THE LEDA CONTROL SYSTEM*

L. Dalesio, D. Kerstiens, P. McGehee#, M. Pieck, M. Stettler, R. Wright, LANL, Los Alamos, NM
D. Moore, WSRC, Aiken, SC
D. Floersch, Allied Signal, Kansas City, MO

Abstract

The Accelerator Production of Tritium (APT) Low Energy Demonstration Accelerator (LEDA) is a CW linac comprised of a 75 KV, 110 mA H^+ injector, followed by an 8m long, 350 MHz, 6.7 MeV RFQ, a short beam transport section and a cooled beam dump. The control system is based upon the popular EPICS [1], [2] distributed control system toolkit. In addition to monitoring and control of the injector, vacuum systems, resonance control loops, high power radio-frequency system, beam control magnet power supplies and beam instrumentation, the control system performs overall timing and synchronisation and equipment protection functions. There are a total of 12 distributed Input-Output Controllers (IOCs) which are VME-, VXI- or PC-based. This paper reports on experience with the new PC-based IOCs, with interfaces to vendor-supplied Programmable Logic Controllers (PLCs), with a new archiver developed for this application; and discusses a number of lessons learned.

1 INTRODUCTION

Since the first beam through the 6.7 MeV RFQ on 16 March 1999, the LEDA control system has been successfully and safety supporting operations and commissioning.

The fundamental purpose of the LEDA Control System is to provide electronic and real-time software support for all LEDA subsystems and diagnostics. In addition to subsystem support it also implements key accelerator-wide services such as Fast Protect, Timing, and Networks.

Within the LEDA Control Room the control system maintains status and control operator interfaces and provides a suite of data handling facilities that encompass archival, display, and analysis.

Additionally, the control system is the foundation for the LEDA integration process as well as supporting the ongoing commissioning and testing.

2 EPICS

The LEDA Control System is based on the Experimental Physics and Industrial Control System (EPICS).

EPICS is a toolkit for building distributed control systems that originated at Los Alamos, and is now developed jointly by a collaboration of over 100 institutions, including telescopes, detector collaborations, universities, etc. The EPICS collaboration grew by more than 20 sites during 1998. EPICS is licensed to two commercial suppliers, who have installed it in large industrial applications.

EPICS runs several accelerators of size comparable to planned APT facility. As an example, the control system for the Advanced Photon Source at Argonne National Laboratory spans 185 real-time IOCs.

LEDA makes use of recent EPICS developments including the most recent version of EPICS, the new standard Application Development Environment, a new data archiver, and PC-based IOCs.

3 LEDA CONTROL SYSTEM STRUCTURE

The control system exhibits a distributed hierarchical structure that at the time of initial beam commissioning is implemented across 12 IOCs.

The top-level of the hierarchy consists of four principal systems that cover the Supervisory Control, Machine Control, Diagnostics, and Safety and Protection functions.

3.1 Supervisory Control

The advanced automation features of the LEDA Control System are implemented using two IOCs and several high-level workstation-based sequencing applications. The real-time IOCs that are involved in supervisory control are the System (or Run Permit) IOC that is responsible for operating mode definition and enforcement, and the Master Timer.

3.2 Machine Control

The Machine Control principal system includes the traditional collection of moderately independent subsystems.

3.3 Diagnostics

The Diagnostics principal system is implemented across 4 IOCs that provide the electronic interfaces and software support for the following suite of beam diagnostics: Phase and Energy measurements, AC Toroids, DC Toroids, Beam Position Monitors, Wire Scanners, Capacitive probes, and Video Cameras.

*Work supported by the U. S. Department of Energy under contract W-7405-ENG-36.

Email: peregrine@lanl.gov

3.4 Safety and Protection

The hardware-based Safety and Protection principal system provides for the personnel safety and equipment protection. The Supervisory system includes the software interface required to determine the status of these critical components.

Personnel safety is insured by the Personnel Access Control System and Backbone Beam Enable services while equipment protection is handled by Fast Protect. All of these systems have the mitigating action of quickly turning off the accelerator beam at the injector.

3.5 List of LEDA IOCs

This table lists the IOCs operating in March 1999 as well as others that will be installed during the remainder of the year. Each IOC is identified by the bus architecture chosen: PC (ISA), VME, or VXI.

Subsystem	**Now**	**Plan**	**Type**
Supervisory	2	2	PC
Injector/ Low Energy Beam Transport	1	1	VME
RFQ and Windows Vacuum	1	1	VME
Resonance Cooling and Control	1	1	VME
Low Level Radio-Frequency	2	4	VXI
High Power Radio Frequency	4	5	PC
High Energy Beam Transport/ Beamstop	1	1	PC
CCDTL	0	1	VME
Diagnostics	0	4	VXI
Total IOC Count	**12**	**20**	

4 NETWORK DESIGN

The LEDA Control System communications service is built around a TCP/IP-based network and using EPICS Channel Access as the primary protocol. Access to the real-time controls network is limited by an Internet firewall that also divides the local network into three distinct sections.

4.1 Internet Firewall

The three major reasons that justified installation of an Internet firewall are that the LANL accelerator complex (TA-53) is one network; that there were limited available public IP address ranges; and that for machine protection issues we required isolation from all public networks.

Outside clients are tightly restricted and can access the interior controls network only via encrypted data channels such as the secure-shell (SSH) protocol. The firewall is transparent to certain inside clients.

4.2 Network Topology

With the Internet firewall installed three separate networks are created.

The interior and most restricted network is dedicated to controls traffic. The machines that exist here include the real-time IOCs, the operator consoles, and the file servers used by the control system.

Within the perimeter network reside the EPICS channel access proxy server and the LEDA HTML server. These hosts have access to the controls network and restrict access by external clients to two specific protocols - HTML and EPICS channel access.

The remainder of the TA-53, LANL, and the global Internet is considered as the public network.

5 NEW DEVELOPMENT TOOLS

5.1 EPICS R3.13.1

This is the latest and most advanced release of EPICS that is in use at several major operational facilities including Advanced Photon Source at Argonne National Laboratory.

5.2 LEDA Specific Development Tools

At Los Alamos National Laboratory a number of tools have been developed specifically for the APT/LEDA program for the purposes of configuration management, visualization, and the creation of EPICS real-time databases.

A collection of utilities has been created to aid developers in setting up new applications and keeping existing ones under configuration control.

IDL, the commercial visualization tool, has been integrated with the EPICS display manager to create more complex operator screens. This is one of the EPICS portable communications server applications that are described in the next sub-section.

The Microsoft Access relational database is now used together with the schematic capture utility CapFast from Phase Three Logic to create databases more quickly.

5.3 Portable Communications Server

Three new applications that are based on the new EPICS communications server have been built for use on LEDA. These include a fault logger, a camera interface, and an interface to IDL. Each of these has the ability to supply control system process variables that are accessible by other EPICS utilities.

The fault logger enables a networked display of current or logged faults from the high power radio-frequency system. This server resides on a UNIX-based operator console (OPI).

The second application is an interface between EPICS and a digital camera controlled by a vendor-provided Windows NT device driver.

On the OPI, there is a software library that mediates between EPICS data and widgets and IDL plotting and analysis routines. This allows IDL to provide information viewable by the EPICS display managers and other channel access clients.

5.4 Data Archiver

A new archiver has been developed for EPICS-based control systems. The archiver is implemented as three programs – a channel archiver, a save-set archiver, and an graphical archive viewer.

The channel archiver deals with all standard data and array types. It can process up to 5000 channels/second on change, at a specified frequency, and on specified conditions, including demand.

Production of IOC warm reboot and set-point restore files is the purpose of the save-set archive tool.

Both channel and save-set archive files can be viewed by the distributed viewer (XARR) that also exports data in tab-delimited format for use by external programs such as Microsoft Excel.

6 PC IOCS

LEDA has deployed the first PC/VxWorks-based I/O Controllers. Each PC-based IOC is characterized by an Intel x86 CPU, ISA-bus architecture, and dual-bootable to both the VxWorks real-time operating system and Microsoft Windows 95. These PC IOCs have been deployed by the System (Run Permit), HPRF, Master Timer, and HEBT/Beamstop subsystems.

6.1 Usage of PC IOCS

LEDA utilizes a mixture of VXI, VME and PC IOCs to meet diverse requirements.

VXI-bus IOCs are used for subsystems that have requirements for custom instrumentation.

When large numbers of I/O modules are required the traditional VME-bus IOC is the preferred choice.

However, PC IOCs have been proven to be a cost-effective solution for systems that either have limited I/O requirements or communicate with external devices such as Programmable Logic Controllers (PLCs).

7 CUSTOM PC BOARDS

Custom printed circuit boards have been developed for LEDA project. These provide specialized instrumentation support for the diagnostics, the low-level and high-power radio frequency systems, the injector, and the machine protection systems. The Industry Pack format is implemented when cross-platform use is required. Each custom board required its own device driver to be created, tested, and integrated with the subsystem EPICS applications.

8 EXTERNAL SYSTEMS

The integration of the LEDA control system required interfacing to subsystems provided by four external vendors. An assessment of the effectiveness of out-sourcing these four subsystems is detailed in [3].

Subsystem	Vendor	Implementation
RFQ Resonance-Control Cooling	Allied Signal	VME IOC, EPICS
High-Power RF Transmitter	Continental Electronics	Allen-Bradley PLC-5/40
High-Power RF Power Supply	Maxwell Technologies	Allen-Bradley SLC 5/03
RFQ Vacuum	LLNL	Modicon PLC

9 SUMMARY

The control system for the Accelerator Production of Tritium program's Low Energy Demonstration Accelerator has been sufficiently developed to safe and reliable support of initial beam operations. The LEDA controls implementation has taken advantage of the most recent version of the EPICS toolkit and has created significant enhancements to the standard EPICS distribution including support for PC IOCs, a new data archiver, and several portable communications server applications.

Since LEDA is a test-bed for an accelerator that will be operated as an industrial or factory-like facility, the next steps in its control system evolution will focus on integration of the diverse machine control and diagnostic subsystems and on the maturation of the supervisory system.

10 ACKNOWLEDGEMENTS

The following individuals contributed to the design, fabrication, and support of the LEDA control system:

J. Booth, G. Cavasos, T. Cote, L. Day, D. Gurd, J. Hill, M. Jenkins, T. Jones, M. Harrington, B. Quintana, G. Salazar, M. Thuot, G. Vaughn, D. Warren, LANL.

S. Hardage, Allied Signal.

P. Gurd, J. Sage, General Atomic.

S. Bolt, WSRC.

11 REFERENCES

[1] The Success and the Future of EPICS, M. Thuot, et al., Proc. LINAC96 (Geneva, 26-30 Aug. 1996).

[2] EPICS URL: http://www.aps.anl.gov/asd/controls/epics/EpicsDocumentation/WWWPages/

[3] A Development and Integration Analysis of Commercial and In-House Control Subsystems, D. Moore and L. Dalesio, Proc. LINAC98 (Chicago, 23-28 Aug. 1998).