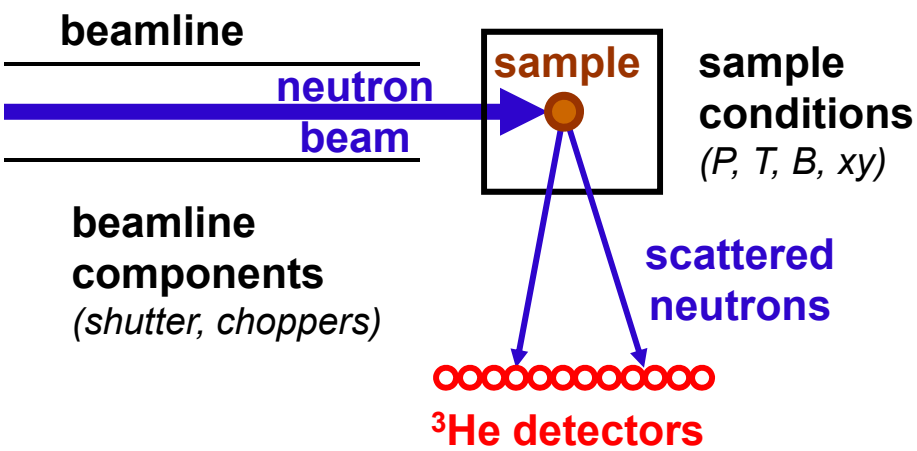
Bragg's law:

$$n\lambda = 2d \sin\theta$$

2θ: scattering angle
λ: wavelength (energy)
d: lattice spacing

Elements of an experiment

- **Detect scattered neutrons**
  - time (energy), position
- **Control sample conditions**
  - pressure, temperature, magnetic field, etc
  - position, orientation
  - sample changers
- **Control beamline**
  - shutters, choppers
  - flippers, polarizers



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Neutron scattering data acquisition and control characteristics

- **DAQ systems can be reasonably homogeneous across instruments and stable over time**
  - Single DAQ system hardware/software accommodates all – one size fits all
  - Common support team
- **Sample environments and beam line components are the opposite – vary widely from instrument to instruments and change from experiment to experiment**
  - One size does not fit all – greater customization and flexibility required.
  - Need an adaptable open architecture that can evolve with demands.
  - Must depend on instrument personnel for much of the automation
  - Need good interface tools usable by non-programmers
- **An integrated control environment is critical**
  - Command-based interfaces to all components to support flexible central control
  - Remote control/access must cover all aspects of instrument operation

Evolution of Lujan Center data acquisition & control

1987-2001 (retired)

- Seven instruments, small detector array, simple sample environments
- VAX/VMS-based systems with FastBus/CAMAC-based hardware
- Centralized architecture, remote from instruments – long cable runs

1999-2010 (now phasing out)

- Major instrument and sample environment upgrades
- Eleven instruments, large detector arrays, complex sample environments
- Windows/VxWorks-based systems with custom VXI/VME-based hardware
- Distributed, networked, architecture located at the beam lines
- Increased dependence on instrument run automation

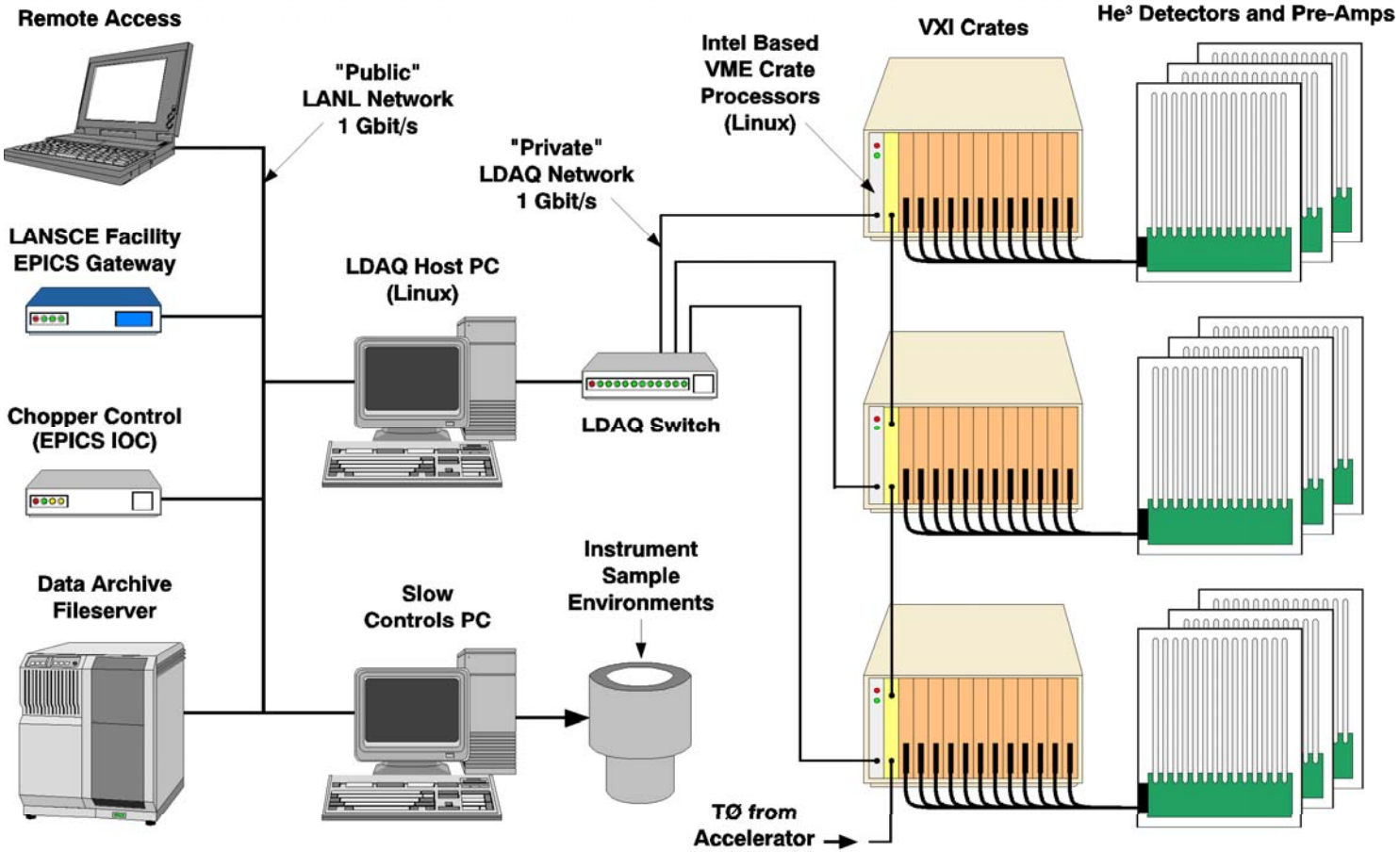
System evaluation 2008

Upgrades 2009-2012 (now phasing in)

- ✓ VXI crate processors
- ✓ Complete rewrite of core acquisition and control software - Linux OS-based
- o Development of a more uniform control architecture – EPICS-based

Hardware architecture – traditional crate-based architecture

- Systems located at the instruments
- VXI-based custom hardware
- Local crate processors
- DAQ and Controls PCs



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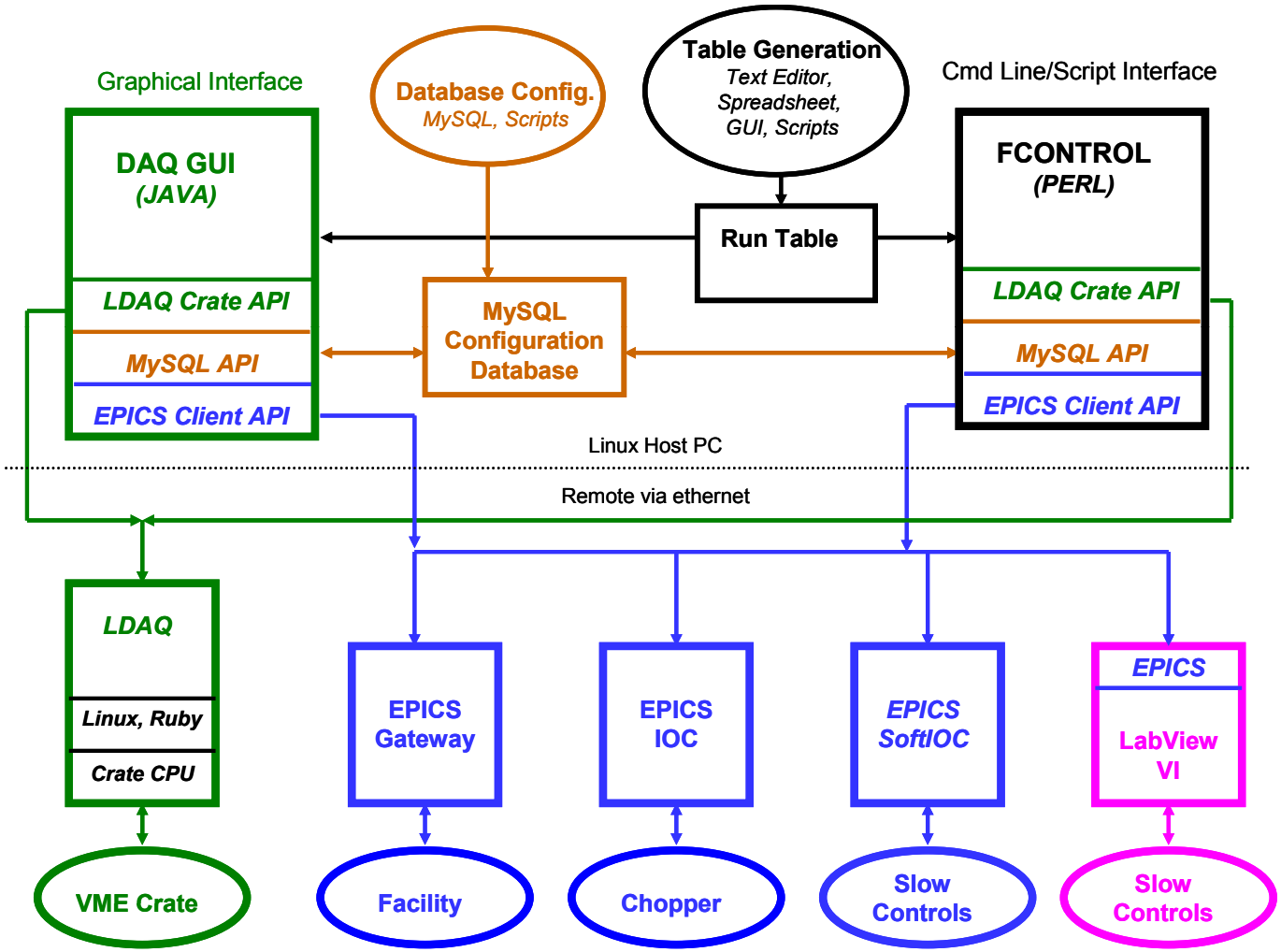
Software control architecture

- Automate and coordinate all aspects of instrument operation
- Open architecture to accommodate a wide variety of local controllers
- Script-based table-driven control for flexibility
- Supports range of table generation approaches



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Summary and status of upgrades

Upgrades

- New crate processors
  - *faster CPUs, more memory, local disks, faster ethernet*
- Move from Windows/VxWorks to Linux
  - *more robust and transparent OS, uniform across platforms*
  - *better multi-user security features*
- Core software rewrite
  - *simpler, faster, more reliable*
  - *added functionality – real time data monitoring, single event collection, etc.*
- Sample controls move from LabVIEW to EPICS
  - *improved EPICS development tools, e.g. softIOC*

Implementation Status

- 2008 run cycle – ran on three instruments, tube detectors
- 2009 run cycle – ran on five instruments, tube detectors
- 2010 run cycle – running on seven instruments and one experiment, supporting area detectors & single event data collection

Current challenges

Support

Transitioning the new LDAQ software from development to production

Technical Design

Decreasing the instrument-to-instrument diversity of control and run automation approaches

Presently the major effort bringing up an instrument with the new LDAQ software is interfacing LDAQ (and Linux) to their specific control and run automation setup.

Compliance

Accommodating evolving computer and network security considerations

Transitioning LDAQ from development to production

Issue

During development and initial testing on a small set “friendly” instruments, software changes and fixes occur rapidly and can be quickly propagated.

But, as the number and diversity of deployed systems increases and user program production considerations come into play, this breaks down.

Maturation process

Necessary, but somewhat mundane and difficult to motivate

Software engineering discipline

Version control – source code and installed executables

Controlling OS and system software versions and updates

Tracking bugs/fixes and new features

New version testing and roll outs

Distribution and upgrade packaging

Administrative infrastructure – servers, backup, user accounts control, etc.

Automated tools are a necessity

Decreasing instrument-to-instrument diversity of control and run automation approaches

More inherent diversity on the control side than the data acquisition side.

- Wider variety of sample environments and beam line controls
- Equipment and physical configuration changes from experiment to experiment.

Control side has been driven by the individual spectrometer teams.

- Evolved different solutions over the past decade to address their needs.
- Present software employs EPICS, Perl, LabVIEW, IDL, Spec, various web tools.
- Diversity has allowed each spectrometer team to meet their particular requirements, but software maintenance is a serious problem.

Considerations

- Careful balance between flexibility and standardization
- Framework in which scientists, post docs, students can reasonably work.
- Based on robust technology with a reasonable future.
- Instruments need a evolutionary path, significant investments cannot be replaced overnight.

Steps on control commonality

Still very much a work in progress – mostly bottom up to date.

Moving toward a more EPICS-based framework

- Standardize abstraction of process variables.
- Provide a common interface for automation scripts and GUIs.
- Take advantage of EPICS "front-end" tools and IOC platforms not available a decade ago.

Standardized, EPICS-compatible, commercial serial and analog/digital hardware interface modules

More EPICS Linux SoftIOC controls, replacing stand-alone Windows Labview control.

APIs to interface to the LDAQ software

Evolving computer and network security considerations

The Internet of 2010 is a far different and less benign environment than the Internet of 2000. *"Can't live with'em"*

Computers and networks are the basis of all modern data acquisition and control systems. *"Can't live without'em"*

Both real concerns & arbitrarily-imposed rules

Computer and network security issues & drivers

Issues

- Remote access – off site control and monitoring
- Shared computers, multiple users – account/password management
- Foreign national staff & users (US-DOE issue)
- Forced OS & system software updates
- Automated network scanning and blocking
- Administrative access restrictions
- Network access restrictions – network segmentation & firewalls
- Increased administrative overhead & effort

Moving target – *"If it isn't broke, don't fix it"* no longer a viable option.

- Rapidly changing rules and environment

Responses

- Linux OS – better suited to handling multiple users
- Minimize # computers – one computer per instrument
- Local expertise and institutional involvement – advanced notice, push back, but time intensive

Summary

LDAQ data acquisition software now running on seven instruments

- Much better performance and reliability

Administrative and support focus on moving LDAQ to production mode

Technical focus is now on better standardizing control and run automation

- More inherent diversity plus added diversity due evolution of present systems
- Working to understand and strike appropriate balance
- Moving bottom-up toward an EPICS-based infrastructure

Ongoing effort to accommodate computer/network security concerns