EXPERIENCE IN THE EXPLOITATION OF A LARGE CONTROL SYSTEM

G.Daems, F.Perriollat, Ch.Serre
PS Division, CERN, CH-1211 Geneva 23, Switzerland

Abstract

Experience of a four-year exploitation of the large control system of the CERN PS accelerator complex is presented with special emphasis on the parameters which are very sensitive to the exploitation team productivity. The software tools suite used in this daily maintenance is described and a particular analysis of the power and benefits of the advanced software technology used for the architecture of this suite is explained. The integration of this suite into the control system is presented, as well as its use in the control system development phase. Some considerations of the potential benefit of an Object Oriented equipment access are outlined.

1. INTRODUCTION

The latest version of the CPS (CERN Proton Synchrotron) control system has now been in use for four years (1992- 5) on six of the nine accelerators forming the CPS complex **[Fig.1]**. The system **[Fig.2 & 3], [1]** is based on the “Standard” model with 3 levels: interaction, front-end computing and equipment control. An Ethernet network running TCP/IP links the user interface, the central services and the real-time equipment processing, while field-buses (CAMAC and 1553) interlink the equipment to the real-time equipment processing. The total number of items controlled is around 10000, not including the instrumentation.

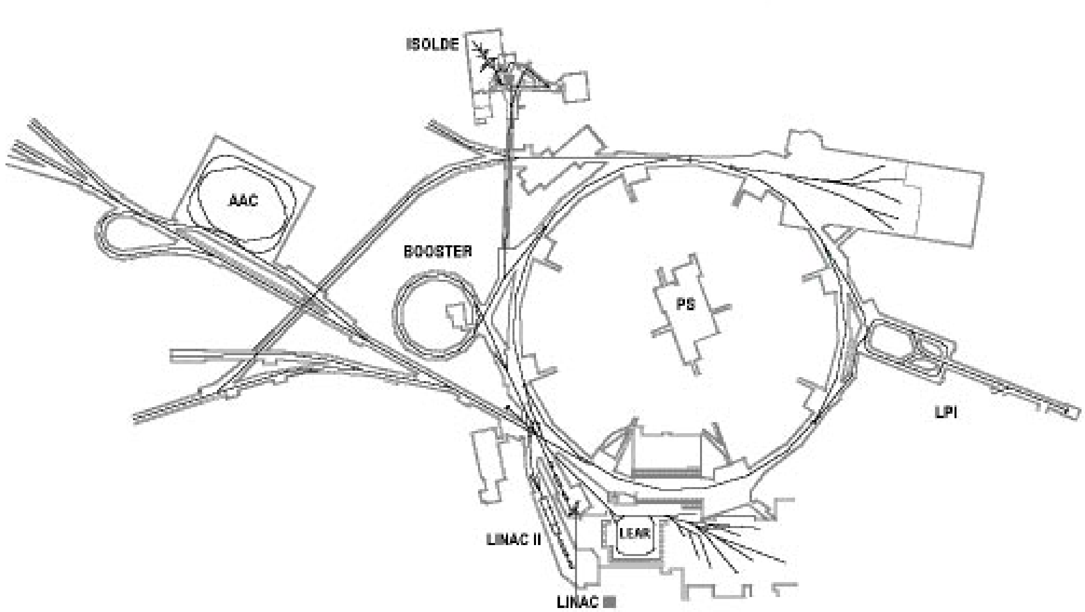

Fig. 1: Layout of the PS Complex

During these four years, the exploitation of the control system has been carried out in parallel with the old one to keep the complex in running order. By exploitation we mean the maintenance, problem solving and improvements to the control system. The people charged with this exploitation have had to adapt their knowledge and tools to the new system in which they also played an active part during its development.

The experience gained in the exploitation of such a large control system is presented, with a special emphasis on the integration and the expected benefits of modern software technologies such as the Object Oriented Programming and Development and the Knowledge Based Techniques.

2. WHAT THE CPS CONTROL SYSTEM EXPLOITATION INVOLVES

2.1 The environment

The CPS Accelerator Complex operation runs round the clock, 24 hours a day, ten months a year, with two short intermediate stops of 2 to 3 days. This means that new installations, modifications and maintenance are not easy. Nevertheless, because the CPS complex is the source of all the particles beams at CERN, its operation evolves continuously. There are several machine development periods interlaced with the normal running of the machines which result in constant modifications and updates to the control system and may require software changes in the operational environment. In addition two points should be noted; the software developers often are only transitory people such as fellows or students, with all the follow-up problems and the exploitation team have to deal with a historical inheritance, translated into a great diversity of interfaces and equipments, some of them only partially renovated due to budget constraints.

The CPS operation requires frequent daily operational changes, for example for antiproton transfers. The present staff policy results in a continuous rotation of operators with short-term contracts which leads to less experienced staff. As the operation of the machines is seen by the operators through a thick control layer, it is necessary for controls people to have some knowledge of how to operate in order to be able to help the operation crew in its daily job. This sometimes allows the exploitation people to identify as operation faults, things that were initially reported as control faults.

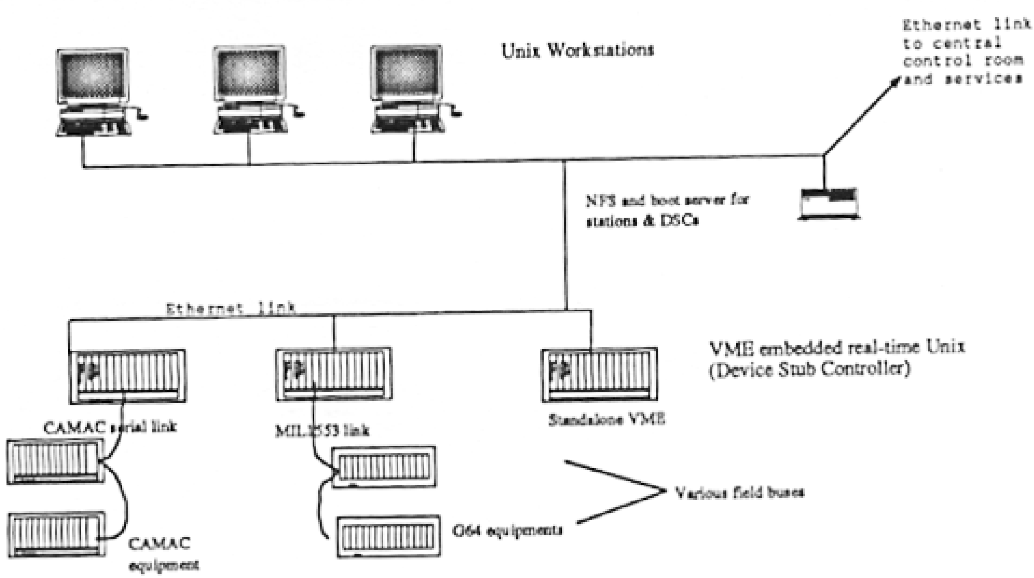

Fig. 2: The standard architecture applied to the CPS complex

2.2 On-line and Off-Line exploitation

The control system exploitation is divided in two types of work, the on-line exploitation, which is the immediate answer to faults or wrong conditions in the control system elements (hardware or software) and the off-line exploitation, which can also be called the follow-up and the solving of problems encountered during the operation of the machines.

The on-line exploitation is the field of a small and well experienced team which take charge of all problems and bad behaviour labelled by the operators as “control faults”. People of this team trace the faults, analyze and correct the faulty control elements (hardware side), check and restart the faulty software components and finally support the operation team to recover and return to the required operational state.

The off-line exploitation involves practically all the people of the Controls Group in order to improve the reliability and the robustness of the control system (hardware as well as software). A regular weekly exploitation meeting enforces a strict follow-up of the different problems and changes. Agreed upgrades, extensions or enhancements are mainly coordinated by the exploitation team. It also proposes and develops the necessary diagnosis and exploitation tools.

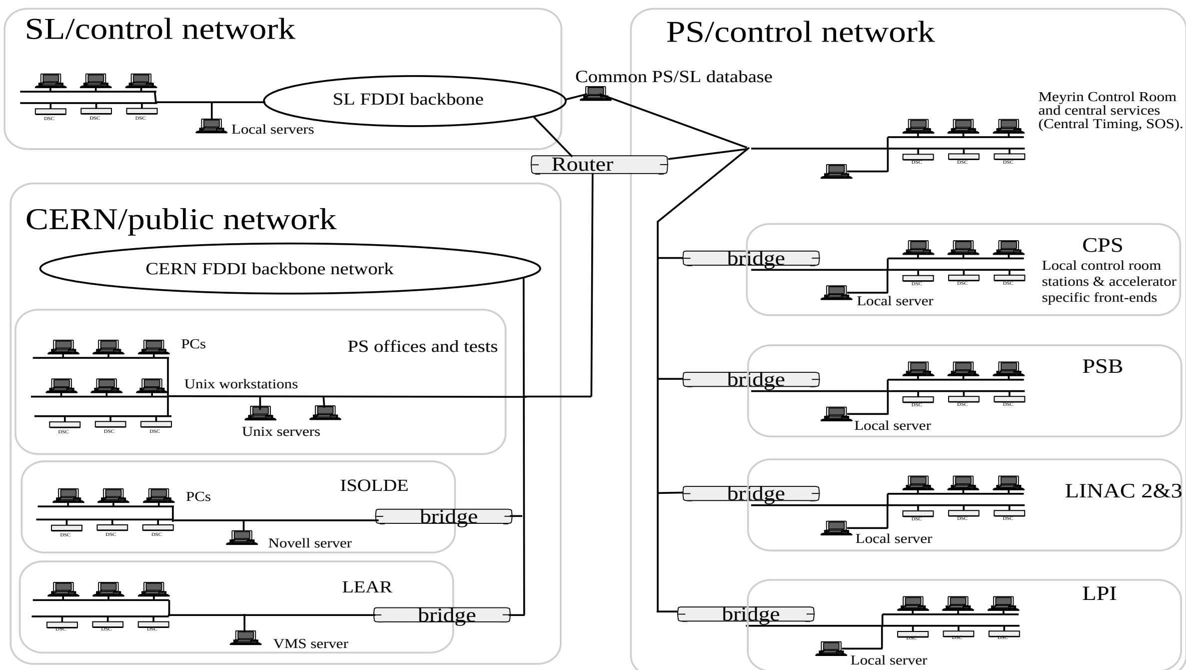

Fig. 3: The CPS Network

2.3 The Exploitation Team ?

The exploitation team is a small team with good experience, an overview of the system and general purpose knowledge and its first priority is to keep the control system. running correctly, whatever the time and the work required. A "piquet" service (5 persons) is in charge of the on-line services; one person is assigned for one week (24 hours a day) to answer as fast as possible the calls from the operation crew if there is any breakdown of the control system components.

This exploitation team provides a single entry point (on-line and off-line) for all the requests concerning the problems, improvements and modifications to the running control system, which enforces directly the homogeneity of the hardware/software solutions. The persons of this team are attached to the other sections of the control group to develop diagnosis and exploitation tools. This is mainly software for interface and equipment access and for the overall survey system.

3. EXPLOITATION TOOLS

The performance of this team depends on the continuous education of the persons, the documentation of the hardware and software components of the control system, the communication between the developers and the members of this team, but also on the tools provided to this team to be able to diagnose, recover, restart and/or set up the components of the control system. Data logging of the element values, easy-to-use links with the data base (ORACLE), automatic configuration of front-end processor devices from the data base, tracing and log of faults with post mortem analysis capabilities **[2]**, testing and setup facilities are the main tools needed by the members of the exploitation team to fulfil correctly their first priority job.

The status of the different controlled elements of the CPS complex are permanently monitored on the screens of the Control Room workstations, in a window generated by the Alarm process **[3]**. This program, used by both the operation and exploitation crews, scans the status of the controlled equipments every 30 seconds, via the uniform equipment access level (Equipment Modules **[4]**). In addition, it surveys the VME and CAMAC crates, both for overall hardware and software status.

This Alarm process is the main entry point for diagnosis tools and information. It allows the presentation of :
- the details of faulty equipments
- the layout of input/output crates (VME and CAMAC), the modules in the crates and the equipments controlled
- the front-end processor status : accessibility, interrupts and errors
- the fault log, the pulsed status and the interrupt layout of the timing system elements.

From this information one can reset a faulty equipment (such as a power supply, a vacuum pump, or a RF cavity) or detect a fault at the element level. A front-end processor not accessible though the control system can be remotely rebooted after verification of its status. The history of the reboots and the errors are logged and can be displayed on request.

Most of the exploitation tools can be called through this Alarm process, either directly or through two important general programs :

The first program, **Equipment Info,** gives the possibility of selecting dedicated programs to diagnose, test and initialize an equipment or a control interface; this is especially the case for the different instrumentation and field-buses (CAMAC and 1553). One can also test a particular equipment access and initialize it if necessary. Special debug or repair commands, documentation concerning the Equipment Module and the layout of subsystems (timing systems for example) are also available from this general panel of services. From an other special panel, an equipment can be accessed through the Equipment Module either by its name or its number or its address. The selected equipment can be tested or controlled up to the last bit.

The second program, **Setup,** is created to reinitialize automatically an equipment or a whole system (a CAMAC crate for example). It is a very important and general purpose tool which is described below.

A few other important tools exist, which can be called for a specific purpose. These are:
- for the verification of the description and synchronization of the different operations of the CPS accelerator complex, where a rule-based consultant can be called to verify if the required schedule is acceptable. This is the Beam Card Desk Checker **[5]**
- for the automatic configuration of the software of the front-end processors directly from the data kept in the ORACLE data base **[Ref.6]**
- for the Data Browser/Editor which gives the possibility to read, compare and modify the operational values stored in the data table of the equipment access modules (Equipment Module); with this tool, the exploitation team can work on the actual operational data, the regularly-saved values and the values called references.

4. SETUP : KNOWLEDGE-BASED TECHNOLOGY

The development of the Setup program is based on an Object Oriented programming, together with a procedural knowledge representation **[7]**. Setup provides the means of initialization and of non-destructive testing for the accelerator equipment based on CAMAC and VME control interfaces. It is a rule-based process which can cope with any unknown initial state of the equipment.

4.1 Utilization

This Setup program is used both by the exploitation and the operation Teams. The primary uses are after a power failure, a shutdown or the replacement of a faulty hardware module or crate; Setup allows one to initialize the hardware with the correct procedures and the correct operational values (last saved values). Setup is also used to reset a faulty equipment (power supply for example) to come back to the normal state. When an instrumentation gives wrong information or does not run correctly, the best solution is to call Setup. Finally Setup can also test an equipment without disturbing or with the minimum disturbance of its normal functioning.

4.2 Main points and Realization [7 ,8]

The Setup system can easily be adapted to the control system environment. It is flexible and evolutive and adapted to a huge variety of hardware/software modules, including the treatment of hardware-coupled equipments. The description authorizes different sets of objects, so that the Setup actions can be process- or hardware-oriented. The access to the control system elements is made using the uniform equipment access method (Equipment Modules).

During the running of the program, the user is informed about the current state of the equipment and about the diagnosis of the procedure in real-time; if an action is not successful, the diagnosis of the faults is given. Post mortem analysis exists for the Setup protocols that have taken place during the test or the reset of an equipment or a process.

The realization of the program is based on the development of an object model which reflects the structure of the Control system equipment access: front-end processor, CAMAC loop, CAMAC crate, CAMAC module and Equipment. The knowledge-based representation gives the description of object classes, control rules and operation algorithms. The concrete object lists are automatically ***"instanciated"*** from the Real-Time Data Base. The realization of the Setup program is based on an expert system shell (PROSC: Procedural Reasoning Object System for Control) which allows object oriented knowledge description, procedural reasoning techniques, real-time features and direct queries to the ORACLE data base.

4.3 Benefits for the exploitation of the control system

The user interface of Setup is done through X-windows/Motif panels which are called by the Alarms process, the exploitation programs or the hardware surveillance at the level of the faulty object. The Setup facility is also accessible from terminals using a certain number of commands (for tele-diagnosis capability).

As stated in the previous paragraph, the Setup rules and algorithms are easy to describe and to change for the different classes of the control system. This results in a well-adapted, up-to-date and reliable tool that executes the necessary actions demanded by the operator, taking into account real-time events and hardware-coupled equipment, which are otherwise invisible on the interaction level.

The automatic generation of the concrete object lists related to a ***"super"*** object to initialize is one of the essential benefits of this setup. The Setup software executes automatically all necessary actions, either when one has to replace one hardware module or to initialize one equipment or a whole CAMAC loop. The setup can be called either from a hardware description layout or from a software equipment level. The Setup operates today on:

- 100 Front end processor VME crates (DSC)
- 130 CAMAC crates
- 3000 equipments
- with more than 100 object classes and 200 control procedures.

It is a necessary and powerful tool for the daily operation of the six machines of the CPS complex controlled by an example of the standard model of control system for accelerators. The technology in use and the integration in the control system provide the capability to evolve with the system without difficulty.

5. CONSIDERATIONS ON OBJECT ORIENTED TECHNOLOGY WITH BENEFITS FOR THE EXPLOITATION

The equipment access software structure of the CPS control system has been Object Oriented since 1988 **[4]**. The previously realized Equipment Module model has proved to be very useful for the exploitation and developers because it is a standard generic facility which gives access to all the process equipment on a standard way and allows the use of powerful and generic tools.

We already found that Object Oriented Techniques facilitate the tasks of the exploitation Team by providing:

- easier maintenance of software programs (produced by temporary or external people)
- faster and safer modifications of the software products

- easy integration of jobs developed outside the site (to benefit from external expertise)
- good integration with an ORACLE Data Base description
- independence of the control system architecture, to be able to follow the technological evolution of the different control system components.

The fields in which we are less confident, due to our short experience, are on the benefits to be gained from object languages. Especially, we have some doubts on:
- the amount of time necessary for a large community of software developers to be fluent in C++ and in the object oriented technology environment
- the difficulty to define and setup the object libraries for the different usage
- the complications in building a coherent set of abstract object models for the various control process provided
- the facility for the casual software developers to use efficiently the object oriented development tools to increase substantially their productivity
- the impact of Object Oriented Databases and their level of standardization
- and, last but not least, the stability of the emerging standardization, especially on standard C++ and the basic object library (both on real-time applications and on object broker technology in a distributed environment)

All these points can have a direct impact both on the long term exploitation (and re-use) of the huge amount of control software, and on the easy integration of third party components.

6. CONCLUSION

One of the main tools used by the exploitation team on the large CPS control system is the Alarms process, which acts both as a surveillance program running continuously on the operational work stations and as a switchboard giving the possibility of calling the other exploitation tools described in this paper.

The other important tool is Setup, which uses the object oriented and the knowledge based technologies to offer a basis for the test, setting up and initialization of the different control system elements, both individually at the equipment level and at the subprocess level. These technologies could be used for other applications such as the timing survey, synchronization generation and the interpretation of complex results. These technologies have shown their capability in solving specific problems and they are able to be integrated in a classical system in a very cost effective way.

Our long experience in use of the Object Oriented Technology gives us full confidence in the future benefits of large scale implementation. However, to be in a position to carry out efficiently the large scale integration of this type of software, we believe that more time is needed and that wider open collaboration and exchange of experience is essential. These points should receive the full support of the management of the major projects in our field of activity.

7. ACKNOWLEDGMENTS

We give special thanks to the members of the exploitation team whose efforts kept the control system running with a high level of availability (< 1% of machine down-time had been due to control problems). We are also grateful to the Control Group members who continuously try to provide excellent exploitation tools using the most suitable and efficient software technologies.

REFERENCES:

[1] F.Perriollat, Ch.Serre, “The new CERN PS control system, Overview and status”, ICALEPCS, Berlin, Germany, October 18-23, 1993, Nucl. Instr. And Meth. A352 (1994) 86.

[2] M.Beharrell, G.Benincasa, J-M.Bouche, J.Cuperus, M.Lelaizant, L.Merard, “Model based, detailed fault analysis in the CERN PS Complex equipment”, ICALEPCS 95, in these Proceedings.

[3] J-M.Bouche, J.Cuperus, M.Lelaizant, “The data driven alarm system for the CERN PS accelerator complex”, ICALEPCS, Berlin, Germany, October 18-23, 1993, Nucl. Instr. And Meth. A352 (1994) 196
J-M.Bouche, “Utilisation du programme Alarm”, 6.03.95, PS/CO/Internal Note 95-17.

[4] L.Casalegno, J.Cuperus, Cl-H.Sicard, “Process equipment data organization in CERN PS controls”, ICALEPCS, Vancouver, Canada, October 30-November 3, 1989, Nucl. Instr. And Meth. A293 (1990) 412.

[5] J.Lewis, P.Skarek, L.Varga, “A rule-based consultant for accelerator beam scheduling used in the CERN PS complex”, ICALEPCS’ 95, in these Proceedings.

[6] J.Cuperus, A.Gagnaire, “Automatic Generation of Configuration files for a distributed Control system”, ICALEPCS 95, in these Proceedings.

[7] J-M.Bouche, G.Daems, V.Filimonov, V.Khomoutnikov, F.Perriollat, Yu.Ryabov, “Representation and Usage of knowledge for Initialization of accelerator control equipment”, presented to RT-95, East Lansing, MI USA, May 23-26, 1995.
J-M.Bouche, G.Daems, V.Filimonov, V.Khomoutnikov, Yu.Ryabov, “Knowledge based Setup facility”, 22.11.94, PS/CO/Internal Note 94-81.

[8] G.Daems, V.Filimonov, V.Khomoutnikov, F.Perriollat, Yu.Ryabov, P.Skarek “A knowledge based control method : application to accelerator equipment Setup”, ICALEPCS, Berlin, Germany, October 18-23, 1993, Nucl. Instr. And Meth. A352 (1994) 325.