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THE LASER MEGAJOULE FACILITY: CONTROL SYSTEM STATUS REPORT

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Abstract

The Laser MegaJoule (LMJ) is a 176-beam laser facility, located at the CEA CESTA Laboratory near Bordeaux (France). It is designed to deliver about 1.4 MJ of energy to targets, for high energy density physics experiments, including fusion experiments.

The first 8-beams bundle was operated in October 2014 and a new bundle was commissioned in October 2016. The next two bundles are on their way. There are three steps for the validation of a new bundle and its integration to the existing control system. The first step is to verify the ability of every command control subsystems to drive the new bundle using a secondary independent supervisory. It is performed from a dedicated integration control room. The second is to switch the bundle to the main operations control room supervisory. At this stage, we perform the global system tests to validate the commissioning of the new bundle. In this paper we focus on the switch of a new bundle from the integration control room to the main operations control room. We have to connect all equipment controllers of the bundle to the operations network and update the Facility Configuration Management.

LMJ FACILITY

The LMJ facility covers a total area of 40,000 m2 (300 m long x 150 m wide). It is divided into four laser bays, each one accommodating 5 to 7 bundles of 8 beams and a target bay holding the target chamber and diagnostics. The four laser bays are 128 m long, and situated in pairs on each side of the target chamber. The target bay is a cylinder of 60 m in diameter and 38 m in height. The target chamber is an aluminium sphere, 10 m in diameter, fitted with several hundred ports dedicated to laser beams injection and diagnostics introduction. A Supervisory and integrated computer control systems ensure the LMJ control system.

LMJ CONTROL SYSTEM

LMJ Control System Functions

The main functions of the control system are shots execution and machine operations: power conditioning controls, laser settings, laser diagnostics, laser alignment, vacuum control, target alignment, target diagnostics [1].

The control system has also a lot of other major functions: personnel safety, shot data processing, maintenance management.

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.

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 in a dedicated building and consisting of a clone of the operational control system at the supervisory levels and a mixture of simulators and real controllers for representing low levels controls and real equipment [2];
- The operational platform, consisting of two sub-platforms: a small one for integrating the laser bundles (integration control room) and one for normal operations (main control room).

For each platform, two redundant cabinets provide redundant Gigabit attachments to twelve subsystems backbones and main servers.

On each platform, virtual independent contexts are configured using Virtual Routing and Forwarding technologies (VRF): on the operational platform this allows simultaneous operation from the main control room and the integration one.

The LMJ control system architecture is architecture with four layers:

- N0 layer: the equipment control;
- N1 layer: subsystems supervisory that allows operators to drive subsystems;
- N2 layer: the System supervisory;
- N3 layer: global LMJ facility (Laser configuration, shot data processing, maintenance management, network management).

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

- 2 DataCore servers, each one managing 20 To of disks;
- 11 ESX Dell PowerEdge R815 servers, with 4x12 cores and 256 Go of RAM;
- 1 VCenter Server to manage the VMware infrastructure.

Each of these infrastructures is dimensioned to execute more than an hundred of virtual machines.

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Software Architecture

All command control software developed for the supervisory layers uses a common framework based on the industrial PANORAMA E2 SCADA from Codra (Fig. 1).

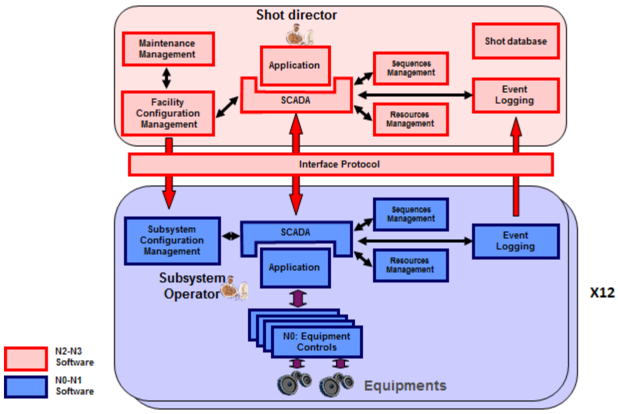

Figure 1: LMJ software architecture.

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 [3];
- Configuration management;
- Event logging.

In this framework the facility is represented as a hierarchy of objects called "Resources" (Fig. 2). Resources represent devices (motors, instruments, diagnostics…) or high level functions (alignment, laser diagnostics). A resource is an object with properties, methods and configuration data. Configuration data are function default settings we can give to execute the action. Resources are linked together through different kinds of relationships (composition, dependency, and incompatibility). There are about 200 000 resources in order to describe the entire LMJ. It is in the Facility Configuration Management and the Subsystem Configuration Management which contains resources and functions default settings.

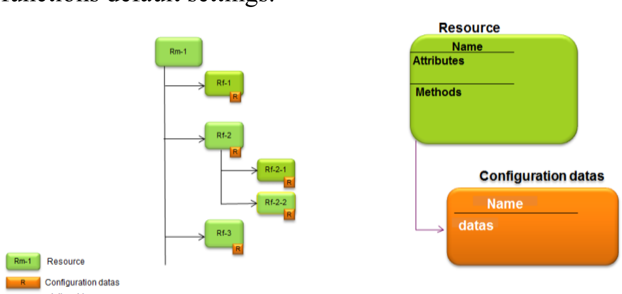

Figure 2: Simplified data model.

INTEGRATION STRATEGY

Since the middle of 2016 we are in the maintenance phase of the LMJ Control System and there is only one contractor. CEA itself is responsible for definition of new versions and subsystems integration.

The integration policy defined for the realization phase is applicable for the maintenance phase [2].

This policy was based on a three steps process:

- Factory tests;
- Integration between subsystems on the dedicated platform (PFI);
- Functional integration on the LMJ facility.

Functional Integration on the LMJ Facility

As bundle commissioning will be a long process spread over several years, the Integration Control Room (ICR) were designed to allow new laser bundles commissioning, while already commissioned bundles are operated for shots and fusion experiments from the main control room.

A second supervisory system was installed in this room and is connected to new bundles, as their commissioning is beginning. From this control room two kinds of tests are conducted:

- First, testing of each subsystem driven by the contractor which is responsible for. It is the first time that the subsystem software package controls the real equipment using the nominal wiring. In a standalone mode, with the same integration tools used at factory, the contractors check the behavior of equipment with the facility wiring;
- Then, testing of the whole bundle driven by CEA. As soon as all the subsystems are integrated on the bundle, CEA makes sure that all subsystems and the high level supervisory system work well together.

When this phase is achieved, we switch the new bundle to the main control room and final testing allows demonstrating that ability of the new bundle to be operated with the others.

The ICR is also used to qualify new version of control command subsystem with real equipment.

Switch a New Bundle from Integration Control Room to the Main Control Room

When we switch a new bundle from ICR to the main control room many operations are required:

- First we move equipment in the operational context by changing the VRF;
- In the second step we update software by using a Setup installer or by cloning the Virtual Machine with VSphere or using Acronis for personal computers;
- In the third step we update framework data;
- And we can perform system tests and declare the bundle operational for experimental campaigns.

Step two depends on the fact we have a new software version or not. Generally, we do in the same time the switch of new bundle and the deployment of new version of supervisory because these operations are made during maintenance period of LMJ facility.

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Sometimes when we have a new version of a Supervisory Subsystem, we have a new data model. So we must update the operational bundles into the new model and keep data. There are many cases (Fig. 3):

- Unchanged resource: very easy – nothing to do;
- Modified resource: warning – we have to update it step by step;
- Moved resource: It's the more spicy – we have to do specific actions which are partially manual action;
- New resource: We update the class and update the instances from the class with default values;
- Deleted resource: We update the class and update the instances from the class.

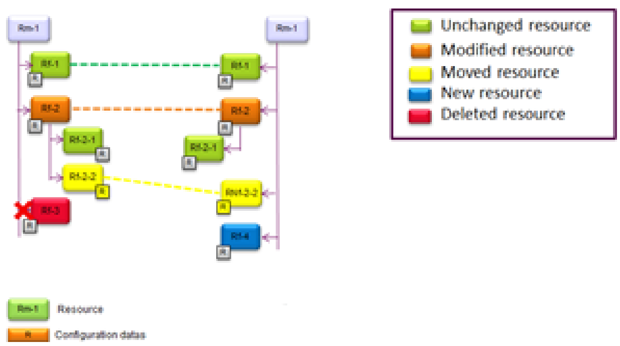

Figure 3: Different cases for updating the configuration data.

Then when the data model and the operational bundle are up to date we can switch the configuration data of the new bundle to the main control room. First, we export, from the integration control room, the configuration data of the bundle. Then we import them into the Facility Configuration Management of the main control room (Fig. 4).

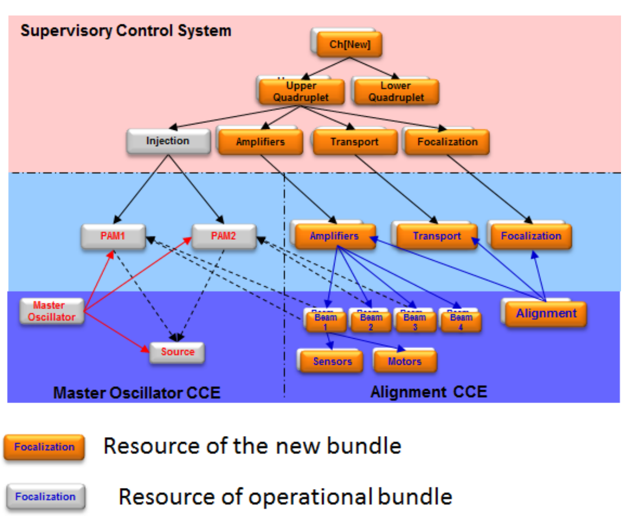

Figure 4: Import the configuration data of a bundle.

All the actions to update the configuration data use functions of the Facility Configuration Management like:

- Export and import class;
- Update instances from class;
- Export and import configuration data of a set of resources.

LMJ PROJECT STATUS

The first laser target interaction experiment was done on fall 2014.

Since ICALEPCS 2015:

- The integration control room was commissioned October 2015;
- A new bundle was commissioned after functional integration on ICR in middle of 2016;
- A global maintenance contract started in the middle of 2016. The fifteen contracts of the command control realization are closed and we began the maintenance phase;
- The first laser target interaction experiment with two bundles was done on fall 2016. The next two bundles are on their way for their integration;
- The commissioning of these two new bundles is planned on start 2018;
- And in the same time several experimental campaigns were done.

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