

## Future Directions in Controlling the LAMPF-PSR Accelerator Complex at Los Alamos National Laboratory\*

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### Abstract

Four interrelated projects are underway whose purpose is to migrate the LAMPF-PSR Accelerator Complex control systems to a system with a common set of hardware and software components. Project goals address problems in performance, maintenance and growth potential. Front-end hardware, operator interface hardware and software, computer systems, network systems and data system software are being simultaneously upgraded as part of these efforts. The efforts are being coordinated to provide for a smooth and timely migration to a client-server model-based data acquisition and control system. An increased use of distributed intelligence at both the front-end and the operator interface is a key element of the projects.\*

### I. INTRODUCTION

The integration of the Los Alamos Meson Physics Facility (LAMPF) and the Proton Storage Ring (PSR) control systems is presenting a series of problems for the operations and support personnel using the two systems. The two systems were developed independently using different personnel, different underlying philosophies and different equipment but developed interdependency when the operating and support groups were combined in 1988. A detailed discussion of the current control systems is presented in a companion paper in these proceedings.

### II. PROBLEMS AND IMPACT

#### A. LAMPF RICE System

The LAMPF Control System (LCS) was built upon the LAMPF-designed Remote Instrumentation and Control Equipment (RICE) System. RICE is the hardware and software interface between the actual accelerator devices, such as magnets and beam-line instrumentation, and the software that operators and developers use to control beams. This system is illustrated in Figure 1. RICE presently utilizes 73 of 80 possible modules handling 10,000 data and control points distributed along approximately 2 km of beam channels.

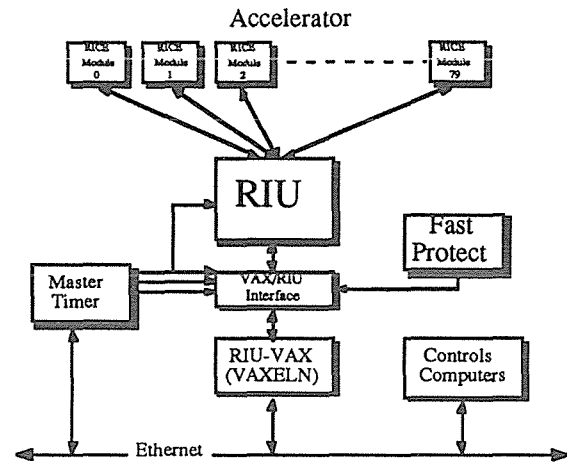


Figure 1. The LAMPF RICE System.

The RICE system has several limitations. First, RICE allows only one timed data request per beam pulse. At the low repetition rates characteristic of tuning beams, this feature can cause requests for device readout to become deeply queued and can cause tuning mistakes as operators react to "old" data. Second, the RICE star architecture places limits on the maximum data rates. Third, the RICE system is fairly rigid. For example, the current implementation of the linac harp system permits data from only two harps at any time and requires availability of greater than 50% of the RICE system to obtain that data. Fourth, there is a need for higher accuracy and precision than is available with RICE. Finally, it is estimated that 30% of the parts in the RICE system are no longer commercially available.

#### B. PSR ISS System

The PSR Control System is based upon a series of PDP-11 computers known as Instrumentation Sub-Systems (ISSes) which communicate with a central VAX system using serial CAMAC [1]. This is illustrated in Figure 2.

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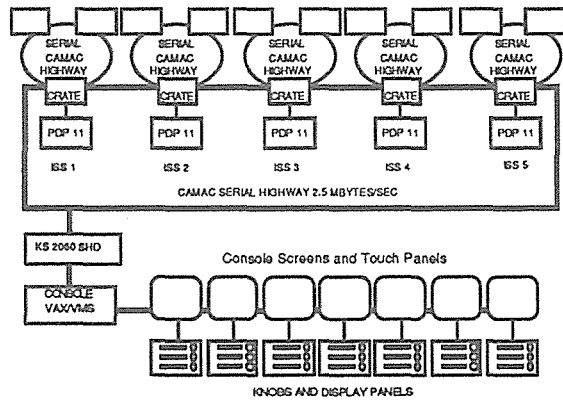


Figure 2. The PSR Control System.

The most significant difficulty with the PSR Control System is that the current update rate is one-fifth of what is considered optimal. This rate is directly limited by the system architecture which migrates all data continuously through the control system CAMAC loops to maintain the system's real-time database. Additionally, the complicated and time-consuming procedures required to modify the PSR database and the PDP-11 software discourage changes during run cycles, restricting the flexibility to correct problems and add devices. Finally, the PDP-11 database size limits are being approached on all five computers now that the system is twice its original design size.

### C. LAMPF and PSR Operator Interface Systems

In the LAMPF control system, data display and entry is handled using color CRTs, graphics scopes, button panels, terminals, trackballs and knob panels [1]. Experience over the last two years has demonstrated that the demands for cpu power and data generated by consoles can easily outstrip any central control computer's ability to service the demand. This indicates that additional computing power is required to support future console demands. In the PSR control system, data display and entry is accomplished using color graphics screens, touch panels, and knob panels. The color graphics systems are creating an increasing maintenance burden due to difficulties in obtaining parts and adequate support from the manufacturer. The PSR touch panels are an inefficient and often ineffective method for interfacing to the control system. The graphics software of both systems is created at a fairly primitive level. This prohibits quick prototyping of application codes and increases the overall time required to create an application program.

## III. GOALS AND CONSIDERATIONS

### A. Performance Goals

Goals have been established for the performance elements capacity and operator console response time. In terms of

capacity, the upgrades should provide the needed capacity to support twice the number of existing consoles and twice the number of data and control points in the system and increase the overall data throughput by a factor of three to 450 untimed read requests per second. Response time should be improved to provide a 5 Hz update rate at the operator consoles during normal operation and human speed, 1-2 Hz, beam profile information.

### B. Availability and Maintainability Goals

Availability is a measure of the combination of failure rate and repair rate. Maintainability is the level of resources required to achieve a given availability. The availability goal for the upgrades is specified as 99.7%. This represents an improvement over the current systems which operate at approximately 99.4%. For these purposes the system is said to be unavailable if a failure occurs that prohibits planned beam tuning, development or production. To achieve this overall availability, the Mean Time To Failure (MTTF) goal is specified as 1 week, up from the current 4.2 days, and the Mean Time To Repair (MTTR) goal is specified as 0.5 hours, reduced from the current 1.3 hours. Achievement of these goals would provide approximately 11 hours additional beam time per typical annual operation period.

In order to support the capacity goals, the upgrades are being designed with maintainability in mind. Currently 9.5 software personnel support 21 control computers accessing approximately 16,000 data and control points. The upgrades specify as a goal that the current staffing level must be able to support a minimum of 40 front-end computers accessing up to 32,000 data and control points. To achieve this, the number of hardware diagnostics, software diagnostics and software tools must increase by at least a factor of two and the number of distinctly different hardware systems utilized must be similarly be reduced by a factor of two.

### C. Considerations

Several specific considerations are being folded into the upgrade efforts. The first is long-term growth potential. This is directing effort toward the use of stable vendors and recognized and developing software and hardware standards. A desire for flexibility and robustness is to be addressed through increased modularity in both software and hardware. It would also be desirable if the systems were designed such that beam line developers could rapidly prototype and develop their own application software to reduce the support required by controls staff.

A major consideration of the proposed plan is the desire to migrate from proprietary systems, languages, and communication protocols to non-proprietary "open system" standards in all areas. For operating systems, the intent is to migrate to the POSIX open system standard when it is implemented. For communications, the Open System Interconnection (OSI) standard DECNET Phase V will be

preferred if it meets performance needs. Portable languages such as FORTRAN, C and C++ will be preferred.

#### IV. THE SOLUTION MODEL

To address the problems a simplified model of the control systems was used. This model, shown in Figure 3, is a statement of the elements and interfaces which must be standardized if the desired results are to be obtained. The model illustrates four levels; Data Acquisition and Control Computers, Communication Systems, Application Systems and Operator Interface Systems.

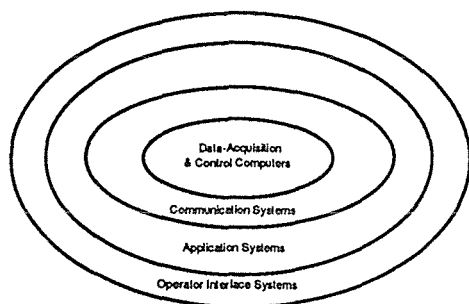


Figure 2. The Solution Model

##### A. Data Acquisition and control computers

This element of the model refers to the remote computer, hardware interface and low level software used to connect the front-end hardware to the communication medium.

##### B. Communication Systems

This element represents the hardware and software support required for a network based distributed computer control system. It provides the necessary interface between application software and the remote computers that actually acquire data and manipulate control points.

##### C. Application Systems

This element represents the algorithms and software systems that relate operator interface tools and beam line elements in a functionally useful manner. Physically, this element is an interface between the operator interface tools and the communication system.

##### D. Operator Interface Systems

This is the set of hardware and software mechanisms established to provide the user with the ability to interact with application software and thus the beam line instrumentation.

#### V. THE SOLUTION IMPLEMENTATION

The application systems, communication systems and remote data acquisition and control computers are already established in the form of existing LCS elements. The additional solutions developed must integrate well with both the existing and developing systems to preserve maintainability goals.

##### A. Data Acquisition and Control Computers

This element will be provided by the proven LCS VAXELN-CAMAC system. It is intended that this element provide both a RICE replacement and the PSR PDP-11 computer replacement.

VAXELN is the preferred remote computer operating system for the upgrade at this time. It provides a large array of development tools, integrates well with the current system and has an apparently solid upgrade path for the next 5-plus years. This implies a commitment to VMS, the development system for VAXELN, for at least this period. The vendor has indicated that both VMS and VAXELN will be POSIX compliant in the future, providing open system compatibility.

As stated, the device interface will be CAMAC, currently in use in the PSR system and in a significant portion of the LAMPF control system. As the PDP-11 computers are replaced, existing applications software will be modified to use a data-on-request approach thereby eliminating the resident PSR database and the current PSR control system over time. As RICE modules are replaced, the hardware that is removed will be used as spare parts to support the remaining RICE modules.

Experience with VAXELN controlled CAMAC systems provides confidence that the performance goals of the upgrade can be met. VAXELN/CAMAC driver testing has determined that CAMAC reads can be accomplished in 35-50 microseconds. A small number of these systems distributed throughout the site can meet the current and predicted data acquisition requirements.

##### B. Communication Systems

The communication system is intimately tied into the performance question. The LCS Remote Procedure Call (RPC) System will be utilized as the basic communication mechanism. Controls staff have performed, and are continuing to design, network performance tests to evaluate the system.

The level of network traffic anticipated for the new architecture has been estimated through measurement of peak demands on the current network with allowance for future expansion. Tests indicate that the current Ethernet/DECnet network is adequate for the near-term future even with the addition of the 10-20 computer nodes predicted for the RICE and PSR Upgrades. The effects of the 5-10 additional nodes needed to support proposed linac upgrades are currently being considered. An Ethernet/DECnet-based network provides a

standard that is compatible with a variety of computer platforms and operating systems.

While a simple network architecture will accommodate current projections, future requirements for segmentation must be included in planning. The addition of increasingly powerful computers to the network is the most likely future growth path and problem. When the networks are no longer CPU power limited, segmentation, through the use of bridges and routers, and new network technology such as FDDI will be required to provide solutions.

### C. Application Systems

An effective application system is dependent upon the standardization of certain sub-elements and the development of a consistent "application viewpoint" of the machine.

The manner in which an application views its relationship to the data it desires is a critical element. The current PSR applications view data as continuously available since the system uses a continuous polling mechanism. This contrasts with the data-on-demand LCS applications. The upgrades recognize that a system that combines polled-data at the remote level with demand-data at the application level may be required to provide the performance that is desired and adapt to the conflicting application viewpoints. A version of such a system is being used in the RIU-MicroVAX [1]. This system continuously polls frequently requested data so that values can be supplied from a real-time database for this data. Less frequently requested data is read from the hardware when demanded.

Questions surrounding application requirements for device control locks, access to global data, data integrity and error handling remain to be addressed. These issues are further complicated in the highly distributed system that is envisioned.

Concurrent with standardization of the applications systems, the standards that are in place for control system software development will be re-examined. These include requirement, design and user documentation procedures as well as configuration management systems.

### D. Operator Interface Systems

It is believed that VAX-based workstations will provide the common interface hardware to replace both PSR and LAMPF console systems. The selection of VMS systems is to provide compatibility with the current VMS-based application and system software. Efforts are underway to evaluate user interface management systems against operator and developer preferences. The rapid development of commercial software tools in this area promises to assist in this effort. The first step in this process is a planned emulation of the existing LAMPF color CRT. This will provide a common interface for all parts of the installation and provide computing power to off-load the central control computer, thereby improving performance. This distributed interface system will similarly

contribute to an increase in control system availability by reducing the number of potential single points of failure.

## VI. SUMMARY OF CURRENT EFFORTS

Several projects have been established to provide the upgrades to the systems as they have been described. The projects are the RICE Upgrade, the PSR ISS Upgrade, the Operator Interface Upgrade and the LAMPF Database Upgrade. Obviously, the pieces are not separate and must interact closely with each other to provide the standard elements of the proposed model. Existing resources and prioritization of the various problems are driving forces in selection of the solutions. Effort is already underway through work on all of the projects at various levels.

The RICE Upgrade has completed the requirements phase and is moving into design. Network and driver testing has been performed to insure that the systems selected will be capable of meeting the performance requirements. Evaluation of computer platforms is underway. The initial steps in defining a diagnostic system that will adequately support the new data system have been taken. Part of this effort is to design a CAMAC-based timed data system to replace the functionality of the RICE system.

The PSR ISS Upgrade is in the requirements phase, working rapidly in order to provide feedback to the RICE Upgrade project to insure that incompatibilities are not designed into the new front-end system. Efforts at defining the scope and complexity of the project are ongoing.

The Operator Interface Upgrade is also in the requirements phase. Much preliminary work has been performed. This work involved evaluating commercial Graphical User Interface's (GUI's), evaluating X-Windows as a graphics tool, determining what solutions are being used at other accelerator facilities and defining LAMPF control system user preferences.

The LAMPF Database Upgrade is in the requirements stage, although significant effort has been expended to bring the LAMPF database philosophically closer to what the PSR system requires. The LAMPF database can now support PSR devices, a necessary first step to integrating the systems [1].

A steering committee within the controls section has been established to coordinate the efforts. Quarterly internal project reviews and an external review of the combined projects are used as a means assuring the quality of the effort. The goals described in this document will be used as a measure of successful project completion.

## VII. REFERENCES

- [1] S. Schaller, R. Stuewe, et. al., "Experience Controlling the LAMPF-PSR Accelerator Complex," these proceedings.
- [2] G. Carr, S. Schaller, et al., "The Status of the LAMPF Control System Upgrade," Proc. Europhysics Conference on Control