EPICS AT DUKE UNIVERSITY *

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Abstract

Since the last Particle Accelerator Conference, the Experimental Physics and Industrial Control System (EPICS) has been utilized for control system development and implementation on several accelerators that have recently been commissioned at the Free Electron Laser Laboratory which is operated under the auspices of the Physics Department at Duke University. The historic Mark III infrared free electron laser formerly located at Stanford University, a recently designed and constructed 280 MeV electron linear accelerator and a 1 GeV storage ring synchrotron are now operating under EPICS control. Commissioning of the new injection linac and the storage ring has gone extremely well.

The authors feel that through the employment of a standard controls development environment such as EPICS, considerable amounts of resources, both financial and human, have been saved. The authors note generally positive experiences with EPICS. The highlights of these experiences, as well as some suggestions for future improvements will be presented in the body of this report.

I. INTRODUCTION

In early 1992, EPICS was selected as the primary controls development environment for the injection linac and storage ring synchrotron projects at Duke. EPICS was decided upon due to various factors such as cost, availability, architecture, and funding structure: EPICS was provided at no cost to Duke by the AOT-8 Group at Los Alamos. The AOT-8 Group graciously pledged to help get EPICS established at Duke. EPICS' architecture conformed to what has been called the Standard Model of Control Systems [1]. Furthermore, the U.S. Army Space and Strategic Defense Command supported both the development of EPICS at Los Alamos and the development of the electron beam controls at Duke. By June 1992, the Ground Test Accelerator Control System (GTACS), the predecessor of EPICS, was being employed at Duke for control system development.

II. ARCHITECTURE

Although, the essential architecture of GTACS and EPICS has been discussed in many other papers [2], a brief description is probably necessary for those who may be unfamiliar with these systems. From the hardware standpoint, the systems are based around an Input/Output Controller (IOC). Although other options are available, the IOC's employed at Duke are of the most common type; VME crates with Motorola MVME-167 CISC based single board microprocessors running Windriver's VxWorks real-time kernal. User interfaces are displayed at Duke using Sun SPARCstations, although ports to other UNIX operated workstations are used at other laboratories. High level communication employs TCP/IP over Ethernet. Thus far, we have not separated the control machines from the Laboratory's business and scientific network. EPICS provides the means to interface to a variety of other I/O buses at the IOC layer. We have chosen to employ VME, CAMAC, GPIB and Allen-Bradley Industrial I/O as the locally supported I/O bus types, but many other buses are in use at other laboratories.

From a software standpoint, EPICS can be divided into various functional subsystems. These subsystems include; a distributed database, a display manager, an alarm handler, a data archiver, a sequencer, and channel access. The distributed database provides local control at the IOC level for data acquisition, data conversion, alarm handling, interlocking and control. A database configuration tool is used to configure the IOC. New device drivers and scan tasks can be added fairly easily to the distributed database to extend the supported hardware, I/O buses, and functionality in a modular form called a `record type' . A subroutine record type can be used to implement complicated new devices or algorithms. Higher level control functionality can be established by interfacing various applications such as TCL/TK running on workstations with the channel access `software bus' of EPICS.

During the months that followed the initial establishment of GTACS at Duke, several representative tasks were selected for controls development. These systems included controls for; the facility's de-ionized water system, the storage ring vacuum system, and the storage ring dipole magnet system. Initially, these systems were controlled and data was acquired using a mix of VME and Allen-Bradley Industrial I/O hardware. Eventually, these GTACS based applications were transferred to EPICS control. During the Summer of 1993, several new drivers were written for various CAMAC function modules that were already on-hand and plentiful. Our initial CAMAC interface was done with the CES Model CBD 8210 Parallel Branch Driver. Early benchmarking of throughput using the Motorola MVME-167A with the CES CAMAC Branch Driver revealed data rates in excess of 10kBytes per second. As it would turn out, the development of this new CAMAC support was quite fortuitous.

III. THE MARK III FEL

The Mark III FEL was originally constructed at Stanford and moved to Duke where it has been rebuilt [3]. It is a broadly tunable infrared source and is in high demand by a diverse users group. The Mark III essentially consists of an electron gun with

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a thermionic cathode of lanthanum hexa-boride, a single Stanford linear accelerating section, a spectrometer, beam diagnostics, beam dump, the free electron laser assembly, and related support equipment. In the early Fall of 1993, a number of problems developed with the existing control system. We realized that we had just completed the necessary drivers for the CAMAC modules that were used in the Mark III control system and we also were testing the CES Parallel Branch Driver on a development IOC. Upon approval from management, a database translator routine was written to move much of the information from the original database into the EPICS database. Two Physics graduate students were given two days of training on EPICS. We moved our development IOC into place near the Mark III CAMAC crate and borrowed an A-2 crate controller and cable from a neighboring laboratory. Within two weeks the transfer of the Mark III to EPICS control was essentially complete. The Mark III was in full operation by the beginning of the third week. Improvements have continued to take the Mark III beyond the original operational capability. To date we have implemented 432 database records on the Mark III. It is expected that the Mark III control system will continue to grow at a steady rate during the coming years. The present records are a mix of analog input and output, and digital input and output for both data acquisition and control structures. Availability and reliability of the EPICS controls for the Mark III have proved to be truly excellent. Initially, we operated the Mark III for over a year without any EPICS related problems at all. However, immediately after the Storage Ring and Injection Linac control systems were commissioned, we experienced two IOC crashes on the Mark III in a period of several weeks. We eventually isolated the cause of these crashes; an unshielded Ethernet drop cable located in the storage ring near the injection kicker. Since replacing this cable with a shielded drop several months ago, we have experienced no further problems with the Mark III controls. Overall, the availability and reliability of the EPICS based controls on the Mark III are essentially one hundred percent.

IV. THE INJECTION LINAC

The Injection Linac [4] essentially consists of an electron gun that is very similar to the one used on the Mark III, eleven Stanford linear accelerating sections, low and high energy spectrometers, beam diagnostics and related support equipment. In the Winter of 1994 it was noted that a high level of overall similarity was present between the Mark III and the Injection Linac from the instrumentation and controls standpoint. The prior existence of the Mark III proved to greatly simplify the requirements definition task and provided a model for our application developers to build upon. From the instrumentation and controls standpoint, most of the work on the Injection Linac was begun and completed during the Summer of 1994. Eventually, 626 database records were established for the Injection Linac. These were again a mix of analog and digital inputs and outputs. The Injection Linac hardware configuration consists of one IOC and three remotely located CAMAC crates. We are using the Hytek VSD 2992 Serial Highway Driver in Bit Serial Mode for this application. We are indebted to the CEBAF Controls Group for sharing their initial development work freely with us. We feel that this is an example of one of the great advantages of collaborative controls development.

As we began to commission the Injection Linac, the control system went through a period of rapid evolution. For a period of perhaps two months, changes were made to the configuration practically everyday. One problem that we noticed, was that it was extremely difficult to find rather minor database entry errors that would cause the system to either slow down, or even occasionally crash. We therefore recommend that tools be developed to efficiently locate such errors for rapid correction. Overall though, these were relatively minor irritations that were perhaps magnified somewhat by the rush of commissioning.

During the past eight months, we have experienced three crashes of the Injection Linac IOC. The cause of these crashes was traced to the same unshielded drop cable that was previously discussed regarding availability and reliability of the Mark III controls. Since this unshielded drop was replaced, we have experienced no further problems with the Injection Linac controls. The availability and reliability of the EPICS based controls on the Injection Linac are essentially one hundred percent.

V. THE STORAGE RING SYNCHROTRON

Due to the high degree of complexity of the Storage Ring controls, a paper in this proceedings is devoted entirely to this topic [5]. Therefore the description of this system will be kept brief. The Duke Storage Ring is built in a racetrack configuration with long straight sections that will soon be filled with free electron lasers and other sources [6]. The storage ring is energized with a radio frequency cavity of Russian design that utilizes a commercial radio frequency transmitter. The cavity tuners, transmitter, vacuum system, dc current transductor, beam position diagnostics, dipole, quadrupole, and trim power supply systems, photomultiplier tubes, de-ionized water system, and other support systems are now under EPICS control. To date roughly 1500 database records have been established. Higher level physics type control structures are implemented with TCL/TK. The Storage Ring employs two IOC's, four CAMAC crates, and four Allen-Bradley crates. The Storage Ring system employs a CAMAC Byte Serial Highway using the Hytek VSD 2992 modules.

During the past eight months, we have experienced perhaps two crashes of the Storage Ring IOC's. As with the other machines, these crashes were traced to the same unshield communications drop mentioned earlier in this report. Again, since the drop cable was replaced, availability and reliability have been essentially one hundred percent.

VI. CONCLUSION

The authors feel that the utilization of EPICS at the Duke FEL Laboratory has saved much time and money. How much has been saved is very difficult to quantify due to a number of complicating factors such as the scope of the Instrumentation and Control Group's responsibilities which is quite broad at Duke, the effect of pre-existing equipment on estimates, differences in scale and requirements from one laboratory to another, and various other uncertainties.

From a functional standpoint we feel that we have implemented an advanced capability that would probably not have been possible had we designed and constructed our own system from scratch given the modest financial and human resources associated with this project.

We wish to emphasize various areas that we feel should be addressed by the International EPICS Collaboration in the future:

- Improved Documentation
- Tools to Efficiently Locate Database Errors
- Reduce Implementation Costs
  - Reduce VxWorks License Cost for EPICS Users (Some reductions have already been realized)
  - Realize PC Based Implementation Capability (Perhaps with Linux)
- Establish a Purpose Funded Version Control and Support Group

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References

[1] Control System Architecture: The Standard and Non-Standard Models - M.E. Thuot, L.R. Dalesio, The Proceedings of the 1993 Particle Accelerator Conference, Washington, D.C., USA

[2] EPICS Architecture - L.R. Dalesio, M.R. Kraimer, and A.J. Kozubal, The Proceedings of the 1991 International Conference on Accelerator and Large Experimental Physics Control System, KEK Tsukuba, Japan

[3] A Review of the Stanford Mark III FEL Program - S.V. Bensen, et al., Nuclear Instruments and Methods A296, 110 (1991)

[4] Accelerator Archeology - The Resurrection of the Stanford MKIII Electron Linac at Duke - P.G. O'Shea, C. Dickey, R. Sachtschale, G. Swift, P. Wang, J.M.J. Madey, This Proceedings, Dallas, TX, USA

[5] The Duke Storage Ring Control System - Y. Wu, B. Burnham, This Proceedings, Dallas, TX, USA

[6] The Duke Free-Electron Laser Facility - P.G. O'Shea, V.N. Litvinenko, J.M.J. Madey, K.D. Straub, This Proceedings, Dallas, TX, USA