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THE TEVATRON CONTROL SYSTEM - 1989

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Abstract The Tevatron control system, which runs all of the accelerators and storage rings at Fermilab, is being upgraded in a number of areas. These include: networking, front end computers, console computers, and microprocessor environment. Details of each of these upgrades are presented.

INTRODUCTION

The system known sometimes as ACNET and sometimes as Tevatron controls is a comprehensive one used to operate all the accelerators, storage rings, and the fixed target switchyard at Fermilab. Although there have been changes in detail, particularly expansions, there have been no upgrades or changes in concept since the specification of this system around 1980. However since that time there have been major advances in the computer field, particularly involving networking, graphics and the user interface, and microprocessor utilization tools. Thus four major modernizations of ACNET are taking place to make use of these advancements. A fifth upgrade is to bring the Main Ring controls, which predate the Tevatron by several years, up to the level of those of the other accelerators; however this work involves no new technology and will not be discussed further here.

This paper details the motivations of the various upgrades, indicates for each the path chosen, and provides a status report. It should be noted that all the work described must be performed in the context of a running accelerator complex; no shutdowns have resulted or will result from any of the modifications described.

A schematic diagram of the system nodes, as they exist at present, is given in Figure 1.

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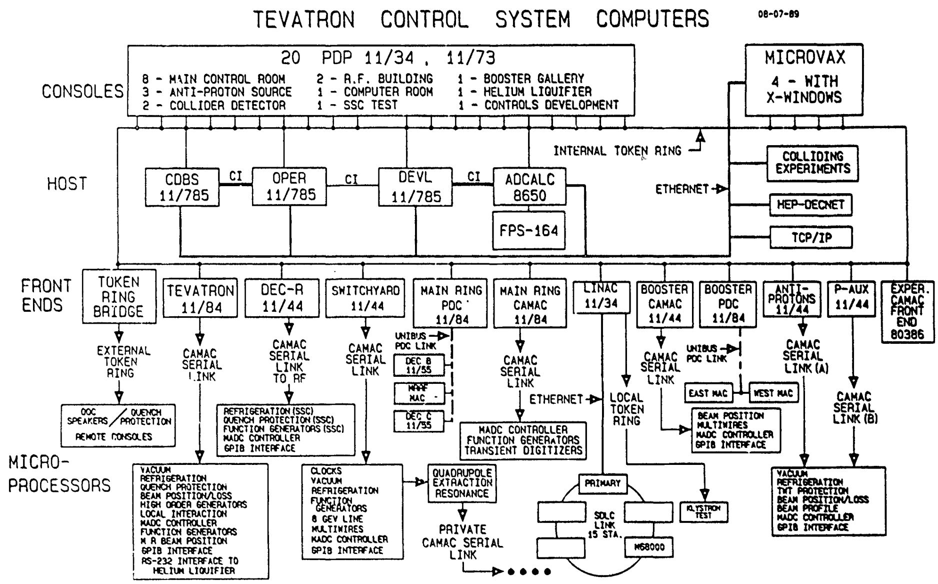

FIGURE 1 ACNET node diagram

NETWORKS

The choice for a new Local Area Network (LAN), as well as Wide Area Network (WAN), is IEEE 802.5 Token Ring as implemented on the chip set produced by Texas Instruments, Inc. In the LAN case this network replaces the proprietary Digital Equipment Ccorporation PCL product. The motivation for the change is the lack of ability to connect PCL to modern DEC equipment - such as the MicroVAX line of computers - or any equipment from other manufacturers. In the WAN case the Token Ring augments, but does not replace, serial Camac.

Hardware has been constructed by us for interfacing Unibus (VAX and PDP-11) and Q-bus (primarily MicroVAX) computers to Token Ring, and software drivers for the RSX and VMS (as well as ELN, though not used in ACNET) operating systems have been written. Additionally interface hardware for VME based equipment has been purchased and that for Multibus II is under construction. The status is that the LAN is now totally converted, with some remnants of PCL remaining in the software (in particular packeting of messages as required by PCL); the WAN ring hardware is also functional, but its connection to the LAN remains to be made.

Most users of DEC equipment, such as ourselves, choose Ethernet for networking due to easy compatibility with their computers and strong support from the company. As is indicated in Figure 1, we indeed do have Ethernet connections on our host VAX computers, and this is utilized for external communications. However we have opted not to use that protocol for real time control system communications. The reason for this is that the means of sharing the hardware medium in Ethernet, a collision detection scheme, does not work so well in a synchronous environment, such as that of an accelerator, as does the token passing scheme of 802.5.

FRONT END COMPUTERS

Front end computers in ACNET are used as drivers of hardware links, specifically Camac for the modern accelerators, PDC for some of the older equipment, and Ethernet for the Linac. The particular concern is with the Camac drivers which reside at the heart of the system - translating between the hardware engineer's view of the accelerator and the more abstract one of programmers, operators, and physicists.

At present the front ends are all PDP-11 computers, coded in assembly language. They are system bottlenecks both in terms of data throughput, being able to utilize only about 10% of the Camac bandwidth, and in terms of personnel, since a limited number of individuals are able to work on such machines.

A survey of commercially available computers which might serve as front ends yielded nothing with the appropriate speed and real time characteristics and at an affordable price. The answer as to the best way to turn, as it often is in the computing field at this point in time, was to institute parallel processing among a number of relatively inexpensive microprocessors. Thus each front end consists of one to several (perhaps three) single board computers utilizing the Intel 80386 processor and housed in a Multibus II chassis. The 80386 was chosen based on performance, price, availability, and the fact that its memory storage byte order for 16-bit words is the same as that of a PDP-11; this latter condition ruled out the Motorola 680x0 processor line. Multibus II was chosen (over VMEbus, the only viable alternative) as a modern backplane with many features conducive to efficient engineering development; it is also a natural home for the 80386, coming from the same manufacturer.

Insofar as possible the code for the new front ends is being written in C, though at very low levels some assembly language is still required, The MTOS operating system kernel, VAX based development tools, and convenient debugging environment are available for this work as for other microprocessor projects as discussed in detail below.

The status is that a prototype system has been purchased and that about half the software and Fermilab built hardware are completed.

VAXSTATION CONSOLES

Modern engineering workstations provide a powerful and cost effective means of producing new accelerator operators' consoles. Some such device is required at Fermilab due to the obsolescence of much of the display equipment of the existing consoles, the need for more consoles, and the desire not to purchase more outdated equipment. Our ground rules are that all programs operating on the present PDP-11 consoles shall also operate on the new ones with minimal alterations, and that the new ones shall be able to co-exist on a network with the old. The first condition is required so that the extensive software effort expended in producing console application code not be wasted or duplicated as the new devices evolve. The second condition is based on the fact that the twenty old consoles represent a considerable investment in hardware, and should be kept in operation even as new ones are produced. This latter condition, due to the byte-order problem also confronted in the selection of new front ends, rules out most Unix workstations and has effectively limited the decision to a choice between VAXstations from DEC running the DECwindows implementation of the X-windows user interface, and PS/2's from IBM running the Presentation Manager interface. VAXstations have been selected due to more advanced software.

As compared with the PDP-11 based consoles the VAXstation based ones have better performance by a factor of roughly five for computation and eliminate the problem of minimal addressable memory which haunts all PDP-11 work. In particular commercial software packages which will not fit on a PDP-11 can be installed on a MicroVAX, and a totally unproductive software activity of overlaying programs in such a manner as to fit in a limited memory is eliminated.

A benefit of the greater processor speed and memory, as well as of the modern windowing environment, is that a greater number of programs can be run simultaneously than was previously possible, and that terminal emulation and debugging can be done on the same screen used for actual console displays, much aiding the software development process. Despite all these advantages, the cost of a new console is less than half that of an old one, and can be expected to decrease with time.

The status of this project is that, with only a few exceptions, all of the software of the old consoles has been ported to the new ones and minimally tested. The new consoles are temporarily networked via Ethernet rather than Token Ring, and real time clock signals are not yet available in them. Though these consoles could in principle be used to run accelerators now, the software - primarily X-windows itself - is not yet sufficiently robust.

Two major decisions remain to be made, involving the number of screens attached to a given console and the evolution of software in the new environment. An old console contains five display devices, which are emulated by windows in a new one. Putting this much information on one screen, and more information if several programs are running simultaneously, leads to a cluttered appearance and inability to view at one time all the necessary data. Thus more than one screen must be made available, at least for any console actually used to run accelerators. Choices as to how to accomplish this involve either multi-screen VAXstations or X-server terminals, which are now becoming available. As to software evolution, all programs thus far have been, as mentioned, ports of ones from the PDP-11 environment and thus have not taken full advantage of the power of the new stations. Software will evolve in interesting new ways as developments specific for the new consoles are undertaken.

MICROPROCESSOR ENVIRONMENT

In the past all microprocessors in the system communicated to console and other computers over a hybrid link of which Camac formed a major part. Communications for new systems will involve the much more sophisticated Token Ring. The added flexibility of this new medium, in particular allowing subsystems to generate and send messages without any outside request to do so, has led to a new protocol known as OOC (Object Oriented Communications) which is under development.

An operating system kernel, MTOS, is utilized for new developments and frees the programmer from concern with the details of scheduling, memory management, and other system related tasks. MTOS was chosen over a number of competing products due to support for both the Intel and Motorola lines of processors. Code for processor based embedded systems, a new quench protection monitor being the first instance, is written primarily in C with calls to operating system services made wherever possible. A new set of VAX based development tools (compilers, linkers), again supporting both processor lines, is utilized. Additionally, in-circuit emulators and debuggers which run on attached Personal Computers are used for testing and debugging at a source code level. All of these modern tools greatly increase the productivity of programmers working on embedded systems, which control a large fraction of the most sophisticated accelerator equipment.

SUMMARY

Upgrades and modernizations of several aspects of the Fermilab accelerator control system have been discussed. One of these, a new Local Area Network, is essentially completed, and another, in the microprocessor area, is fully utilizing new software tools in the developmant of a prototype modern system. The other projects are being pursued, but are farther from actual implementation.

ACKNOWLEDGMENTS

The work described here represents the efforts of many members of the Accelerator Controls Department at Fermilab. Their hard work has led to the successes which have occurred and those which are to come. Much of this work was specified under the leadership of Dr. Dixon Bogert.