Status Report on the TRIUMF Central Control System

M.M. Mouat, B. Davison, S.G. Kadantsev, E. Klassen, K.S. Lee, J.E. Richards, T.M. Tateyama, P.W. Wilmshurst, P.J. Yogendran
TRIUMF 4004 Wesbrook Mall, Vancouver, B.C., Canada, V6T 2A3

Abstract

This paper presents the current status of the TRIUMF 500 Mev cyclotron central control system (CCS). The original TRIUMF CCS employed Data General Nova computers and for more than 20 years Nova CPUs were at the heart of the CCS. A modest upgrade project was commenced in earnest in 1993 to replace these Novas and accomplish several other goals. The status of the CCS is described now that the Novas are removed and the other goals have been largely met. The current hardware and software configurations are discussed and the experience gained during the upgrade is examined. Reliability, performance, error diagnosis, and the development environment are also described.

1 Introduction

In 1968 TRIUMF was established as a physics laboratory jointly operated by a group of four Canadian universities. The primary accelerator is the 500 Mev cyclotron which is presently capable of producing four simultaneous beams of protons at various energies ranging from 180 to 520 Mev and currents ranging up to 180 uA on the high current beamline. There are both experimental and applied programs ongoing and there is a new radioactive beam facility (ISAC) under construction.

The central control system for TRIUMF 500 Mev cyclotron was originally installed in 1973 and since that time the evolution of the central controls has occurred at a slow rate with some accelerated periods. The most recent significant change started in 1993 when a project was authorized to replace the existing control system computers. Neither the human nor financial resources were firm but a budget and a three year schedule were established. These old computers have now been replaced and the new system is installed and running very reliably. This upgrade was accomplished with a minimum of disruption to cyclotron operation and no alteration to beam schedules due to control system needs. The current system couples the newer computers and the older but successful data acquisition hardware architecture. This is definitely not a “standard model” control system.

In addition to the upgraded central control system, other developments have been completed since the last time that the status of the TRIUMF central control system was reported, and still other projects are underway or being planned. These non-upgrade projects include such items as two somewhat isolated control systems which have been partially integrated into the central system, the completionof controls for the Proton Therapy Treatment Facility, and support for the new 2A extraction system and beamline.

2 The central control system upgrade

In April 1993 a project was commenced to replace the principle computers and their peripherals in the 500 Mev cyclotron’s central control system. This included replacing 6 Data General Nova computers running realtime code and another 4 Nova and Eclipse computers used for support. The work had to be done without affecting the cyclotron’s operation or beam schedule and without additional staff. Financial resources were found to cover the basic hardware requirements.

2.1 Mandate and current status

From upgrade proposals going back more than 10 years, a rather simple set of goals was targeted. The primary aim was to replace the old computers. This was needed for several reasons. The hardware was failing reasonably often, replacement parts were no longer available, the software was written in assembler and thus hard to maintain, the computers were slow due to their old technology, and the memory address space was full so new software could not be accommodated. It should be noted that all things being considered, these computers and their software ran remarkably well and only contributed a relatively small fraction of the overall cyclotron downtime. The larger issues were that the hardware was so old that it might break irreparably and new software functionality could not be supported.

In addition to replacing the computers, several software goals were identified. The three primary goals were to eliminate assembler code wherever possible (and use more modern high level languages), to use commercial databases, and to employ an operating system that would support larger address spaces. Enhanced performance and an improved user interface were anticipated.

These goals have now been achieved. At the end of December 1996 the last Nova was decommissioned. The Nova software could not really be ported because it was in assembler so it was rewritten. The only remaining assembler code is the VAX/VMS CAMAC driver, even the Alpha/VMS CAMAC driver is written in C, and the VAXes will likely be replaced in due course. Oracle is now widely used for database applications in both two and three tier configurations. The computers in use are VAXes and Alphas with sufficient address space and physical memory.

2.2 General philosophy

The central control system configuration is definitely not a “standard model” in either hardware or software. There is effectively just one level of computer. The concepts of front end computer and application computer are combined thus eliminating the need for interprocess or interprocessor communication to access equipment. This setup provides a very simple software and hardware approach with good performance. Diagnosing software or hardware problems is relatively straight forward because of this simplicity. Although the need for greater bandwidth is not a requirement at present, the bandwidth can be easily expanded in a linear fashion by adding more computers or executive crates. In addition, the learning curve for understanding the system is relatively small, again because of the architecture.

2.3 The hardware configuration

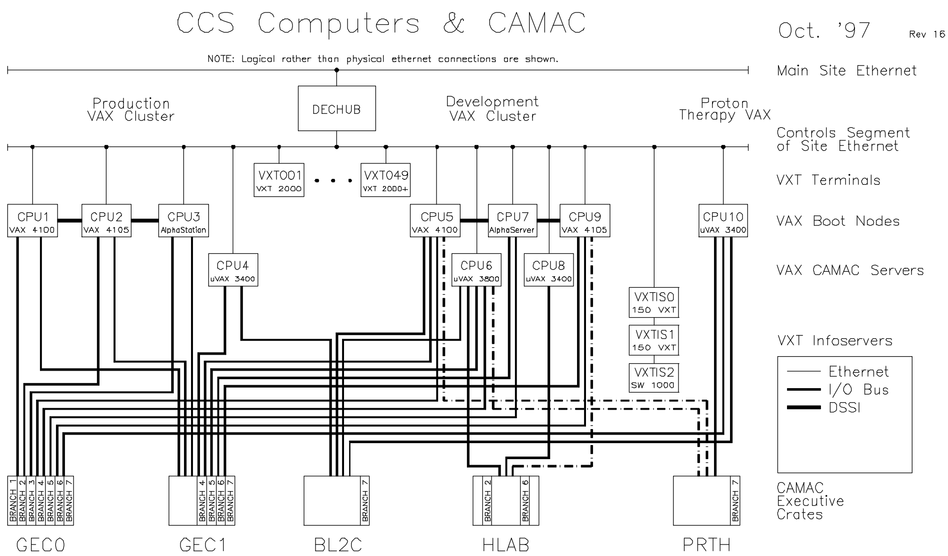

Figure 1 Hardware Configuration

The current hardware configuration is shown in figure 1. This setup was adopted going into the upgrade project and has proven its worth.

The computers are setup in two clusters, a production and a development cluster. Originally there were only VAX computers running OpenVMS but this has evolved to mixed clusters of VAXes and Alphas. Until recently, the Alphas provided the same functionality as the VAXes with one exception, the software handling of CAMAC interrupts had not been developed in the Alphas. This development has recently been completed [1] and now the VAXes will be phased out in favour of Alphas, as allowed by financial resources.

The control system equipment is bridged off from the main site FDDI backbone via a switching bridge located in a local network hub. The controls group employs 4 ethernet segments. The network activity is low on all of the segments, with the largest component being activity to X window terminals and running at a fairly constant 10% on that segment and less than 5% on each of the other segments.

The original data acquisition and control system is still in use. This system uses a CAMAC executive crate which normally supports seven CAMAC branches and allows access by multiple computers via fast hardware arbitration. This configuration has been replicated to support increased requirements. Currently there are 5 executive crates with 15 serial and parallel CAMAC highways, containing both copper and fiber optic connections. Links to GPIB, STD, VME, and VXI are supported from the CAMAC. CAMAC interrupts, known as LAMs, are supported and allow quick response to a variety of events. The performance of the hardware exceeds the present requirements. On the newer computers, the CAMAC standard CFSA call to access a device takes approximately 25 microseconds. Device access calls at a higher level, that take longer to execute, are commonly used and the timing of these calls depends on the complexity of the action. To fully handle a CAMAC interrupt takes between 150 and 200 microseconds.

The Operations Group does most of its work from the main console in the control room. This console comprises a variety of equipment including 18 X window terminals with mouse, keyboard, and touch screen interfacing, and a variety of assignable and dedicated knobs and buttons. In addition, there is remote console support via X window and character cell applications.

2.4 The software configuration

The two cluster configuration has been both reliable and flexible. The clusters have similar functionality in most respects but are used in differnet ways. Source code for applications is developed and maintained on the development cluster and then when the code is ready for regular use, only the executable image and support files are moved to the production cluster. The use of two clusters has advantages. There is the knowledge that the applications can be run on development computers even if all production computers are inoperable. Because tight control is maintained over what is running on the production cluster, a predictable response can be maintained and this is seen as important for operational use. Predictable response is not assumed on the development cluster which allows diagnostics, beam development, and other special operational procedures to be run without affecting regular operational aspects.

The software environment is built around VAX and Alpha OpenVMS, currently at version 6.2. The vast majority of cyclotron information is displayed using X window applications and the Motif window manager. Oracle is used for a number of database applications including the cyclotron device information, asset information, fault reports, message information, etc. X window interfaces to Oracle are most common but some web based facilities are available.

A good set of hardware and operating system diagnostics exist. The hardware diagnostic programs are mostly developed for the CAMAC system and are extremely useful in handling faults. These programs are maintained by the group members responsible for the hardware.

2.5 Experience gained

One perspective of the experience gained is of the issues that went smoothly and those that were more difficult. Most activities went well and that was a result of a number of items. The basic architecture of TRIUMF's CCS was, and still is, a configuration that supports access by multiple computers to device resources (multi sourcing). This philosophy and implementation allows various computers to independently access equipment knowing that they will not interfere with the other processors. This requires distributed resource lock management for those items that need it. However, most actions are atomic and do not need locking. TRIUMF's architecture allowed new computers to co-exist with the old ones and made the phase over much easier.

The Operations and other groups were cooperative and understanding. This meant that time and energy were not spent in political delays. Working relatively closely with the Operations Group meant that applications in the new system were generally well accepted.

Because a functioning control system existed, the basic requirements were already defined and not much time or money needed to be spent on analysis. The Nova applications were entirely coded in assembler. Without documentation, the complexity of many applications made deciphering the code beyond difficult. For a programmer to understand the code by simply reading it would surely have been qualification for canonization at a later date. In these cases, the cooperation of the Operations Group was essential for determining precise functionality.

As parts of the control system were being moved from the old system to the new system there was a long period where system users had difficulty in locating and properly using the correct applications. There is a common problem of whether to use the new facility or the old. This can be very confusing for users of the control system. Word of mouth and special notes located in a book for such purposes helped to ease this issue.

It appears that human nature is such that when a functioning application exists, many people are reluctant to see it change in form even if the new functionality is a superset of the old. This may be nowhere more true than for accelerator operators. Accepting the wisdom of these operators, there is clearly some value in having the rewritten applications appear very similar to their old counterparts.

2.6 Schedule and cost review

Software and hardware developments had been occuring in a rather unorganized manner for a number of years prior to the official funding of the Nova replacement program in April of 1993. A very ambitious 3 year schedule was established which identified the functions in each of the Nova computers and a date when each computer would be decommissioned. This schedule was followed and, with a slippage of approximately 8 months, the old computers were fully removed by the end of December 1996.

In 1988/89 and 1989/90 there were hardware purchases that amounted to $265 K Can. and contributed to infrastructural support. During the 1993/94 to 1996/97 period a total of $224 K Can. was budgetted for the Upgrade project, leading to a total of $489 K Can. spent for capital expenditures. From 1988 to 1997 this was supplimented from the regular Controls budget by an unknown amount but likely in the range of $300 K Can.

In 1993 before the start of the project there were 3 people involved in central control system hardware development and maintenance. At the same time there were 11 people doing software development, maintenance, and administration, bringing the pre-project group total to 14. There were no new hires or reassignments to assist during the project. By December 1996 this total had been reduced to 9 by attrition. During the project, those involved retained their normal maintenance duties in addition to any project responsibilities. Luckily, other groups significantly reduced their expectations during this period which allowed less time to be spent on regular developments and maintenance, and thus permitted the project to be completed.

3 Other completed projects

In addition to the removal of the Nova computers, other projects have been supported. Two examples of other central control system activities are the operator interface work on the Proton Therapy Treatment Facility and aspects of the beam extraction system for the new beamline BL2A.

3.1 Proton therapy

The Proton Therapy Treatment Facility is a facility for treating eye cancers [2]. This installation delivers a beam of protons, via a primary beamline, to the patient located in a specialized chair in the treatment area. The operator interface software and hardware, modelled on the central control system, was produced and is maintained by the Controls Group. Patients are now being treated on a regular basis.

3.2 BL2A extraction

A radioactive beam facility is under construction at TRIUMF [3]. This facility will receive a beam of 500 Mev protons via a new beamline known as beamline 2A (BL2A). The BL2A extraction system, including the controls aspects, has already been completed [4].

4 New projects and directions

As the evolution of the central control system continues, a goal will be to phase out all of the VAXes and replace them by Alphas. This will provide better performance and simplify system administration. As this happens, all of the CAMAC interrupt handling will be moved to the Alphas and a transition to 64 bit addressing and operating system support will be adopted. There are also a number of enhancements involving messaging, event handling, displays, and other topics that are envisioned.

The remainder of the BL2A central controls will be implemented and integrated into the central control system. Related work will involve a link to the ISAC control system.

Database activities are an important aspect of the central control system. The existing X window interfaces to Oracle will be supplimented and possibly replaced by web based utilities. Some web/database applications are already in use and others are in development. A reliable, three tier, database configuration employing Oracle, web servers, and web browsers is seen as a desirable goal.

5 Summary

The project to replace the aging Nova computers has been successfully completed. The current configuration is running very reliably, providing good performance, the required functionality, easy system management and fault analysis, and flexibility for both maintenance and development. The operator interface for the Proton Therapy Facility and the CCS controls for BL2A extraction have also been completed. Enhancements to the existing CCS and support for new facilities such as beamline 2A are anticipated.

References

[1] K.S. Lee et al, "Handling CAMAC Interrupts in Alpha OpenVMS/PCI", Proceedings of ICALEPCS 97, Beijing, China

[2] E.W. Blackmore et al, "Operation of the TRIUMF Proton Therapy Facility", Proceedings of PAC 97, Vancouver, Canada

[3] P. Schmor et al, "Status of the TRIUMF ISAC Facility for Accelerating Radioactive Beams", Proceedings of PAC 97, Vancouver, Canada

[4] D. Morris et al, "The Control System for a New Proton Extraction Probe at TRIUMF", Proceedings of ICALEPCS 97, Beijing, China