

CHANGING HORSES MID-STREAM: UPGRADING THE LCLS CONTROL SYSTEM DURING PRODUCTION OPERATIONS*

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Abstract

The control system for the Linac Coherent Light Source (LCLS) began as a combination of new and legacy systems. When the LCLS started operating, the bulk of the facility was newly constructed, including a new control system based on the Experimental Physics and Industrial Control System (EPICS) framework. The Linear Accelerator (Linac) portion of the LCLS was repurposed for use by the LCLS and remained controlled by a legacy system, built 25 years ago. This legacy control system is being upgraded to EPICS during LCLS production operations while maintaining the 95% uptime required by the LCLS users. The successful transition is made possible by thorough testing in sections of the Linac that were not in use by the LCLS. Additionally, a system was implemented to switch control of a Linac section between new and legacy control systems within 10 minutes. Rapid switching enables testing during maintenance periods and accelerator development days. If any problems are encountered after a section has been switched to the new control system, it can be quickly switched back. At this time, 50% of the Linac sections are operating under control of the new EPICS system. This paper describes the system upgrade with emphasis on the deployment scheme.

BACKGROUND

Hybrid Control System

The LCLS has a combination of control systems: a newly built EPICS control system and a legacy control system. The legacy system was built for the SLAC Linear Collider (SLC) 25 years ago and has been continuously improved since. The system uses distributed RMX microcomputers ("micros"), each supporting up to 15 CAMAC crates, to monitor and control accelerator components. There is a centralized host, an Alpha 6600 running the VMS operating system, which coordinates the micros, maintains a centralized database, and handles all operator interface functions [1]. Two years into LCLS user operations, this system is still used to control some functions in the Linear Accelerator (Linac) area of the LCLS. Specifically, it supports the accelerating RF system and its timing, various diagnostic signals, and the operator interface to the safety systems. The LCLS Linac is split into 11 areas, called sectors. Each sector contains a micro and four or more CAMAC crates that interface to

accelerator components. Most sectors are very similar to one another and contain identical signals and devices.

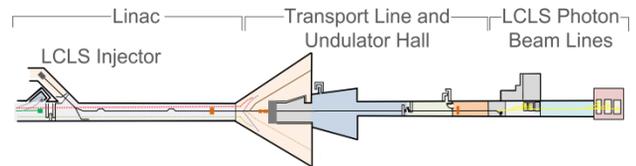


Figure 1: Overview of LCLS. [2]

Legacy System Data Access

The primary means for operators and physicists to interact with the legacy control system is a graphical user interface called the SLC Control Program (SCP). In more recent years, two additional interfaces have been developed that provide access to legacy system variables from the EPICS control system. The first is the SLC Channel Access Server (SLCCAS) [3], which provides read access to many variables over Channel Access (CA). The second is Accelerator Integrated Data Access (AIDA) [4], which provides read and write access to many variables from Matlab, Java programs, and scripts.

Upgrade Project

In order to improve LCLS uptime and reliability, dependencies on the legacy control system are being removed. In the LCLS Linac this effort has two phases. The first phase replaces the SLC micros with EPICS IOCs, fully integrating the CAMAC-controlled devices into the LCLS EPICS control system. The second phase will upgrade the CAMAC to new hardware. This paper discusses the first phase.

Challenges

The legacy control system has benefited from decades of refinement and is feature-rich. Additionally, thousands of signals in the LCLS Linac must be ported to EPICS. Reproducing features and accurately copying all signals are two main challenges of this project. Another challenge is to perform the upgrade during a production LCLS run, while meeting strict uptime requirements for LCLS users.

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DESIGN

System Architecture

Each Linac micro is being replaced by a standard LCLS EPICS IOC, which consists of an MVME6100 processor running the RTEMS operating system installed in a VME crate. A serial CAMAC driver board was developed to enable an IOC to communicate with CAMAC hardware. EPICS CAMAC drivers, EPICS databases, and higher-level IOC software were also created to replace the legacy software.

A switching interface chassis was built for each sector. Each chassis determines whether that sector is controlled by a legacy micro or a new IOC. Control can be switched locally or remotely. Thus some sectors can be controlled by the legacy system while others are controlled by EPICS, and sectors can be tested or upgraded independently. The switching chassis also greatly aided testing, allowing developers to compare live data between the IOC and micro by switching back and forth.

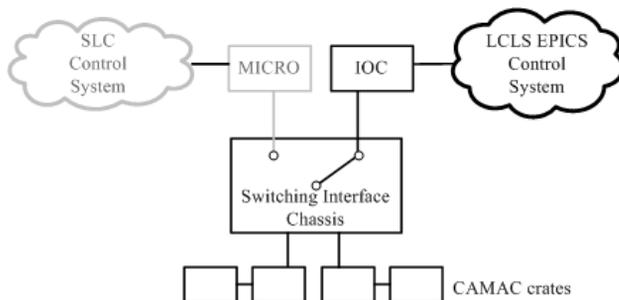


Figure 2: Hardware to enable switch between micro and IOC control.

Automated Data Transfer

Thousands of signals were ported to EPICS. To reduce errors, scripts were written to transfer and update data. For example, scripts were used to:

- Generate EPICS databases from the SLC database.
- Copy variable values to the new system when switching a sector to EPICS control. Variable values were not automatically copied from EPICS to the legacy system when switching back. This provided a known good configuration to return to in case of problems, with the disadvantage that when switching back to the legacy system, some variable values had to be copied manually.
- Modify existing user displays, replacing old PV names with new names.

Application Programming Interface

Before the upgrade, many high-level software applications used AIDA to read and control RF system variables. These applications did not need to be modified. This is because AIDA was updated to read and control

these variables through EPICS as well. Additionally, the AIDA directory service is updated when a sector is switched over and thus AIDA accesses the data from the appropriate control system. Applications that used Channel Access to access SLCCAS data had to be updated with the new PV names.

When converting SLC database variable names to EPICS Process Variables (PVs), some names were changed to comply with the LCLS naming conventions.

UPGRADE TO EPICS

Development Testing

Initial testing was performed in a lab test stand with two CAMAC crates. Fortunately, two unused Linac sectors were available for several months of the initial testing, on which much of the software could be tested. These sectors' RF systems were not all available, however, so not all software could be thoroughly tested there.

Transition Infrastructure

In parallel with the development testing, some infrastructure was released to production to support and ease the transition, and to facilitate the switching of individual sectors. These were done months before the upgrade:

- PV gateway: A PV gateway was installed to translate the old SLCCAS PV names to the future EPICS PV names [5]. Scripts were written to reconfigure the gateway, based on which system was controlling each sector. This gateway allowed clients to begin using the new names early for read-only purposes.
- Data archiving: PVs were added to the Channel Archiver early in the project so that control system users would have access to months of data history when sectors were switched over. The users agreed that this provided sufficient archived history in the new system and that they would use the old system if they needed older data.
- User interfaces: New and existing EDM screens, using the new PV names, were released to production. The original displays remained available for comparison or as a backup—in case users suspected problems with the new displays.
- Alarms: Signals were added to the alarm handler. On a per-signal basis, these alarms were automatically disabled if the associated sector was not under EPICS control.
- Data sources: Scripts were written to update the AIDA directory service when a sector was switched.

Switchover Tool

Scripts were created to perform most of the tasks associated with switching a sector. Using these scripts, switching a sector took less than 10 minutes. These scripts were made available on operator displays, so operators could switch a sector back to the legacy system if needed. This happened on several occasions, when operators needed to use a feature that had not yet been implemented in the new system or to compare data in the new system with the familiar legacy system. This made the control system users more comfortable with leaving a sector under EPICS control, knowing they could easily back out if needed. This also made it convenient to test for a relatively short period. These scripts did the following:

- Reconfigure and restart the PV gateway
- Update AIDA directory service
- Boot IOCs
- Copy settings over (one way)
- Restart some Channel Access clients

Production Testing

In production, testing was done on the LCLS Linac during scheduled maintenance periods and accelerator development days. As individual sectors could be switched, it was sometimes possible to test a sector that was not needed for that day's accelerator program. Most of the tests lasted a few hours. The sector was switched to EPICS control before testing and back to the legacy system afterward. These short tests provided opportunities to find problems and then fix them without using valuable beam time. Adding all the time up, testing required about 25 hours during maintenance periods and for about 60 hours during physics studies. Further testing took place during a 2-month scheduled downtime when all sectors were switched to EPICS control. This allowed maintenance groups to become familiar with the new system, although it did not allow extensive testing as most systems were off.

PRESENT STATUS

At the present time, about half of the sectors are under EPICS control. Small bugs are being fixed and remaining features are being completed. The remaining sectors will be switched to EPICS in the next month or two. This design is expected to be used when upgrading other (non-LCLS) areas of the SLAC Linac.

CONCLUSIONS

Extensive testing in a lab and in unused Linac sectors greatly aided development. The ability to switch between control systems and compare data was found to be invaluable during testing.

Great effort was taken to create an implementation scheme with minimal disruption to the user program. This was found to be worthwhile. To date, interruption to the user program has been less than 30 minutes.

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