Common Control System for the CERN accelerators

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Abstract

The PS and SPS Accelerator Control Systems are becoming obsolete and need urgent rejuvenation. After a control users forum, where users expressed their needs, two main Working Groups were set up, consisting of Control and Equipment Specialists and experienced Machine Operators. One Working Group studied the architecture and the front-end processing and the other a common approach to the application software needed to run the CERN accelerator complex. The paper presents the technical conclusions of their work and the policy to implement it, taking into account the necessity to operate both machines without interruption of the Physics Program.

I. INTRODUCTION

The complex of CERN accelerators is divided in two sets of different characteristics. The PS set is constituted of ten different accelerators which represent the source of all particles accelerated in CERN (maintained by PS division); they are small and mainly fast cycling machines. The SL set is composed of two bigger machines, the SPS and LEP which are slow cycling accelerator or particles colliders (maintained by SL division). The two sets are, broadly speaking, separated by the Swiss-French frontier.

The PS and SPS accelerators control systems were conceived and implemented some 15 years ago. They are based on 16 bit computers, with a proprietary operating system and a star network. These components do not permit the use of modern industrial software packages and communication standards. Their maintenance is expensive and is becoming more and more difficult. The consolidation of the control systems has become necessary and urgent, and it was felt that one should profit from this consolidation to aim at a real convergence of CERN's accelerator control systems.

In order to work out a common technical solution, the collaboration between the PS and SL control groups has been reinforced considerably since the beginning of the year 1990. A common consolidation project is the result of this collaboration and it was elaborated by working groups of the two divisions. Joint working groups were set up to study the different aspects of the project and to reach the necessary consensus on what should be done. [1]

The first working group designed the common control system architecture, the front end processing and discussed the network characteristics, the local control facilities and the interface between the controls and equipment groups.

The second working group defined a common approach to the application software needed to run the accelerators, discussed the programming environment and the possible software tools and studied the future layout of the work place in the control rooms.

Other groups, linked with the two previous ones, worked on specific subjects like the Equipment Control Protocols, the common on-line data base, the Man Machine Interface, the Timing and Synchronization problems. They generally worked out common solutions which are today in the implementation phase.

II. ARCHITECTURE

The new Common Control System consists of three layers: Figure 1

- the control room layer with its consoles and central servers;
- the front end computing layer distributed around the accelerators;
- the equipment control layer with the Equipment Control Assembly (ECA) crates which form part of the equipment.

The hardware and software used on each level reflect the considerable variety of accelerator components to be controlled. The new architecture offers more flexibility and will allow continuous partial upgrading as technology evolves.

A. Control Room Layer

It must fulfil two main functions:

- Provide the operators with a reliable, user-friendly interface to the accelerators. Modern workstations running the commercial software package X - windows with a suitable commercial tool kit to construct the user interface were chosen. The operator work places are very demanding in terms of graphic and interaction facilities. The key point in selecting the new platforms is the interoperability with the existing equipment and the portability of the software between them. We hope the choices made, UNIX operating system (OSF based in the future) with X-Window and Motif tool kit and communication by the TCP/IP protocol, will allow a smooth transition from one generation of hardware to another.
- Offer a number of central services through servers (which are generally more powerful machines of the same family as the workstations). These central services can be the coordination of various control tasks, central data and file storage, model computing and collection of alarms.

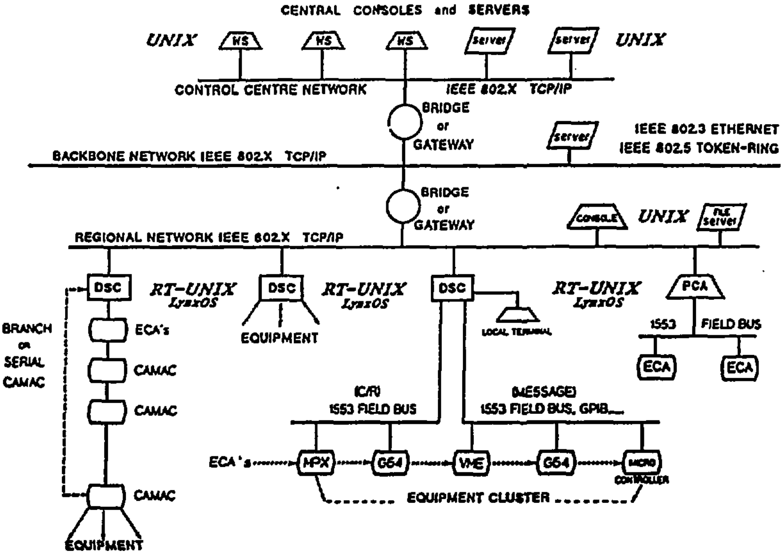

Figure 1. Control System Architecture

B. Networking

The communication between the Control Room layer and the Front End Computing layer, as well as the communication within these layers, is based on modern standards using TCP/IP as the main inter networking protocol suite. The network is composed either of Token Ring or Ethernet segments linked together through bridges or routers. However, where required, routers are implemented in order to filter the access to the control systems from offices, laboratories or the outside world.

The future use of FDDI as an additional fast network is in test between Meyrin and Prevessin sites (utilization by both control systems of an ORACLE on-line data base server).

A Remote Procedure Call (RPC) mechanism offers a way for the programmers to call the libraries located in remote computers, hiding as much as possible the network (CERN designed RPC including an interface to the old control network). TELNET and FTP are also available in connection with the TCP/IP protocol suite.

C. The Front End Computing layer: The Device Stub Controller (DSC)

The Front End Computing layer is centered on the Device Stub Controllers (DSC) which are based on both standards PC and VME crates with 32 bit embedded microprocessors. A diskless Real Time, UNIX compatible, and POSIX compliant, operating system is run in the DSC. The diskless solution was chosen because the disks of the Process Control Assemblies (PCA) of the LEP control system proved to be a weak point and because the back-up procedures and management of files and data are supposed to be easier if storage is less distributed.

The main functions of the DCS are:

- to provide a uniform interface to the equipment as seen from the workstations;
- to provide direct control and acquisition for equipment like beam instruments, interfaced directly to the DSC;
- to act as a master and data concentrator for distributed equipment, interfaced via a field bus.

The choice of the standards for the DSC, PC and VME bus, was not easy. With the limited resources (staff numbers decrease while the number of new projects increases) the Control groups initially intended to provide support for the VME bus only. However, after long discussions, because of the 65 existing LEP PCA (Process Control Assembly) based on PC and because of quite complementary advantages, it was decided to give support to the two standards, PC and VME bus. This decision mainly became possible with the availability of an open Real-Time, UNIX compatible, operating system which runs on both platforms. Figures 2 and 3

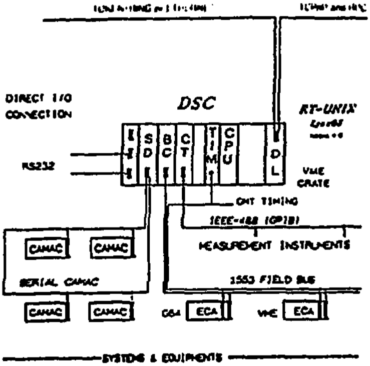

Figure 2. Device Stub Controller

This Real Time UNIX compatible operating system, LynxOS, has been chosen to allow running several tasks concurrently (beam measurement, statistics, alarms, diagnostic programs), and to provide a fast and deterministic response to external events when necessary (Pulse to Pulse Modulation for example). It will make it relatively easy to port the XENIX system libraries and servers developed for the LEP PCA to the new operating system.

To provide disk service for the diskless DSC and workstations (as well as boot server, secure disk space for application and data and back up facilities) file servers will be made accessible. Central file servers are used in general. However, in order to keep the load on the backbone network acceptable and to maintain local control alive in case of communication problems, it has been decided to implement regional file servers on important network segments.

Associated to the DSC, one can distinguish between three different types of local man machine interface:

- Local display (for the DSC based on VME): a graphic VME module is directly driven by the CPU. It could be completed by a touch-panel when a more convivial interface is needed for local operation.
- Local terminal: connected to the CPU of the VME crate with an RS232C line. This access can be used during debugging or testing.
- Regional console: a workstation, a PC with UNIX or a X-terminal, directly connected to the network segment, could be seen as a local use of the services available in the Control Rooms, and can be directly used as a local terminal with TELNET connection.

D. Equipment Control layer

The control crates of the third layer, the Equipment Control Assemblies (ECA), are connected to the DSC via field buses. Since no predominant standard exists, a certain variety of solutions, both for the ECA and for the field buses, is considered to be acceptable. As the main front end computing device is supposed to be the DSC, the computing on the ECA level should be reduced to a minimum.

E. Field buses

In the present CERN accelerator Control Systems, three field buses are used to a large extent: the 1553 field bus [2] and the GPIB in the LEP area and serial CAMAC in the PS area and the SPS experimental areas. At the PS complex, the CAMAC crates will be controlled directly by a VME module that drives the serial loop [3] whilst in the SPS experimental areas the CAMAC crates will be connected to the VME or PC DSC via the VICbus. The SPS main ring equipments will mostly be interfaced to the 1553 field bus. Proprietary field buses delivered with turn-key industrial systems will be interfaced directly to the DSC. [4] Due to the large investment in the associated interface equipment, all three field buses will be supported in the DSC environment.

F. Support to Equipment groups

The equipment groups may need to develop software to control their equipment either in the DSC itself or at the ECA level. When the DSC is directly dedicated to an equipment through interface cards, the control group will offer assistance (cookbook, basic driver "frame") to write the drivers accessing the specific hardware. When the equipment is connected to the DSC through a standard field bus , the Control Group will

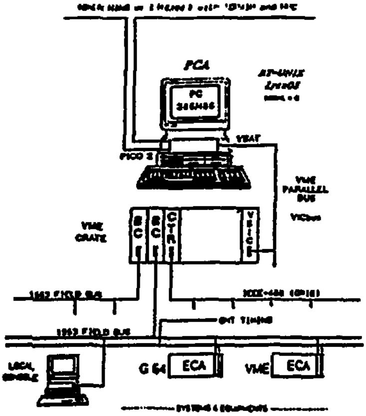

Figure 3. Process Control Assembly

provide the equipment access functions in the DSC. At the level of the ECA, the use of OS9 and LynxOS will get some support from the Control Groups.

G. Proposed Equipment Control Protocols [5]

The best result for the control of a given equipment is obtained when the Equipment Group is totally responsible for its implementation. It is proposed, and already in the beginning of implementation, to use a general operational control protocol which leaves the equipment specialists dealing with all the intricacies of their equipment (either at the level of the DSC or the ECA, where applicable), whilst the control groups take care of the operational requests for this equipment as well as the communication part.

In this scenario, the accelerator operation crew defines a uniform frame for a given equipment interaction, the specialist realizes the specific, local software in the most adequate way for each device, and the controls provide a uniform software interface to translate the operator requests into control sequences for the equipment.

III. APPLICATIONS

A. Basic buildings blocks and tools

The basic building blocks and the tools for the Applications are centered around Open Software Standards. UNIX is confirmed as the operating system of the workstations, the development environment of the DSC and the network servers. The DSC operating system is a UNIX compatible system with real-time performance. (LynxOS) TCP/IP protocol suite and NFS are the basic components for all distributed facilities. Compliance with standards is enforced. The POSIX IEEE 1003.1 interface definition must be respected. The X-Windows is selected as the base graphic system for workstations : for general data presentation facilities and user interactions, all future developments will be based on the X-Windows protocol and the OSF Motif toolkit.

B. Data Management

A well supported set of data management facilities inside the CERN accelerator control systems is needed to cope with the large quantity of data provided by modern electronic equipment and beam instrumentation. The study of the database services sub-group concluded that a dedicated PS/SL database server running ORACLE would be useful. The host machine for this service is installed and first tests and measurements concerning the performance of ORACLE as an on-line database are in progress.

C. Software development facilities

The use of modern CASE tools are encouraged for analysis and design of software projects, but one cannot expect to enforce a systematic application for all projects and to all participants. Source code management tools provided with UNIX are available for keeping track of the history of consecutive versions. "C" is the common base language, as it is well integrated in UNIX platforms and offers a good portability (as accepted by the Portable C compiler). The NODAL interpreter (written in C) is available on the DSC and on both workstation platforms in use, DEC and Hewlett-Packard. Fortran may be used, but only for mathematical applications. (mainly modeling)

D. Environment of application software

The development environment should be as similar as possible to the operational environment in order to ease the transition from development to operation and to allow good productivity and maintainability by the knowledge of a single environment. Standard procedures must be established for validation by the users (operation, accelerator physicists, equipment groups) and controls exploitation staff. A complete application program must be designed with integration into the Console Manager in mind; the Console Manager is the supervisor of all activities induced by the workstation.

E. Application run-time environment

No synchronization with the cycle of accelerators will be done through workstations. The equipment cannot rely on software for its protection, and the equipment groups will have to provide means to protect their equipment against unallowed actions through the control system.

F. Man Machine Interface

The major goal is to reach as much uniformity as possible for the operation environment. To preserve the future software investment in MMI, the OSF tool kit MOTIF will be used on top of the well established and widely used X-Windows standard display protocol. The console manager activates and coordinates the various processes according to the requests of the user. Synoptics will be widely used in the controls of the accelerators (as they are also the natural tool offered for various industrial equipment); the DVDraw/DVtools product, encapsulated in a man machine interface, will be used for the production of such synoptics. [6] [7]

G. General Control room environment and operator desk

The operation of accelerator clusters through the control system is done by operator teams working 24 h a day in the central control rooms and using consoles as the main tool for machine interaction. The notion of "work place" is now preferred to the one of console. The powerful workstations are the main interactive tool composing a work place; they are the tools to select, visualize and drive the batch of application programs to control a selected part of an accelerator. The work place is completed by tools to observe and select analog and video signals, and to display alarms.

Beside the workplaces, an accelerator control center must contain tools to display general information summarizing the status of the accelerator complex, means to communicate with local building and other control centers, means to access other network facilities, and tools to manage personal safety which must be treated separately from accelerator control.

IV. CONVERGENCE POLICY

Because of the large hardware and software investment needed, the limited manpower available today, the similarity of the control requirements for the various machines and the increasing complexity of the software tools for running them, it is mandatory to reduce the diversity of control implementations at CERN.

The constraints imposed on the convergence by the history of the different machines, the large amount of investment in existing hardware and software, the different types of machines to be controlled, and the habits adopted by the operation crews interacting with these machines must be taken into account when defining a common PS/SL policy.

This common policy will be based on a common control system architecture, using well established industrial standards for control networks, communication protocols, equipment, operating systems and man machine interface. This architecture will profit from and enforce the use of Open-System products supported by many manufacturers and consortiums. (UNIX, OSF, X-Windows for the software; Ethernet and Token-Ring with TCP/IP for the control network; UNIX workstations for the man machine interface; PC and VME for the DSC and equipment interfaces).

As much software as possible must be written independently of the development platform (using industrial products), opening the possibility to transfer application programs between the different accelerators.

An other main goal of the common policy must be to preserve the existing hardware and software investment. The application software developed for the exploitation of the accelerators represents hundreds of man-years of investment which has to be maintained, improved and optimized to ensure uninterrupted operation. The proposed architecture makes provision to integrate the hardware investment in CAMAC and MPX in providing adequate tools to access these crates. The software investment in the SL-PCA is preserved by using a UNIX compatible real time operating system in the DSC.

V. CONCLUSION

This is the summary of the consensus which has emerged from the discussions about the architecture of CERN's accelerator control systems, their main components and the general aspects of the application software. A major concern was to preserve the existing hardware and software investment, together with a non-duplication of the effort inside CERN's accelerator community.

Our main aim was to propose an architecture which permits continuous partial upgrading, as technology evolves, *in order to avoid any "big bang" operation in the future*. The main components of our control systems are based on open standards, for the hardware as well as for the software, to become independent of a given manufacturer.

Finally, to monitor the progress of the consolidation project and to ensure that all our efforts stay directed towards a common goal, the working groups (or at least an emanation of the two working groups) continue to meet during the implementation of the different steps of the project.

VI. REFERENCES

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