Laser Megajoule Facility (L.M.J.)
Control system status report

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PRESENTATION OVERVIEW

• The Laser MegaJoule (L.M.J.) facility

• Prototype = the Laser Integration Line (L.I.L.) facility

• The control system architecture and industrial policy

• The high level supervisory software

• The control system road map
The Laser Megaloule (L.M.J.) facility

- The **Simulation program** forms the basis for the guarantee of the safety and reliability of French nuclear weapons
  - similar to the US Stockpile Stewardship Program

- LMJ is a cornerstone of this program
  - The LMJ project is similar to the US NIF project

- Prototype = LIL

![LMJ & LIL (CEA/CESTA site near Bordeaux)](image)
The LMJ facility overview

30 bundles of 8 beams located in 4 bays = 240 beams

1.8 MJ of 350 nm UV light on a target
Conducting an experiment with LMJ

Target (mm)

Target chamber diameter: 10 m

Building 100 m x 300 m

Target bay diameter: 40 m
The LMJ building
LMJ Project status
The LIL facility = the LMJ prototype

- LIL was commissioned in March 2002
LMJ Control system functionality (simplified)

- Shot Director
- Power Conditioning Control
- Laser Parameters Settings
- Laser Diagnostics Acquisition
- Laser Alignment
- Vacuum Control
- Target Alignment
- Target Diagnostics Acquisition
- Personnel Safety
- Access Control
- Building monitoring
- Capacitor Bank
- Pulse Generation
- Amplifier
- Timing
- Shot Data Processing
- Shot Director

A function = a subsystem
The LMJ control system
a layered architecture

N3
Facility planning
and operations

N2
System supervisory

N1
Subsystem control

N0
Equipment control

Control Points
500 000

Alarms
150 000

Processors 700

Shot data
\(\sim 1 \text{ GB} / \text{ shot}\)

2 years on line
LIL industrial policy

High level supervisory perimeter

N3
Facility planning and operations

N2
System supervisory

N1
Subsystem control

N0
Equipment control

LIL Subsystem Perimeter

Prime contractor

Interface protocol

Laser or Target Equipment

Equipment control

Subsystem supervisory

Shot Director

Network Administration

Shot data Archiving and analysis

Maintenance Management

Shot Data

Laser Config.

Any LIL contractor
LIL experience feedback

• Development phase
  – Frequent changes brought to the high level supervisory software
    • because of unexpected modification of the equipment hardware under development
    • the interface level between contracts was too low
  – Interface toolkit not standard and insufficiently tested
  – Subsystem software behavior insufficiently specified

• Factory acceptance
  – Factory acceptance tests were degraded by an acceleration of the Project planning

• Integration with surrounding subsystems
  – Difficult Integration due to limited factory acceptance tests
  – Integration platform not sufficiently representative
LMJ industrial policy

High level supervisory perimeter

N3
Facility planning and operations

N2
System supervisory

N1
Subsystem control

N0
Equipment control

LIL Subsystem Perimeter

Prime contractor

Interface protocol

Any LIL contractor

Laser Megajoule Project
ICALEPCS 2007
October 2007
LMJ industrial policy

High level supervisory perimeter

N3 Facility planning and operations

N2 System supervisory

N1 Subsystem control

N0 Equipment control

Any LMJ contractor

Any LMJ contractor

CEA Interface protocol

LMJ Subsystem perimeter

Laser or Target Equipment

Equipment control

Subsystem supervisory

shot data Archiving and analysis

shot data

Network Administration

Maintenance Management

Laser Config.
Mandatory LMJ Interface protocol and library of basic mechanisms

- The (N1-N1 and N1-N2) interface protocols are fully standardized

**Low level protocol** = Web-Services + OPC-DA
(.OPC-UA is under consideration)

**High level protocol** = a library of basic mechanisms imposed to every LMJ contractor via a data model

- Fault tolerance Management
- Alarms & lifecycle States Management
- Maintenance Management
- Network Administration
- Post Shot Data Management
- Reservations Management
- Shot planning
- Sequences Management
- Shot Data Configuration Management
- Synchronization Management
- Working Modes Management
Transverse requirements (1/3)

- The LMJ control system = a dozen contracts (one by subsystem)
- Necessity of transverse requirements to guarantee a certain level of standardization.
- Three examples of requirements in this presentation

1. Objectives for software reliability

   Procedure recommended by the French company Mathix:

   1. Contractors perform tests based on the software mission profile
   2. They plot cumulated number of failures vs. test duration on a chart
   3. Shape of this chart + LIL experience feedback + Mathix know-how = an estimate of the present and future software reliability (required for factory acceptance by CEA)
## Transverse requirements (2/3)

### 2 – Mandatory hardware and software

<table>
<thead>
<tr>
<th>Mandatory choices</th>
<th>Layer N0</th>
<th>Layer N1</th>
<th>Layer N2</th>
<th>Layer N3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>PLC (Schneider or Siemens) or industrial PC</td>
<td>PC</td>
<td></td>
<td></td>
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<tr>
<td>Language for PC</td>
<td>Free</td>
<td></td>
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<tr>
<td>Language for PLC</td>
<td>CEI 61131-3 standard</td>
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<tr>
<td>Operating system</td>
<td>Free</td>
<td>Windows Vista or later</td>
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<tr>
<td>SCADA</td>
<td>Panorama E2</td>
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<tr>
<td>N1, N2, N3 Networks</td>
<td>Ethernet 100 Mbits or Gigabits - Brand: Alcatel-Lucent</td>
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<tr>
<td>Instrument Bus</td>
<td>IEEE488, VXI, IEEE1394</td>
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<tr>
<td>N1, N2, N3 software interface</td>
<td>Imposed in the LMJ interface protocol</td>
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<tr>
<td>Development tools</td>
<td>Free</td>
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</tbody>
</table>
3 – Tests and Integration

• Development phase
  – Closer management of the contractors during design and qualification phases.
  – Use of an interface simulator to avoid dependence between subsystems and high level supervisory developments.

• Factory acceptance tests
  – The software under test will be connected to two simulators.
    • an upward simulator supplied by CEA simulating the high level supervisory.
    • a downward simulator, developed by the subsystem contractor, simulating the totality of his equipment hardware (30 bundles) (otherwise this test could not have been conducted until the end of the production).
  – Factory tests had to be refined to make them more exhaustive.
Transverse requirements (3/3)

- **Integration Platform**
  - Built with real software (N0 to N3) + laser and target equipment simulators.
  - Subsystems will then be integrated one after another.
  - Objectives:
    - Verify software installation procedure
    - Verify operation and conduct virtual shots

- **On site qualification**
  - qualification performed bundle by bundle from a dedicated control-room before connection to the operational control network

<table>
<thead>
<tr>
<th>High level SUPERVISORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SubSyst CONTROL</td>
</tr>
<tr>
<td>Laser Equip SIMUL</td>
</tr>
<tr>
<td>SubSyst CONTROL</td>
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<tr>
<td>Laser Equip SIMUL</td>
</tr>
<tr>
<td>SubSyst CONTROL</td>
</tr>
<tr>
<td>Target Equip SIMUL</td>
</tr>
</tbody>
</table>

- Offsite testing = no impact on LMJ operation
High level Supervisory software

**GMC**
- Equipment Configuration Manag.
- Maintenance management

**GTIR**
- Management of shot goals files
- Shot data processing and archiving

**SVP**
- Shot sequence execution

**ADM**
- Network administration

Shot goals file

Equipment configurations

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**Subsystem Controls**
- Laser Diag
- Align
- Target Diag

**PANORAMA E^2**

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**Post Shot Data**
The LMJ control system road map

<table>
<thead>
<tr>
<th>Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<tbody>
<tr>
<td>Contracts</td>
<td>Reviews</td>
<td>System supervisory</td>
<td>Laser bay</td>
<td>Target bay</td>
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<tr>
<td>Supervisory</td>
<td>Integration platform</td>
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<tr>
<td>Common requirements</td>
<td></td>
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</tbody>
</table>

Laser bay

Target bay

Subsystem controls

Supervisory & control
Any questions?