THE LASER MEGAJOULE FACILITY CONTROL SYSTEM STATUS REPORT

J.P. Arnoul CEA/CESTA, Le Barp, 33114, France
J. Nicoloso CEA/DIF, Bruyères le Châtel, 91297, Arpajon, France

Abstract

The French Commissariat à l'Énergie Atomique et aux Energies Alternatives (CEA) is currently building the Laser Megajoule (LMJ), a 176-beam laser facility, at the CEA Laboratory CESTA near Bordeaux [1], [2], [3], [4]. It is designed to deliver about 1.4 MJ of energy to targets for high energy density physics experiments, including fusion experiments. The assembly of the first amplification lines is almost achieved and functional tests are planned for next year.

The first part of the presentation is a photo album of the progress of the assembly of the bundles in the four laser bay, and in the target bay.

Then, we will focus on the general software integration strategy. Sub-systems controls software applications are first independently commissioned with each contractor on its own site and then assembled with others on the LMJ software integration platform, before at last being installed on the LMJ hardware platform to drive the first bundles.

The LMJ commissioning strategy is then to have several steps towards full energy by successively commissioning each bundle from a secondary control room inside the LMJ building, and at the same time, using the commissioned bundles for shots and fusion experiments from the main control room.

THE LMJ FACILITY

Main Characteristics

The LMJ facility is a high power laser facility dedicated to study high density plasma physics. For the French government it is one of the most important tools of the Simulation Program, that forms the basis of the safety and reliability of French nuclear weapons.

Like its American equivalent NIF, the Laser Megajoule, (LMJ) has been designed to achieve inertial confinement fusion (ICF) through indirect drive with ignition of a central hotspot. LMJ is the "sister facility" of NIF, but will be fully operational a few years later.

The most studied fusion reaction is that between deuterium (D) and tritium (T), where two hydrogen isotopes fuse to form a helium nucleus and emit a very high energy neutron. So how we do that? We fill a 1 mm spherical capsule of glass with a fuel of DT and then we focus hundreds of laser beams onto it.

The laser will generates a burst into the target of about 1.4 MJ of energy during few nanoseconds.

When focusing the laser beams on the target we have to meet the requirements of a very precise shape for the laser pulses and very precise timing and pointing conditions. If these conditions are respected, the fuel in the target is heated and compressed so that fusion reactions are initiated and can propagate in the medium.

Laser Bays

The LMJ facility is designed with 22 bundles of 8 beams in 4 laser bays (3 bays with 5 bundles, and one with 7 bundles). All these bundles are already assembled in the laser bays, but have to be equipped with optical Line Replaceable Unit's before their commissioning.

Today, only one bundle is completely equipped with all its optical LRU's.

The first bundle activation will be achieved in 3 steps:

- Activation of the Amplifying Section where the first automatic alignment loop was successfully achieved in April by the alignment software contractor
- Activation of the Transport Section where the bundle is split in two quads that are switched to the Frequency Conversion and Focusing system (FCF equipment), one at the top and the other one at the bottom of the target chamber. The contractor is currently finalizing the Transport Mirrors alignment test
- The integration and activation of the major target alignment equipment's, like target positioner and chamber centre reference, is finished, and final tests are planned for next December

The power conditioning modules were also installed in their dedicated rooms, and are now under test on resistive loads, before connection to the amplifier flashes

Target Bay

Concerning the switchyard, we have already installed the 4 times 6 mirrors TM1 to TM6 of the upper Transport Section quad. Those of the lower quad are currently under installation.

Concerning the Frequency Conversion & Focusing System (SCF equipment's), the first quad is under on line tests and the second will be in December. The LMJ chamber nose assemblies include several components: unconverted light absorbers, vacuum window, debris Shields and 3ω calorimeter.

The first 10 upper chamber nose assemblies are already installed and equipped with their vacuum valve.

ISBN 978-3-95450-139-7

Only one chamber nose is already installed on the lower quad of the first bundle. Now, we are proceeding with the installation of the other lower assemblies.

The different chamber equipment's are installed: chamber vacuum facilities, alignment common reference device, non-cryogenic target positioner. We are waiting for the first Diagnostic Inserter Manipulator.

LMJ ICCS STATUS

LMJ Control System Functions

The main goal of the facility is to shoot targets for experiments. So the main functions of the control system concern shots execution and machine operations: power conditioning controls, laser settings, laser diagnostics, laser alignment, vacuum control, target alignment, target diagnostics.

All these components will be triggered with a high precision by the Timing and Triggering system.

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

Conducting a shot is composed of two phases: first a master countdown to prepare the machine and secondly an automatic sequence that executes the shot from the power conditioning charging to the target implosion.

The master countdown has an expected duration of about four hours and the automatic sequence lasts a few minutes for power conditioning and less than a microsecond for shot execution.

The master countdown coordinates manual operations or automatic programs that prepare the machine: automatic settings computation and associated downloading, laser and target alignment, diagnostics preparation. This can take 2 or 4 hours.

Then, when the laser is ready, the automatic sequence is started: the power conditioning is charged. This takes a few minutes. Then the computer system hands over to the electronic timing system [5] that guides the laser pulses from the master oscillator sources to the target through the amplifiers and transport sections. And this takes about 1 microsecond.

Logical and Physical Architecture

The LMJ control system architecture is divided into 4 layers, inspired by the CIM model, from bottom to top:

- Layer N0 for local and basic equipment control, such as signal conditioning, or stepping motor controls, based on industrial PC's or PLC's
- Layer N1 for the subsystem supervisory controls (for example laser diagnostics controls),
- Layer N2 for the central subsystem supervisory controls, i.e. the coordination of subsystems and shot sequence,
- Layer N3 for the information system, shot planning, data processing and maintenance management.

Layers N1 and N2 are developed under Windows 7, and use a common framework developed around PANORAMA E² software product.

The major software components of the Centralized Supervisory system (layers N2 and N3) were developed by 3 different contractors.

For the layers N0 and N1, we have a dozen of major contractors, one per subsystem. Each of these contractors supplies both the (laser or target) equipment's and the associated control and supervisory systems.

CEA is responsible for the functional requirements, the initial design (ie. how the system is divided into subsystems), the interface protocols, and last but not least the technical framework that is imposed to all contractors for the supervisory systems on the upper layers.

All N1, N2 and N3 layers are virtualized using VMware and DataCore solutions. We have developed and installed 2 different platforms, one for the LMJ, and the other for the software integration platform, outside the LMJ building. Each platform consists of two virtualization infrastructures composed of:

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

Each of these virtualization infrastructures is dimensioned to execute more than one hundred of virtual machines. The integration and operational platforms of the LMJ control system represent hundreds of virtual machines hosted by around fifteen 48 cores / 128 Mbyte servers.

To insure a good availability of this hardware architecture, we have installed in the LMJ computer room a small data center infrastructure. An Uninterruptible Power Supply (UPS) device gives us more than 1 hour of autonomy. The IT housing has a hot corridor cooling infrastructure, and the In Row coolers are directly supplied with chilled water supplied by the LMJ facility building.

Control Room

On the LMJ we will perform one or two shots per day. It will be directly operated in 2 shifts with a team of about 20 operators.

The LMJ shot team operators dispose of different multifunctional consoles to drive the facility:

- Laser front end and timing system,
- Laser alignment and laser diagnostics,
- Target diagnostics alignment and configuration,
- Target alignment and Diagnostics Inserter control,
- Utilities and vacuum control,

ISBN 978-3-95450-139-7

- Plasma Electrodes Pokels Cells (PEPC) and power conditioning.
- Plasma diagnostics and data acquisition,

The LMJ organization is quite similar to the LIL one. (The LIL facility which is the prototype of the LMJ, was commissioned in 2002, and has been used up to now for physic experiments, and LMJ component validation. Its operation gave us a fair experience feedback.)

So the shot team is only composed of about 20 operators in normal conditions, but the Shot Director can get assistance as much as he needs between 6am to 9pm, on-call to:

- Safety team (safety and security engineer for instance)
- Maintenance team (command control engineer for instance)
- Support operations team (laser sub-system engineer for instance)

The control room was designed with an ergonomics expert who interviewed the operators of the LIL shot team to optimize and rationalize the relations between participants.

The shot director and his deputies, the lead operator and the security engineer, are facing the operator team.

Software Integration Strategy

CEA has also imposed a general software integration strategy. A second specific hardware platform, called the PFI (Software Integration Platform) installed in a building outside the LMJ facility area, is used to qualify and integrate all contractors control software packages before deploying them on the LMJ operational computers [6].

Ramp up Period Commissioning Strategy

The operation of the LMJ will start at the end of 2014, with the first experimental campaign. Further, the physic experiments will continue simultaneously with the activation and commissioning of the other laser bundles.

For this purpose, a secondary control room allows new laser bundles commissioning while already commissioned bundles are operated for shots and fusion experiments from the main control room.

.A second supervisory and control system were installed in this room and connected to the integration network; subcontractors will perform the industrial tests using their integration tools. Then, CEA will perform the system tests using the dedicated control system from the secondary control room.

The other bundles from two to twenty-two will be integrated and commissioned from the integration control room before being switched to the main control room. The secondary control room is also used for operators training.

The first bundle is an exception: it is integrated from the main control room. Industrial tests are performed by the contractors to check the behaviour of equipment's with the real wiring; the software is installed in the computer room and connected to the operation network; system tests are performed by CEA to make sure that all subsystems work well together.

At last, all equipment controllers of the bundle will be connected to the operations network.

Milestones

Today, all our efforts are focused on the next step: the first physics experiments at the end of 2014.

Most of the amplification section subsystems control software are already tested on the integration platform, and are available on the LMJ for the 1ω energy ramp-up

By the end of 2013, all of the equipment's for the first bundle commissioning will be mounted (1ω and 3ω alignment system, computer control system, personnel safety…).

We are confident to demonstrate that the facility is ready to start the first laser target interaction experiments with two quads focused on the target chamber centre (TCC), so the first experimentation campaign is planned in 2014 winter.

REFERENCES

[1] www-lmj.cea.fr

[2] The Laser Megajoule facility: control system status report, ICALEPCS 2007, by J.P. Arnoul, F. Signol CEA/CESTA, Le Barp, 33114 France, P. Bétrémieux, J.J. Dupas, J. Nicoloso CEA/DIF, Bruyères le Châtel, 91680 France.

[3] The Laser Megajoule facility: control system status report, ICALEPCS 2009, by J.J. Dupas, J. Nicoloso CEA/DIF, Bruyères le Châtel, 91680 France.

[4] The Laser Megajoule facility: control system status report, ICALEPCS 2011, by J. Nicoloso CEA/DIF, Bruyères le Châtel, 91680 France, J.P. Arnoul, CEA/CESTA, Le Barp, 33114 France.

[5] THCOCA404: Integrated Timing and Triggering System, by Joel Nicoloso, Jean-Jacques Dupas, CEA/DIF, Bruyères le Châtel, 91680 France.

[6] MOCOBAB03: The Laser Megajoule ICCS Integration Platform, by Jean Fleury CEA/CESTA, Le Barp, 33114 France.

ISBN 978-3-95450-139-7