THE STATUS OF THE LHC CONTROLS SYSTEM SHORTLY BEFORE INJECTION OF BEAM

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Abstract

At the time of the ICALEPCS 2007 conference, the LHC main accelerator will be close to its final state of installation, and major components will have passed the so-called "hardware commissioning."

In this paper the requirements and the main components of the LHC control system will be described very briefly. Out of its classical 3-tier architecture, those solutions will be presented, which correspond to major development work done here at CERN. Focus will be given to the present status of these developments and to lessons learned in the past months.

THE CONTROLS INFRASTRUCTURE

The LHC controls infrastructure is based on the classical 3-tier architecture as described in fig.1.

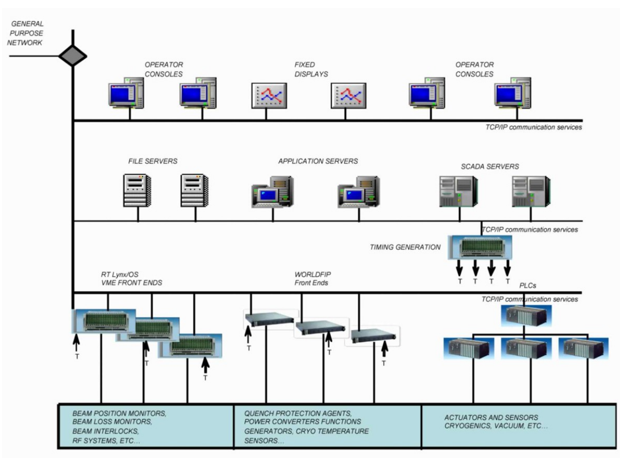

Figure 1: The LHC controls infrastructure.

It is a new software and hardware architecture built with the many years of experience of controlling the CERN injector chain. The level of effort estimated devoted to the LHC controls amounts to 300 my and 21 MSFR over 4 years.

The following paragraphs will describe each of the 3 tier of fig.1.

THE RESOURCE TIER

The resource tier gathers all the controls equipment located in the field close to the accelerators.

The Front-end hardware for LHC consists of a set of about 250 VMEbus64x subracks and about 120 Industrial PCs distributed in the surface buildings along the 27 km of the machine. The mission of these systems is to perform Real-time direct acquisitions and measurements close to the machine and to serve this information to the application software running in the upper levels of the control system.

These embedded systems use various home-made and COTS hardware modules and serve as managers for various types of fieldbuses, such as WorldFIP, a deterministic bus used for the real-time control of the LHC power converters and Quench Protection system.

This resource tier covers also Programmable Logic Controllers (PLCs) driving various sorts of industrials actuators and sensors for systems (e.g. LHC Cryogenics systems or the LHC vacuum system).

Finally the local connections to the devices are done via supported FieldBuses (e.g. Mil1553, WorldFIP, Profibus)

THE MIDDLE TIER

The middle tier is mainly located in the Central Computer Room (CCR) close to the LHC control centre. It consists of:

- Application servers hosting the software required to operate the LHC beams and running the Supervisory Control and Data Acquisition (SCADA) systems
- Data servers containing the LHC layout and the controls configuration as well as all the machine settings needed to operate the machine or to diagnose machine behaviors.
- File servers containing the operational applications

More than 100 servers have been installed to provide all the services mentioned above. Special care for redundancy and fault tolerant has been applied with dual power supply, dual UPS power source, hot-swappable system and data RAID disks.

The central timing which provides the cycling information of the whole complex of machines involved in the production of the LHC beam and the timestamp reference are also located in the CCR and are considered as part of the middle tier.

THE PRESENTATION TIER

At the LHC control room level, consoles running the Graphical User Interfaces (GUI) will allow machine operators to control and optimize the LHC beams and to supervise the state of key industrial systems.

Dedicated fixed displays will also provide real-time summaries of key machine parameters

CERN Control Centre

The LHC operation will be performed from the new CERN Control Center (CCC) that has been built 2 years ago (Fig.2) to host all CERN accelerators and technical services operation.

Figure 2: The CERN Controls Centre.

The CCC is divided in 4 islands, each island being devoted for a specific task (CPS, SPS, Technical services and LHC). Each of these 4 islands is made of 5 operational consoles (Fig. 3)

A typical LHC operational console is composed of 5 computers:

- 2 PCs running LINUX with 3 19” screens each, on which the interactive applications are executed
- 1 PC running LINUX with 2 19” screens used as fixed displays, on the second level
- 1 PC acting as video displays allowing to select 4 video sources out of around 100 channels distributed in the CCC
- 1 PC running Windows connected to the Public Network that can be used for office activities (mail, documents, web browsing, …)

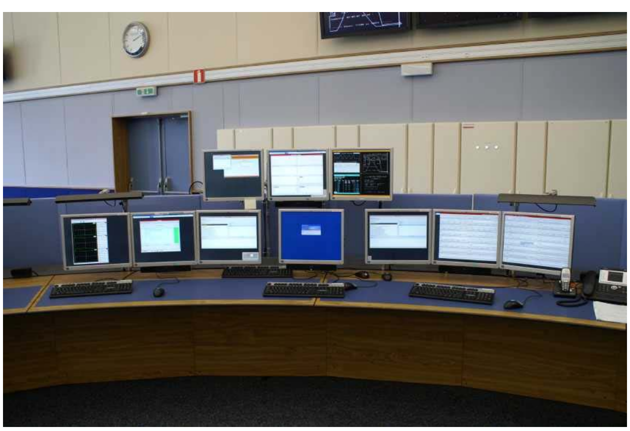

Figure 3: A typical LHC operation console.

THE LHC CHALLENGES

In order to correctly operate the LHC many challenges have to be studied and understood in order to propose the right controls infrastructure and the correct technical proposals.

LHC Is Large

The LHC is the largest accelerator in the world by its number of components and by the diversity of systems.

“Some 500 objects are capable of moving into the aperture of either the LHC Ring, or the transfer lines, ranging from passive valves up to very complex experimental detectors”

P. Collier - AB/CO LHC Workshop January, 2005

LHC Is Complex

The complexity of operation will be extreme due to the following:

- very critical technical subsystems
- large parameter space
- need for online magnetic and beam measurements
- need for real time feedback loops.

“The complexity of the accelerator is unprecedented and repair of damaged equipment would take long, for example, the exchange of a superconducting magnet takes about 30 days”

R. Schmidt

http://cern.ch/rudi/docs/VisitLHCWuppertal2006.ppt

LHC Energy Is Enormous

The energy stored in the beams and the energy stored in the magnets exceed present machines by more than 2 orders of magnitude.

To illustrate this energy, one can take the following comparisons:

- The energy of an AirBus A380 at 700km/hr corresponds to the energy stored in the LHC magnet system
- Kinetic Energy
  - One bunch out of 2808 carries the equivalent of a 5kg shot travelling at 800 km/h
  - 1 small aircraft carrier of 104 tons going 30 km/h
  - 450 automobiles of 2 tons going 100 km/h
- Thermal Energy
  - The energy accumulated in the beam could melt 500 kg of copper
  - Or raise 1 cubic meter of water 85ºC: “One ton of tea”
- Chemical Energy
  - This energy can be compared to that of 80 kg of TNT

Therefore the LHC machine must be protected at all costs. In the case of an operational incident operation should be able to analyze what has happened and trace the cause. Moreover no operation can be resumed if the machine is not back in a good state.

LHC Cryogeny

The LHC is the first superconducting accelerator built at CERN. There will be 4 large scale cryoplants with 1.8 K refrigeration capability.

TECHNICAL SOLUTIONS TO THE LHC CHALLENGES

Many technical solutions have been studied, designed and deployed in the LHC Controls Infrastructure. The following paragraphs describe some of them.

Network Security (CNIC)

The Computing and Network Infrastructure for Controls (CNIC) is a CERN-wide Working group setup in 2004 for the definition of :

- CERN wide security policy
- CERN wide networking aspects
- Operating systems configuration (Windows and Linux)
- Services and support

The major outcomes today are :

- Network Security Policy document
- Formal isolation between General Purpose Network (GPN) and Technical Network (TN)
- Connection to the TN requires formal authorization
- MAC address authentication
- Windows and LINUX OS and patches deployment and management centrally managed

Role Based Access Control (RBAC)

In close collaboration with FERMI National Lab, a ‘role-based’ access to equipment (RBAC) in the communication infrastructure has been deployed.

The main motivation to have RBAC in a control system is to prevent unauthorized access. RBAC is an inexpensive and preventative way to protect the accelerator. With RBAC a user is prevented from making the wrong settings or from logging into the application in the first place.

RBAC works by giving people roles and assigning the roles permissions to make settings. An RBAC token containing many information about the user, the application, the location, the roles, etc (see fig. 4) is obtained during the Authentication phase. This token is then attached to any subsequent equipment access and is used to grant or deny the action.

Depending on WHICH action is made, on WHO is making the call, from WHERE the call is issued and WHEN it is executed, the access will be granted or denied

This allows for filtering, for control and for traceability on the settings modifications to the equipment

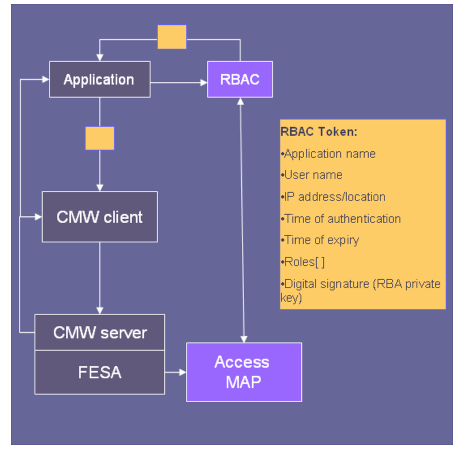

Figure 4: RBAC tokens and access maps.

LASER

LASER, the LHC Alarm SERvice, delivers an alarm service for the operation of the CERN accelerator chain and technical infrastructure. It is used operationally for the SPS and LHC accelerators, and more recently adapted for the PS Complex [1].

The services provided by LASER are the collection, analysis, distribution, definition and archiving of information regarding abnormal situations, fault states (FS), to either dedicated alarm consoles, running mainly in the control rooms, or specialized client applications.

The actual detection of a FS is not performed by LASER but by user surveillance programs, which are either running in distributed front-end computers or centrally in servers. LASER processes about 180'000 alarm events each day, and currently has over 120'000 definitions. Since it is relatively simple for equipment specialists to define and send alarms, one challenge has been to control the number of both events and definitions to a useful human limit for operations as is recommended best practice [2].

Diagnostics and Monitoring (DIAMON)

The controls infrastructure of the LHC and its whole injector chain spans over large geographical distances and is deployed using a big diversity of equipment. In order to allow for the best availability of the controls infrastructure, all these controls parts of the chain need to be constantly monitored. And in the event of a problem detected it has to be notified to the Control Centre and means to repair it has to be proposed.

The purpose of the DIAMON project is to propose to the operators and equipment groups tools to monitor the AB Controls infrastructure with easy to use first line diagnostics and tools to solve problems or help to decide about responsibilities for first line of intervention.

The scope of the project covers around 3’000 agents, piece of code that monitors a part of the infrastructure, ranging from the hardware of the consoles, the back-ends, the front-ends, the communication packages, the field-buses, the application software, etc.

The DIAMON project is designed in two main parts, the monitoring part that constantly checks all the items of the controls infrastructure and reports about problems and the diagnostic part that displays the overall status of the controls infrastructure and proposes support for repair.

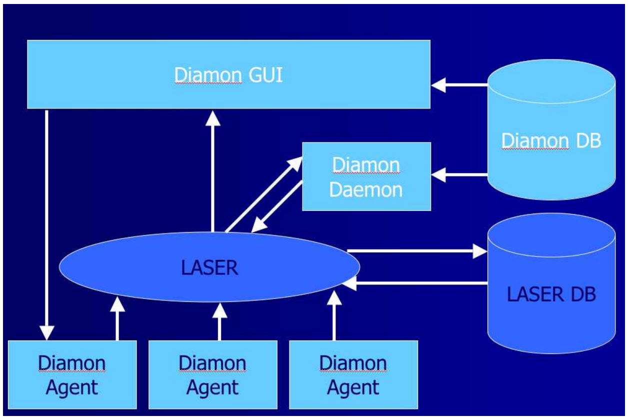

Figure 5: DIAMON architecture.

Integrated Suite of Control Room Applications LSA (LHC Software Application)

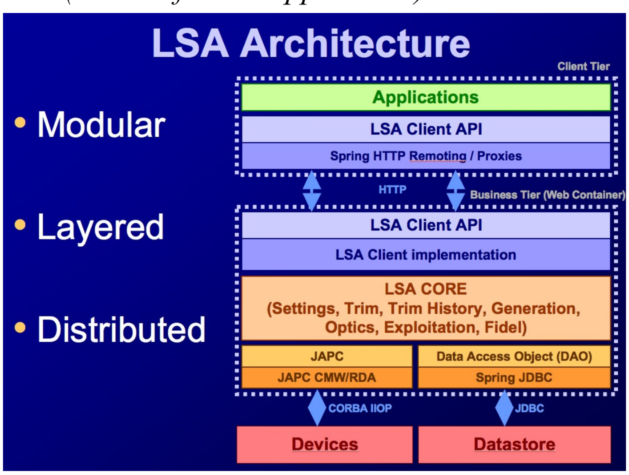

Figure 6: The LSA architecture.

Framework for front-end computers (FESA)

A dedicated Real-time front-End Software Architecture has been developed. This framework offers a complete environment for the equipment specialist to design, develop, deploy and test his equipment software. In spite of the huge diversity of devices, such as beam-loss monitors, power converters, kickers, cryogenic systems, pick-ups, etc…, FESA has successfully standardized a high level language and an object oriented framework to describe and develop portable (meaning across CERN's accelerators) equipment software. FESA reduces the time spent developing and maintaining equipment software and brings a strong consistency across all equipment software deployed over all accelerators at CERN.

Framework for Industrial Controls UNICOS

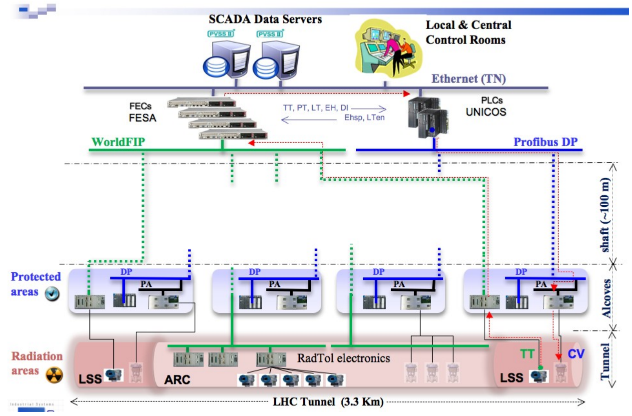

Figure 6: UNICOS framework.

Other Technical Solutions

Many other important technical solutions have been studied, developed and deployed in the Controls Infrastructure to cope with the stringent and very demanding challenges of the LHC. The following list is just to give the reader an invitation for further reading.

- Specific hardware developments (high SIL levels) for machine protection (PIC, BIC…)
- LHC Software Interlocks System (SIS)
- Fully integrated asset, layout, configuration database system
- Extension to the Injector timing system
- Fast Magnet Current Change Monitors

OUTLOOK

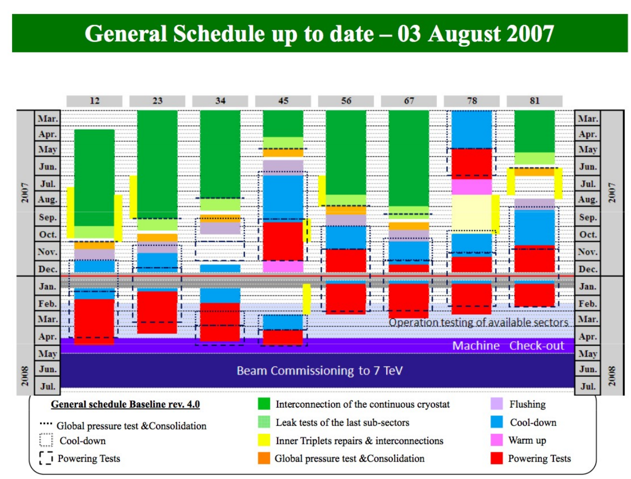

Figure 8: LHC schedule.

The above LHC schedule plans the first LHC beam commissioning for summer 2008. But our LHC Controls Infrastructure will be heavily used in the coming weeks for the LHC Transfer Lines commissioning. And for the LHC Hardware Commissioning (red areas in the above schedule) in the coming months, with massive parallelism early 2008.

SUMMARY

We have addressed the LHC challenges and appropriate solutions have been deployed

The LHC infrastructure has been tested almost completely on previous milestones (LEIR, TI2/8 Transfer Lines, CNGS, SPS, LHC HWC) and we are confident that we can meet the LHC challenges.

Part of the enormous human resource effort invested for LHC comes from international collaborations. Their contribution is highly appreciated and we are looking forward to more fruitful collaborations

We have scheduled our efforts for the 450 GeV engineering run in November 2007

We are now ready and eager to see beam in the LHC

REFERENCES

[1] K.Sigerud, N.Stapley, M.Misiowiec, "First Operational Experience with LASER", ICALEPCS 2005, Geneva, October 2005.

[2] EEMUA 191, "Alarm Systems: A Guide to Design, Management and Procurement", Engineering Equipment & Materials Users Association, 1999.

Papers presented during this ICALEPCS conference related to the LHC Controls Infrastructure:

TPPA04 – Role-Based Access Control for the Accelerator Control System at CERN - Suzanne Renee Gysin,

TPPA12 – User Authentication for Role- Based Access Control - Andrey Petrov

TPPB23 – LHC Powering Circuit Overview: A Mixed Industrial and Classic Accelerator Control Application - Frederic Bernard

WOAA03 – LHC Cryogenics Control System: Integration of the Industrial Controls (UNICOS) and Front-End Software Architecture (FESA) Applications - Enrique Blanco

WOPA03 – LHC Software Architecture [LSA] – Evolution Toward LHC Beam Commissioning - Grzegorz Kruk

WOPA04 – Front-End Software Architecture - Michel Arruat

WPPA04 – OASIS Evolution - Stephane Deghaye

WPPB01 – CTF3 Beam Position Monitor Acquisition System - Stephane Deghaye

WPPB02 – The LHC Central Timing Hardware Implementation - Pablo Alvarez

WPPB03 – Software Interlocks System - Jakub Pawel Wozniak

WPPB08 – Role-Based Authorization in Equipment Access at CERN - Wojciech Gajewski

WPPB17 – ScientiFIP: The Long-Term Support of the WorldFIP Fieldbus for Scientific Applications - Raymond Brun

WPPB38 – Computing and Network Infrastructure for Controls (CNIC) - Stefan Lueders

RPPA03 – The LHC Functional Layout Database as Foundation of the Controls System - Pascal Le Roux

RPPA35 – The DIAMON Project – Monitoring and Diagnostics for the CERN Controls Infrastructure - Pierre Charrue

RPPB01 – The CERN Control Centre: Setting Standards for the XXIst Century - Django Manglunki, Pierre Charrue

RPPB03 – Alarms Configuration Management - Peter Sollander

RPPB05 – Applying Agile Project Management for Accelerator Controls Software - Wojciech Sliwinski

RPPB13 – The First Stage of the Post Mortem Analysis Software Used for the Hardware Commissioning of the LHC - Alessandro Raimondo

RPPB31 – Distributed Timing Diagnostic Applications - Paul Kennerley

FOAA03 – The CERN LHC Central Timing, a Vertical Slice - Julian Howard Lewis