ARIEL CONTROL SYSTEM AT TRIUMF – PROJECT UPDATE

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Abstract

The Advanced Rare Isotope & Electron Linac (ARIEL) facility at TRIUMF, scheduled for Phase 1 completion in 2014, will use a control system based on EPICS. Discrete subsystems within the accelerator, beamlines and conventional facilities have been clearly identified. Control system strategies for each identified subsystem have been developed, and components have been chosen to satisfy the unique requirements of each system. The ARIEL control system will encompass methodology already established in the TRIUMF ISAC & ISAC-II facilities in addition to adoption of a number of technologies previously unused at TRIUMF. The scope includes interface with other discrete subsystems such as cryogenics and power distribution, as well as complete subsystem controls packages.

FACILITY OVERVIEW

The ARIEL facility [1] will be composed initially of a 300KV Electron Gun, three superconducting RF accelerators, and beamline facilities to deliver beam to a beam dump and to target facilities. Ancillary systems to support the E-Linac include RF, Cryogenics, Vacuum systems, Beam Optics systems, Beam Diagnostics systems, a Machine Protect system, and a Cooling Water delivery system. Conventional Facilites components, such as an O2 Depletion monitoring system and Nuclear Ventialtion will also be supported by the controls group, although not technically part of the ARIEL Control System (ACS)

CONTROL SYSTEM ARCHITECTURE

As a continuation of methods, policies, and systems developed for the ISAC and other control systems [2] at TRIUMF, the ARIEL Control System will inherit from the predecessor. New systems will be put in place to accommodate requirements that did not exist for ISAC, but as much as possible, existing work will be re-used. In addition to the ISAC Control System as a precedent, the VECC test stand facility will be used as a proving ground for some new technologies and subsystems that will be later deployed in the ACS.

Initially, controls for a 300KV Electron Linac will be deployed, with first beam scheduled for March 2014. Subsequently, a full target hall will be instrumented and controls deployed.

The control system for ARIEL will use, at the top level, EPICS. The overall architecture of the control system can be decomposed into several discrete susbsystems that are defined along boundaries of accelerator and beamline functions, as well as by the controls technolgies that will be used to satisfy the specific requirements of those subsystems.

Some susbsystems are turnkey packages provide by contracted vendors. These include an Air Liquide Advanced Technologies (ALAT) cryogenics system, Ampegon klystron power supply, conventional facilities interfaces, 12KV power switchgear, and some minor cooling water control hardware.

Other subsystems include traditional beamline optics, vacuum systems, beam diagnostics, interface to low-level RF controllers, ion source hardware, and a Machine Protect System.

A combination of hardware platforms including Schnieder PLCs, VME-hosted I/O, fieldbus and CPU, and various network-attached CPUs will be deployed. Devices to be controlled will use a variety of fieldbuses.

To a significant degree, there is a mapping of PLC or EPICS device support technologies to the hardware type that is being controlled. As much as possible, the intention is to map EPICS technologies along both hardware-type and geographical boundaries.

SPECIFIC TECHNOLOGIES

While using EPICS as the central controlling and supervisory component, there are several system-specific device support and fieldbus types which will be deployed. These are a result of systems provided by outside vendors who implement turnkey systems with built-in control systems. Primarily, these are PLC based control systems, and the ACS will use TRIUMF PLC device support to communicate with those PLCs. Vendors have been cooperative about supporting the EPICS interfaces to these PLCs, and have provided address mapping for process variables of interest to the ACS, and in one case, augmented their standard PLC control system to include suppport for a fieldbus protocol that was specifically requested by TRIUMF.

The standard for PLCs used in the forerunner control system in ISAC at TRIUMF is the Schnieder Electric Quantum series and similar PLCs. Historically, these have used the Modbus+ fieldbus to connect PLCs and their associated IO drops. In ACS, the Modicon PLCs will use newer technology CPUs and communications modules which have ethernet communication between PLCs and IO drops. Special loop-oriented topology in this product is provided to promote redundancy in the communications channels between PLCs and IO drops.

The standard operating system for all control system CPUs will be Linux. For server and desktop hosts running primarily Intel x86 style CPUs, major Linux distributions will be used. Future upgrades to newer versions is anticipated and rollouts will be performed as necessary. It

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is a goal to remove as much depency as possible from EPICS and other software versioning. One role of some server hosts is that of application server, running common operator inteface tools, and other common EPICS based applications. Because of this, development host versons must match software verson of production fileservers.

HARDWARE TYPES SUMMARY

Table 1: Mapping of Control Hardware Types and EPICS Device-support Types to Subsytem Types

Subsystem Description	Hardware/EPICS Device-Support
ALAT Cryogenics	PLC hardwire interface + Siemens Fetch/Write network interface
Ampegon Klystron PS	Siemens Fetch/Write network interface
Low-Level RF	In-house Windows PCAS server (under review, possible change to asyn/StreamDevice)
Beam Optics PS's (most)	Ethernet with asyn/streamDevice
Beam Optics PS's (other)	VME analog and digital IO
Beam Diagnostics, Beam Position Monitors	Ethernet, asyn/streamDevice
Cooling water facility	In-house programmed Schneider PLC with in-house EPICS Support
Cold Distribution System	In-house programmed Schneider PLC with in-house EPICS Support
300KV Egun	In-house programmed Schneider PLC with in-house EPICS Support
SF_6 Control	In-house programmed Schneider PLC with in-house EPICS Support
Machine Protect System interface	VME hardwire IO and EPICS Channel Access direct connection. (under review)
Beamline Vacuum	In-house programmed Schneider PLC with in-house EPICS Support
Camera Viewscreen (beam diagnostics)	UVic provided. Uses EPICS asyn + areaDetector Support

FIELDBUS TECHNOLOGIES

Although the control system deployed for the ARIEL E-Linac project will be based on the prior model used in ISAC-I and ISAC-II, some differences in the types of devices being controlled will need to be accomodated. Hitherto, the dominant method for controlling power supplies, both electrostatic and magnetic, has been through a network of controllers, each pysically attached to a power supply under control, and networked via a CANbus network mastered by an EPICS IOC, usually in a VME form-factor host.

More recently, power supply manufacturers have begun using TCP/IP over ethernet interfaces for remote control of power supplies. This will result in some departure from the prior model used to control the power supplies.

Earlier use of ethernet in the ISAC control system did not distinguish between low-level, fieldbus oriented purposes, and higher-level application oriented traffic. The strategy for ARIEL E-Linac controls will be to segregate all fieldbus oriented traffic off of the main control system network. This is expected to minimize propagation of network traffic, reducing the overall traffic volume. It will reduce the possibility of unintended interaction between device, as well as allow the control system group to deploy devices without the need for support from site-wide networking staff in assignemnt of IP's, nameserver entries, and similar administrative support. It has been shown that many network-attached devices are unable to handle high volumes of traffic, especially UDP and other broadcast-enabled traffic. Isolating these 'weak' devices from such traffic volumes will increase reliability.

HYBRID CONTROL TYPES

Typically, the interfaces on commercial power supplies do not provide a method to interlock them against prohibited turn-on and to trip them off. External relay-based logic will therefore be used to disconnect the power supplies from their respective magnets in the event of over-temperature conditions, or in the face of inadequate cooling water flow. These interfaces will be implemented in conjunction with relay-based polarity-switching gear that will be controlled fromVME based IOCs. The combination of VME-based direct IO inconjunction with ethernet-based controls marks a departure from the previous philosophy that all control of a particular device should be conducted through a single interface type. Control of all of these special classes of power supplies will be performed on a sinlge IO host, providing VME IO and ethernet TCP/IP IO. No network connectivity will be required for coordination of IO types.

LINUX ADVANTAGES

In the ARIEL E-Linac Control System, Linux will be used as the host OS for all front-end controllers, file and application servers, and operator consoles. The use of the Linux operating system provides some unique advantages over other candidate operating systems. In the

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predecessor ISAC Control System, vxWorks was initially used on all VME host CPUs, and this usage will be replaced by the more cost effective Linux OS. Linux affords us the opportunity to run multiple EPICS IOC applications on a single host, or to run non-EPICS applications at the same time as EPICS IOCs on front-end hosts.

The use of Linux as a platform for hosting IP routers facilitates the architecture of discrete islands of ethernet fieldbuses. Using the Linux kernel netfilter module and either in-house developed or open source *iptables* scripting, router/firewall functionality can co-exist with EPICS IOCs.

Linux allows the use of numerous standard tools for testing and diagnosis of common problems, such as host diagnostics, runtime configuration of hardware such as communications and networking, and flexible scripting for configuration of system startup. Limiting the use of operating systems to a single type reduces the burden on staff to learn multiple systems, and makes movement of code to other hardware types easy.

ISAC LINUX

The ISAC Controls group has developed a specially crafted flavor of Linux[3]tailored for use with EPICS front end controller hosts. ISAC Linux is built for Intel x86 compatible PC architecture hosts. Desktop style PCs as well as several models of x86 VME hosted CPUs are supported. In developing the custom Linux package, emphasis was placed on minimizing the memory and disk storage footprint, boot and re-boot speed, and reducing or eliminating all software elements not vital for use as an EPICS front end controller.

The small footprint allows the use of purely RAM based filesystem, and no solid state or spinning media disk storage is used on EPICS front end controller hosts. Network booting is employed, using the industry standard PXE system, and all hosts boot using a single root filesystem image. Centralized distribution of software updates are easily accomplished using this method. A highly customized system of startup scripting permits flexible use of the kernel commandline argument list to specify one or more EPICS applications that should start up at boot time.

INFRASTRUCTURE

Deployment of a control system for particle accelerators benefits from automation for at least two basic reasons: efficiency and consistency. The ACS will be built and deployed using the system of in-house tools that were developed during deployment of the ISAC Control System.

This toolset provides the ability to enter and organize device oriented data, generate EPICS runtime databases, generate EPICS operator interface screens, perform consistency checks of PLC programs against formal specifications, assist in the release of software and testing of newly deployed systems, and maintain up-to-date documentation of hardware and some software. These services allow efficient deployment of software for new systems, as well as agility to perform upgrades, diagnostics, and other maintenance activities, and adherence to quality assurance standards.

Fileserver facilities to host the software development and production environmants will make heavy use of virualization and hardware redundancy. RAID-based storage systems, redundant power supplies, and reliable hardware will be deployed. Virtualizaton will allow for independence of OS and application software from the host hardware, and will provide a method to perform data and software backup in an efficient manner.

Disk storage usage patterns will be closely observed, and upgrade of storage capacity is anticipated. The use of high resoluton camera images in the control system is novel at TRIUMF, and usage patterns will need to be determined.

SCHEDULE

The facility is expected to produce first beam in March of 2014. Full power beam delivery to a beam dump is required by September of 2014.

This schedule imposes tight time scheduling and allows for little or no slippage in delivery of susbsytem controls packages. The experience gained from the precedent ISAC Control System will be invaluable, and efficiency gains through automation will be vital to the success of the ARIEL Control System.

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