# THE ARGONNE BEAMLINE-B TELESCOPE CONTROL SYSTEM: A STUDY OF ADAPTABILITY*

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## Abstract

A beam-expanding telescope to study high-precision $H^-$ particle optics and beam sensing was designed by the Accelerator Technology Division at Los Alamos National Laboratory and will be installed on beamline-B at Argonne National Laboratory. The control system for this telescope was developed in a relatively short period of time using experience gained from building the Proton Storage Ring (PSR) control system. The designers modified hardware and software to take advantage of new technology as well as to meet the requirements of the new system. This paper discusses lessons learned in the process of adapting hardware and software from an existing control system to one with rather different requirements.

## Introduction

To test many of the output optics components of the Ground Test Accelerator to be built at Los Alamos National Laboratory, a heavily instrumented beam-expanding telescope is being installed on the 50-MeV $H^-$ beamline at Argonne National Laboratory. The task of designing and implementing a control system for the Argonne telescope was given to the section that developed the PSR control system at Los Alamos. In designing the PSR control system,[1,2] every effort was made to keep the design flexible so that hardware and software changes could be incorporated into the system with minimum effort. Because the design and development schedule for the Argonne telescope allowed only a short implementation time, and because many of the diagnostic instruments used represented an evolutionary development of the instruments used on the Proton Storage Ring, adapting the PSR control system seemed the sensible approach to the task.

## Hardware Configuration

The hardware chosen for the Argonne beamline-B telescope control system represents a natural evolution from the PSR control system hardware. For the Argonne telescope control system, one VAXstation II GPX color graphics workstation serves as both the operator-interface graphics system and the equipment control computer. All of the CAMAC hardware is connected directly to the VAXstation Q-bus on a CAMAC serial highway. The PSR experience suggested that, given the fewer than 500 channels of the Argonne telescope, one MicroVAX would provide sufficient processing power for both machine control and operator-interface software.

Mostly, the same CAMAC hardware will be used for the Argonne telescope as was used for the PSR, with the addition of a new timing plug-in and the exclusion of some obsolescent modules. To simplify the connection of the device channels to CAMAC, printed circuit boards were designed for each system to allow the cable that connects each CAMAC module to the terminal strips to be mass-terminated at both ends. This board also connects power and ground to the terminals as needed (Fig. 1.).

The PSR control console was well-received; however, graphics systems have changed dramatically since the PSR control

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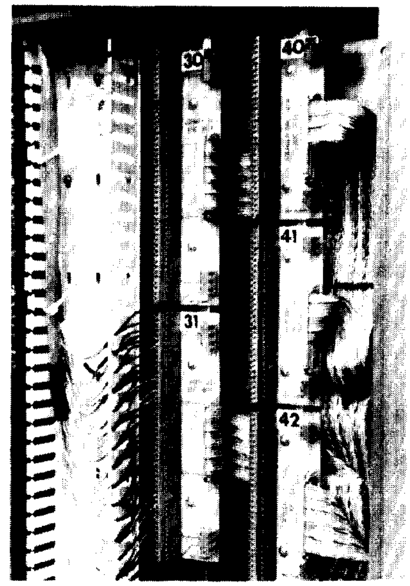


Fig. 1. Mass-termination modules simplify the connection of CAMAC plug-ins to the terminal strips.

system was designed. Graphics workstations are now relatively inexpensive and are designed to provide a comfortable operator interface. The VAXstation II workstation allows several programs to be run on one high-resolution screen. A mouse-controlled pointer moves into various workstation windows, giving a more up-to-date operator interaction on the computer with the same type of architecture as that used for the PSR.

The Argonne telescope control console will incorporate the functionality present in the PSR system in a much smaller physical package, as is shown in Fig. 2. It will include the VAXstation, an additional color display terminal, one set of four analog control-channel knobs, four video monitors with a 15-channel video multiplexer for selecting a particular input to a video digitizer, an oscilloscope, and a patch panel for analog signals to be brought to the oscilloscope.

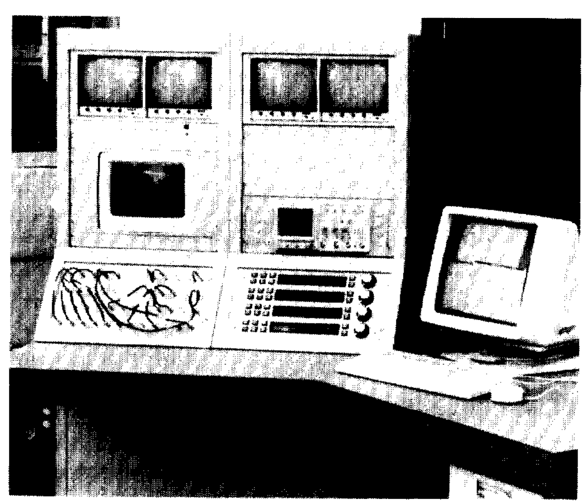

Fig. 2. The Argonne beamline-B telescope control console.

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The Argonne VAXstation will be linked to a VAXstation at Los Alamos with a point-to-point DECnet link over a leased line. This will allow the Los Alamos physicists and control system developers to access the Argonne control system data, to run many of the application programs, and to assist in correcting any problems.

### Software Configuration

The software design for the Argonne telescope system kept the features of the PSR system that had contributed to its ability to adapt to various hardware and system requirement changes. Separation of configuration information from device control logic through the use of a central run-time database derived from an ASCII database was one of the features of the PSR system that enabled it to adapt to hardware changes with minimal impact to the software. Layered software was another feature of the PSR control system that made it possible to isolate changes to the system. The layers of the Argonne telescope software are shown in Fig. 3. This diagram is very similar to the diagram of the PSR system software with the software layers of the separate processors compressed for a single computer.[2]

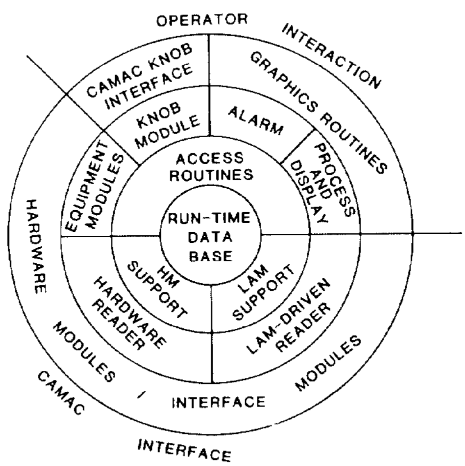


Fig. 3. Software layers of the control system.

The run-time database is the main depository of information needed by the running system as well as the primary communication path between device control and operator-interaction programs. The next layer is made up of the hardware module and interface module routines used by the input readers, the knob program, and the equipment modules, whereas the graphics routines comprise the top layer for the alarm module and the various process or display programs.

### ASCII Database Parser

One area of dissatisfaction with the PSR control system was the slow and awkward method of data entry into the ASCII database, which resulted from the use of a general-purpose database system. Text files created using any standard text editor replaced the general-purpose database; key words were used to denote the various fields. A database parser program was written to interpret these text files and to generate the run-time database. It proved much simpler and faster to enter the data into the text files to make needed changes in the ASCII database. The run-time database generation was reduced from many hours to less than five minutes.

### Run-Time Database

As in the PSR system, all inter-process communication is through the run-time database. The single-processor design removes the need for the migrator of the PSR control system. The input data flows through the hardware readers to the central database and thence to the display and device control programs; the output data path takes operator commands and transfers them to control-channel data fields from which they are accessed by device control programs that perform safety checks before writing the data to the hardware.

One desirable change was the use of data structures, especially the use of pointers, to make the database access routines more efficient. The PSR routines used data structures created out of FORTRAN arrays, but this made some of the code difficult to understand and maintain. Because VMS allows subroutines written in any supported language to be accessed in any other supported language, it was possible to code the database access routines in C to use C's data structures and still be able to access the routines from FORTRAN. The calling sequences and the functionality of the routines were kept similar to the PSR database access routines.

### Hardware Reader and LAM-Driven Reader

For the Argonne telescope control system, the hardware-reader program, the LAM-reader program, the CAMAC initialization program, and the hardware modules (software that runs on the LSI-11/73 computers in the PSR system) have been modified to run on the MicroVAX. The CAMAC interface software on the VAX was used for the Argonne system with a few modifications for compatibility with the hardware module logic.

The input hardware module logic was copied directly from the PSR system. A few changes were made to take advantage of VAX FORTRAN features that were not available in PDP-11 FORTRAN-77. The output hardware module routines were slightly redesigned to make them parallel to the input routines.

The surveillance timer is new to the Argonne system. It allows input channels to be read at different rates, thus reducing the processor time needed for reading data from CAMAC. The use of a surveillance timer was considered for the PSR system but was deemed unnecessary because of the large amount of front-end processing power in that system. The hardware input reader still uses a timed loop, but on the Argonne system it reads only those channels that have had the read flag set by the surveillance timer.

The LAMs on the Argonne system are handled quite differently from the PSR system. The Argonne system employs a LAM reader that is responsible for booking LAMs for all the plug-ins that can set an interrupt on data changes, including most of the binary input modules. The LAMs on the PSR system are booked to a particular program, usually an equipment module.

### Device Control

Equipment Modules on the PSR system contain the logic necessary to operate a device such as a magnet power supply or a beam diagnostic and maintain it in a safe operating condition. The Argonne system will use equipment or device modules in the same fashion.

Using the new VAXstation hardware and software required some modification in the style of operator interaction with the system. The mouse and pop-up menus replaced fixed buttons and touch screens. Up to five windows on a single graphics screen replaced multiple screens.

## Main Control Program

The Argonne system main control program brings up a diagram of the telescope showing all the devices that can be controlled. This diagram serves as the main menu from which all other programs are run. Placing the mouse cursor over the desired device and pressing the activate program button brings up a control window associated with that device. For more complex devices or processes, a new process display window will also be activated. If all visible windows are being used, the operator will be prompted to see if he wants to cancel a window or overlay one. The main control program also displays summary information and status.

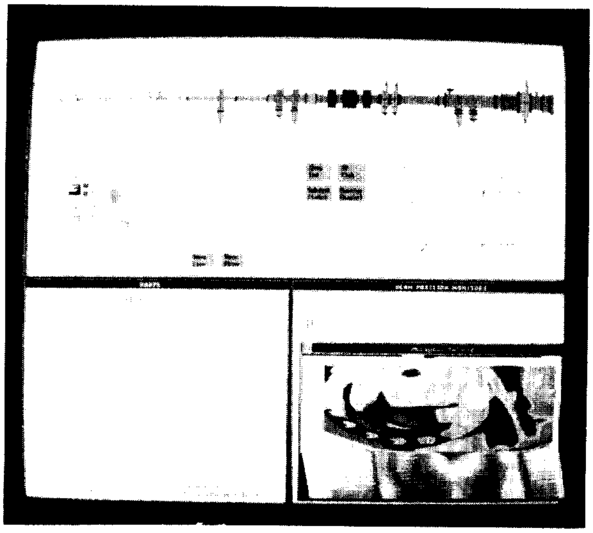

Fig. 4. Main operator screen for the control console showing the menu bar and four operator windows.

## Display Programs

Plotting data on the PSR system was handled in two ways: a generalized plot program displayed a plot of any channel over time, and individual programs contained plotting routines written using Lexidata graphics library routines. For the Argonne system, an X-Y plotting subroutine was created to be called by any application program. Specifying channels for plotting to the PSR general plot program was awkward; it required using a typewriter keyboard drawn on the color graphics monitor. The Argonne system operators use a keyboard for entering character-string information. The workstation logically attaches the operator's keyboard to the currently selected window, thus avoiding the clutter of multiple keyboards on the console work area.

Image processing for digitized video images of the phosphors was an enhancement desired for the PSR control system and the Argonne telescope. The image processing software was developed on the Argonne telescope VAXstation using digitized image data files from the PSR. The similarity of the two systems will enable programs created for the Argonne telescope control system to be retrofitted to the PSR control system.

## Conclusion

Building on the PSR experience allowed the control system programmers to code the database parser, the graphics routines, database access routines, input channel readers, and the set of hardware interface routines in one month. The principal factors contributing to the PSR's adaptability were the separation of the data in the system from the logic controlling the system; the use of a central run-time database for configuration information and communication between programs; and the modularity of the software, which isolated software changes.

The requirement that the PSR control system be designed for flexibility in adapting to software and hardware changes has provided the additional benefit of a basic control system design that can be readily adapted to the needs of other accelerator control systems.

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