THE LANSCE CONTROL SYSTEM CURRENT STATE AND UPGRADE OUTLOOK*

Martin Pieck#, Eric A. Björklund, Gary Carr, John A. Faucett, Jeffrey O. Hill, Debora M. Kerstiens, Pilar S. Marroquin, Michael A. Oothoudt, and Stuart Schaller,
Los Alamos National Laboratory, Los Alamos, NM 87545, USA
Peregrine M. McGehee, California Institute of Technology, Pasadena, CA 91125, USA

Abstract

The LANSCE (Los Alamos Neutron Science Center) runs its LINAC control system based on 30(+) year old technology. While some peripheral upgrades have been made over the years, the control system will need some major improvements over the next five years in order to continue to support the user facility's mission. The proposed multi-million dollar LANSCE-R (Refurbishment) project creates a unique opportunity to upgrade the existing control system. We intend to use the EPICS (Experimental Physics and Industrial Control System) control system with the following goals for effective control at modest cost: (1) Replacing our VMS based MicroVAXes; (2) Replacing the RICE (Remote Instrumentation and Control Equipment) subsystem with Programmable Logic Controllers (PLCs) to handle regular data acquisition and control, and custom hardware to handle "flavored" data acquisition; (3) Replacing the Master Timer subsystem with a modern event system; (4) Converting Fortran programs running on VAX/VMS computers to Java Programs running on Linux-based desktop PCs. The boundary condition, as usual, is that we must implement these major changes on a running accelerator.

LANSCE CONTROL SYSTEM HISTORY

LAMPF (Los Alamos Meson Physics Facility), as LANSCE was called until the late 90's, was one of the first major accelerators to be designed in the 60's for computerized control. The original control computer was a System Engineering Laboratory SEL 840. All access to accelerator data was through a locally designed, centralized system with remote acquisition and control hardware called RICE (Remote Instrumentation and Control). From the beginning the control system was in a continuous state of modifications. CAMAC devices were added to the system to complement RICE. By 1978 the control system provided access to approximately 4000 command-able devices and ~12,000 data points. Roughly ninety percent of these devices were accessed through RICE and roughly ten percent through CAMAC (local, serial, and remote). In the early 80's, the SEL 840, which used discrete-component DTL logic, was not manufactured anymore and we began a program to replace it with a dual VAX 11/780 cluster. The cluster computers were continuously updated throughout the 80's and 90's. In the late 90's we finished installing the cluster of five VAX 4000-96 workstations that are still in use today. In the early 1990's we began integrating EPICS into the LANSCE control system During a control room upgrade new Sun workstations running Solaris 2.6 were introduced. These six-headed machines displayed the operator interface screens connected to EPICS applications and also interfaced to the VAX-based applications through X-windows technology. It is important to note that most of the recent upgrades and modifications were made on a small and tight budget that usually was considered "spare money."

*This work has benefited from the use of the Los Alamos Neutron Science Center at the Los Alamos National Laboratory. This facility is funded by the US Department of Energy and operated by Los Alamos National Security for NSSA under Contract DE-AC52-06NA25396. Paper LA-UR-07-3928.
pieck@lanl.gov

REPLACING VMS-BASED MICROVAXES

The LANSCE Control System (LCS) is still utilizing 5 VAX/VMS machines. Many still are vital for operating and tuning the accelerator. However, with 15-20 year old technology come a suite of very common problems:

- spare parts are increasingly more difficult to get
- maintenance is becoming a problem with many of the original control system designers already retired
- new controls members are hard to get trained on this ancient technology
- unique design concepts (i.e. gateways) that were required to make the partial transition from VAX to Solaris and EPICS add unnecessary complexity

While in the 90's Sun Solaris workstations were the first choice among accelerator facilities, today there is hardly any control room that is not using Linux desktop computers. The main reasons why Linux is the preferred operating system are:

- open source
- very good cost / performance ratio
  - low maintenance cost (no license)
  - runs on cheap hardware
- choice (large available number of Linux distributions give you the choice to pick the best for your field)
- fast and easy installation
- compatibility (runs all common Unix software)
- full use of hard disk (works well even when hard disk is full)

 1-4244-0917-9/07/$25.00

During the LANSCE-R project our goal will be to replace all of the existing 5 VAX machines with Linux machines. Some problems that we face by converting these machines are related to the four primary input/output console devices that were used with the VAX-based system:

- Color CRT — A CAMAC-based color character-cell CRT at the center of each console. The driver software shared the CRT screen among a program demand line, a message area, and application program displays.
- Graphics scopes — Terminals driven by Tektronix graphics output. These were Tektronix 4014 compatible graphics terminals.
- Touch panels — Originally VT100 terminals with an add-on infrared touch panel interface. These were later replaced by Tektronix compatible graphics terminals using mice or trackballs to emulate touches.
- Knobs — Home-built, CAMAC-based knobs which provided command of analog channels.

While the controls group has worked hard over the years to overcome all the above listed hardware dependencies, there is still one function that can't be eliminated until the hardware itself is eliminated. The RICE data system (further described below) interfaces to the LCS data system through MircoVAXes that boot from the VAX machines to be replaced. During LANCSE-R we intend to replace the RICE system, allowing us to eliminate all VAX Machines.

REPLACING RICE WITH PLC'S

The initial description of the RICE hardware was given at the very first Particle Accelerator Conference in Washington, D.C., in 1965 [1]. For a more in-depth discussion of the RICE system in the context of the history of the LAMPF/LANSCE control system, see [2].

With thirty year old technology come many problems. Many of the discrete components in RICE electronics can no longer be purchased and supplies of spares are dwindling. Plastic connectors are becoming brittle and spares are not available. Calibration capabilities were not built-in, raising questions about year-to-year comparability of settings. Lack of any vendor support means all maintenance and repair must be done in-house. Non-standard electronics means all in-house maintenance people must receive extensive RICE-specific training. Retirement of the original designers and builders of RICE makes extended re-engineering necessary to understand the reasons for the current architecture and implementation.

A proposal was made in the early 1990s to rebuild the system in standard electronics, providing a complete duplication of RICE capabilities. Declining budgets and high cost, along with the undesirability of an extended accelerator downtime, prevented funding of the effort.

LANSCE-R takes a different approach. Review of channel usage shows that full RICE capabilities are needed for only about 10% of the channels in the system. A "divide-and-conquer" approach will be used, moving approximately 9,000 "slow control" channels to commercial Programmable Logic Controllers. The remaining 1,200 diagnostic and RF channels that require full RICE capabilities will be implemented in special-purpose VME electronics.

During the LANSCE-R project Commercial PLC systems can readily meet our needs for slow control data. Evaluations at SNS [4] have measured read speeds under EPICS [5] that are well in excess of our needs and in fact may support a 10 Hz update rate for our channel count. This is highly desirable for channels that are controlled by knobs, such as magnet currents.

We propose to replace each RICE module with an Allen Bradley ControlLogix PLC. An EPICS Input-Output Controller (IOC) in a VME crate will be used to control three to six PLCs in a geographical area; connection will be made via Ethernet, with an Ethernet switch used to isolate the IOC-to-PLC traffic from the rest of the network. To replace the slow-control channels for a typical RICE module, a PLC will have three ControlLogix crates containing six analog input modules, two digital input modules, six stepper motor controller units and two digital output modules. There will also be one DAC for diagnostic purposes.

Accelerator downtime will be limited but new hardware needs to be installed. This will result in running the accelerator with a mixed RICE/PLC system for several years.

REPLACING MASTER TIMER SUBSYSTEM

The current LANSCE timing system consists of a centralized timing pattern generator (the "Master Timer") that distributes timing signals on dedicated coax cables to all the locations in the accelerator where timing is needed. The timing pattern is supplied to the centralized RICE Interface Unit (RIU). The RIU uses the timing pattern information to schedule requests for data that occur only when a specific type of beam (referred to as a beam "flavor") is scheduled. With the elimination of the centralized RICE system, we need a method to make the timing pattern more distributed as well so that we can continue to satisfy requests for "flavored" data.

We propose to replace the Master Timer system, with a modern event system based on the Micro-Research Finland (MRF) event system currently in use at the Swiss Light Source (SLS), the Stanford Linac Coherent Light Source (LCLS), the Diamond Light Source, and several other facilities. The MRF event system uses 2.5 GHz Ethernet technology, which will allow us to increase the resolution of our timing signals by a factor of 100 (from 1 microsecond to 10 nanoseconds). It will also allow us to

1-4244-0917-9/07/$25.00

distribute other timing-related information, such as the current and next cycle of the timing pattern or whether a machine fault occurred, on a per-cycle basis. This information will allow decisions about flavored data acquisition to be made at the local level rather than at a centralized point.

Several challenges remain to be met in the design of a new LANSCE timing system. Among them are:

- The paradigm shift from a centralized gate generator to a distributed event system
- Handling special cases such as single-shot experiments and cycle-to-cycle pulse width variations.
- The correct balance between simplicity and flexibility
- Reliability issues such as redundancy, failover, fail-safe conditions, and maintaining the correct balance between hardware and software in the pattern generation and distribution.

CONVERTING FORTRAN PROGRAMS TO JAVA PROGRAMS

More than 200 person-years of effort have been invested in the VAX-based application software that is still needed to diagnose, tune, and run the accelerator. As discussed before, replacing these VAX computers will require conversion of all its VAX applications. While most of the code is written in Fortran and one could think of having them run on modern Linux system, the real problem is that the Graphical User Interfaces (GUIs) are written in a hardware dependent way, i.e., many of the Fortran application use the Touch Panel or Color CRT GUI. Rewriting the GUI is more like rewriting the whole code. In particular at the time when the code was written object-oriented programming had not reached the software engineering community. Keeping this experience in mind we decided to convert our Fortran applications to Java. Other applications, where appropriate, will be converted to EPICS. Java has gained enormous popularity since it first appeared. Its rapid ascension and wide acceptance can be traced to its design and programming features, particularly in its promise that you can write a program once and run it anywhere. This will serve us well as we will upgrade our computer hardware in the future. Other aspects that convinced us to go with Java are:

- Java is simple - No language is simple, but Java is considered a much simpler and easier to use object-oriented programming language when compared to the popular programming language, C++
- Security - Java is one of the first programming languages to consider security as part of its design.
- Java is multithreaded - Performing several tasks simultaneously within a program opens up a new dimension; however, it can also create problems when not used carefully.

EXPERIENCE SO FAR

During a three-day maintenance period RICE binary input/output channels in the RICE module controlling the last accelerating module of the LINAC were rewired to a PLC. An EPICS IOC was installed to interface the PLC to the remainder of the control system. Control system software was modified to access these RICE channels through the IOC. The system was tested and a few software problems corrected.

For the last couple of years we have been successfully converting Fortran programs to Java programs or EPICS applications. The biggest problem may be that the accelerator operators have to get used to the new “Look & Feel” of the software.

Just this spring we finished replacing all our control room Sun Solaris machines with 6-headed Linux desktops computers.

SUMMARY AND OUTLOOK

The LANSCE-R project creates a unique opportunity to bundle our efforts to upgrade the LANSCE control system. Many of the components will be replaced to improve the reliability and guarantee that the facility will be capable of supporting its mission for the next 15 years. Considering that this is an upgrade rather than a green-field approach under the condition that the accelerator needs to serve it’s users with over 3000 hours yearly of beam time while the upgrade is done, we are still facing enormous challenges to fit this in the beam delivery schedule.

REFERENCES

[1] T.M. Putnam, R.A. Jameson, and T.M. Schultheis, “The Application of a Digital Computer to the Control and Monitoring of a Proton Linear Accelerator,” IEEE Trans. Nucl. Sci., NS-12 (1965) 21.

[2] S.C. Schaller, “A LAMPF Controls Retrospective: The Good, the Bad, and ‘It Seemed Like a Good Idea at the Time’,” 1993 Int. Conf. on Accel. and Large Experimental Physics Control Systems, Nucl. Instr. and Meth. A 352 (1994) 516-520.

[3] Michael Oothoudt, Stuart Schaller, Eric Björklund, Mary Burns, Gary Carr, John Faucett, “The LANSCE RICE Control System Upgrade”, Proceedings 20th Particle Accelerator Conference, May 2003, Portland OR, USA. http://epaper.kek.jp/p03/PAPERS/WPPE013.PDF

[4] K.U. Kasemir and L.R. Dalesio, “Interfacing the ControlLogix PLC over Ethernet/IP,” *Proceedings of the 8th International Conference on Accelerators and Large Experimental Physics Control Systems*, November 2001, San Jose, CA., THDT002, http://www.slac.stanford.edu/econf/C011127/proceedings.html.

[5] L. R. Dalesio, et al., “The Experimental Physics and Industrial Control System Architecture: Past, Present and Future,” *Proceedings of the International Conference on Accelerator and Large Experimental Physics Control Systems,* 1993, pp. 179-184.