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F. Perriollat and C. Serre

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The New CERN PS Control System Overview and Status

F. Perriollat and C. Serre, for the PS/CO Group (CERN, CH-1211 Geneva 23 - Switzerland)

The CERN PS control system is being completely rejuvenated. The existing system, whose design options were frozen in 1978, uses 16 bit minicomputers for process computers and for conventional consoles and services. These are being replaced by the agreed CERN Standard Architecture, using UNIX workstations as operator interface and VME based processors or PC frontends, under LynxOS. All CAMAC is essentially preserved. The project covers about five years and proceeds in steps of one year. Switch over takes place in the annual shutdown, early in each year. No interference with the machine operation schedule is tolerated and this implies that no extra machine stops are planned for controls. The first two steps have been completed and operate to the complete satisfaction of the users ; the LPI (Lep Preinjector) machines run since March 92 and the Proton Linac was started in March 93. The control system of the Lead Linac is being commissioned during 93 and 94. The third step of rejuvenation concerns the Booster machine and is under implementation now. The paper describes the architecture, the techniques used, the major components and the experience gained up to the conference time.

1. Introduction

The CPS (CERN Proton Synchrotron) control system is being rejuvenated from a Norsk Data minicomputer based control system (designed around 1978) to the agreed CERN standard architecture for the control of the accelerators [Ref.1]. The standard architecture was designed by a close collaboration of the CERN accelerator divisions; this collaboration took place as a joint PS/SL divisions project for the implementation of the accelerator control system on CERN machines. The replacement of the obsolete 16 bit minicomputers, used both for console and front end processors, is done by UNIX workstations as operator interface and by VME based processors or PC front ends under LynxOS. For budget and managerial reasons the CAMAC investment at the PS is essentially preserved, and only new equipment is passed on other buses like MIL1553 or directly controlled by VME based modules.

The CPS rejuvenation is a six year project which is implemented by annual steps, and the switch over between the actual and standard control system takes place for every machine during the annual shutdown, at the beginning of a year. No interference with the machine operation schedule is tolerated, so no extra machine stops are planned for the controls. To date, the two first steps are completed, LPI (LEP Pre Injector) machines in 1992 and Proton Linac (Linac2) in 1993, the third one, the PS Booster, is in preparation for the shutdown of 1994. The first two steps are operational to the complete satisfaction of the users, and the Lead Linac (Linac3) continues its commissioning using the very

same system as the Linac2 one. The PS itself, the Beam Transfer Lines and Experimental areas, and the LEAR machine together with delayed items will be switched over during the next three years.

This paper gives an overview of the architecture, the techniques used, and the major components of the CPS control system. It will refer, whenever possible, to particular CERN reports or conference papers. It describes the experience gained during these implementations up to the conference time, and reports the actual status of the system.

2. Overview of the CPS Control System.

2.1 Architecture

The standard model used in the CPS complex is the image of the common architecture of the CERN accelerator control system [Fig. 1]; it consists mainly of three different layers:

- i) control room layer with workstations and central servers; the connection to this layer is done only through the Ethernet cable,
- ii) front end computing layer distributed around the machines, based on Device Stub Controllers (DSC),
- iii) equipment control layer with ECA (Equipment Control Assembly) control crates which form part of the equipment and are controlled by the DSC through buses.

The network between the two first layers is divided into central and regional LANs. The central LAN includes the operator interface workstations and their servers together with the Central Services and

[Fig.1] The standard architecture applied to the CPS complex.

the Real Time Data Base server (on line RT DBMS ORACLE shared by PS and SL control systems). The different regional LANs incorporate the DSCs, the local workstations and the server belonging to one or a complex of machines. These control LANs are separated from the development workstations and

DSCs, office PCs and the CERN Public Network by a router box (CISCO) [Fig.2]. On a separate segment, the development environment (workstations and DSCs) is kept as identical as possible to the control environment.

[Fig.2] The network architecture.

2.2 Technologies used

The common architecture is based on well established industrial standards for control networks, communication protocols, equipment, operating systems and man machine interfaces. The architecture profits from and enforces the use of Open-System products supported by many manufacturers and consortiums and enables us to be as independent as possible from a given manufacturer. With the same goal in mind, the software is written as independently as possible from the development platform (using industrial products), opening in addition the possibility to transfer application programs between the different accelerators.

The communication between the control room and the front end processor layers is based on a TCP/IP network; the network is composed of Ethernet segments linked together through bridges or routers. A Remote Procedure Call (RPC) mechanism is used to call libraries located in remote computers; TELNET and FTP are also available in connection with the TCP/IP protocol suite as well as NFS. The workstations and the DSCs are diskless machines for easy backup procedures, comfortable file and data management and for reliability. In the CPS control system the workstations and servers are DEC5000 stations and machines running ULTRIX; the DSCs are mainly VME crates with embedded M68030 or M68040 processors and with the RT-UNIX LynxOS operating system; occasionally the PCs are used with the same OS, especially when the hardware interface is only available for this type of platform.

2.3 Major Components

2.3.1 Interaction

Up to date powerful workstations provide the operators with a reliable and user-friendly interface to the accelerators; they run commercial operating systems (ULTRIX, the Digital flavor of UNIX) and software packages (X-Windows, OSF MOTIF) with suitable commercial tool kits to construct the user interface. The user interface consists of a console manager [Ref.2] and a set of generic programs. The console manager offers the selection possibility through menus opening a certain number of "widgets" allowing the observation and the choice of a given set of operational parameters (WSET), the control of these selected parameters (Knobs), the display of instrumentation data and the presentation of the faulty equipment which is surveyed regularly (Alarms) [Ref.3]. This console manager allows the

operators to call the synoptics and other programs which were created using commercial software packages (DataView, Wingz, Mathematica).

The generic and specific programs interact with the accelerator parameters via a "Software Bus" which hides the network topology of the control system from the programs [Ref.4]. Two main functionalities are provided through this Software Bus:

- i) a command respond protocol, with multiple equipment, multiple action, multiple data transaction to the Equipment Modules (EM). This function gives the application the illusion that the control system is completely centralized in the user workstation,
- ii) a data pipeline from multiple equipment (in DSCs) to the application. It uses a subscription mechanism for the operational data: the data flow is driven by the remote processes. The arrival of these data are fully integrated into the event procedure of UNIX.

A third access method provided by the software bus is a gateway to the data stored in ORACLE DBMS; these data are used as reference parameters. It is identical to the common respond protocol, only the requested actions have to be flagged with a reference tag.

This uniform software bus provides the application programs with an easy way to build and update displays. Standard frames were developed to facilitate the production of some classes of applications. A fast access using the DBM UNIX facility allows reading control configuration information through the on line RT Data Base.

A widely used user-oriented tool is the CERN NODAL interpreter language which is often applied in the accelerator control. The workstation version includes the equipment interface and some facilities based on Motif [Ref.5]. In addition, most of the facilities which were supported on the previous Nord based consoles (TP, TB, Knobs, Video displays) are emulated via compatible functions and environments. This convenience allows a quick and easy porting of former Nodal console programs into the workstation console manager, and also is a simple way of introducing newcomers into the workstation programming intricacies.

A controlled bridge between the CPS control system and the PC office network (Novell based) provides an access from the office PC's, through the Microsoft tool set, to the accelerator parameters for

machine studies, equipment prototyping or report edition [Ref. 9].

2.3.2 Equipment control

The equipment control layer is based on the Device Stub Controllers (DSC). In the CPS control system, mainly VME crates with 32 bit embedded processors (M68030 or M68040) are used; they replace both the Nord front end minicomputers and the CAMAC embedded microprocessors (TMS9900 and M68000). A diskless real time, UNIX compatible and POSIX compliant operating system, LynxOS, runs in these DSCs. It was chosen because it guarantees a predictable response time to external events, it is available both for VME processors and PC based DSCs, and provides TCP/IP and NFS. The main functions of these DSCs are:

- i) to isolate the upper layer from the real time constraints and to manage the dynamic equipment data, according to the Pulse to Pulse Modulation (PPM),
- ii) to provide a uniform interface to the equipment as seen from the workstation through the "Software Bus",
- iii) to act as a master and data concentrator for distributed equipment, interfaced via field buses (serial CAMAC, MIL1553, GPIB, X25),
- iv) to afford direct control and acquisition for equipment like beam instrumentation which needs intensive data processing using a specific equipment software.

The structure for equipment access by Equipment Modules (EM) remains unchanged. This software, formerly located in the Nord front end and in CAMAC embedded micros, is ported to the DSC processors. The EM and their control data (in local Data Tables) use the UNIX shared memory segment. The code of these programs will call a shared library where the equipment access routines are stored. The same interface library is reused by real time tasks mainly needed for the Pulse to Pulse Modulation (PPM) mechanism handled in the DSC processor.

A control protocol has been implemented on a large scale for equipment belonging to different families in the CPS control system [Ref.6]; these equipments are beam instrumentation (Beam transformer, Pickup, Q-Measurement, Wire Beam Scanner), power converters, RF systems, vacuum systems, control of mechanical movements [Ref.7]. This protocol is introduced between the Equipment Module Property codes (or the associated real time task) and the specific equipment software (either in the same DSC or in a remote ECA). The main advantages of the operational control protocol are to

define a clear separation of responsibilities between standard and specific software, to give the specialist the possibility to solve his specific problem in the most suitable way, and finally to facilitate and simplify the maintenance.

The detection of equipment alarms has been incorporated [Ref.3] into the equipment access software layer, through a uniform Equipment Module Property, which can return an alarm indication, for all classes of equipment.

The local interaction facilities are of two main types:

- i) a local terminal, connected to the processor of the VME crate with a RS232C line, used during debugging and testing. This line is also connected to an IP terminal concentrator for login and remote access,
- ii) a regional console, workstation or X-Terminal, directly connected to the regional LAN which can be seen as a local use of the services available in the control room and can be used as a local terminal with TELNET connection.

Timing and Pulse to Pulse Modulation (PPM) is renewed. It will use a common broadcast bus for the two types of information: coarse timing events (1 ms clock) and PPM telegram. This bus and the associated hardware and software are developed in close collaboration with the SL division, opening a way for a common Timing System for CERN accelerator control [Ref.10].

3. Experience gained

Since the beginning of the rejuvenation project in 1991, the original implementation schedule has been modified due to external constraints [Ref.8] like the introduction of new accelerators, suppression of physics programs and other managerial or technological changes. That means that the initial project schedule and budget covering 5 years need yearly modification or adaptation to fit these restraints. The schedule must be flexible because the implementation of a project in the computing environment cannot be successful if it planned for more than 5 to 6 years in advance.

Once decided, a step by step implementation needs a careful preparation which requires the full support of the division management to guide the specialist groups involved. The coordination of the requests of the machine operation crew, taking into account the possibilities of the control and service groups (budget and manpower), is also necessary. The

preparation includes a certain number of "Milestones" (2 or 3 during the last quarter of the year) which involve and motivate the staff, but also serve to discover faults which can then be corrected before final integration and test during the annual shut down. A step is declared completed when the operation crew uses the control system to startup the machines.

If the main part of the existing hardware interface (CAMAC loops, crates and modules) can be preserved without too many difficulties, it is absolutely necessary to introduce up to date operating systems, compliant with the rules of well accepted standards (POSIX). That is true also for the software development tools and the user interface tool kits (X-Windows, OSF Motif). To accommodate the technological evolution in software as well as in hardware, it is mandatory to use commercial products, to be able to profit from the updated versions that appear periodically (workstations, software tools, hardware modules, processors and operating systems).

The part of the network that handles the control of the accelerators is isolated from the public network by means of routers (CISCO boxes) to give the possibility to filter the control requests coming from processors in the offices (PC or development workstations), in the laboratories, from the development segment and also from the external world, known (e.g. interaction from home) or not. The control part of the network is divided both into a backbone which manages the central services, the control rooms workstations and servers and the common PS/SL on line Data Base, and into Ethernet sub LANs separated by bridges which are in charge of regional servers, workstations and DSCs, belonging to a machine or a complex of machines. This separation provides facilities for the diskless workstations and DSCs, keeps the load on the backbone acceptable and can maintain regional control alive in case of communication problems or shut downs (very important point for the commissioning of new machines). It has been proved that the architecture of the network is one of the most sensitive parameters for the reliability of the control system.

Personal involvement is needed, not only from the operation crew, but also from the maintenance team to get introduced into the complexities of the common control system. The exploitation must continuously adapt to this new system; the best solution was to integrate the different people of the team inside distinct parts of the development of the system. The console manager and the generic programs were also used to provide the team with

exploitation tools, with central, local, regional or remote accesses (e. g. from home). An on line documentation and fault logging are also available to direct and to help the team during their interventions.

4. Conclusion

The main aspect of the "Standard Model", another name for the Common CERN Accelerator Control System, is an architecture which permits continuous partial upgrading as technologies evolve. The main components of the Common Control System are based on open standards, so that the hardware and software become independent of the manufacturers. In the implementation of the CPS part of the Common Control System, we have preserved the existing hardware investment, and we keep the interdivisional collaboration alive during the step to step integration. The common convergence policy is based on well established industrial standards for control networks, communication protocols, equipment, operating systems and man-machine interfaces. As much software as possible is written independently of the development platform, leaving open the possibility of transferring application programs between the CERN accelerators, in case a unique control room is envisaged for the very different accelerators existing on the CERN site.

The collaboration with the specialist and operation groups of the CPS is a daily fact during the control system implementation, and it is maintained with the other CERN accelerator divisions as well as with European laboratories. The software (and hardware) sharing avoids duplication of efforts and the use of external expertise. The utilization of commercial products ("buy rather than develop") complements this exchange in a period where the lack of manpower and cuts in budget allocations necessitate a lot of imagination and a drastic increase in productivity.

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