Submitted to Eighth Conference on Real-Time Computer Applications
in Nuclear, Particle and Plasma Physics
June 8-11, 1993, Vancouver, B.C. Canada

THE BNL ACCELERATOR TEST FACILITY CONTROL SYSTEM*

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Abstract

Described is the VAX/CAMAC-based control system for Brookhaven National Laboratory's Accelerator Test Facility, a laser/linac research complex. Details of hardware and software configurations are presented along with experiences of using Vsystem, a commercial control system package.

I. INTRODUCTION

Over the last few years, there has been increasing interest in the production of high brightness electron beams, particularly for use as drivers in free electron lasers and in high luminosity linear colliders. Also, interest in advanced methods of particle acceleration have pointed to the need for investigations of the interactions of intense electromagnetic radiation and high brightness electron beams. Such a research program is underway at Brookhaven National Laboratory's Accelerator Test Facility (ATF), a laser/linac complex featuring a high-brightness laser-photocathode RF gun, a 45 to 75 MeV 2.856 GHz electron linac, a 1 GW, 6 ps Nd:YAG laser, a 10 GW, 6 ps CO2 laser system and an experimental hall housing 3 beam lines.

Although a relatively small user facility, its role in the community as an accelerator physics "breadboard" demands the ATF be prepared to respond in short periods of time to a wide range of experimental operating conditions. The task is complicated further by severe limitations in the number of personnel (one full-time software engineer and one part-time graduate student) available for systems development. Thus the ATF requires a computer control system sufficiently flexible and simple to respond to these challenges and yet still capable of providing state of the art performance. These seemingly contradictory needs are met by following a strategy of purchasing as many off-the-shelf components (both hardware and software) as possible, supplemented by in-house efforts when a commercial product is prohibitively expensive or simply not available.

*Work performed under the auspices of the U.S. Department of Energy, under contract DE-AC02-76CH00016.

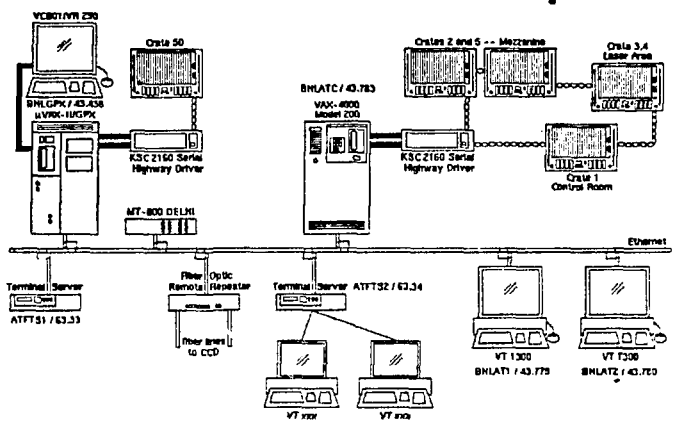

Fig. 1

II. HARDWARE CONFIGURATION

Figure 1 shows a schematic of the hardware configuration for the ATF control system. The system is built around the host CPU, a Digital Equipment Corporation VAX 4000 model 200. The VAX is a 32-bit processor operating at a clock speed of 114 MHz and is equipped with 56 Mb main memory, 1.7 Gb disk storage, streaming tape drive and an Ethernet interface. A similarly equipped (but far slower) Micro VAX-II/GPX is used for offline development, testing and debugging. Operators work at 19-inch color X-window stations equipped with keyboard and mouse. Both computers and the X-terminals are linked by a thickwire Ethernet backbone which runs throughout the facility and is bridged to the lab-wide BNL local area network. All data acquisition is via a Kinetic Systems Corporation model 2160 CAMAC serial highway driver connected directly to the VAX Q-bus backplane. [1] Five CAMAC crates are located at various positions around the facility, the host communicating with them over a 5 MHz twisted multiple-pair byte-serial data highway. Each crate has an L-2 serial crate controller, LAM grader, and diagnostic dataway display and control cards. Depending on the local control operations required, the remaining slots in each crate are filled with CAMAC cards for various interfaces: RS-232, IEEE-488, digital-to-analog converters, analog-to-digital converters, switch contact inputs and outputs, stepping motor controllers, etc. There are no custom designed interfaces; all CAMAC cards are off-the-shelf products

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available from commercial vendors.

III. SOFTWARE CONFIGURATION

The host CPU uses primarily the Open-VMS operating system, supplemented by POSIX. Network communication is through both DECnet and TCP/IP (TGV Multinet) protocols. Language compilers, debuggers and software development tools are provided for both the C and Fortran programming languages. Operator display windows are supported through X-window/MOTIF. Software for the control system proper comes from two sources: a commercial product, Vsystem, marketed by Vista Control Systems, Inc. and code developed in-house.

IV. SYSTEM CONSTRUCTION AND DEVELOPMENT

Selection of hardware interfaces and their implementation is relatively straightforward. Most equipment manufacturers provide intelligent controllers accessible through a standard communications interface. Fast beam diagnostic systems use analog signal processing and data acquisition triggered by the facility timing system.

Constructing control systems software is somewhat more complicated. Traditional views (held by many) are that no commercial software products can respond to the needs of accelerator control systems and that a relatively large team of in-house computer analysts are needed to build from scratch a system which will. We have not found this to be true: by purchasing the Vsystem package from Vista Control Systems, Inc., and combining it with some 60,000 lines of code written in-house, the ATF is able to provide a system capable of sophisticated control requirements with greatly reduced needs for in-house software engineering.

The Vsystem package contains software development tools for database generation, database access, drawing, tools for construction of graphic user interfaces, task sequencing, alarm handling and miscellaneous support utilities. This permits the ATF staff to focus more on those software tasks specific to the accelerator and not on generic exercises in window management, database generation, record locking, etc.

Additions of new control functions require editing an ASCII file to define database channels. Each record in this file describes one channel of the database and all its attributes. These attributes include the channel type (real, integer, character, binary, date/time), engineering units, clipping limits for operator inputs, hardware location information (i.e. which CAMAC branch, crate, station, subaddress and function to use), alarm limits and the name of the software module which handles I/O for this channel. Five 32-bit fields are available for user-defined hardware information. Additionally ten 32-bit fields are available for any user defined purpose. In its early design, the ATF database held some 8000 channels with no problems. The present ATF system operates with a cleaned-up, restructured database of 3500 channels. Vsystem is then used to generate the memory-resident database, draw an operator window, attach those channels to the drawing and start the appropriate hardware handler tasks.

Once the base hardware and software are installed, users can begin simple control operations after just a few days of learning. Simple polling of data gathering hardware can be accomplished with tools supplied in Vsystem. Experience at ATF and other sites shows that most in-house software development efforts are in response to requirements for higher performance interrupt driven operations where user code is needed to bridge the gap between the high level routines and the low level CAMAC driver. [2] For example, beam diagnostics must be read synchronously with beam pulse arrival. Similarly, knowledge of a particular device's communication protocol may require user code to interface with Vsystem. IEEE-488 interfaced equipment is one example where extensive coding is required to implement communications. ATF handles these issues by executing user-written tasks which run as background jobs updating the database and servicing interrupts from the hardware itself as well as operator requests. As in other systems, a job running at high priority handles all fast task operations. [3] Slower, less real-time intensive programs execute at lower priority. It should be noted that while Vsystem doesn't handle these problems directly, it does provide an excellent set of library routines for user programs to extract the best possible performance from the database and the CAMAC hardware. Using this approach, ATF has easily achieved its requirement of updates at 6 Hz, the facility pulse repetition rate. It has, however, been measured at over 100 Hz before serious system degradation occurs.

Although ATF uses CAMAC, Vsystem can be used with any type of data acquisition equipment (VME, VXI, Allen-Bradley, etc.) for which a hardware connection to the host and a supporting driver can be established. Vsystem also supports distributed systems with built-in network protocol handling.

V. OPERATIONS

Operators using the ATF control system are presented with a graphic user interface, essentially a blueprint-like plan view of the facility. Using the workstation mouse, one can "point and click" at any area of the complex, zooming in on any device(s), bringing up various levels of detail in control and status windows. Almost all equipment in the facility is accessible through more than 400 such displays: timing systems, RF system, vacuum system, magnetic optics elements, real-time beam diagnostics, collimation devices, video camera switching, laser optics

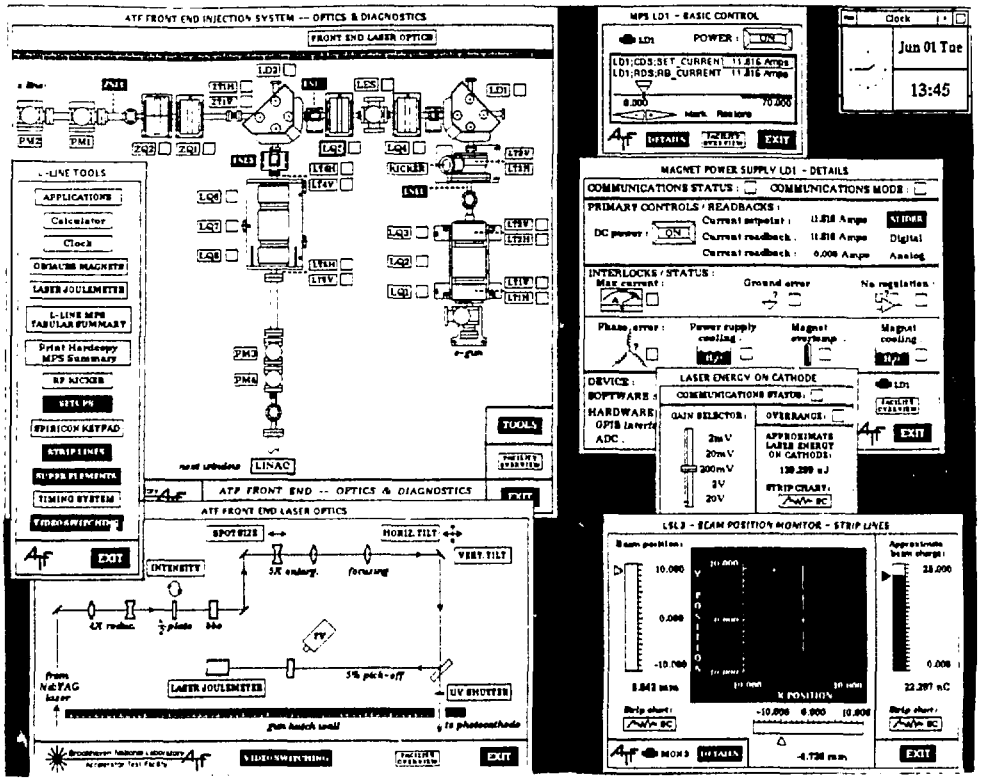

Fig. 2

stages, etc. Applications programs such as beam transport modeling and automatic beam emittance measurements are similarly accessed. Figure 2 is a typical dump of a console screen as seen by an operator.

VI. CONCLUSIONS

Following our policy of purchasing as many off the shelf products as possible, we have been able to bring up a fully functional and sophisticated control system for the ATF with about 3 person-years of effort. This includes all tasks, from equipment delivery to the present. We feel that this success is due, in part, to the availability of the Vsystem package.

VII. ACKNOWLEDGEMENTS

We wish to thank our BNL colleagues K. Batchelor, A. Fisher, H. Kirk, S. Krinsky, K. Leung, R. Palmer, J. Rogers (now at Cornell), J. Sheehan and X. Wang for their sound advice and helpful discussions. Special thanks must go to the ATF technician group, without whose help there would be no facility to control: C. Biscardi, W. Cahill, R. Harrington, M. Montemagno and T. Monahan. K. Loverro expertly prepared this manuscript for publication. D. Sutter, Chief of the US DOE Advanced Technologies Research Branch, has provided continuing support and encouragement for all facets of the ATF. The staff at Vista Control Systems (P. Clout, G. Dore, V. Martz, R. Rothrock and R. Westervelt) also deserve credit for providing us with outstanding support in troubleshooting problems at critical times.

VIII. REFERENCES

[1] **CAMAC Instrumentation and Interface Standards** (IEEE Press, New York, 1982).

[2] Greiner, B. F. and Caswell, D. J., "Evaluation of a Commerical System for CAMAC-based Control of the Chalk River Laboratories Tandem-Accelerator-Superconducting-Cyclotron Complex," IEEE Transactions on Nuclear Science, Vol. 39, No. 2, April 1992, pp. 210-214.

[3] Krauter, K. and Crane, M., "MPS Beam Control Software Architecture," presented at the American Physical Society Particle Accelerator Conference, Washington, DC, May 17-20, 1993.