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# THE LMJ TARGET DIAGNOSTICS INTEGRATION

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*Abstract*

The French Laser Megajoule (LMJ) is, behind the US NIF, the second largest inertial fusion facility in the World. The main activity of this facility is the acquisition of several physical phenomena as neutron, gamma, X rays produced by the indirect attack of hundreds of high power laser beams on targets through measurement devices called "target diagnostics".

More than 30 diagnostics will be installed and driven in a huge and complex integrated computer control system. All these Target Diagnostics are coming one by one, each with its own specificity and complexity. The Tango framework and the Panorama SCADA are used for command and control.

The aim of this paper is first, to introduce how Target Diagnostics are progressively integrated in the command control. We will then see how Target Diagnostics are managed to cohabit even if they are in different phases of their integration process.

Finally the paper explains how Target Diagnostics are configured and computer-driven during the shot sequence.

## INTRODUCTION

Since it definitively abandoned nuclear testing, France has relied on the Simulation Program to guarantee the operational performance and safety of its nuclear deterrent weapons throughout their lifetime.

Successful simulation requires both:

- Qualified computer codes that integrate laboratory-validated physics models to simulate weapon functioning;
- Teams of qualified physicists to use these codes.

In this respect, the Megajoule Laser (Fig. 1) is used to validate the numerical codes and certify the skills of French physicists.

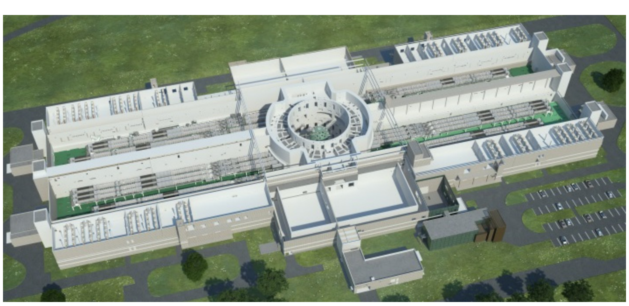

Figure 1: LMJ view.

On October 23, 2014, French Prime Minister Manuel Valls declared the facility operational after starting up the first experiment.

Target Diagnostics (TD) are a key for numerous physical data acquisition. CEA will develop more than 30 of these equipments during next twenty years (Fig. 2).

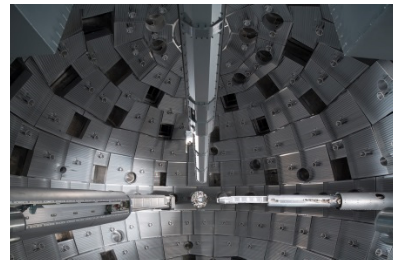

Figure 2: Target chamber view.

Each Target Diagnostic will be dedicated to one or several kind of measurements like X-ray, visible, UV or parti-cles like neutron (Fig. 3).

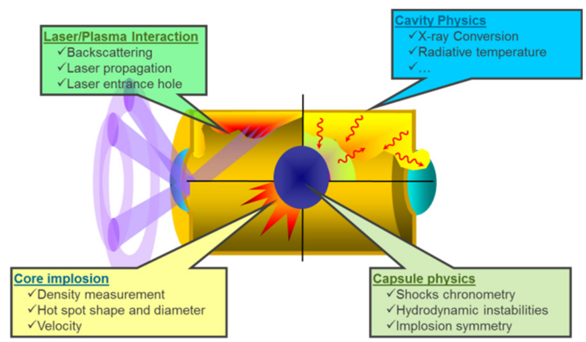


Figure 3: Target diagnostics measurements.

These Target Diagnostics are classified in 5 families (Fig. 4):

- Insertables TD
- Specific mechanical TD
- Visible/UV TD
- Neutronics TD
- Petal+ TD

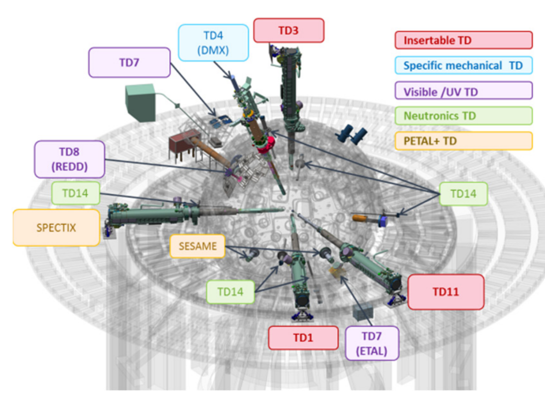


Figure 4: Target diagnostics families.

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This paper presents shortly the Target Diagnostics command-control. It shows how a new Target Diagnostic is progressively integrated into the different layers of the command-control system. We will see step by step the cycle life of a Target Diagnostic from its arrival inside the LMJ facility to its use in a LMJ shot. Then, we will introduce the Target Diagnostic integration. Finally, we will present how Target Diagnostics are managed to cohabit even if they are in different phases of their integration.

## TD COMMAND CONTROL

The LMJ command control architecture is controlled by the 4 classical component layers. As shown in Fig. 5 Layers 2 and 3 are devoted to the common control system (administration, main supervisory, prediction and tuning system 0]0, sequences).

Layer 1 is devoted to the main subsystems command controls (target and laser diagnostics, synchronization 0) and interfaces between them.

Layer 0 is the main layer for equipment communications. It includes drivers, communication protocols as well as maintenance and qualification tools.

Layer 1 is common for all Targets Diagnostics and as many as necessary drivers included in Layer 0 for each defined Targets Diagnostic. PANORAMA E² is the Framework used for Layers 1 to 3.

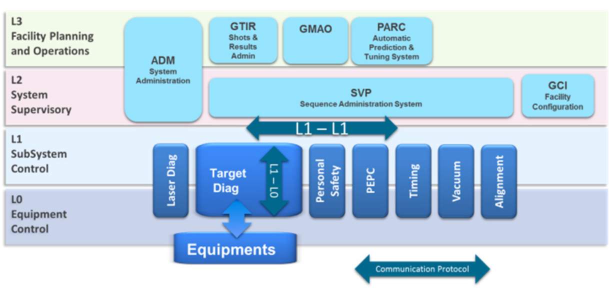


Figure 5: The LMJ command control architecture.

## TD ARCHITECTURE

The Fig. 6 shows the Target Diagnostic architecture.

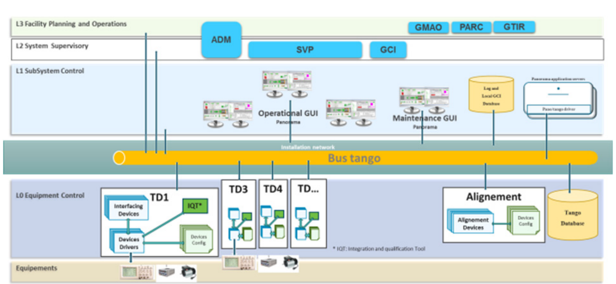


Figure 6: The TD architecture.

### *Layer 0*

In layer 0, the low level software of a target diagnostic can be decomposed into four main parts.

Devices drivers including simple driving functions, unitary driving and equipment attributes and properties,

Devices configuration files mostly to initialize the Tango database,

Interfacing devices which provide functions and attributes available for level 1,

Finally the integration and qualification tool (Fig. 7), which serves as low level General User Interface.

Figure 7: Integration and qualification tool.

Tango is used as the low level framework and Python is the main language. For each Target Diagnostic, Layer 0 is structured as this and supported at least by one computer. The tango database manages all the targets Diagnostics properties and attributes. The alignment software is a common framework for all Target Diagnostics.

### *Layer 1*

Layer1 is the supervisory Layer using the French SCADA PANORAMA E². It allows driving all the Target Diagnostics in the context of a unique user interface.

This Layer is composed of 3 main sublevels:

- The user interface used also for maintenance (Fig. 8)

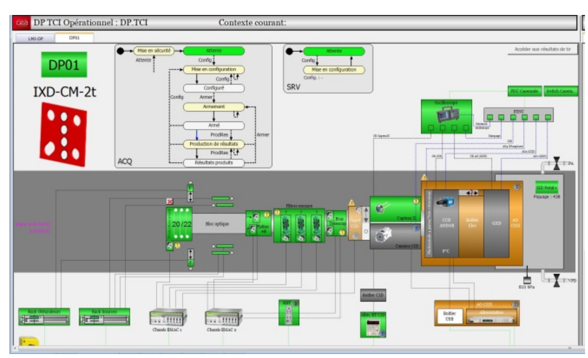


Figure 8: XRay layer 1 interface.

- The log and local configuration database that manages the configuration of all TD and records application logs,
- The PANORAMA application servers that are the heart of the command control system. The application server also implements a PANORAMA / Tango binding that interfaces the Tango bus with PANORAMA.

Layer 2 and 3 provide shared tools and shot sequences.

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The Target Diagnostics command control is in interface with others LMJ command controls subsystems as timing system, vacuum, common reference.

## TD LIFE CYCLE

Due to manufacturing delays, the Target Diagnostics integration can only be achieved shortly before first use.

The integration process progressively begins with Layer 0, then includes Layer 1 and finally is include in the shot sequence.

To understand how Targets Diagnostics integration works, let us depict the Target Diagnostic life cycle. First of all, the Target Diagnostic itself and its driving software is manufactured in factory (Fig. 9).

Figure 9: TD factory production.

Before delivery, unitary tests are made. The different parts of the Target Diagnostic are put together at the Equi-nox background Platform (Fig. 10). It is the first time where the Target Diagnostic meets its driving software.

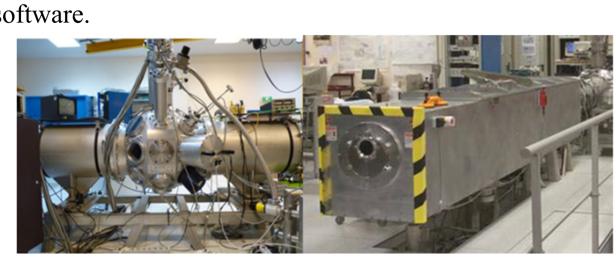

Figure 10: TD equinox platform.

Then the Target Diagnostic is sent to the LMJ Bench test (Fig. 11). After being assembled, some unitary tests are made.

Figure 11: TD LMJ bench test.

Finally the Target Diagnostic is set up in the experimental campaign process (Fig. 12).

The first integration tests are made here before the TD can be used during the shot sequence.

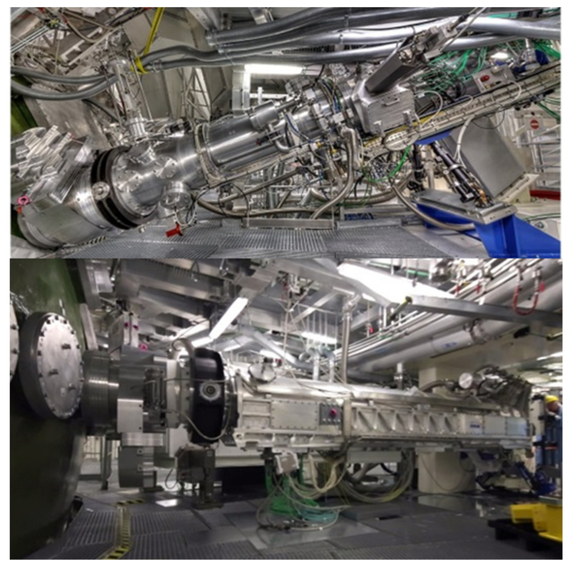

Figure 12: TD LMJ campaign position.

When the campaign is over, the insertables Target Diagnostics can potentially return back to the maintenance platform or to the Equinox platform for maintenance.

Then, they come back to a new position for the next campaign. But some Diagnostics may use shortcuts.

For each step, the software is used to test the diagnostic (Fig. 13). The Software Integration Platform is used to test the software itself and its integration in the global LMJ command control. In the background platform and the bench test, the integration and qualification tool is used for the tests. It is also used to begin the integration of the Tar-get Diagnostic in its campaign position (Layer 0). Finally, the integration ends with tests with the operational general interface (Layer 1).

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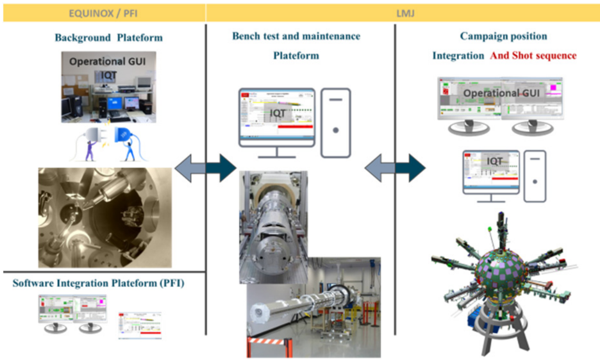


Figure 13: TD integration.

## NEW TD INTEGRATION

When a new Target Diagnostic arrives in the LMJ, all the command control Layers are impacted. First of all, a new Layer 0 command control needs to be developed. This leads to add its properties in the Tango Database. Then, a new user interface and application is integrated to the Layer1. Finally, the Target Diagnostic has to be integrated in the shot sequence (Fig. 14).

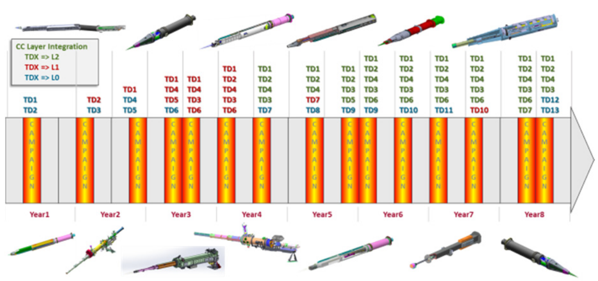


Figure 14: TD CC integration.

The integration in Layer 0 is fully independent to the other Target Diagnostics Layer 0 command control subsystems. The Tango Database is enriched with the new Target Diagnostic attributes and properties.

The integration of a new Target Diagnostic in Layer 1 needs to upgrade all the Layer1 command control as this framework is common to all the TD.

A new user interface has to be added.

A new version of the application server has to be deployed.

The configuration database has to be enriched with the new Target Diagnostic parameters.

As the LMJ is in operation mode, the new target diagnostic integration cannot disturb LMJ operations. This means that the integration of a new Target Diagnostic has to be done without any impact of the existing Target Diagnostics command control. So, to reach this goal, three design rules are necessary for software development:

- Target Diagnostics are different but by the use of common components, the same components are using the same code,
- Each Target Diagnostic application has the same structure,
- Each Target Diagnostic application is independent even if they use common functions.

### *Target Diagnostic Supervision Editor*

A tool named the Target Diagnostic Supervision Editor was developed to reduce the impacts of the integration on existing diagnostics.

It is used for:

- TD application Implementation,
- TD application generation.

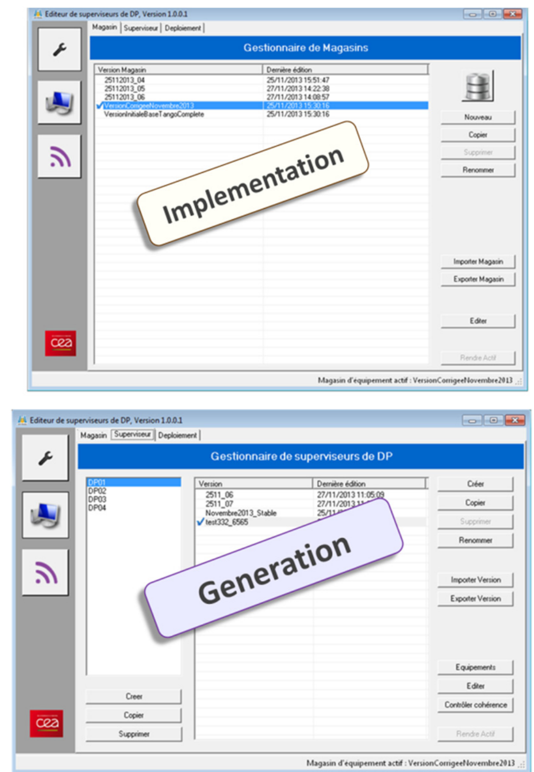


Figure 15: TD supervision editor GUI.

The Target Diagnostic Supervision Editor works like Russian Dolls (Fig. 15).

First of all it provides common elements as enumerates, data structures.

It offers an Equipment Library that gives the implementation of all known devices.

For the implementation of a New Target Diagnostic, the tool is used to generate a Target Diagnostic skeleton application. Then, the application is completed with specific components, functions, user interface and parameters. The Equipment Store is used for known devices and enriched by new devices.

Then a New target Diagnostic is available in the tool.

The operator chooses the Target Diagnostic he wants to include in the application.

The tool generates the global application including the Equipment Store the supervisory software and the configuration database containing.

With this tool, we guarantee that the existing TD are not impacted by a new TD.

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### *TD New Location*

Some TD location can change before a new shot campaign. Because of this movement, the hardware of the TD has to be connected to the new location racks. To make it easier, each location is equipped with the racks compatible with all the target diagnostics. When the Target Diagnostic arrives it is only necessary to connect the equipment to the cabinets.

The software needs also to be configured. From a software point of view, the main changes concern the network configuration and the connection to the common timing system hardware responsible for triggers delivery. Some of the devices need to adjust their parameters as an example of the trigger delays. We also have to attach devices to their new location in order to make maintenance operations easier.

So, when a Target Diagnostic moves, two situations have to be assessed: a new location or an already used location.

For a new location, the operator has to configure the software. Then, he saves this specific configuration.

For an already used position, it is only necessary to load the Target Diagnostic Position Configuration.

For this reason, a tool has been developed to create the new location Target Diagnostic Configuration. This tool produces the configuration files necessary to fill up the Target Diagnostic Configuration Database.

## TD SHOT SEQUENCE

The integration of a new TD is in order to use it during the shot sequence.

We will present now the main steps of the shot sequence (Fig. 16). First is the alignment step. This step guarantees that the Target Diagnostic will see the shot. Then the Target Diagnostic is configured for the shot. That means acquisition configuration for cameras, oscilloscopes etc. It also concerns equipment safeguarding by closing shutters, switching off alignment beams and so on. Next step is to arm all measurement devices. Then measurement devices receive the trigger from the timing system at the right mo-ment of the shot. Finally, measurement devices retrieve the results. The Results Recovery process permits the storage of all these results.

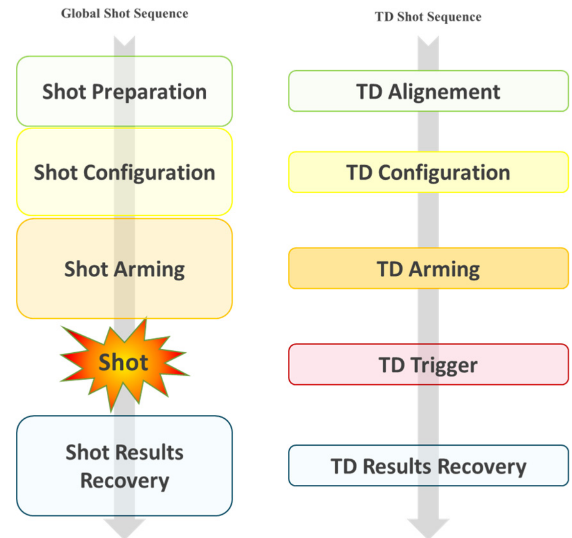


Figure 16: TD shot sequence.

Then, some integration tests are made and finally the TD can be used in the shot sequence.

### *Target Diagnostic Layers Functions*

In a Shot Campaign, we are using the TD in different steps of integration. That means that some of the TD are driven by Layer 2 in the shot sequence, then by Layer 1 application and at last by Layer 0 applications. First, we have to present the difference of the driving mode in these three Layers during the shot sequence (Fig. 17).

Layer 2 drives the global Shot Sequence process. It automatically gives the correct parameters for each function. It also guaranties the global synchronization of the equipment and the results recovery. It controls the global installation configuration and Resource management.

Layer 1 assures the TD resource management. It manages all the Target Diagnostic parameters. Interfaces with other CC are also provided by this Layer. It gives to the operators global functions and the ability to drive more than one TD. It provides the general user interface for the Target Diagnostic supervision.

Layer 0 provides low Level functions. The interface with other Command Control and the resource management is voice made. There is no multiDP driving or global functions.

We can take as an example the Configuration step. For Layer 2, the Target Diagnostic operator only needs to supervise. For Layer 1, the operator needs to execute only one function. In Layer 0, he needs to execute more than fifty functions.

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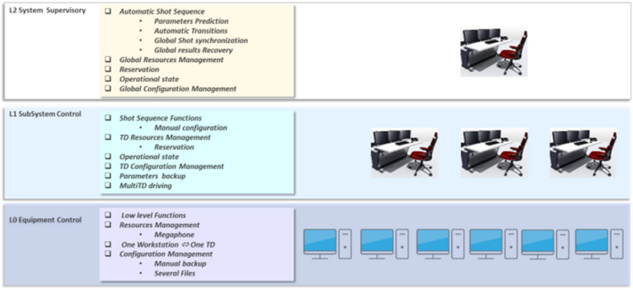


Figure 17: TD layer main functions.

Thus, Layer 1 makes easier the use of the Target Diagnostic in shot sequence but not as much as Layer 2 does. The number of Target Diagnostics is increasing and if we don't include them within the shot sequence we won't be able to manage them all, without a lot of operators and workstations. Until the whole Target Diagnostics are integrated in Layer 2, they have to be driven apart from their integration Layer. To allow the cohabitation of all Target Diagnostics during the Shot sequence, each Layer needs specific configuration.

### *Target Diagnostic Layers Configuration*

In this part, the main elements of configuration for the shot sequence are presented.

In the shot sequence, a Target Diagnostic used in Layer 0 is not connected to the other Layers.

Each Target Diagnostic is driven by a specific workstation. The operators notify to Layer 2 when the specific Target Diagnostic is ready for the shot. After the shot, the operator checks the results and makes them available to the shot director.

Since some Target Diagnostics are controlled by Layer 2, all the Layer 1 is connected to Layer 2. Thus, it is necessary to configure the two Layers in order that the Target Diagnostics are controlled during the shot sequence.

The Layer 1 target diagnostics are driven in accordance with their family using a workstation by family.

Layer 1 and 2 are using a common framework. This one implements LMJ data model and some services as re-sources management and configuration management (Fig. 18).

With the Reservation management each layer (1 or 2) can define the resources used during the shot sequence.

So they include the resources they have to control and exclude the others. For example, the Target Diagnostics triggers are include in layer 2 reservation management and exclude from layer 1.

Another common function is the facility configuration management. For instance, in shot sequence, it allows to remove from the local configuration database unused Target Diagnostics.

With the common framework functions, each layer is able to control the Target Diagnostics securely, apart from the other layers.

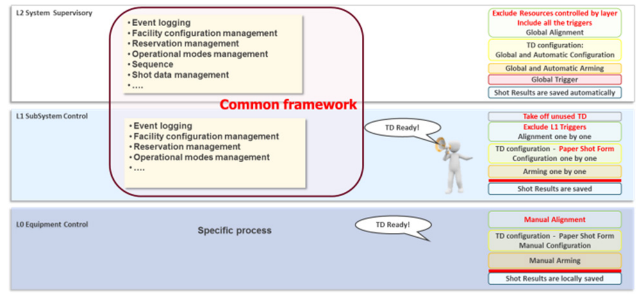


Figure 18: TD shot sequence adjustments.

## SUMMARY

At least two new Target Diagnostics are integrated each year. More than fifteen are under construction. This paper describes how we manage to integrate new TD on the LMJ facility. This progressive integration has to fit into the shot campaigns process. Thus, some tools had to be developed to reach this aim without any impact to existing diagnostics.

The Global Shot Sequence allows driving the TD in their different layers of integration. This paper also describes how the layers configuration allows this cohabitation.

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