CONTROLS

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Abstract

The demands that safe and efficient operations will have of the control system will be considerable. A summary of the perceived requirements that LHC Operations has of the control system are presented as a description of work-in-progress in the fields of software infrastructure and real time control. Some important conclusions from the recent forum of LHC Controls and Operation are highlighted.

1 INTRODUCTION

The SL Controls Group has been active in the past two years trying to understand how the new challenges of controlling the LHC can be met within the current controls framework at CERN. In certain areas the introduction of new techniques seems essential and various standards and commercial solutions have been evaluated. Where possible these studies have also involved the PS Controls Group, PS-CO, with a view to identifying common solutions for all the CERN accelerators.

2 HIGH LEVEL CHALLENGES

2.1 Real Time Control

At the LHC Workshop on Dynamic Effects and their Control [1] the knowledge of the dynamic behaviour of LHC magnets and the required control of field errors required to meet the beam dynamics tolerances were reviewed. The certainties with which the mutipole field content of the dipole magnets can be predicted during injection and start of acceleration are limited by understanding of persistent current decay and snap-back. The workshop recommended that "Although it is not clear today which parameters require or eventually will use on-line control, *it is recommended that the machine is prepared to accept slow feedback as far as the control, power converter and RF systems are concerned*. Best estimates suggest a rate of up to a few Hz, but this will depend, for instance, on the exact magnet ramping speed. Likewise field and beam instrumentation should be suitable for inclusion in such a feedback scheme."

This request implies the flexibility to establish feedback channels between a high proportion of the beam and field monitors and active beam components around the accelerator. These channels must support deterministic communication and treatment of the data. The overall functionality of the system must not be compromised when new applications are required. This is a new challenge for accelerator control at CERN.

2.2 Integration of Technical Controls

It is anticipated that the tight coupling between beam operation and complex technical procedures will complicate the regular operation of the LHC Accelerator. Operation's teams may face about 3 magnet quenches / week followed by a 3 - 8 hour recovery period [2], about 10% of the scheduled beam time. Federation and management of data from the cryostat and beam monitoring systems will be necessary to improve the understanding of quenches. The technical systems may involve actors in several control rooms. They will be controlled with hardware and software solutions provided by industry. Practices are evolving rapidly using SCADA, Web and Windows tools. As an example the cryogenic control system is already being procured.

2.3 Application Software

At the Controls and Operations (COOP) Forum[1], held at CERN 1-2 December 1999, it was concluded that application software needs to be "rigid but flexible". While there were statements that operational procedures must be rigorous, nevertheless there will doubtless be a steep learning curve during commissioning requiring the flexibility to improve the procedures in a controlled manner. Instrumentation and controls will be the keys to increasing the understanding of machine behaviour and operation. Later, to reach nominal and peak performances, well founded high-level application software will be required to set beam control parameters to the necessary tolerances.

An important asset for attaining these goals will be a suitable control system infrastructure so that application software development can be focused on the physics and operational issues. This software must be well aimed - taking account of the experience of other laboratories and at CERN.

3 LESSONS FROM LEP

Control System Engineers and Engineers in Charge may hold rather varying opinions about the success of

[1] http://nicewww.cern.ch/LHCP/TCC/PLANNING/TCC/Forum99/Forum.htm

the LEP Control System. On the positive side the machine was commissioned and delivered physics results within record time [3]. Certain basic choices in the system have stood the test of time: TCP/IP, UNIX, usage of fieldbus as well as the basic architecture which has been dubbed “the standard model” [4]. Nevertheless a more critical judgement might point out the fragmentation of the high level applications, perhaps resulting from specifications being generated by a wide range of component and machine specialists. There is also a perception of slowness expressed by the operators which is difficult to explain in terms of the equipment and architectural decisions made by the Controls Group!

For the LHC it is recommended that architectural choices and high level software design are driven, where possible, by the capture and analysis of the operational requirements. This approach[2] was outlined during the COOP Forum.

4 WORK IN PROGRESS

In the following sections certain key developments taking place with the participation of the SL Controls Group are described. For each a brief description is given, followed by the current status of the work and the intentions for the coming year.

4.1 Java API

It is anticipated that Java will become an increasingly important language for application software. The SL Controls Group is preparing to introduce support for Java applications in collaboration with PS-CO. The Java API[3] will provide a common accelerator device model for equipment access for the CERN accelerator chain. In the device model accelerator components are grouped in classes which have properties. For example the “power converter” class with the property “current”.

The Java API implements the setting and reading of properties for the application software as indicated in Figure 1.

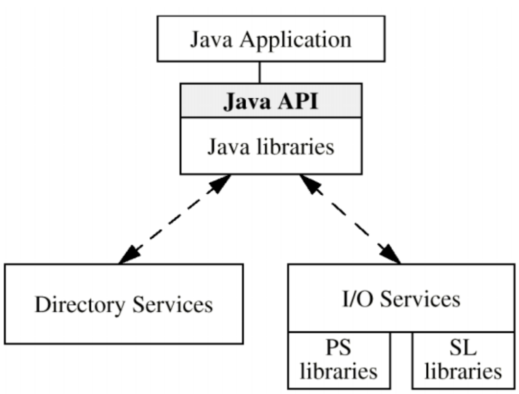

Figure 1: The Java API

[2] http://nicewww.cern.ch/LHCP/TCC/PLANNING/TCC/Forum99/transpos/MVE3_3.pdf
[3] http://hpslweb.cern.ch/pssl/

These devices may, as in the example, be physical or virtual - this allows more powerful device/properties such as Ring_1/Tune. The Java API has been implemented by TJNAF, the directory service by PS-CO. The SUN RPC package connect to SL_EQUIP at SL while CORBA connects to PS_EQP at PS.

While the initial goals of this work have been met it remains to connect the API to the future accelerator Middleware. This will overcome the limited subscription service and replace the CERN RPC with standard or commercial software. The specification of this API is still being discussed and certain aspects - transfer of structured data, the timing interface, may be revisited.

4.2 Middleware

Middleware is a “software bus” for distributed applications. Just as a hardware bus connects specific hardware modules to common services the Middleware allows application software to communicate with various services using defined interfaces. Modern Middleware goes beyond the “Client-Service” model. It allows interaction with the service abstractions offered by objects distributed across a networked system. Middleware is frequently employed to integrate exotic systems such as legacy databases. For the LHC it may be the key to achieve close integration of CERN controls and industrial systems.

The field is very dynamic and difficult to embrace. A Middleware Project was launched, in collaboration with PS-CO, at the end of 1998 and considerable effort has been invested into understanding these technologies and the CERN requirements [5]. A White Paper [6] is in final preparation, the top priority is to provide support for the Java API. The first operational version of the Middleware is planned before the end of 2000.

4.3 Distributed Real Time Control

A real time system may be defined as a computing / communication system for which the correctness of the calculations / transmissions not only depends on the logical behaviour of the system but also on the instant at which the result is produced.[4] In order to meet the beam feedback requirements for the LHC hard real time computing and communication services, distributed around the machine, are being prepared. A solution, based on today’s technology, has been proposed [7], see figure 2. This is based on ATM[5], WorldFIP[6] and LynxOS[7] and can meet the requirements as known in Autumn 1999. A real time demonstrator has been set up and is being used to investigate solutions for global

[4] http://nicewww.cern.ch/LHCP/TCC/PLANNING/TCC/Forum99/transpos/pr3_8.pdf
[5] http://www.atmforum.com/
[6] http://www.worldfip.org
[7] http://www.lynx.com

beam control with monitors and active elements distributed around the machine and a central server for correction algorithms.

Topics that should be pursued in 2000 cover three areas. Networking: it is hoped to complete prototyping activities with ATM and to evaluate the use of other technologies in this layer. An ATM mesh is being installed at the SPS and could be a candidate for the first applications. Concerning systems a decision on the bus standard for the beam position monitors and beam loss monitors must be taken this year and a better analysis of the LynxOS/PowerPC environment is needed. Finally it is expected to validate the date distribution over the WorldFIP from a GPS reference and to supply a stable WorldFIP driver in LynxOS for the String 2 operation.

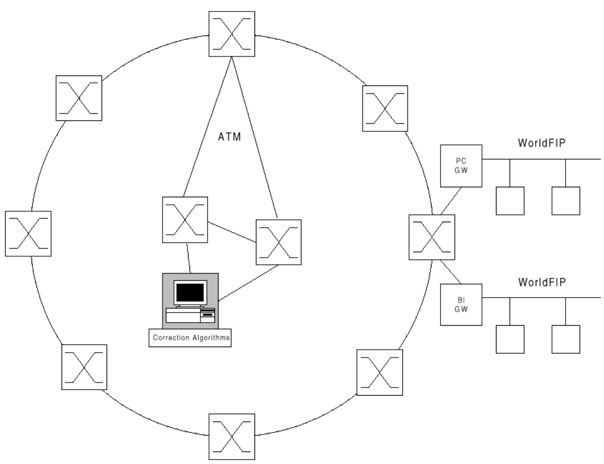

Figure 2: Proposed Real Time Control Topology

5 WHAT CAME OUT OF THE COOP FORUM?

This cannot be an attempt to collect all the information relevant to LHC Control that was presented. Instead the most significant topics are briefly reviewed.

5.1 Dynamic Effects

Field and multipole errors during persistent current decay and snap-back cannot be predicted with sufficient accuracy to respect beam parameter tolerances. Nevertheless empirical models are improving and can remove some 80% of the uncertainty. While real time control techniques will be required to reach the peak performances, cycling procedures, construction data and feed forward will be required from initial commissioning.

Updated information on the data traffic generated by the major beam instrumentation systems was also presented. This data may be used in feedback systems.

5.2 Operational Tuning

Machine tuning in the absence of any aperture margin will lead to dangerous loss of beam. An adequate and rugged collimation scheme is essential. Use of the control system to protect systems would require special solutions requiring techniques and resources that are not being considered within the context of the current efforts on LHC Control. Neither can a general purpose control system provide special solutions to ensure the correct operation of sensitive equipment!

5.3 “Slow Controls”

LEP operators’ perception of slowness of the control system has not changed since the early years of operation. In the meantime the control system infrastructure has witnessed orders of magnitude improvement in performance.

Tuning the collisions for LHC physics will require an optimisation of a large number of parameters, intensity, life-time, emittance, orbit, and luminosity information for all the 2835 bunches is of interest.

The proposed approach to these issues is to consider architectural issues after a careful analysis of the associated control room activities.

5.4 Data Management

Explicit requests are being made concerning the federation and archival of data from diverse systems. At the Forum data sources mentioned included cryostat instrumentation, beam instrumentation and the magnet references. There are certainly others: information for the INB, alarm information.

5.5 Operation without Beam

Talks were given highlighting the complex interaction of the LHC technical systems before beam can be injected or after a quench. A study of the operational procedures for recovering after the quench of a dipole magnet revealed that implications for the interfaces between these systems has not been studied despite the advanced developments of certain systems.

5.6 Reports from the Working Groups

A list of 13 working groups tackling controls issues was presented at the Forum. Reports were heard on Dynamic Effects, Communications, Timing and Power Converter control. Other work was reported indirectly. Timing has close links with machine performance and operation. That working group were able to demonstrate a detailed catalogue of low-level signals required by systems around the accelerator but as yet no high level timing model has emerged.

6 CONCLUSIONS

Studies aimed at upgrading the Controls Infrastructure available at CERN are progressing well. These are aimed at meeting new challenges for the operation of the LHC accelerator. Real time requirements are being clarified and appropriate commercial technologies to are being evaluated. The software infrastructure for the development of high level applications is being updated. This is driven by the need to integrate the industrial control systems for the LHC technical services and to meet the challenge of providing rigid but flexible high level applications.

REFERENCES

[1] P. Proudlock, "Summary of the LHC Workshop on Dynamic Effects and their Control", LHC Project Report 99, March 1997.

[2] P. Cruikshank, P. Proudlock, G. Riddone, R. Saban, R. Schmidt, "General Parameters for Equipment installed in the LHC", LHC-PM-ES-0002.00 rev.1.1, April 1999.

[3] S. Myers, "The Performance of LEP and Future Developments", 2nd EPAC, pg 13, Nice 1990

[4] M.C.Crowley-Milling, W. Busse, Preface to the Proceedings, 3rd ICALEPCS, Berlin 1993

[5] V. Bagiolinni et al., "PS/SL Middleware Project - User Requirements Document", SL-Note-99-016 CO, 1999

[6] V. Bagiolinni et al., "The Technology and Techniques for the PS/SL Middleware", SL-Note-2000-008 CO, January 2000.

[7] R. Lauckner, R. Rausch, P. Ribeiro, T. Wijnands, "A Large Flexible Real Time Communications Topology for the LHC Accelerator", 11th IEEE-NPSS Real Time Conference, Santa Fe, New Mexico USA, 14-18 June 1999