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THE INTEGRATION OF TWO CONTROL SYSTEMS*

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During the past year the Continuous Electron Beam Accelerator Facility (CEBAF) has installed a new machine control system, based on the Experimental Physics and Industrial Control System (EPICS). The migration from CEBAF's old control system, Thaumaturgic Automated Control Logic (TACL), had to be done concurrently with commissioning of the CEBAF accelerator. The smooth transition to EPICS was made possible by the similarity of the control systems' topological design and network communication protocol. Both systems have operator display computer nodes which are decoupled from the data acquisition and control nodes. The communication between display and control nodes of both control systems is based on making named requests for data, with data being passed on change of value. Due to TACL's use of a central communications process, it was possible to integrate both control systems' network communications in that process. This in turn meant that CEBAF did not require changes to any other software in order to support network communication between TACL and EPICS. CEBAF implemented the machine's control under EPICS in an evolutionary, controlled manner.

I. TACL NETWORK

TACL adheres to the "classic" control system model, with distributed front-end computers performing data acquisition and control, and dedicated console computers for operator displays. The front-end computers are Hewlett-Packard UNIX workstations communicating with CAMAC crates through a GPIB port on each workstation. Client processes execute on HP workstations, typically displaying machine data in a graphical format. Communication between the front-end computers and client processes utilizes a "Star" process, which mediates communications between all front-end computers and clients of the control data originating on the front-ends, Figure 1 [1]. Communication between the Star and other processes is based on named data. Availability of data on the front-end computers is made known to the Star by name, and when client processes wish to obtain data values they make that request by name. A data request sets up a logical stream for the data. On first request the data value is sent, and subsequently only changes in data value are passed to the requester. The data stream remains in place until either the client dies or terminates the stream.

II. EPICS NETWORK

The Experimental Physics and Industrial Control System (EPICS) also follows the "classic" control system model. In

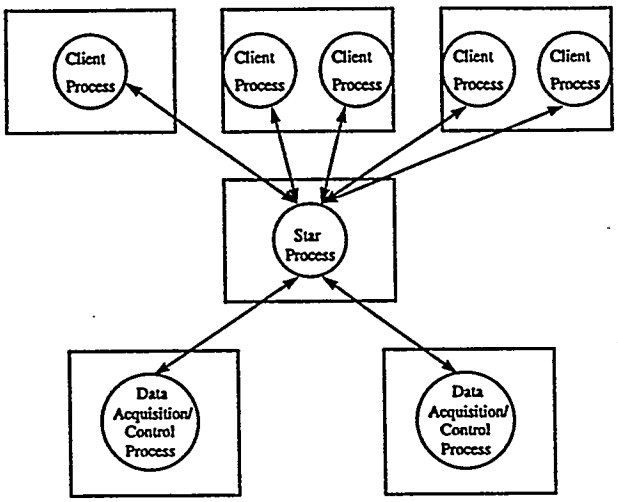

Figure 1: Communication Links in TACL

EPICS, distributed single-board computers serve as front ends, acquiring data and executing control algorithms. EPICS uses independent workstations that function as operator displays. The single-board computers are typically M68040-based, and execute the operating system VxWorks. Client processes can execute on a wide variety of platforms, from Sun and HP machines running UNIX to VMS-based VAX computers and even machines running WindowsNT.

There is no mediation between client processes and front-end computers in EPICS, Figure 2. A client broadcasts a data request by data name, and the front-end computer which is the source for that data responds. As with TACL, each data request is a logical stream, and data is passed on change.

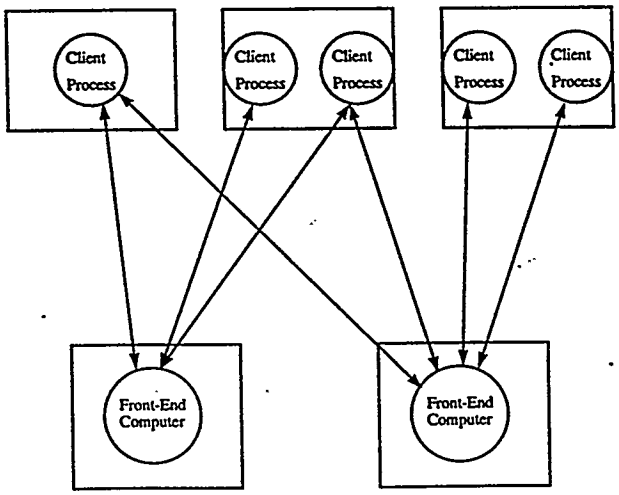

Figure 2: Communication Links in EPICS

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III. INTEGRATION TECHNIQUE

In TACL, the Star is a point source for failure of the control system. While the existence of such a failure mode is generally indicative of a poor system design, it made the integration of the two control systems quite manageable. The Star served as the focal point for all inter-control system communications, and made accelerator operations feasible while CEBAF used a hybrid of both control systems.

The migration was evolutionary, so that operators could continue to use the TACL display tools with which they were familiar, even though some of the data they viewed originated on a different control system. From the point of view of the Star process, all of EPICS was treated as a single TACL front-end computer, figure 3. This meant that small pieces of the control system could be moved to EPICS independently, without altering client processes in the TACL part of the system. If a TACL client process made a request for a channel which came from a TACL front end, the TACL system worked as before. If the channel came from EPICS, the Star established a logical data stream with the appropriate EPICS front-end computer. When data updates were provided to the Star from EPICS, the data was forwarded to the client process. The source of the data, either TACL or EPICS, was transparent to the client.

There was no development effort to support EPICS clients obtaining values of data directly from TACL. This decision was based on the philosophy that the hybrid system was purely a stopgap while CEBAF developed expertise in using EPICS, and completed development of the control system applications. There was a management decision that the significant effort required to provide this functionality was not worth the limited benefit, since operators would always be able to operate on the EPICS portion of the control system using EPICS displays.

In TACL, the Star is made known of the names of existing data on front-end computers dynamically, when the computers establish communication with the Star. It was not possible to duplicate this functionality with EPICS. Instead a disk file was used to define which channels were available from EPICS. This was a limitation, because the addition of new data channels to the EPICS side meant that changes to the channel definition file were also required. This procedure was automated to simplify the burden on software developers. A side benefit of this technique, however, was that it enabled the development of name aliases for EPICS fields. Without the aliasing, additional EPICS records would have been required to map CEBAF's flat naming convention onto the EPICS 2-dimensioned namespace (<record>.<field>).

Pushing Data into EPICS

CEBAF needed a mechanism to support EPICS control applications which obtained information from TACL front-ends. An example of this is the viewer system, which has components sprinkled around the entire accelerator. Viewers give machine operators immediate feedback regarding the characteristics of the beam at the viewer insertion point. However, in order to prevent their destruction, viewers can only be inserted when the electron gun is in a current-limited state. The current-limited control was implemented in TACL (as was the rest of the gun control software), but the control algorithm to manage individual viewers could be in EPICS, depending on the viewers' locations. In order to insert a viewer, the individual control had to obtain from TACL an authorization that the gun was in fact current-limited.

It would have been very difficult to make the Star process act like an EPICS front-end computer. While this solution would have made the two control systems completely transparent to each other, the time required to implement this was on the order of 1 man year. Instead, a different approach was used. In effect, the Star process was told to push particular TACL data values into the EPICS control system, creating a virtual client process which was the entire EPICS control system. Once the data was in EPICS it could be distributed to oth-

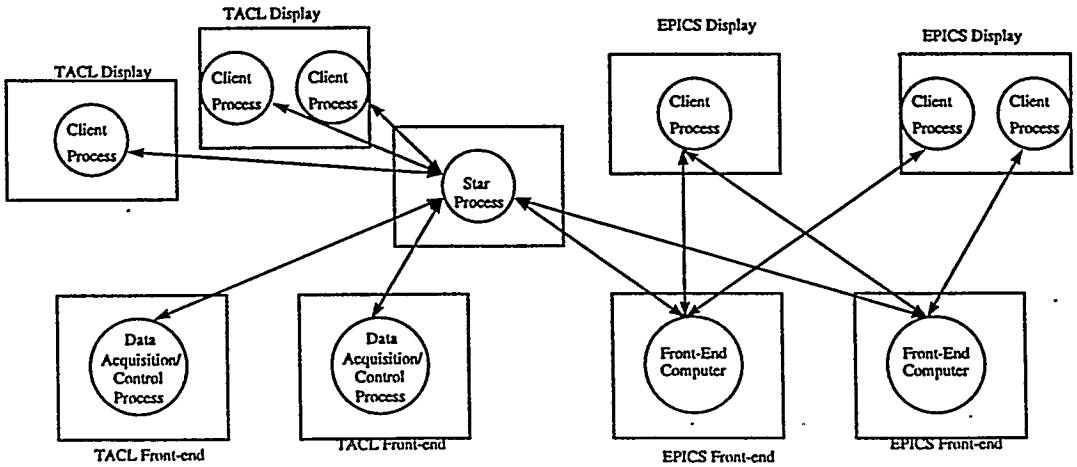

Figure 3: A Combined TACL and EPICS Control System

er EPICS front-end computers using standard tools available with that control system.

IV. MIGRATION PROCESS

CEBAF began the process of migrating the control system from TACL to EPICS by converting the existing low level applications running on HP workstations to run on EPICS IOCs. The conversion was planned as a phased implementation with the Star allowing TACL and EPICS to peacefully coexist.

In the first phase, the low level controls for the RF application were converted. The TACL local computer devoted to control of two full cryomodules in the injector was replaced with an EPICS IOC, and the TACL logic was replaced by an EPICS database. The GPIB crate controller used for TACL were replaced with an L2 crate controller attached to a Serial Highway. The EPICS data was passed through the STAR to allow the TACL user interface to remain in place during testing. Once this proof of principle project was shown to work, the RF control database was replicated for the other 40 RF zones throughout the accelerator and was used for commissioning. The TACL screens were then replaced with EPICS screens.

As soon as the RF control of two cryomodules was functioning in EPICS, work was begun on the conversion of control algorithms for CEBAF's magnets and other diagnostic hardware. For most hardware the effort was devoted to simply reproducing the functionality of the TACL control system in EPICS. The devices in this category include harps, BPMs, BLMs, FSD, viewers, vacuum and valves. CEBAF took advantage of the control system changeover, however, to extend the capability of the magnet control software and add some long-desired features. The added functionality included automatic hysteresis and concurrent runtime control of magnets in units of either BDL or current. All of the diagnostic databases were installed on operational EPICS IOCs, first in the linacs and later in the arcs.

The devices mentioned above are duplicated and installed in many locations in the accelerator. Because control of these duplicates is identical for all copies (other than hardware addresses), it was possible to replicate in short order their control algorithms throughout the accelerator control system, as TACL local computers were replaced with new EPICS IOCs. The conversions and installations took place during CEBAF commissioning and with the exception of a few short scheduled downtimes for hardware installation, the control system was operational during the entire migration process.

After EPICS was put into use in the linacs and arcs, the CEBAF injector was converted. Changeover of this region of the accelerator involved converting control algorithms for several unique devices, so opportunities for algorithm replication were limited.

Currently, the CEBAF accelerator is running under EPICS control. The Central Helium Liquefier (CHL) remains under TACL control. A "spy" program is used to allow communication between the two systems, through the Star. Work is in progress to convert the CEBAF Cryogenic Test Facility to EPICS, which will serve as a first step to converting the CHL. Due the high reliability need for CHL and CEBAF's operating schedule, it is anticipated this conversion will not take place immediately, but will be phased in over time.

V. REFERENCES

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