STRATEGY FOR THE INTEGRATION OF THE LMJ (Laser Megajoule) CONTROL SYSTEM

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Abstract

The French CEA (Commissariat à l'Énergie Atomique) is currently building the LMJ (Laser Megajoule), at the CEA Laboratory CESTA near Bordeaux. The LMJ is designed to deliver a high energy of 0.35 µm light sufficient to reach the ignition of the fuel included in a tiny target. CEA has imposed an industrial policy by dividing the LMJ development and construction into a dozen major contracts. Each of these contracts supplies the hardware (e.g. Capacitor bank) and the associated control System. CEA is the project manager of the centralized supervisor and the communication protocols between the several subsystems. CEA is also responsible for the subsystems integration which is a major challenge.

This presentation discusses the integration strategy. It is a three step process, each taking place in a different site: factory acceptance tests at the subsystem level, integration tests of the whole control system on a dedicated "Integration Platform", and finally on site tests from an "integration control room" (which is different from the operation control room). This paper will describe the necessary integration and simulation tools and the tasks related to these three steps.

LMJ FACILITY

The Laser Megajoule facility (LMJ) is presently under construction at the CEA/CESTA site near Bordeaux (France). LMJ is a 176 beams laser system upgradeable to 240, to study inertial confinement fusion and the physics of extreme energy densities and pressures. LMJ is capable of focusing a high energy of ultraviolet light on an extremely small micro-target in an extremely short space of time. The characteristics of this facility were defined to obtain the temperature and pressure conditions required to reach a D-T ignition. These laboratory experiments will involve tenths of a milligram of matter in which nuclear fusion reactions will be produced. LMJ is an element of the Simulation Program that forms the basis for the guarantee of the safety and reliability of French nuclear weapons. LMJ will also welcome national and international scientific collaborations, in order to become a privileged place of scientific exchanges.

The LMJ building covers a total area of 40,000 m² (300 m long x 150 m wide). Four laser bays, 128 m long, are situated in pairs on each side of a target bay. The target bay is a cylinder, 60 m in diameter and 38 m high, which contains an experiment chamber. This chamber is an aluminium sphere, 10 m in diameter, fitted with about hundred ports for injection of the laser beams and introduction of diagnostics.

The beams are grouped in bundles of 8 beams in the laser bays and in quads in the target bay. Numerous diagnostic instruments will be placed in the target chamber around the target to record essential measurements. They will observe the behaviour of the target during its implosion and at the time of ignition. These diagnostics are the prime tools for the physicists to determine the characteristics of the plasmas they are studying.

LMJ CONTROL SYSTEM

The great number of equipment and the necessary accuracy require an appropriate control system to operate LMJ. It makes it possible to perform with a high level of automation:

- The preparation of the shot (automatic alignment, beams synchronization, set up of laser and target diagnostics),
- The execution of the shot (countdown sequence, laser beams triggering and shot data acquisition),
- The post shot processing of the acquired data.

In an operation control room, a shot director, assisted by about 20 operators, is in charge of the shot operation. They control the LMJ facility via some hundred graphical user interfaces (GUI's). A shot can be regarded as a countdown like the one for launching a rocket.

To operate the LMJ, the control system will require about 150 computers located in a computer room and about 450 PLC's or rack mount PC's near equipment. The control system will be able to manage 500,000 control points, 150,000 alarms, and one gigabyte of data per shot, with 2 years on line storage.

The LMJ control system is distributed on a pyramid which has 4 different levels: the laser or target equipment controllers on the level N0, subsystem supervisory on the level N1, system supervisory on the level N2 and facility management on the level N3.

CEA has imposed a general industrial policy. From an industrial point of view, a dozen of major contracts correspond to the main LMJ functions (Capacitor Bank, laser diagnostics, etc.).

Each contractor supplies a subsystem which is a collection of equipment performing the specific function including the control system. The majority of the subsystems includes the equipment (for instance: Capacitor bank), the associated equipment controllers (level N0) and the subsystem supervisory (level N1).

CEA acts as a prime contractor for several functions of the levels N2 and N3. CEA is the project manager of the high level supervisory system. This system coordinates the subsystem control systems of the level N1. This

system includes a shot sequences execution system of the level N2 and three systems of the level N3: shot data processing and management, network management and computers administration, configuration and maintenance management.

The subsystems are allowed to communicate with each other on the level N1, and can thus provide direct services to each other (e.g. required timing for triggers). CEA is responsible for the interface protocols (low level N1 - N2 and N1 - N1). They are imposed to every LMJ contractor. At least CEA supplies also the common recommendations for the standardization of computers, operating systems, virtualization and network hardware.

INTEGRATION STRATEGY

CEA is responsible for the integration of all the components resulting from his industrial policy. To achieve this, a functional integration strategy is imposed by CEA and in particular, includes requirements for the control system function.

CEA wants to qualify software packages out of the LMJ facility before transferring them to the LMJ:

- To correct the default settings as soon as possible.
- To debug without any risk system processes like shot sequences.
- To reduce as much as possible the activity of the LMJ facility during laser commissioning.

Consequently, the use of an Integration PlatForm (PFI) is required. The heart of the PFI is supplied by a contractor which is also in charge of the integration tasks of the LMJ control system. On the PFI, it performs integration tests between the different control subsystems and the high level supervisory system. A call for tenders is on the way.

To separate the developments of the control systems and to allow the interface tests at the factory and PFI, it is necessary to simulate the subsystem software packages in interface. EXTernal Interfaces Simulators (SITEX) are supplied by CEA to every subsystem contractor. They implement protocols and simulate the interfaces, i.e. they don't represent the internal behaviour of the equipment. SITEX are developed by the CODRA Company which is already in charge of the package of the shot sequences execution.

CEA wants to operate the already operational bundles (for adjustments or experiments) simultaneously with the commissioning of a new bundle. For this reason, a specific integration control room is created which is different to the operation control room. After their validations on the PFI, the software packages supplied by the contractors are installed on a small network (Integration Network) located in the LMJ building but not linked to the operation network. The network is connected to the bundle under integration.

STRATEGY STEPS

The strategy for the integration of the LMJ control system is a three steps process, each taking place in a different site:

- Factory acceptance tests, separately for the equipment and the control system,
- Integration tests on the PFI without equipment, subsystem by subsystem,
- Functional integrations in the LMJ building from an integration control room, bundle by bundle,

On the PFI, the subsystems are integrated with a normal scheduling according to the dependencies between them. The least dependent are the first.

On the LMJ building, new bundles are progressively added to the already operational bundles for validations and experiments from the operation control room.

The steps of this software integration are obviously closely interwoven with the general LMJ integration ones.

Factory Acceptance Tests

Among the most important requirements to enforce during the factory acceptance tests we find:

- An acceptance test for the software that must be different from the tests of the hardware it controls.
- The contractor's obligation to demonstrate the proper functioning of a full LMJ configuration (e.g. the power conditioning hardware must control the capacitor banks of all the bundles).

Because all equipment cannot be present at the factory, this configuration must at least include a physical equipment set of each type. Other equipment must be replaced by equipment simulators. A simulator is only based on computers. Its inputs and outputs are similar to those of the real equipment. In addition to correct operation, it allows the simulation of abnormal behaviours that would be impossible to obtain with real equipment (safety, cost, etc.). The equipment simulators are supplied by each contractor. Their software packages are supplied to the PFI with the subsystem packages.

The simulators allow the whole internal functional tests. The SITEX allow all the protocols tests. Both allow the reliability tests and the automation of the tests. The software reliability is a major requirement.

The contractor also needs an "integration tool". It is mainly a software package that will allow him to check, in a stand alone mode, the behaviour of his equipment (e.g. that a command operates on the right motor and that this motor rotates in the right direction).

Integration Tests on the PFI

Initially, the integration contractor provides and configures the PFI heart to receive the subsystem software packages for their integration with the other packages.

Then hardware and software from subsystem contractors are added once they have been accepted at the factory: high level supervisory system at the first time,

then equipment controllers, supervisory subsystem, simulators and integration tools for each subsystem.

The PFI heart includes a large database which will ultimately contain every software package constituting the LMJ control system. The software configuration management will allow compatibility rules between different versions to register. It will be possible to generate disk or virtualized images ready to be downloaded into the LMJ control computers.

The tests on the PFI are performed in three phases:

- Global tests for the high level supervisory system,
- Then global tests for each subsystem control system,
- Finally, qualification of the whole control system.
- The tasks of the integration contractor relating to the global tests on the PFI are the following ones:
- At the arrival of a subsystem package, the integration contractor checks the absence of virus on a dedicated computer (airlock). Then he installs the software package on a newly formatted machine, in order to check that all software components have been delivered.
- Then, he briefly checks that there is no functional regression in comparison with the factory acceptance tests by operating the package with its equipment simulators and its SITEX.
- After, he disconnects the associated SITEX, connects the subsystem to the already integrated subsystems and run the integration tests by checking the overall functioning.

As soon as all the laser (or target bay) subsystems are integrated, the next and third phase is the qualification of the whole laser (or target) control system. As all the hardware equipment are replaced by simulators (22 up to 30 bundles), the integration contractor can fully carry out and validate the system sequences that he has developed and the settings automatic computations. Sequences are macro-programs that allow the automation of a succession of high level operations (i.e. to charge the capacitor bank of a particular bundle, to align a bundle, to perform a shot, to archive data, etc.). Sequences can be configured for different types of shots. Thus, the integration contractor can fully execute virtual shots on the PFI.

Physically, the operator's consoles of the PFI are located in a control room, near the LMJ building. The associated racks are housed in an adjacent computer room. The PFI building covers an area of 450 m².

Functional Integration in the LMJ Building

The functional integration in the LMJ building is performed in two phases: industrial tests for each subsystem, then system tests of a bundle or of the target area.

The first bundle and the target area are directly integrated from the operation control room. The contractors download the disk or virtualized images generated on the PFI into his computers connected to the operation network. All the computers related to the levels N1, N2 and N3 are located in the computer room. The operator's consoles are located in the operation control room. The equipment controllers (or front-end processors) used for this integration are the operational ones, located under the laser bays or in the target bay.

It is the first time that the subsystem software package controls the real equipment using the nominal wiring. In a stand alone mode, with the same integration tool used at the factory, the contractors can check the behaviour of equipment and the wiring which have been installed by a wiring contractor according to them requirements.

As soon as all the subsystems of the bundle or of the target area are integrated, CEA operators run the system tests. CEA makes sure that all the subsystems and the high level supervisory system work well together (right working settings, shot sequences, accuracy, etc.).

The bundles 2 up to 30 are then integrated with the same logic as the first bundle but from the integration control room. New computers of the levels N1 to N3 and new consoles are installed in this room. They are connected to the integration network as all the equipment controllers of the bundle under integration.

As soon as a bundle is fully integrated, all the associated equipment controllers are switched to the operation network where the LMJ control system is. From the operation control room, this time, CEA can validate this added bundle with the already operational bundles and carry on the experiments.

LMJ CONTROL SYSTEM MILESTONES

The challenge of CEA acting as a prime contractor is to coordinate the dozen contracts and to integrate their software deliveries according to the general LMJ integration. Six major milestones are described below:

- First, qualification of the high level supervisory system on the PFI,
- Second, factory acceptance tests of each subsystem control systems,
- Third, qualification of the laser control system on the PFI,
- Fourth, qualification of the target control system on the PFI with the already qualified laser control system,
- Fifth, delivery of the first bundle in the LMJ building to the operators for laser experiments,
- Sixth, delivery of the target area to the operation team for commissioning.

The first experiments on the target are expected end 2014.

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