

SUMMARY OF THE NSCL CONTROL SYSTEM

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Introduction

This paper will summarize the NSCL control system, as it stands immediately after the completion of the NSCL's Coupled Cyclotron Project (CCP).

Communications Backbone

100base-T Ethernet is used to connect the major control system components (VME crates, PLCs and operator workstations) with each other. VME crates and PLCs are connected to a pair of 24-port Ethernet switches, which will become part of an isolated Ethernet segment once an upcoming network upgrade is completed. Primary operator workstations will also be connected to this segment, and routers installed such that only legitimate lab workstations have any access to the isolated nodes.

Operator Workstations

Operator workstations for the control system consist of Intel x86-based computers running one of the various Microsoft Windows operation systems. There are 14 official control workstations in the main and cryogenic control rooms and scattered throughout the vaults and beam lines. The majority of these are running Windows 2000, though a few older nodes are still configured with Windows NT. Windows 2000 PCs installed in each of the experimental control "Data U" areas provide control system access and monitoring capability to experimenters.

Numerous other workstations, located in staff members' offices, also have control system software installed. While these are primarily used for monitoring, they can perform very nearly all of the functions of the official operator workstations. These workstations run everything from Windows 95 up to pre-release evaluation copies of Windows XP for their operating systems.

In addition to the Windows-based PCs, a pair of Sun/Solaris SPARC workstations is used for EPICS development, and these also serve several native control applications to control system PCs via X-Windows. Boot files for the VME crates are also stored on these nodes, to allow for rapid rebooting and testing cycles during software development.

EPICS/VxWorks VME crates

There are currently 20 VME crates in the control system, running EPICS (Experimental Physics and Industrial Control System, originally developed at ANL and LANL) version 3.13.2 on top of Wind River's VxWorks real-time operating system. Motorola PowerPC-based MVME 2302 CPU boards are used in all crates.

A typical VME crate contains a CPU and a memory board, which holds device settings in battery-backed memory over crate reboots. Most crates contain analog and binary I/O boards, and there are 8-port MacroLink MVC-Quick serial boards in several crates for serially controlled power supplies, probes and beam current monitors. These serial boards run NSCL software that performs all necessary serial messaging overhead, such as hex-to-ASCII conversions and checksum calculation and verification, and also take care of managing queues of requests to multiple slave devices on the same multi-dropped RS-485 serial lines.

VME crates load their boot files from the Sun/Solaris workstations while in development, but under running conditions load their files from PCMCIA flash cards on their CPU boards.

An I/O record summary for the individual VME crates follows. The "other" record type encompasses intermediate software ("soft") records as well as specialized I/O records, such as those that map

PLC I/O channels directly to EPICS records via Ethernet queries to the PLCs (as is done in the cryoplant VME crate).

VME Crate	Analog I/O	Binary I/O	Serial I/O	Other	Total
4 pi	48	256		147	451
A1900 A	136			192	328
A1900 B	96			117	213
A1900 C	48		8	62	118
Coupling Line 1	48			47	95
Coupling Line 2	88			106	194
Cryogenics				2363	2363
ECR 1	160	80		171	411
ECR 2	144			223	367
ECR 3	144		6	166	316
Control Room	48			1735	1783
K1200 Magnet	48	31	30	255	364
K1200 RF	80	128		45	253
K1200 Vault	96	256	28	109	489
K500 Magnet	48	7	23	227	305
K500 RF	80	128		36	244
K500 Vault	48	136	29	102	315
N1 Vault	6			8	14
S800 Vault	80		41	71	192
Transfer Hall	144		19	264	427
TOTALS	1590	1022	184	6446	9242

Modicon PLCs

Industrial-hardened Modicon Quantum model 534, 113, and 424 PLCs are used for state control and interlock management throughout the facility, and increasingly are also used to provide top-level analog and binary I/O for devices such as power supplies and flow, pressure and temperature monitors.

Channel access server software, based on source code provided by the EPICS consortium, provides EPICS access to all PLC channels at NSCL. PLCs are also often addressed directly over Ethernet to obtain channel data, using the PLCApp application described in a later section.

An I/O-point summary of the individual PLCs follows. A “network” here consists of 7 rungs of ladder logic in the PLC program.

PLC	Networks	Drops	Binary I/O	Analog I/O	Total I/O
ECR	184	4	560	108	668
Accelerators	825	12	2512	430	2942
N4 Vault	3	3	336	176	512
Beam lines	564	10	2176	380	2556
Cryo Plant	328	8	704	648	1352
Cryo Load	561	6	352	424	776
Exp	9	3	416	67	483
4 pi	23	1	96		96
LCW	4	1		6	6
TOTALS	2501	48	7152	2239	9391

Control Applications

A number of applications make up the control system software installed on operator workstations. Most of these were written at NSCL, but several in use are provided as a part of EPICS.

Anet MDI

A very simple windows MDI (multiple-document interface) program, that allows users to view and control channels in multiple windows with text-box arrays of channels from 1x1 to 8x6 in size. The program name stems from historical reasons, when the NSCL control system used Arcnet as its transport medium.

Chart Recorder

An 8-channel strip-chart program with user-selectable time scale. Each of the 8 channels can be configured with their own color, offset, scaling and chart type, and can be hidden or shown as desired.

Knob/Meter Control Application

An application that allows users to assign channels to hardware knobs and meters located at the operator workstations. Up to 8 channels can be “ganged” on a knob with individual scaling factors, so that knob turns effect the settings of each ganged channel simultaneously. Channel settings can be saved to and restored from 4 individual holding areas, so that a previously saved “good” state can be instantly returned to if an attempted tweak does not work as expected.

Magnet Control Application

Used for both the K500 and K1200 cyclotron main magnets, this application displays interlock and power supply statuses and allows the operator to ramp the magnets to any desired current. Field tuning capability is also included, using equations to calculate the required magnet currents needed to effect a desired differential field change from a given set of base currents. The actual main magnet control is done by specialized, dedicated processes running on the magnets’ associated VME crates, with the PC application merely acting as a front end.

PLCApp

A program that allows operators and experimenters to construct simple control screens with pushbuttons and several types of control templates (indicator, readout and bar-graph) to monitor and control hardware. Plug-in data access software modules provide communication to serial, Modbus-Plus and Ethernet PLCs directly, and also to EPICS channels on the VME crates. Connecting directly to the PLCs, this application is how almost all state and interlock control is performed at NSCL.

Probe Control Application

A program to control the speed and positions of the various probes in the two cyclotrons, with a graph providing an X/Y plot of any 6 control system channels’ value versus the probe position.

LabView Applications

An increasing number of specialized control applications are now constructed using National Instrument's LabView App-Builder package, with an ActiveX control written at NSCL (described below) providing access to control system channels via EPICS. Applications currently exist for the K500 and K1200 RF systems, the K500 and K1200 vacuum systems, the cryogenic system, the LCW (low conductivity water) system, and the non-intercepting beam probes of the A1900 beam line.

EDM

EDM is a Sun/Solaris hosted application in development at ORNL, which allows a designer to create control screens containing multiple graphical elements. EDM is currently used at NSCL in the "Barney" control application, which provides a graphical view of the accelerators and beam lines with numerous controls and status indicators, making it possible to see at a glance the state of the devices and the resultant beam.

MEDM

Similar to EDM, MEDM is available from the EPICS consortium as a Sun/Solaris application or as a native Win32 application. The Win32 version is used at NSCL to provide many detailed control screens for the cryogenics system.

DDE Interface

A Microsoft Windows DDE server has been written to provide EPICS channel data to DDE-aware commercial applications, such as the Microsoft Excel spreadsheet. Excel macros have been created to handle constructing the complex text expressions needed to bring DDE data into Excel.

ActiveX Interface

An ActiveX (or OCX) component has been written to allow ActiveX-aware applications, such as National Instrument's LabView or Microsoft Visual Basic, to have access to EPICS channels in a more sophisticated event-driven fashion than is possible with DDE. Currently all LabView applications (described above) at NSCL make use of this component, and a deflector testing and conditioning application for Visual Basic has also been written.

A Few Code Details

Summary information for selected NSCL software follows. "Lines of code" consists of the code in the main application itself, not necessarily including the many libraries the code may call upon. The Delphi applications appear rather lean, as the vast majority of MS-Windows screen I/O and other API routines are encapsulated within bundled objects.

Software Item	Language	Lines of code	Platform
Anet MDI application	Pascal (Delphi)	1050	Win32
Chart Recorder application	Pascal (Delphi)	3750	Win32
Knob/Meter application	Pascal (Delphi)	3400	Win32
Magnet Control application	Pascal (Delphi)	3850	Win32
PLCApp application	Pascal (Delphi),	10500	Win32

	MSVC++		
Probe Control application	Pascal (Delphi)	4050	Win32
LabView applications	LabView	-	Win32
DDE Interface	Pascal (Delphi)	2600	Win32
ActiveX Interface	Pascal (Delphi)	2200	Win32
Magnet Control task	GNU C++	3150	VxWorks/EPICS
PLC-to-EPICS CA server	MSVC++	6300	Win32
Serial support (VxWorks side)	GNU C	6200	VxWorks
Serial support (MVCQ side)	GNU C	7300	ColdFire CPU
BCM97 (embedded code)	Z-World Dynamic C	2150	Zilog CPU
68701-based controller	assembly	1800	68701 CPU
Model 400 controller	C, assembly	3950	68332+68HC11 CPUs
NSCL specialized EPICS records (47)	GNU C	38600	VxWorks/EPICS

Planned Upgrades

Immediate plans include the isolation of the control system Ethernet segment from the rest of the facility's Ethernet. This will be implemented by the purchase of additional Ethernet switches, some rewiring, and the installation of a router/firewall combination of some kind yet to be determined.