THE LASER MEGAJOULE FACILITY: CONTROL SYSTEM STATUS REPORT

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Abstract

The French Commissariat à l'Énergie Atomique (CEA) is currently building the Laser MegaJoule (LMJ)[1], an up to 240-beam laser facility, at the CEA Laboratory CESTA near Bordeaux. It is a Megajoule class facility, designed to deliver a high energy to targets for high energy density physics experiments, including fusion experiments. LMJ technological choices were validated with the LIL, a scale 1 prototype of one LMJ bundle. The construction of the LMJ building itself is now achieved and the assembly of laser components is on-going.

The presentation gives an overview of the general control system architecture, and focuses on the hardware platform being installed on the LMJ, in the aim of hosting the different software applications for system supervisory and subsystem controls[2] (Fig. 4).

This platform is based on the use of virtualization techniques that were used to develop a high availability optimized hardware platform, with a high operating flexibility, including power consumption and cooling considerations. This platform is spread over 2 sites, the LMJ itself of course, but also on the software integration platform built outside the LMJ to provide system integration of various software control system components of the LMJ.

LMJ FACILITY

The Laser Megajoule facility (LMJ) is presently under construction at the CEA/CESTA site near Bordeaux (France). LMJ is an up to 240-beam laser system designed to study inertial confinement fusion (ICF) and the physics of extreme energy densities and pressures. LMJ will be capable of focusing its energy of ultraviolet light on to an extremely small micro-target in an extremely short space of time. The characteristics of this facility were defined to obtain the temperature and pressure conditions required to reach thermonuclear ignition. Experiments will involve tenths of a milligram of matter in which nuclear fusion reactions will be produced. LMJ is an element of the Simulation Program that aims the guarantee of the safety and reliability of French nuclear weapons. It is comparable to the US NIF facility. LMJ will welcome national and international scientific collaborations, in order to become a privileged place of scientific exchanges.

The LMJ building covers a total area of 40,000 m2 (300 m long x 150 m wide). The four laser bays, 128 m long, are situated in pairs on each side of the target chamber. The experiment building (target bay) is a cylinder of 60 m in diameter and 38 m in height. The target chamber consists of an aluminium sphere, 10 m in diameter, fitted with several hundred ports for the injection of the laser beams and introduction of diagnostics. The 240 beams are grouped in 30 bundles of 8 beams in the laser bays and in 60 quads in the target bay. Numerous diagnostic instruments will be placed in the target chamber around the target to record essential measurements. They will make it possible to observe the behaviour of the target during its implosion and at the time of ignition. These diagnostics are the prime tools for the physicists to determine the characteristics of the plasmas they are studying.

LMJ PROJECT STATUS

The building itself is now complete; the mechanical assembly of the bundles in the two first laser bays is achieved and the assembly of the two others is in progress. The LMJ commissioning strategy is to have several steps towards full energy by successively providing each bundle with its optical components and control system, and at the same time using the already commissioned bundles for shots experiments.

A petawatt beam called PETAL is also under construction and will be coupled to LMJ's quad in the next few years.

The first experiments are scheduled on the LMJ facility for the end of 2014.

LMJ CONTROL SYSTEM ARCHITECTURE

General Architecture

The LMJ control system has to manage over 500 000 control points, 150 000 alarms, and several gigabytes of data per shot, with a 2 years on line storage.

It is composed of a dozen of central servers supporting about two hundreds of virtual machines at the central controls level and about 450 PLC's or rack mount PC's at low levels.

All these equipments are distributed on a pyramid of 4 layers: equipment microcontrollers and PLC's on the N0 layer, subsystem supervisory controls on the N1 layer, central controls on the N2 layer and facility management on the N3 layer.

From an industrial point of view, LMJ is divided into a dozen of major contractors, one for each LMJ subsystem. Each of these contractors supplies the N0 and N1 control system levels corresponding to the function he is responsible for. CEA itself defines the common technology and standards and is responsible of doing the integration of the different subsystems.

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Software Architecture

All the command control software developed for the N1 and N2 layers by the different contractors uses a common framework based on the industrial PANORAMA E2 SCADA from Codra.

In this framework the facility is represented as a hierarchy of objects called “Resources”. Resources represent equipments (motors, instruments, diagnostics…) or high level functions (alignment, laser diagnostics). Resources are linked together through different kinds of relationships (composition, dependency, incompatibility) and the resources life-cycle is described through states-charts. Control-Points, alarms, states and functions can be attached to any resource. Dedicated mechanisms manage the resource reservation and propagate properties and states changes into the tree of resources through relationships. There are about 200 000 resources in order to describe the entire LMJ.

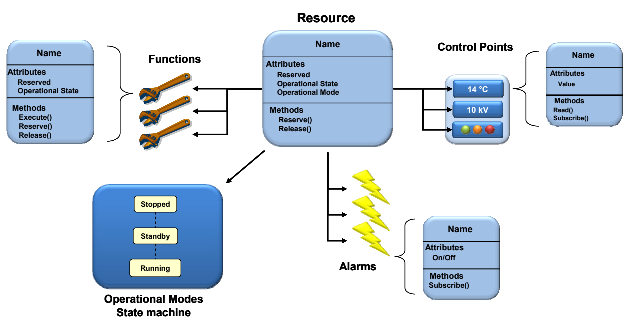

Figure 1: Data model.

The framework implements the data model described above as .net components inside the PANORAMA E2 SCADA and adds some common services to the standard features of PANORAMA E2:

- resources management,
- alarms management,
- lifecycle states management,
- sequencing,
- configuration management,
- event logging

Hardware Architecture

From the hardware point of view the LMJ control system is constituted of two platforms located in two different buildings:

- one for system integration (PFI), which is in operation at the present time in a dedicated building and consists of a clone of the operational control system at the N1, N2 and N3 layers and a mixture of simulators and microcontrollers for representing the N0 layer and real equipments.
- The operational platform (PCI), that will be integrated in the LMJ building at the beginning of next year and which consists of two sub-platforms: a small one for integrating the laser bundles and one for nominal operations.

For each platform, the network architecture (Fig. 2, 3) is composed of two redundant Alcatel-Lucent OmniSwitch 9702E chassis which provide redundant Gigabit attachments to the twelve subsystems backbones and 10 Gigabits attachments to the central controls servers.

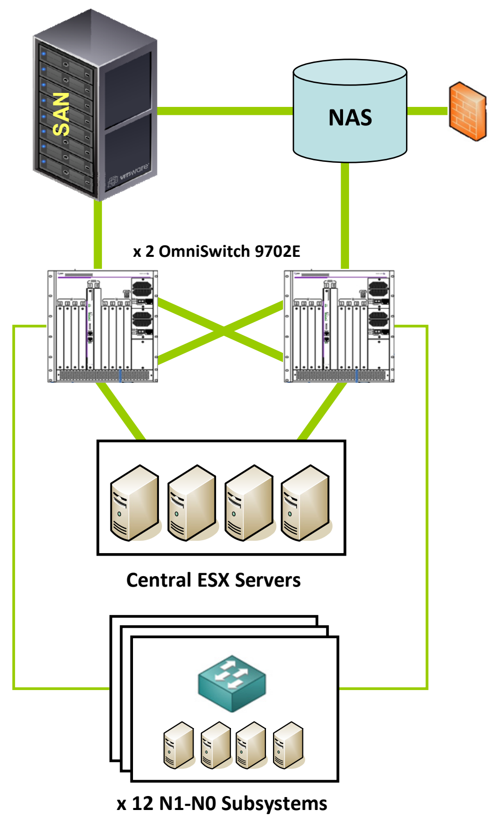

Figure 2: Network architecture.

On each platform, virtual independent contexts are configured using Virtual Routing and Forwarding technologies (VRF): on the PFI this allows to simulate different test contexts at the same time with identical IP address spaces, and on the PCI this allows simultaneous operation from the operational control room and the integration one.

All the N1, N2 and N3 layers are virtualized using VMware and DataCore solutions. Each PFI & PCI platform consists of one virtualization infrastructures composed of:

- 2 DataCore servers, each one managing 12 To of disks,
- 6 to 8 ESX Dell PowerEdge R815 servers, with 4x12 cores and 128 Go of RAM,
- 1 VCenter Server to manage the VMware infrastructure.

Each of these virtualization infrastructures is dimensioned to execute several hundreds of virtual machines.

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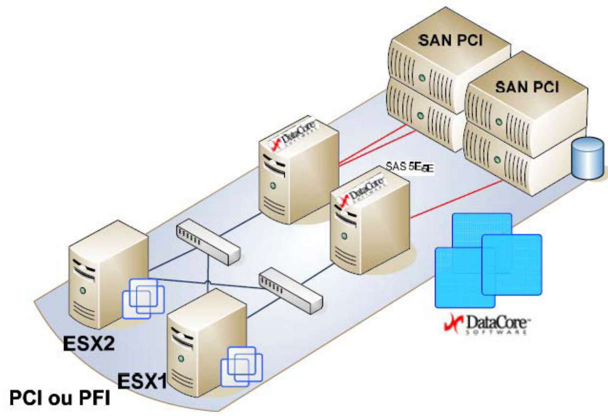

Figure 3: Network architecture.

From the configuration management point of view, application software is generated on the integration platform and stored on a 30 To Network Area Storage (NAS). Images stored on this NAS are made available to the operational platform across a 1 Gigabit dedicated link.

In conclusion the integration and operational platforms of the LMJ control system represent about 500 virtual machines hosted by around fifteen 48 cores / 128 Mo servers.

LMJ CONTROL SYSTEM ROAD MAP

The software framework was commissioned during summer and is now available to contractors to allow them realizing their supervisory systems. The N2-N3 software is currently integrated on a dedicated platform and his commissioning will be accomplished before the end of this year.

The next milestone is to integrate the N2-N3 software with the hardware of the integration platform that will be installed in the PFI building at the end of this year. The integration platform will then be ready to receive control subsystems of the N0-N1 layers from the middle of 2012.

All the N0-N1 subsystems will be integrated to the N2-N3 subsystem on this platform in 2012-2013, before being installed on the operational platform and integrated with laser equipments of the LMJ.

REFERENCES

[1] Michel L. André, "The French Megajoule Laser Project (LMJ)", Fusion Engineering and Design, Volume 44, February 1999 (p.43-49).

[2] J. Nicoloso, J.J. Dupas, J.C. Picon, F. Signol, F. Signol, “LMJ control system Status Report”, ICALEPCS 2009, October 2009.

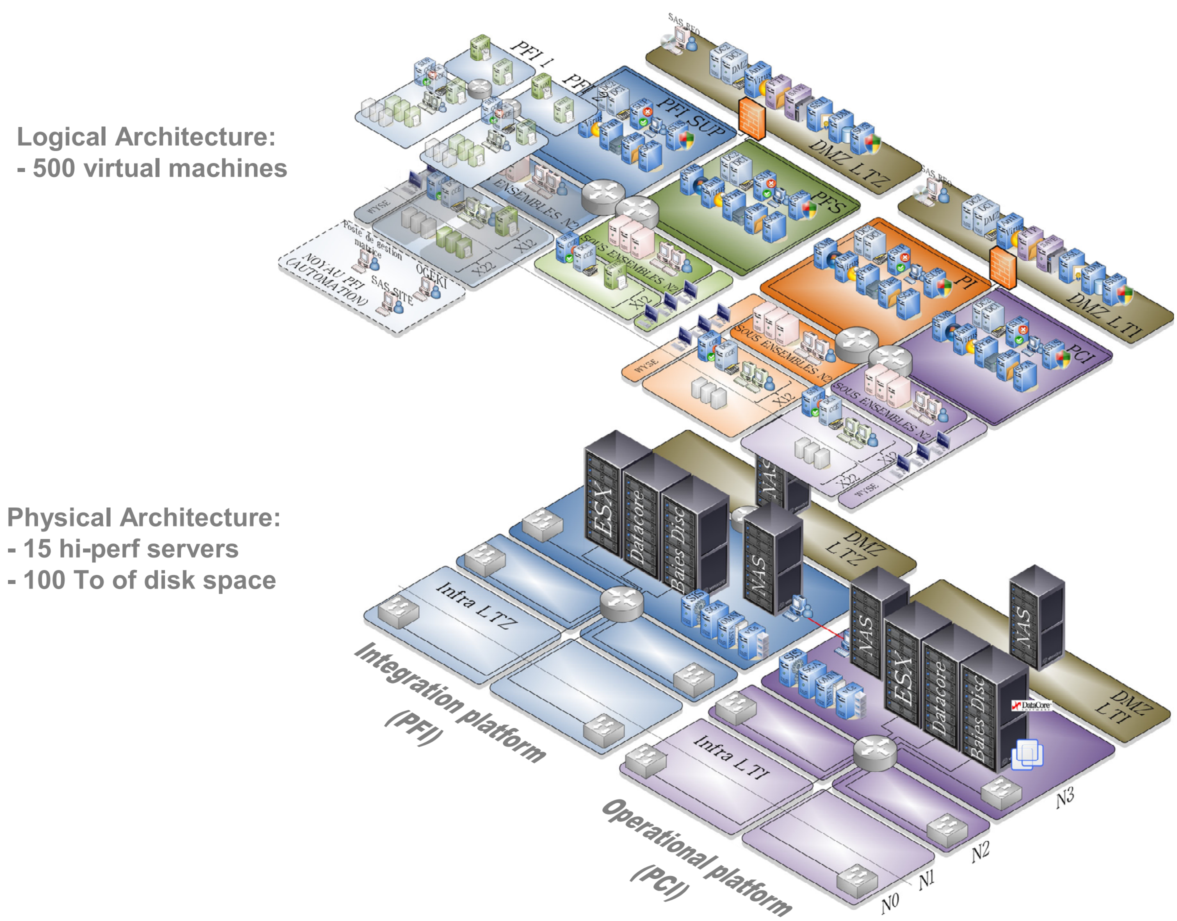

Figure 4: LMJ Central Controls Hardware Platforms, one dedicated for control system integration, one for laser operations.

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