ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-FRAPP01

THE LASER MEGAJOULE FACILITY: COMMAND CONTROL SYSTEM STATUS REPORT

H. Durandeau, R. Clot, P. Gontard, S. Tranquille-Marques, Y. Tranquille-Marques
Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Le Barp, France

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 on a target, for high energy density physics experiments, including fusion experiments. The first bundle of 8-beams bundle was commissioned in October 2014. Today five bundles are in operation.

In this paper, we focus on two specific evolutions of the command control: the Target Chamber Diagnostic Module (TCDM) which allows the measurement of vacuum windows damages (an automatic sequence activates the TCDM that can be operated at night without any operator) and new Target Diagnostics integration. We also present a cybersecurity network analysis system based on Sentryo Probes and how we manage maintenance laptops in the facility.

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 aluminum 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 COMMAND CONTROL SYSTEM

LMJ Command 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.

Software Architecture

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

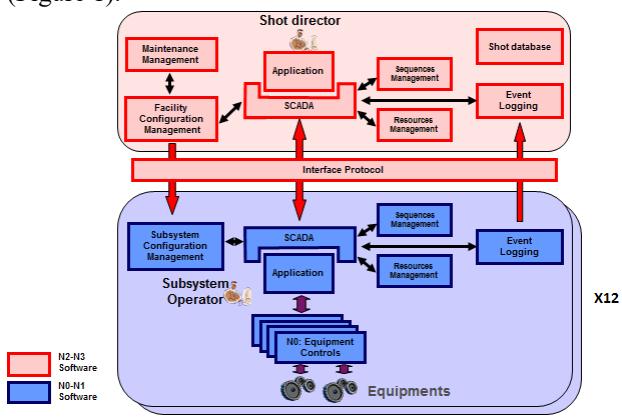

Figure 1: LMJ Software architecture.

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 [2];
- Configuration management;
- Event logging.

MAJORS EVOLUTION

Many version of command-control of each subsystem are provided using the integration policy of the maintenance phase [3]. 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.

We present two major evolutions depending on new equipment we have to manage.

Target Chamber Diagnostic Module (TCDM)

This new laser Diagnostic Module allows the measurement of vacuum windows damages (Figure 2:).

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-FRAPP01

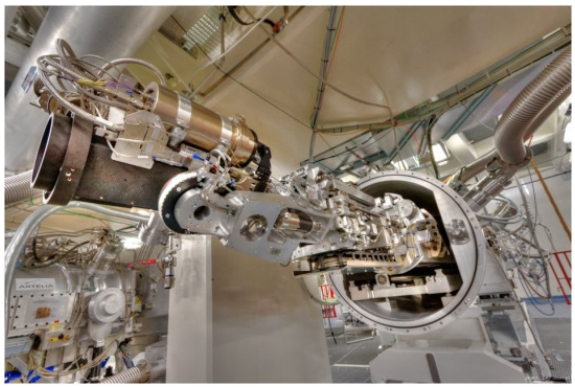

Figure 2: TCDM.

This module is driving by the laser diagnostics subsystem. Its main functions are:

- measurement of vacuum windows and 3ω gratings damages;
- Measurement useful energy target bay;
- Near field measurement 3ω.

We have to scan all vacuum windows after each shot. So we also commissioned a new automatic sequence to operate it at night without operation team.

We can see in the next picture an example measurement (Figure 3).

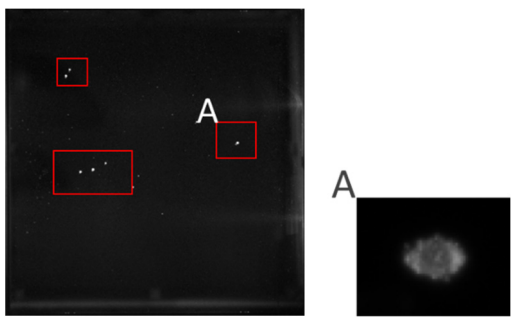

Figure 3: Example of damages.

News Target Diagnostics Module

In the last two years many news target diagnostics module are commissioned in two steps [3]:

- Commissioned the N0 software;
- Commissioned the N1 software with new N0 softwares.

About the N0 softwares we have commissioned four in 2018 and three in 2019. About the N1 software we have commissioned a new version every year in order to integrate new N0 softwares.

The last N0 software commissioned is the Neutron Pack which is a set of several diagnostics to measure neutron yield, ion temperature, neutron bang time and the ratio of secondary to primary neutron reactions during D2 and DT implosions. A first set of 6 nTOF (neutron Time of Flight) using re-entrant tubes (Figure 4):

- 2 perpendicular axis in the equatorial plane;
- a near polar axis (16°);
- measurement @ 3.6 m from TCC (gated PMT w/ scintillators

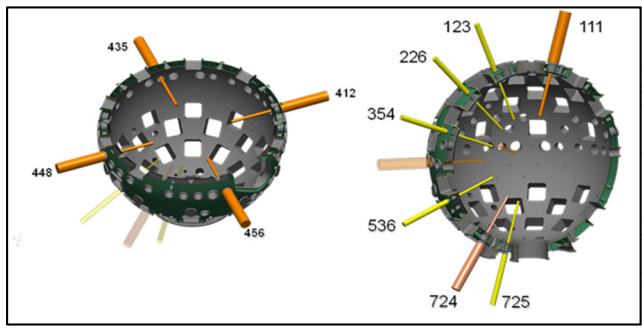

Figure 4: A first set of 6 nTOF.

CYBERSECURITY

The cybersecurity is an important aspect of the LMJ Facility. There are many advises in order to protect and make our installation more and more secure [4]. We present two examples of cybersecurity solutions.

Cybersecurity Network Analysis

The cybersecurity network analysis system is based on the Sentryo Probes which are:

- A french solution labelled France Cybersecurity;
- 100% passive sensors edge so as not to disturb the industrial networks;
- Usable "mobile" system;
- The analysis of the different catches gives us;
- Hardware and application mapping (Figure 5: Mapping);
- Control DNS type queries and network flows.

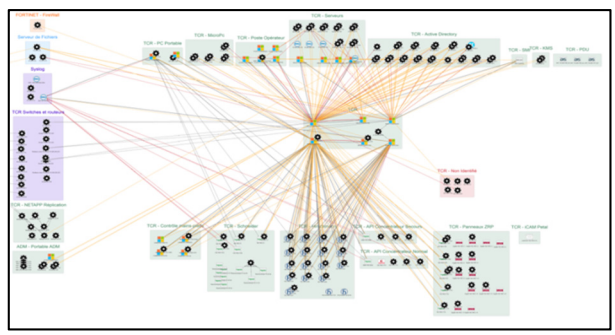

Figure 5: Mapping.

This contributes to Cybersecurity by detecting vulnerability or unknown equipment and also helps us to solve some functional problems.

Maintenance Laptops Management

Cybersecurity requirements apply to use of maintenance laptops:

- No internet connection;
- Attribution process;
- Virus definition and security updates.

Lockers with RFID chip and specific network connection allow (Figure 6):

- Control access;
- Always 100% charged battery;
- Backup;
- Virus definition and security updates.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-FRAPP01

Figure 6: Locker with RFID chip.

LMJ PROJECT STATUS

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

Since ICALEPCS 2017 [5]:

- Five new bundles where commissioned after functional integration on ICR;
- The new target Chamber Diagnostic module was commissioned in 2018;
- Seven Target diagnostics module where commissioned;
- A new version of subsystem command control was commissioned each year;
- The first laser target interaction experiment with five bundles was done on fall 2018;
- The first laser target interaction experiment with seven bundles is planned on fall 2019;
- And in the same time several experimental campaigns were done.

From its commissioning in 2014, the Laser Megajoule operational capability is growing up. This extends the possibility to address new physics.

REFERENCES

[1] J. Nicoloso, "The Laser Magajoule Facility: Control System Status Report", in *Proc. ICALEPCS'15*, Melbourne, Australia, Oct. 2015, pp. 1165-1168. doi:10.18429/JACoW-ICALEPCS2015-FRA3O02

[2] Y. Tranquille-Marques *et al.*, "The LMJ System Sequences Adaptability (French MegaJoule Laser)", in *Proc. ICALEPCS'15*, Melbourne, Australia, Oct. 2015, pp. 533-536. doi:10.18429/JACoW-ICALEPCS2015-TUB3O04

[3] S. Tranquille-Marques and P. Prunet, "The LMJ Target Diagnostics Integration", presented at the ICALEPCS'19, New York, NY, USA, Oct. 2019, paper TUCPL03, this conference.

[4] S. Perez, "Cyber Threats, the World Is No Longer What We Knew…", in *Proc. ICALEPCS'17*, Barcelona, Spain, Oct. 2017, pp. 1137-1141. doi:10.18429/JACoW-ICALEPCS2017-THBPA01

[5] H. Durandeau, "The Laser MegaJoule Facility: Control System Status Report", in *Proc. 16th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'17)*, Barcelona, Spain, Oct. 2017, pp. 2007-2009. doi:10.18429/JACoW-ICALEPCS2017-FRAPL06