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SEP 28 1999

Completion of the ATLAS Control System Upgrade

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Abstract. In the fall of 1992 at the SNEAP (Symposium of North Eastern Accelerator Personnel) a project to upgrade the ATLAS (Argonne Tandem Linear Accelerator System) control system was first reported (1). Not unlike the accelerator it services the control system will continue to evolve. However, the first of this year has marked the completion of this most recent upgrade project. Since the control system upgrade took place during a period when ATLAS was operating at a record number of hours, special techniques were necessary to enable the development of the new control system "on line" while still serving the needs of normal operations. This paper reviews the techniques used for upgrading the ATLAS control system while the system was in use. In addition a summary of the upgrade project and final configuration, as well as some of the features of the new control system is provided.

INTRODUCTION

ATLAS is a heavy ion accelerator that has roots dating back to the early 1960's. ATLAS has been designated a National User Facility, and attracts experimentalists from all over the world. The facility operates 24 hours a day, seven days a week.

As early as the late 1970's it was recognized that ion accelerators and their associated peripheral equipment were becoming complex devices. Some of these accelerators were already becoming too complicated to be controlled and monitored with traditional methods. These methods often employed the use of several electronic racks consisting of a host of potentiometers, meters, dials, switches, and indicator lamps. Today there are conferences devoted to the subject of accelerator control systems.

The early 1980's saw the construction of the accelerator system that would later evolve to become today's heavy ion accelerator facility, ATLAS. This system consisted of an electrostatic Tandem accelerator injecting beams into a booster linear accelerator employing RF (Radio Frequency) technology. Those responsible for the design of the control system for the newly constructed linear accelerator realized that the complexity of this new accelerator called for a computer assisted control system. Consequently, the resulting accelerator system was controlled and monitored by a hybrid control system. The more traditional control system was retained for the

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Tandem, while the computerized control system was implemented for the new linear accelerator.

By the end of 1991 two additional linear accelerator sections, an ion source, and a more elaborate beam transport system were added to the facility. Due to evolutionary and operational constraints, the resulting control system consisted of the older traditional methods and three separate isolated computerized control systems. In 1992 work began on upgrading the ATLAS control system to provide a more cohesive system based on a singular control and monitor design.

THE SYSTEM TO BE UPGRADED

Prior to the start of the upgrade, control and monitoring of the accelerator was accomplished through the use of three DEC (Digital Equipment Corporation) PDP-11 computer systems (2). Control and monitoring of the ATLAS PII (Positive Ion Injector) was performed by one of the above mentioned computer systems, while control and monitoring of the primary accelerator section was controlled by a second system. All beam transport components external to the accelerator were serviced by the third system. All three systems contained separate and isolated databases.

Two separate CAMAC (Computer Automated Measurement And Control) Serial Highway subsystems were used as the primary interface between the computer systems and the various accelerator components as shown in Figure 1.

FIGURE 1. This figure depicts the system to be upgraded.

Control of the accelerator was accomplished using two separate control consoles. One console was remotely located, and was used to allow development of the new positive ion injector without interfering with normal day to day operation of the primary accelerator section. The second console was located in the main control

room. Operator interfaces included a variety of touch screens, monitors, terminals, knobs, keypads, and switches.

UPGRADE STRATEGY AND IMPLEMENTATION

It was decided that the upgrade needed to provide a system that was modular, expandable with a minimum of effort, and conformant to current and emerging software and hardware standards to ensure long-term viability. Since the facility was entering a period where a record number of operational hours were planned, it was crucial that the new system be integrated into the overall control system without interfering with accelerator operations.

Specialized in-house written processes existed on the old control system that was the result of years of programming effort. The decision was made to provide a new system that was capable of accepting as much of the existing process code as possible. Due to the large investment in CAMAC components, the CAMAC I/O subsystem was retained, but the initial plan for the upgrade called for replacing all of the PDP-11 computers.

The staff responsible for the day to day operation of the control system, as well as achieving the upgrade goals, typically consisted of one full time system manager/programmer, one full time operator/programmer, and one part time co-op student/programmer. The size of this staff, given its responsibilities, provided a strong preference for acquiring an established control system software package that would form the real-time portion of the new control system.

Both commercial and non-commercial candidates were researched. Since the software package known as EPICS (Experimental Physics and Industrial Control System) was just being developed through a collaborative effort of participating national laboratories, there was a convincing motivation for adopting this control system software. However, only one package provided both CAMAC Serial Highway and CAMAC in-crate processing support as well as guaranteed technical support. Therefore, based on the size of the staff, and other considerations, the software package marketed under the name "Vsystem" by Vista Control Systems, Inc. was acquired (3).

In order to accomplish the previously described goals the initial upgrade strategy called for four overlapping phases. Since the initial goal of the upgrade was to centralize control of the entire accelerator in the main control room, the first step in phase one was to integrate control and monitoring of the positive ion injector into the main control system. The PII development computer system and the main computer system maintained two separate and isolated databases and two CAMAC subsystems. The two databases were combined to create one database, and the two separate CAMAC Serial Highways were combined to form one CAMAC Serial Highway.

Once this was accomplished the PII development computer system was no longer needed. Therefore, the first of the three PDP-11 computers was retired. The resulting system is depicted in Figure 2.

FIGURE 2. This figure shows the system configuration after the first upgrade phase.

The second phase called for porting all of the beam transport processes to the new control system. To help accomplish this a second I/O subsystem was installed. This was an Ethernet based LAN (Local Area Network), which is used to connect the various control system computers. A DEC MicroVAX was installed and connected to the newly installed LAN.

Two new database structures were installed on this new machine. The first database was the more dynamic "Vsystem" real-time database. This database provides the software or logical link to the CAMAC hardware. Changes made to this database causes CAMAC I/O to occur. The second database is a relational database, which uses the data management software product "Oracle Rdb" (4). This database contains static information about accelerator devices that would be inappropriate to store in the Vsystem real-time database. Information such as a device's name, the associated channel name in the real-time database, chassis rack location, and any other constant-like parameters associated with a device are stored in this database.

Cooperating communication processes were written for both the MicoVAX and the PDP-11. Since at this time the PDP-11 was still physically interfaced to the CAMAC subsystem, these two processes provided a means for the PDP-11 to issue CAMAC I/O requests on behalf of the newly configured computer system. This scheme provided the means for developing processes on the new system without affecting the configuration or operation of the old system.

Two additional cooperating processes were written for the MicroVAX and the PDP-11 that were responsible for maintaining database consistency between the two systems. This allowed an operator the flexibility of controlling a device from either the old system or the new system. If a device parameter was changed on the old

system, the database of the new system would be updated. Likewise, if a device parameter was changed on the new system the database of the old system was updated.

At the end of the second phase of the upgrade all of the processes used for the control and monitoring of all beam transport devices were moved from the PDP-11 that was responsible for this task to the newly installed MicroVAX. This enabled the retirement of the second of the three PDP-11 computers. The configuration after phase two is shown in Figure 3.

FIGURE 3. This figure is an indication of the system configuration after upgrade phase two.

During phase three, as more processes were moved to the new control system, the PDP-11 was issuing an increasing number of CAMAC I/O requests on behalf of the MicroVAX. This consequence led to a degradation of overall system performance. It was at this time that the physical connection of the CAMAC Serial Highway was moved from the PDP-11 to the MicroVAX.

Also in phase three a method for storing complete accelerator tune configurations was put in place. The Oracle Rdb relational database plays a key role in the archiving of complete accelerator tune configurations. Using this archived information a tune configuration for a given experiment can be stored for future experiments. A Corel product called Paradox was installed to provide the operator with a graphical interface to the archived tune data (5). This was done to eliminate the need for an operator to learn, and use commands in SQL (Structured Query Language) to manipulate data in the relational database. The implementation of this interface provides the operator with a "point and click" windowing environment for retrieving data from the archive database.

When the final process that was executing on the remaining PDP-11 was moved from the PDP-11 to the MicroVAX, this remaining PDP-11 was retired. The configuration after phase three is shown in Figure 4.

FIGURE 4. This figure shows the system configuration after the third upgrade phase.

Since from the beginning of the project it was planned that the interim MicroVAX computer system would be replaced when the DEC/Compaq Alpha technology became available, an inexpensive machine was purchased with a maximum memory limit of 64 MB (6). Once all control processes had been moved to the new system, and due to this memory limitation, system performance became less than desirable. Since the Alpha technology was now available, a new AlphaServer was purchased to replace the MicroVAX.

A new CAMAC Serial Highway interface and software driver was purchased from Kinetic Systems Inc., and both were tested offline (7). All control processes, databases, and operator display files were moved to the new AlphaServer. When all was ready the last step was to physically move the two CAMAC Serial Highway cables from the MicroVAX to the AlphaServer completing the fourth and final phase.

THE NEW CONTROL SYSTEM

The new control system provides the operator with all the features of the old control system as well as new features. The current hardware configuration of the new control system is depicted in Figure 5.

The new system consists of one AlphaServer, four AlphaStations, and seven PC workstations. The AlphaServer is at the core of the system, and provides the single link to the CAMAC Serial Highway. Two of the AlphaStations are physically located in the main control room, and provide the primary operator interface to the control system. The remaining two AlphaStations will be remotely located at the facilities' two ECR (Electron Cyclotron Resonance) ion source control consoles, and will provide an operator with a local interface to these devices. Six of the PCs are distributed throughout the facility and provide remote control and monitoring functions. The seventh PC is located in the main control room, and is used to provide a graphical interface to the archiving relational database system.

FIGURE 5. This figure depicts the current configuration of the control system.

Two I/O subsystems are utilized by the new control system. The first is a CAMAC Serial Highway, which currently links 18 crates, and operates at a clock speed of 2.5 MHz. The second subsystem is a 10 MB/s Ethernet LAN. This LAN is used to link all of the computers, and is the means by which data is exchanged.

Oracle Rdb and Paradox provide the database structures for archiving purposes. Vsystem provides the foundation for the real-time aspects of the control system. This system was chosen, as previously discussed, largely due to the relatively small size of the control system staff. Vsystem is a network distributed control system software that provides distributed database access and CAMAC I/O processing. While the ATLAS control system does not currently make use of the distributed CAMAC I/O processing feature, it does take advantage of the distributed operator interfacing capabilities. Through the use of the "X Windowing System", operator interface processing is distributed among the various workstations (8).

In-house written software comprises an estimated 75% of the control system processes. This software is written in "C", "FORTRAN", "SQL", or Paradox's native language. These processes were written specifically to address needs unique to the ATLAS facility. Some of these processes were available on the old system, and have been rewritten for the new system, while others were written specifically for the new system. A few of the processes that comprise the control system include the following:

- A process that automates the procedure of setting a resonator to its maximum energy gain amplitude and phase values is provided. Once initiated this process can typically set the entire LINAC (Linear Accelerator) to its full energy setting for a given ion species.

- Once the LINAC is in a full energy configuration, a process that automates the steps in setting the LINAC to a requested energy is made available.
- Integrated into the control system are processes that provide surface barrier detector measurements for both energy and time. Dynamic plotting of this data is an inherent feature of the system.
- A process is provided that continually measures "time of flight", and displays the result as an energy measurement.
- A process was written to periodically update the archiving database with values from the real-time database.
- An automated process is available to provide a complete mass scan of a given beam of ions. Once initiated this process ramps the magnetic field of a selected magnet plotting magnetic field versus faraday cup current.
- An automated process is provided that continually scans all operating resonators to ensure that each resonator continues to operate at the last requested phase setting.

FUTURE PLANS

ATLAS has two ECR ion sources. The newest ion source was brought online during the period when the control system was being upgraded. Consequently, control and monitoring of the new ion source was included in the new control system. The old control system, however, was retained for the original ECR ion source to ensure that the operating schedule of the accelerator would not be jeopardized. The new ECR source will now allow for the retrofitting of the original ion source's control system.

Demands on the system will no doubt grow in the future. It has been demonstrated that one of the better ways to deal with increased demand is distributed I/O processing. To ensure that the system will be prepared for future demands plans to implement distributed I/O are underway. To accommodate the increase in Ethernet traffic the control system LAN will be upgraded from 10 MB/s to 100 MB/s operation.

CONCLUSION

The control system resulting from the upgrade has met all of the design goals of the upgrade project. The development effort took place on line, and simultaneously with the operating schedule of the accelerator. Except for negligible periods of time the accelerator's operating schedule never suffered due to upgrade activities. This was accomplished during a period when the accelerator's operating schedule was designed to achieve a record number of operational hours.

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8. "X Windowing System", A windowing system that is the result of a collaborative effort of a consortium of vendors and the Massachusetts Institute of Technology.

* Work supported by the U. S. Dept. of Energy, Nuclear Physics Div., under contract W-31-109-ENG-38.

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