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Experience Controlling the LAMPF-PSR Accelerator Complex*

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Abstract

In recent years, control system efforts at LAMPF have emphasized the provision of uniform control for the LAMPF linear accelerator and associated beam lines and the Proton Storage Ring and its associated beam lines. The situation is complicated by the presence of several control philosophies in the operator interfaces, data base mechanisms, and front end data acquisition and control interfaces. This paper describes the current system configuration, including the distributed operator interfaces, the data and control sharing between systems, and the use of common accelerator diagnostic software tools. Successes as well as deficiencies of the present system will be discussed with an eye toward future developments. *

I. BACKGROUND

The Clinton P. Anderson Meson Physics Facility -- also known as LAMPF, the Los Alamos Meson Physics Facility -- is composed of an 800 MeV proton linac plus associated beam lines and targets, and an 800 MeV Proton Storage Ring (PSR) plus its beam lines and a neutron spallation target that serves the Los Alamos Neutron Scattering Center (LANSCE). The linac accelerates beams of H+, H-, and polarized H- (referred to as P-) ions up to 120 times per second in pulses of up to 1000 microseconds width. The average H+ beam current can be as much as 1 mA. The proton storage ring serves as a beam compressor, taking a full H- macro-pulse from the linac and ejecting it in several hundred nanoseconds.

When LAMPF was built in the 1960's it was one of the first accelerators to be designed for computerized control. Since the IEEE CAMAC standard did not exist at that time, a significant amount of effort went into the design and construction of LAMPF-specific data acquisition hardware. The system that resulted was called RICE (Remote Instrumentation and Control Equipment). RICE hardware is still used for more that 60% of the linac equipment. Over the years, the control system was expanded to include CAMAC hardware accessed on demand through remote computers. With the addition of remote operator consoles, the initial star architecture has evolved into a much more distributed configuration.

The Proton Storage Ring was designed in the early 1980's to be independent of LAMPF with a separate control room and beam lines. As a consequence, the PSR Control System was designed and implemented with only minimal consideration of LAMPF requirements. The PSR system did provide recognition of its effect on linac timing requirements and it used a device naming scheme that was similar to LAMPF's. The PSR system emphasized continuous update of a centralized database.

In 1988, responsibility for the Proton Storage Ring was transferred to LAMPF. This paper describes the present configuration of the two control systems and the attempts that have been made to integrate them in a useful manner. We conclude with a brief description of our plans for the future. More information about our plans can be found in a companion paper at this conference [1].

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II. CURRENT CONFIGURATION

A. LAMPF Control System (LCS)

The evolution of the LAMPF Control System (LCS) has been described in detail elsewhere [2-4]. The LCS is currently composed of a network of VAX computers connected via an Ethernet using DECnet for communications. Computer systems in the LCS network are of two types, (Figure 1). A typical LCS operator console computer runs VMS and drives one or more LCS operator consoles. Such a computer may also have a CAMAC-based data acquisition and control capacity. A typical LCS data acquisition front-end computer runs the VAXELN real-time kernel and handles hard real-time data acquisition through CAMAC. The VAXELN nodes do not have local disks.

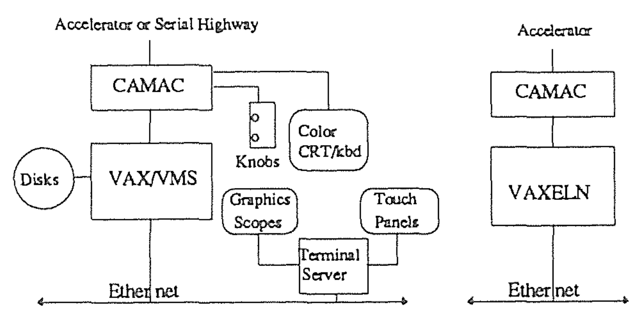

Figure 1. LAMPF Operator Interface and Front End Computers

Each LCS operator console is composed of one or more color character-cell CRTs which are shared between a number of application programs, several graphics scopes, trackball-based touch panels, and a set of analog control knobs. The graphics scopes and touch panels are attached to the computer

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through terminal servers. The color CRT and knobs are attached through CAMAC.

The color CRT in the LCS operator interface allows any LCS program to be called up at the operator's demand. This interface also gives the operator access to a number of supervisory tools which allow the state of any devices to be displayed and controlled. The touch panels also allow access to a fixed number of application programs.

LCS operator consoles are now supported in the LAMPF Central Control Room (CCR), the Injector Control Room (ICR), and the LANSCE Control Room (LCR). (See Figure 4 for a geographic representation of this distributed functionality.) The main CCR control computer was the center of the original star configuration. It still maintains its central position as it drives four of the five LCS operator consoles in CCR and serves as the central repository for LCS software and databases.

Since the RICE hardware was and still is a primary feature of the LAMPF Control System, a VAXELN front-end computer is dedicated as its interface with the rest of the control system (Figure 2). The RICE system is composed of 73 hardware data acquisition modules arrayed along the linac and in the injector and experimental areas. A distinct advantage of the RICE system is that it supports simultaneous timed data takes on each RICE modules. This provides a very powerful method for acquiring longitudinal snapshots of the entire linac at a particular time on a particular beam pulse. For untimed data takes, data caching facility is provided. In addition, the RICE system interfaces with the accelerator "fast protect" system. If a hardware monitor determines that too much beam is being spilled, the fast protect hardware sends a signal that simultaneously inhibits the injector and notifies the RIU computer that a fast protect has occurred. The RIU computer immediately reads the state of all hardware monitors to determine where the fast protect occurred.

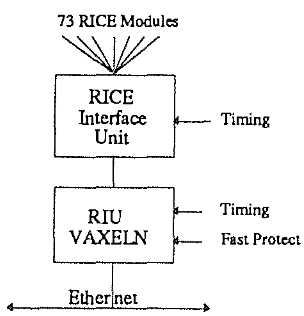

Figure 2. LAMPF RICE Interface Front End Computer

LCS data acquisition is demand driven. Each node in the LCS network contains a static database derived from a master database on the main CCR computer. Application programs request data and issue commands through a standard data access interface which uses the local database to resolve device addresses at run-time. Application programs may be split up among several nodes. A locally designed Remote Procedure Call (RPC) interface allows the pieces to communicate without dealing with the complications of DECnet. Programs that know they need large amounts of data can improve their system throughput by forming "aggregate devices." The LCS data access interface makes use of information supplied by the program to optimize network usage.

Because of the uniformity of data acquisition interfaces, if the correct application programs and databases are supplied to it, any LCS operator console on the network could run the entire accelerator.

B. PSR Control System

The PSR Control System attempts to achieve high data throughput and reasonable operator interface response by tightly coupling a central database to external computers that are continuously polling data. Detailed descriptions of this system have been published elsewhere [5-6].

A diagram of the PSR operator interface and front end computers is given in Figure 3. All PSR operator consoles are attached to the PSR VAX. This machine serves as the operator interface computer and the central data concentrator. A typical PSR operator interface screen consists of a color graphics scope whose face is overlaid with a touch sensitive surface. The graphics scope is driven directly from the computer bus; the touch panel is driven through a terminal server on Ethernet. A set of analog control knobs is controlled via CAMAC. The top level screen on each color graphics scope provides an entry to a tree-structures menu of possible programs that can be started.

The PSR front-end computers are PDP-11s each connected to a CAMAC serial highway for data acquisition and control. These front-ends are know as Instrumentation Sub-Systems (ISSes). They continuously update their local databases with data from their serial highways. The ISSes are also connected to each other and the PSR VAX via a separate CAMAC serial highway over which the PSR VAX reads the latest data from the ISS databases and transfers changes in control values.

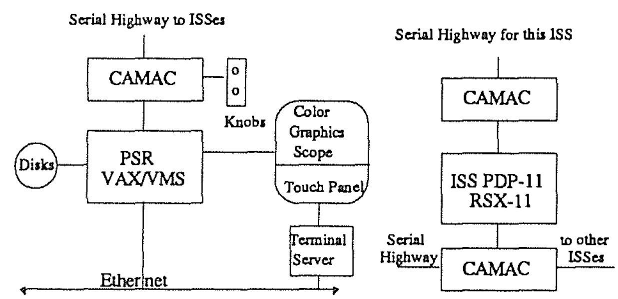

Figure 3. PSR Operator Interface and Front End Computers

Application programs running on the PSR VAX typically have exclusive access to a single graphics scope. The programs access data and set control values in the central database. They can also be notified asynchronously of changes in database values. Device data addresses in the central database are resolved at link time for many of the PSR application programs. This limits run-time overhead, but results in problems if the database structure changes.

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C. Control Systems Integration

When the Proton Storage Ring was first commissioned, it was controlled entirely from LCR. LAMPF at that time had operator consoles in CCR and ICR, although most operations activities took place in CCR.

The first attempt at LCS/PSR integration was to place PSR control consoles in CCR. Since we also wished to keep LCR available for PSR beam development, we had to pull cables between the two control rooms to physically connect the remote PSR consoles with the PSR VAX. At the same time a LCS console (CPU, color CRT, graphics scope, and knobs) was installed in LCR.

We then approached the more difficult job of sharing data and controls between the two systems [7]. By adding software (mainly run-time libraries and a copy of the LCS database) and LCS console hardware, we were able to make the PSR VAX into an LCS operator interface computer. This meant that PSR application programs could access LCS data through the LCS data interface. Several PSR applications that were interested in linac data were so modified.

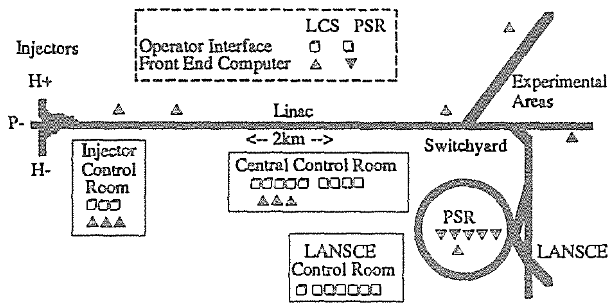

Figure 4. Distributed Functionality in the LAMPF-PSR Network

The situation with LCS programs was a bit more difficult. Since only programs residing on the PSR VAX could access the PSR database, we added an LCS Data System server process to the PSR VAX. This process (which is a variant on the standard LCS Data System server) handles network requests for information on PSR devices. Since the LCS programs make standard requests for data, all the LCS programs, including the supervisory display and control tool, the LCS knobs, and the LCS data archiver could get PSR data.

Figure 4 show the geographic distribution of LCS and PSR consoles and front-end computers. This figure does not show details of CAMAC highways, Ethernet connections, RICE cabling, or timing distribution.

III. EXPERIENCE

A. Front Ends

The RICE hardware system presents some unique problems to the control system. Since more than 60% of the LCS hardware is attached through the RICE system and is only accessible through the RIU front-end computer, this represents a major bottleneck. The fact that we have a limited amount of RICE hardware available means that we cannot easily expand the system.

The RICE interface can only perform one timed data take per beam pulse. This severely restricts tuning operations which are typically performed at low rep rates. We would like to improve on this performance even though we would like to keep the capability for doing synchronized timed data takes. Other RICE problems include not being able to send analog commands to more than one device in a RICE module at a time. This constraint creates problems when one is trying to scan wires in two wire scanners in the same RICE module.

The primary problem that we have found with the PSR ISSes is that of performance. The PSR equipment modules which reside in the ISSes are flexible and can acquire data rapidly. But the overall response is slow because data is scanned and transmitted regardless of its usefulness. The inherent flexibility becomes a problem because some modules respond differently to the standard read and command requests that are issued from the application programs. We need a carefully designed application program model of the world and disciplined equipment module implementations that ensure standard responses.

B. Databases

A database system in an experimental installation must be able to add and change device definitions quickly without taking the control systems offline. The LCS database succeeds in this respect; the PSR database does not. After a PSR device definition has been modified, it can take hours to regenerate a new PSR database. To be able to communicate with PSR devices, the LCS database must contain the PSR device names. This is possible because both systems use the same device naming scheme. Unfortunately, there is no automatic scheme for rationalizing the names that occur in the two databases. For now we use editors to compare lists of names to determine what should be a changed.

C. Application Programs

The difference in design philosophies between the two control systems is most noticeable in the application programs. The absence of a notification on change in the LCS data access interface makes it hard to allow PSR programs to access LCS data through the PSR data access mechanism. As a compromise, we have made it possible for PSR programs to access LCS data through the LCS access mechanism. On the other hand, it was relatively easy to enable LCS programs to access (possibly old) PSR data. For application programs driving a future common LCS/PSR operator interface we should like to have data from both systems provided in a uniform manner.

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D. Operator Interfaces

Neither the LCS nor the PSR operator interface lend themselves to upgrade. The LCS technology is old and cannot integrate graphics and control functions. The PSR screens are becoming unmaintainable and cannot be moved to other nodes in the network because PSR applications need to access the central PSR database directly. The LCS supervisory tools allow operators to directly access any device. The PSR tools must be recompiled to allow access to new devices. We have found that the flexibility provided by the LCS interface is vital in running a basically experimental accelerator.

E. Reliability and Maintainability

Hardware reliability and maintainability has been a key issue during recent accelerator runs. The RICE hardware is getting old and becoming difficult to maintain. Replacement hardware is no longer being manufactured. While CAMAC hardware is available for replacements and additions, its use in harsh environments sometimes leads to short lifetimes.

The use of long serial CAMAC highways, especially in the PSR system, has led to difficulties in problem isolation. Frequently it is necessary to remove one crate controller/fiber optic driver at a time from the highway in order to isolate a fault. This can be a very time consuming operation, especially if it has to done during production.

We have also been concerned about single points of failure within the control system. As the systems stand now, the failure of a single LCS operator interface or front-end computer only means that the CAMAC attached to that machine is inaccessible. As mentioned above, with the correct data files and programs, any LCS operator interface computer in the network, including the PSR VAX, can run the accelerator.

The failure of the RIU front-end computer would be more serious for then we would loose all RICE data, a significant portion of the accelerator's data.

Loss of the PSR VAX would mean loss of the entire PSR system since the serial highway connections are only to that machine and the central PSR database resides on it.

IV. THE FUTURE

The concerns described in the previous sections are being dealt with through several projects being currently planned or implemented at LAMPF. The projects and several other considerations are described in detail in a companion paper at this conference [1]. In the remainder of this paper we will briefly summarize these projects.

At the lowest level, the front end data acquisition hardware will be upgraded to meet new requirements for reliability and maintainability. The plan is to use VAXELN-based micro-VAXes as the standard front end computer. These front ends will be used to replace the PDP-11s currently being used for the PSR ISS interface to CAMAC. At the same time, it is planned to replace the RICE hardware with CAMAC and again use VAXELN front ends. The effect of these two projects will be to unify all device access through a common client-server model.

A new common operator interface project has also been proposed. A common interface will reduce both training and maintenance requirements. We plan to use VAX-based workstations as the primary operator interface. We plan to use a user interface management system to keep the development and maintenance of the operator interface more manageable.

Since the new data access mechanism will not automatically put the data in the PSR database, existing PSR application programs may have to be changed. There is the possibility that some of these programs may be rewritten to make use of the new common operator interface. In the long run, this is what we hope to do with all application programs.

To improve the overall responsiveness of the control system, we hope to pursue several hardware upgrades beyond replacing the front end computers and introducing operator interface computers. Since, for a while, some application programs will still be using the old interfaces through the LCS and PSR central control computers, we hope to replace them with higher performance VAXes which can be clustered to provide hardware and file backup for each other.

With these upgrades we will be able to respond to increased demands on the LAMPF control systems in the future. Of most immediate interest are the controls necessary to support the proposed Pion Linear Accelerator (PILAC) to be built at one of LAMPF's beam lines. There are also proposals to upgrade the PSR from 100 to 300 μA to drive a possible pulsed lepton source, and to use LAMPF for prototype work in using an accelerator to transmute radioactive waste.

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