EXPERIENCE IN THE EXPLOITATION OF A LARGE CONTROL SYSTEM

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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 advance software technology used for the architecture of this suite is explained. The integration of this suite in 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 CPS (CERN Proton Synchrotron) Control system is now in use since four years (92-95) on 6 of the 9 accelerators of the CPS complex [Fig.1]. The system [Fig.2 & 3], [Ref.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, central services and real time equipment processing, while field buses (CAMAC and 1553) interlink the Equipment to the real time equipment processing. The total number of controlled equipment is around 10000, not including the instrumentation.

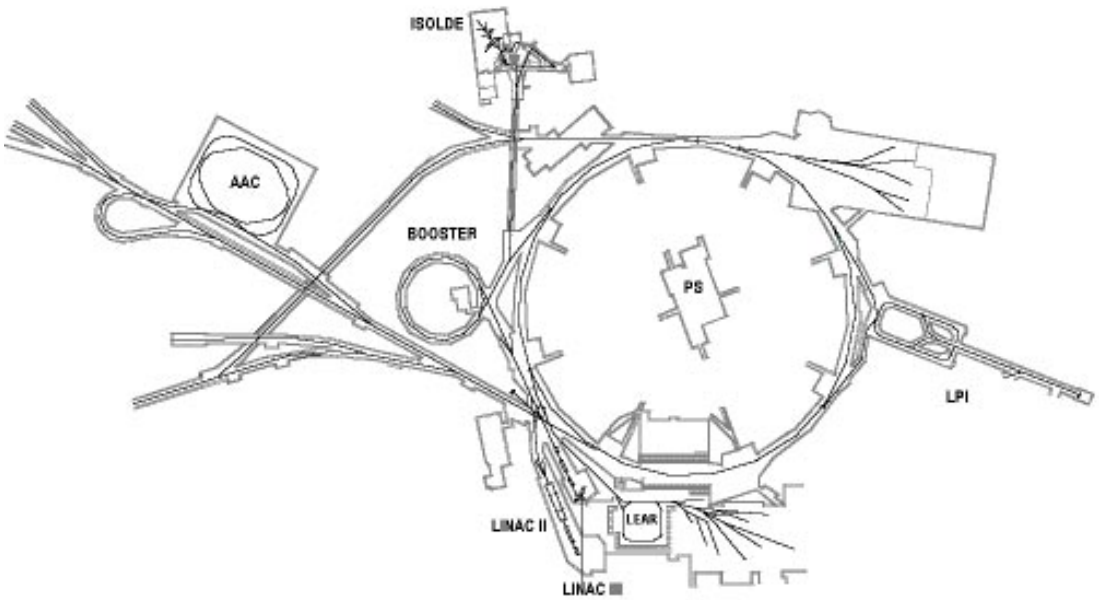

Fig. 1: Layout of the PS Complex

During these four years, the exploitation of the Control system has been done in parallel with the old one to keep the complex in running order. People in charge with this exploitation have had to adapt their knowledge and tools to the new constraints, and they were also active developers of the new system.

The experience and organization in the exploitation of such a large control system will be presented, from the actual environment to the tools used, with a special emphasis on the integration and the expected benefits of modern software technologies like the Object Oriented Programming and Development and the Knowledge Based Techniques.

2. WHAT REPRESENT THE CPS CONTROL SYSTEM EXPLOITATION ?

2.1 In what environment ?

The CPS Accelerator Complex operation runs around the clock, 24 hours a day, ten months a year, with two short intermediate stops (2 to 3 days); that means that new installation, modification and maintenance are not easy. Nevertheless, because the CPS complex is the source of all the particles beams at CERN, its operation evolves continuously, without speaking of the several Machine Developments interlaced with the normal running of the machines; this imposes constant modifications and updates to the Control system and ***conducts*** to software changes in the running operational environment. In addition two points must be noted, the software developers often are only passing people like fellows or students, with all the follow-up problems and the Exploitation is confronted with an historical inheritance, translated into a great diversity of interfaces and equipments, some of them only partially renovated due to budget constraints.

Moreover the CPS operation requires frequent daily operational changes, for example for pBar transfers. The actual staff policy induces a continuous rotation of operators with short-term contract which leads to less experienced staff. As the operation of the machines is seen by the operators through a thick control layer, the control system is a very sensitive tool and obliges control people to know partially how to operate in order to be able to help the operation crew in its daily job. That situation induces the exploitation people to identify operation faults, initially reported as control faults.

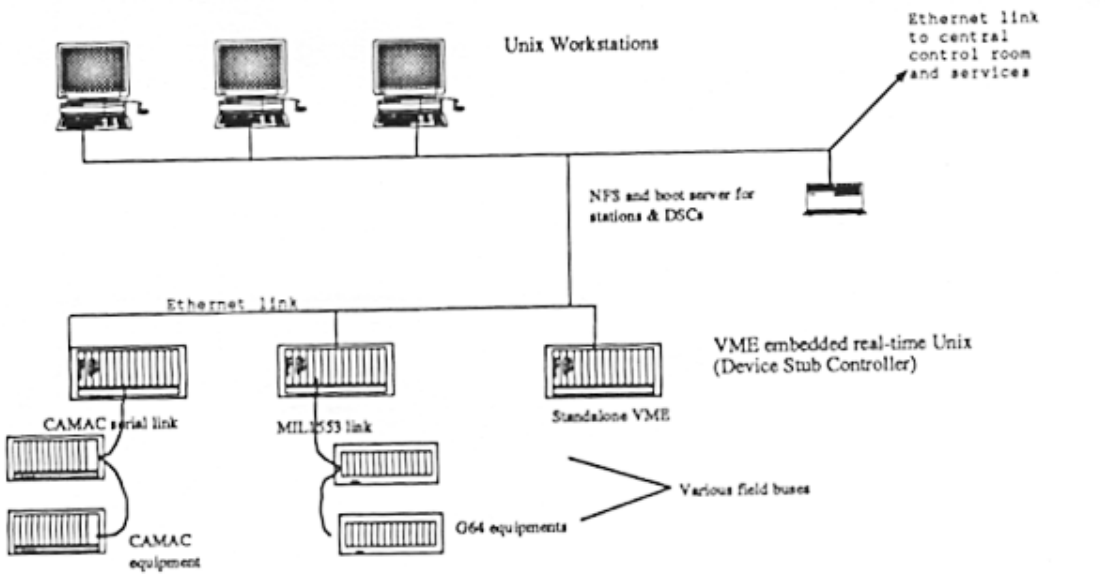

Fig. 2: The standard architecture applied to the CPS complex

2.2 On-line and Off-Line exploitation

The control system exploitation is divided in two types of works, the on-line exploitation, which is the immediate answers to faults or wrong conditions in the control system elements (hardware or software), and the

off-line exploitation, which can be called also 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 in charge all problems and bad behaviours 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 components, and finally support the operation team to recover and find back the right operational state.

The off-line exploitation implies 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.

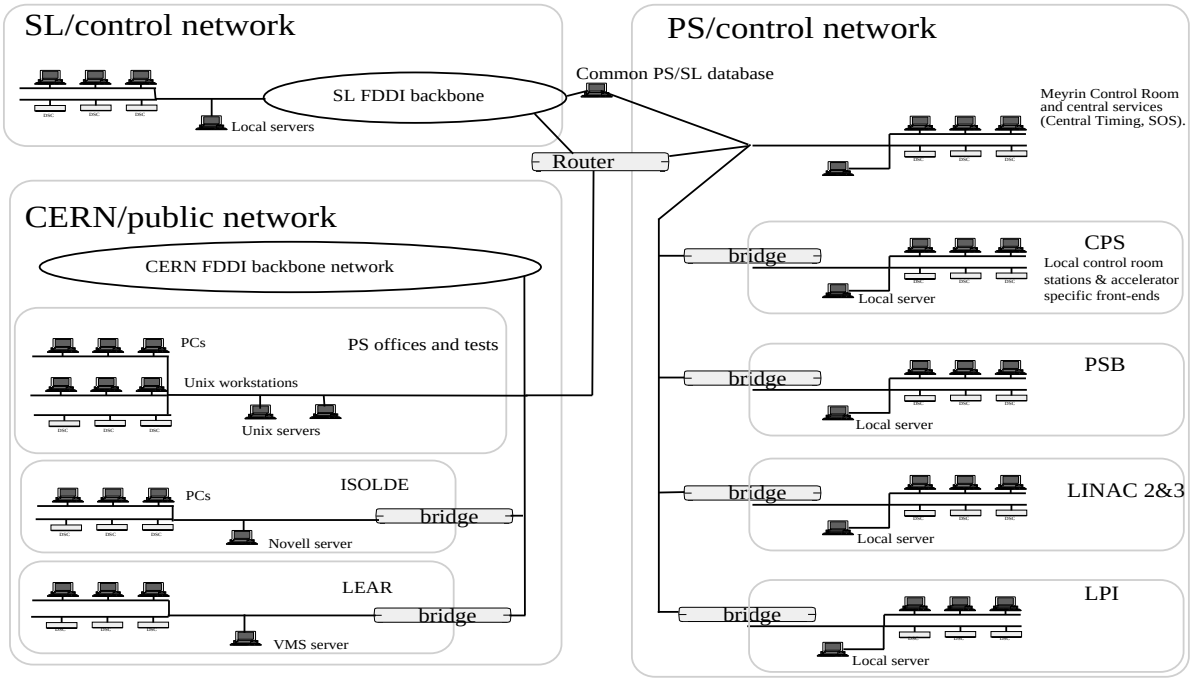

Fig. 3: The CPS Network

2.3 What is the Exploitation Team ?

The exploitation team is a small team with good experience, overview and general purpose knowledge; it has as first priority job, whatever the time and the work to keep a correct running of the control system. 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 on the possible breakdowns of control system components.

This exploitation team represents the unique single entry point (on-line and off-line) for all the requests concerning the problems, improvements, modifications on the running control system, which enforces directly the homogeneity of 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 acces, and for overall survey system.

3. EXPLOITATION TOOLS

The performance of this team depends on the continuous formation 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 Setup the components of the control system. Data logging of the element values, easy links with the data base (ORACLE), automatic configuration of Front end processors devices (from the data base), tracing and log of faults with post mortem analysis capabilities [Ref.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 work stations, in a window generated by the Alarm process [Ref.3]. This program, used both by operation and exploitation crews, scans every 30 seconds the status of the controlled equipments via the uniform equipment access level (Equipment Modules [Ref.4]). In addition, it surveys also the VME and CAMAC crates, both for overall hardware and software status.

This Alarm process is the main entry point for diagnosis tools and informations. It allows the presentation of :
- the details of faulty equipments
- the layout of input/output crates (VME and CAMAC): modules of the crate, equipments controlled
- the Front End Processor status : accessibility, interrupts and errors
- the log of the faults, the pulsed status and the interrupt layout of the timing system elements.

From these informations one can reset a faulty equipment (like a power supply, a vacuum pump, a RF cavity, ...) or detect a fault at the element level. A front end processor not accessible by 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.

Mainly all the Exploitation tools can be called through this Alarm process, either directly or through two important programs :

The general program, **Equipment Info,** gives the possibility to select dedicated programs to diagnose, test, 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 general program, the **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 worth a chapter due to the used technology (see chapter 4).

A few other important tools exist, which can be called for a specific purpose. That is the case :
- 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, the Beam Card Desk Checker [Ref.5]
- for the automatic configuration of the software of 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 [Ref.7]. The Setup provides 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 Exploitation and Operation Teams. The primary uses are after a power fail, a shutdown or a replacement of a faulty hardware module or crate; the Setup allows to initialize the hardware with the correct procedures and the correct operational values (last saved values). The Setup is used also 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 the Setup. Finally the Setup can also test an equipment without disturbing or with the minimum disturbance of its normal functioning.

4.2 Main points and Realization [Ref.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 done 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 occurred 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 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 ORACLE data base.

4.3 Benefits for the exploitation of the Control system

The user interface of the Setup is done through X window/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 the operator demands for, 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 6 machines of the CPS complex actually controlled by 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 is Object Oriented since 1988 [Ref.4]. The already realized Equipment Module model has proved to be very useful for the Exploitation and developers because it is a standard generic facility which gives the visibility of all the process equipment on a standard way and allows the use of powerful and generic tools.

So, we already experienced that Object Oriented Techniques facilitate the tasks of the Exploitation Team for :
- 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 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++ language and in Object Oriented Technologies environment
- the difficulty to define and setup the object libraries for the different usage
- the complications to build 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 Data Base and their level of standardization
- and, last but not least, the stability of emerging standardization, especially on standard C++ and basic object library (both on real time applications and on object broker technology in distributed environment)

All these points, concerning mainly the software developers, 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 tool 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 to call the other exploitation tools described in this paper.

The other important tool is the 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 like the timing survey, synchronization generation, complex results interpretation. These technologies have shown their capability to solve specific problems; with a moderated ambition, 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. But, to be quickly in an efficient position for the large scale integration of this type of software, we believe that more time is needed and that wide size open collaboration and exchange of experience is requested. These points must 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 due to Control problems). We are also grateful to the Control Group members who continuously try to provide excellent exploitation tools using the best suitable and efficient software technologies.

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