OAK RIDGE National Laboratory

SNS Status Report

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EPICS collaboration Meeting Fall 2022

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ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

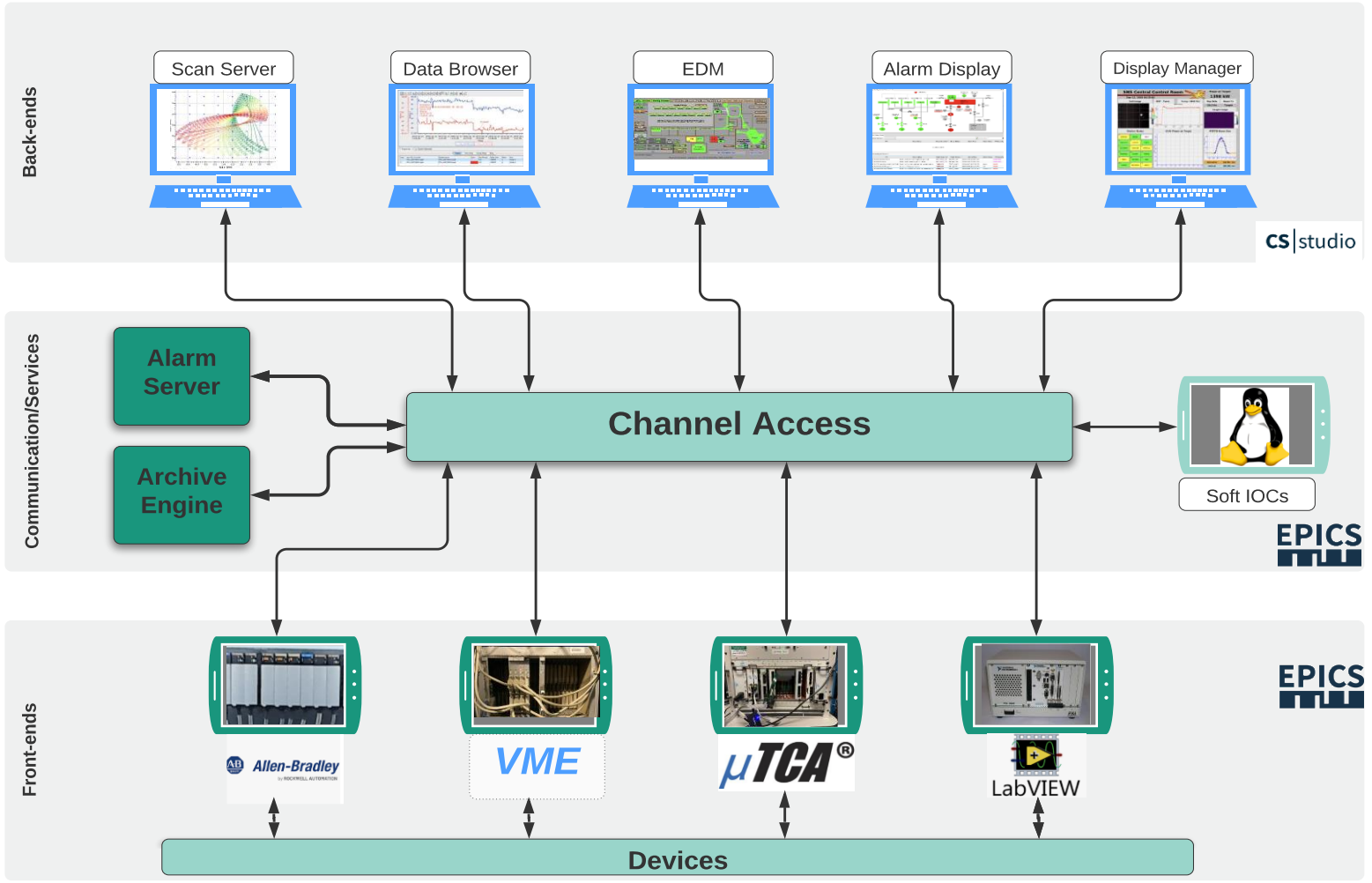
About the Spallation Neutron Source

- Accelerator based neutron source in Oak Ridge, TN, USA
- DOE user facility for neutron scattering research
- Built by a partnership of six DOE laboratories
- Completed in 2006, began user program in 2007
- The SNS now operates ~4500 hours per year and has 20 instruments available for users
- Two facility upgrade projects in progress
  - PPU – will increase machine power from 1.4 MW to 2.8 MW by 2024
  - STS – Will build a second target station with a new suite of instruments for users; beam will be shared on a pulse-by-pulse basis CD-1

How the Control System was built

- Partner labs delivered sub-systems with controls based on SNS standards
- Controls group at SNS was responsible for global systems and integration and long-term operations and maintenance
- Selected standards included:
  - EPICS framework and tools
  - Allen Bradley PLCs
  - Motorola VME IOCs w/ VxWorks
- EPICS used to integrate controls based on a diverse set of hardware platforms, giving the operators a common view

Control System Architecture



Control System Growth

	2006	2022
VME IOCs	168	167
Linux IOCs	46	152
µTCA	0	9
Windows IOCs	248	170
PLCs	100	189
MPS inputs	923	1000
PVs	395000	603000

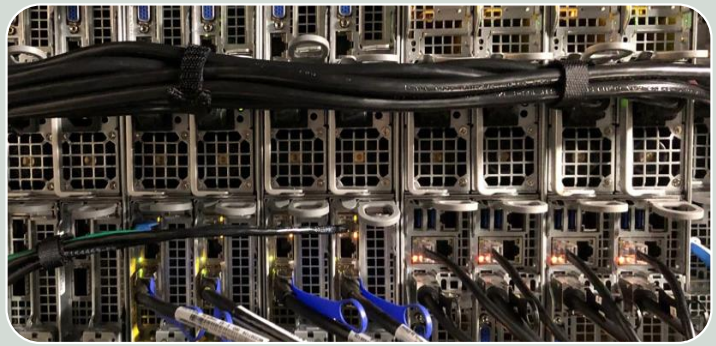
Upgrading control system on an operational facility

- Post commissioning, upgrades:
  - Address performance/availability issues
  - Add controls for new devices as needed for other subsystems
  - Develop better operational tools
  - Mature processes
- A few years later
  - Hardware and software obsolescence
  - Upgrades to timing and machine protection
- More recently
  - Project driven upgrades
    - Currently PPU
    - Future STS

Upgrading control system an operational facility

- Challenge - No longer possible to have the control system down for an extended period so upgrades must be phased in during scheduled outage periods
- Staying ahead of obsolescence requires work on most systems
- Upgrades limited by labor resources and procurement funds
- Many things need to done, important to prioritize
- Staff turnover requires the development of early career staff

Global Systems



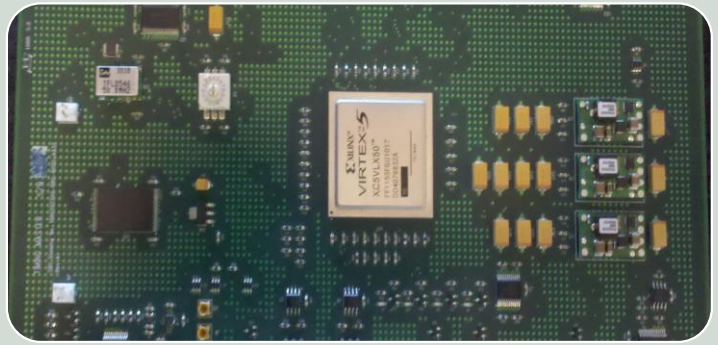
Infrastructure

Network and computing technology refresh

Upgrade from 32 to 64-bit Linux and environment

Network requires segmentation for additional growth

Migrate from servers to virtualization cluster



Timing

New distribution hardware

New master

New software

Completed 2019

MPS

New field nodes

New master

Firmware, software, testing progress

EPICS, Services and Back-end tools

EPICS

Upgrade to EPICS 7

EPICS 3 systems peacefully co-exist with EPICS 4 systems

Run Channel Access and PV Access

First converting soft IOCs to EPICS 7 (20%)

Services

Developed new in CS-Studio

New archive engine

New alarm handler

Subsequent refactoring from Eclipse RCP to Phoebus

Tools

Developed tools in CS-Studio, provides interoperability and common look/feel/behavior

Archive Browser

Alarm Display

Display manager

Web Display

Soft IOCs

Increasing use of Linux based soft IOCs:

For systems that do not need a direct hardware connection

To create composite or calculated PVs

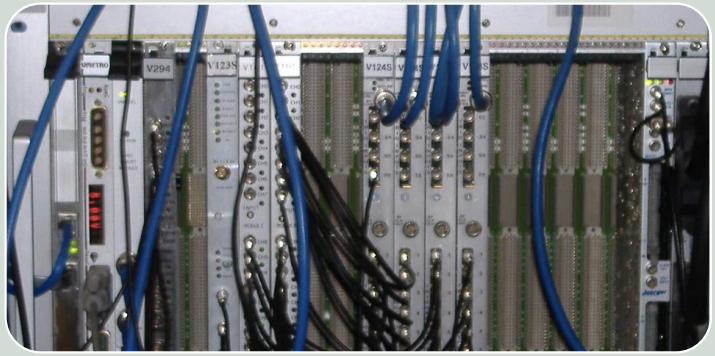
Front-end systems

Slow Controls

Allen Bradley PLCs

Upgraded processors in 2009 due to manufacturing issues

Need to convert slow, obsolete ControlNet and DeviceNet communications to Ethernet

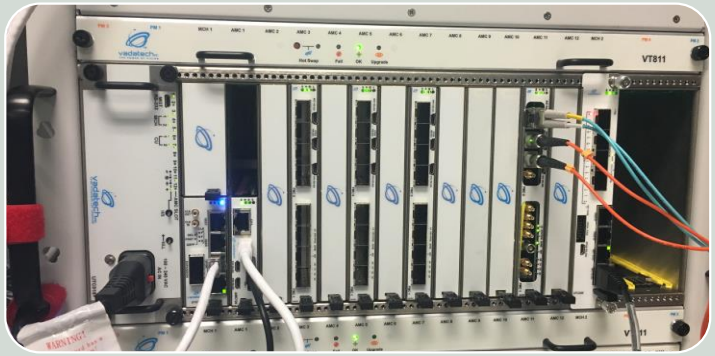


VME

Increasingly difficult to get VME modules, many obsolete

Some VME based systems don't need high performance and can be converted to PLC based systems (e.g. motor controls)

Real-time systems upgrade path is µTCA



µTCA

Used for new real-time systems

Ring/Linac LLRF

Kicker Waveform Generation and Monitoring

MPS

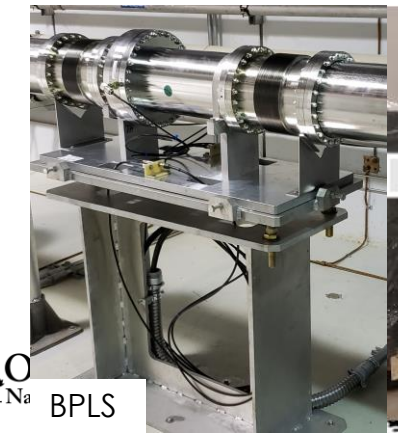
BPLS

Upgrades for PPU

- PPU increases SNS machine power from 1.4 to 2.8 MW by adding 7 cryomodules, additional magnets and a new type of target
- Control system upgrades to include integration of additional devices; changing designs due to obsolescence where required
  - Cryomodule controls, obsolete VME motor control design replaced with PLC design
  - Beamline and cryomodule vacuum controls, extended, replicated
  - HPRF controls replicated
  - LLRF developed new system due to obsolescence and to support STS two beam flavor operations
  - Network, MPS, timing extended
  - PPS adds new Beam Power Limiting System, first use of FPGA for a credited control at SNS
  - Target controls upgrades for new target utility systems
  - CF controls added for system capacity upgrades

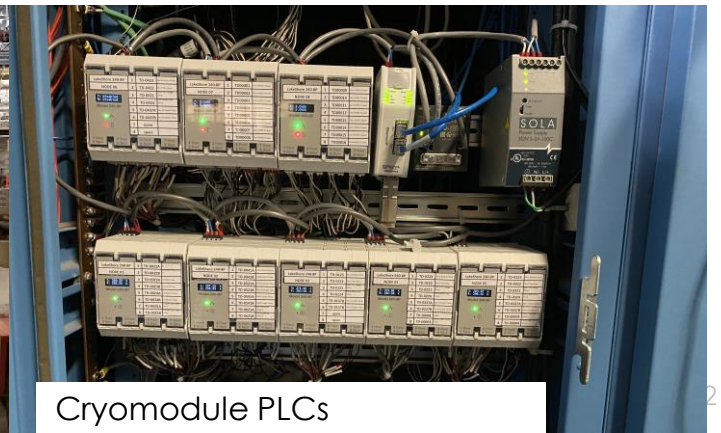
Controls challenges for PPU

- As usual, some systems are very late providing requirements leaving little time for control work to meet schedule
- Some vendors did not deliver working controls per contract and SNS controls personnel had to complete these systems
- Supply chain issues put some controls delivery at risk of missing schedule deadline



BPLS

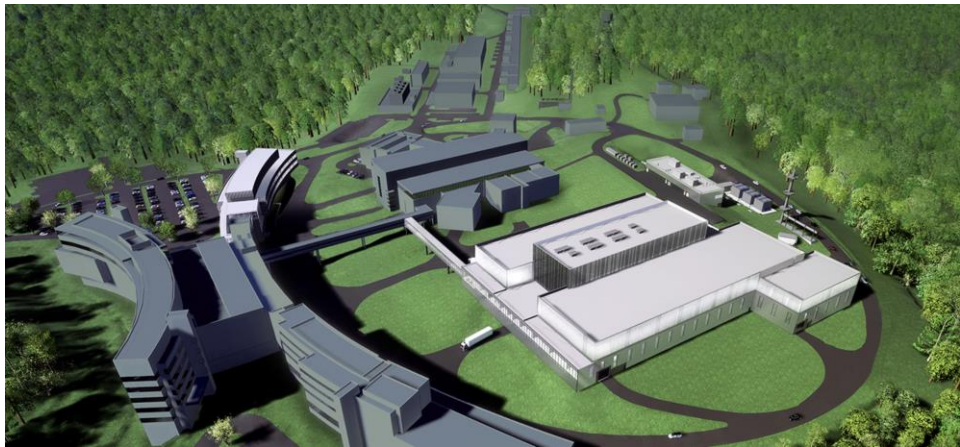
Inside view



Cryomodule PLCs

Upgrades for STS

- STS will add a new target station doubling scientific output potential
- Accelerator will continue to operate at 60 Hz with every fourth pulse directed to STS, deliver beam to either target station or both
- Builds on the existing architecture of the SNS machine and instrument control systems using EPICS 7 and CS-Studio
  - Extends accelerator control system for new beam transport line
  - Original LLRF system will be replaced with new design from PPU
  - Modify LLRF, timing, kickers, MPS, etc. for two beam operation
  - Develop new Run Permit System to manage two beam operations
  - Develop target and CF controls for new target station and buildings
  - PPS add a credited control to limit beam power to target
  - Instruments follow existing EPICS based controls and data acquisition



Credit Steven Hartman

Conclusions

- The SNS control system has been growing, evolving since original machine commissioning
- Controls is particularly vulnerable to vendor technology cycles causing obsolescence
- Current challenges with supply chain and staff turnover
- Original control room tools were basic, needed improvement and were replaced by the CS-Studio services and tools
- Changes need not be disruptive due to the EPICS based architecture; it has proven reliable, extensible and sustainable
- No shortage of work

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Thanks

- Thanks to the many people who have contributed to the construction, maintenance and upgrades of the SNS control system over the last twenty years!

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