THE LASER MEGAJOULE FACILITY: CONTROL SYSTEM STATUS REPORT

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Abstract

The French Commissariat à l'Énergie Atomique (CEA) is currently building the Laser MegaJoule (LMJ), a 240 beam laser facility, at the CEA Laboratory CESTA near Bordeaux. LMJ will be a cornerstone of CEA's "Programme Simulation", the French Stockpile Stewardship Program. LMJ is designed to deliver about 1.8 MJ of 0.35 µm light to targets for high energy density physics experiments, among which fusion experiments. LMJ technological choices were validated with the Ligne d'Intégration Laser (LIL), a scale 1 prototype of one LMJ bundle, built at CEA/CESTA. Plasma experiments started at the end of 2004 on LIL. The construction of the LMJ building itself started in March 2003. An important milestone was successfully achieved in November 2006, with the target chamber put in place into the building. LMJ will be gradually commissioned to allow for first experiments at the end of 2012..

This presentation discusses LIL experience feedback, transverse requirements intended to ultimately integrate control packages from different contractors, strategy for developing the Centralized Supervisory Controls and process for computer control system global integration.

THE LMJ FACILITY

The Laser Megajoule facility (LMJ) is presently under construction at the CEA/CESTA site near Bordeaux (France). LMJ is a 240-beam laser system to study inertial confinement fusion (ICF) and the physics of extreme energy densities and pressures.

LMJ is capable of focusing its energy of 1.8 MJ ultraviolet light on to 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 thermonuclear 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. It is comparable to the US NIF facility.

The LMJ building covers a total area of 40,000 m2 (300 m long x 150 m wide). The four laser bays, 128 m long, are situated in pairs on each side of the target chamber. The concrete slab supporting the laser system is separated and stabilized by a large number of pillars. The experiment building (target bay) is a cylinder of 60 m with a height of 38 m. The target chamber consists of an aluminum sphere, 10 m in diameter, fitted with several hundred ports for the injection of the laser beams and introduction of diagnostics.

The 240 beams are grouped in 30 bundles of 8 beams in the laser bays and in 60 quads in the target bay.

Numerous diagnostic instruments will be placed in the target chamber around the target to record essential measurements. They will make it possible to observe the behavior 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.

THE LMJ PROJECT STATUS

The target chamber was put in place in the target bay in November 2006. The conventional facility of the building is now complete, and the assembly of the first bundle in a laser bay is in progress.

The LMJ commissioning strategy is to have several steps towards full energy by successively providing each bundle with its optical components and control system, and at the same time using the commissioned bundles for shots and fusion experiments.

THE LIL FACILITY

The LIL facility is a prototype that was designed to validate the technological options adopted for LMJ. It consists of a unique laser bundle of LMJ. It is capable of delivering 30 kilojoules of laser energy. LIL was commissioned in March 2002. LIL has already fired numerous shots for the physicist community of CEA/DAM. A petawatt beam is under construction and will be eventually coupled to LIL's quad.

THE LMJ CONTROL SYSTEM

The great number of equipments involved in a shot requires a control system to operate LMJ. It makes it possible to perform with a high level of automation:

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

The LMJ control system is composed of four layers: layer N0 corresponds to the basic control of a laser or target equipment, layer N1 to sub-system (collection of equipments performing a specific function) supervisory,

layer N2 to shot planning and operation and layer N3 to facility operation and planning.

From an industrial point of view, LMJ is divided into a dozen major contracts which correspond to the main functions (power conditioning, laser diagnostics …). Each of these contracts supplies the function hardware (e.g. Capacitor bank) and the associated control. A high level supervisory coordinates these subsystem controls.

For LIL, subsystem contracts supplied the layer N0 and the high level supervisory contract provided the upper layers (N1, N2, N3). A prime contractor was in charge of the interface protocol. The communications between subsystems had to transit by the high level supervisory.

The LIL experience feedback is quite comprehensive. During the development phase, frequent changes had to be brought to the high level supervisory software because of unexpected modifications of the equipment hardware under development. The problem was related to the interface level between the two contracts that was too low, too close to unstable hardware. Several problems also occurred with the non standard interface toolkit and the insufficient specification of the subsystems software behavior. Then, the integration of the subsystems proved difficult and lengthy because factory acceptance tests were degraded by an acceleration of the Project planning. Furthermore, the Integration platform was not sufficiently representative of the actual equipment hardware.

For LMJ, the interface level was moved upwards, so that the subsystem contracts now supply also their own supervisory (N0+N1). CEA acts as a prime contractor and is responsible for the interface protocol. The subsystems are now allowed to communicate with each other at the N1 level, and can thus provide direct services to each other (e.g. requiring timing distribution).

The interface protocols (N1-N2 and between N1 of different subsystems) imposed to every LMJ contractor via a data model were fully standardized: at the low level with the adoption of Web-Services and OPC-DA (OPC-UA is also under consideration), and at the upper level with a unique set of universal basic mechanisms (resource reservation, timing request, alarm management, coordination for transitions between lifecycle states, sequences …). Additional transverse requirements (mandatory choice of computers, operating systems and network hardware) were written. Two of them are presented in this paper.

The first transverse requirement concerns reliability objectives for subsystem software. This requirement is based on a method developed by the French company Mathix ALL4TEC. During the development phase, subsystem contractors must perform tests in relation with the mission profile. Then they have to record the software failures and plot their cumulated number versus the test duration. From the shape of the resulting chart, with the LIL experience feedback and the assistance of Mathix, CEA will be able to estimate the present and future software reliability. These elements ares required for factory acceptance by CEA.

Another transverse requirement concerns a certain level of standardization of computer hardware and software. The priority is given to cost reduction and to commercially available products. The SCADA imposed to every contractor is PANORAMA E2 from the French CODRA company. PC and Windows Vista are imposed for the upper layers.

Acceptance tests and integration process were refined, particularly with the introduction of the concepts of simulators and integration platform. Two types of simulators were defined. One, supplied by CEA, simulates the high level supervisory software. It allows a subsystem contractor to independently develop its control software. The other simulator developed by the subsystem contractor simulates the totality of his equipment hardware (30 bundles). It allows him to test his software without having to wait for the end of his equipment production. These simulators will later be installed on the integration platform together with the whole operational software (N0 to N3). Subsystems will be gradually integrated. Virtual shots, with the 30 virtual bundles, will be conducted in order to fully test the software independently of the LMJ facility.

The final step is the qualification test of an individual LMJ bundle. This stand alone procedure will be conducted from a dedicated control-room. The qualified bundle will then be connected to the LMJ operational network.

THE HIGH LEVEL SUPERVISORY SOFTWARE

For LIL, a company was a prime contractor for the high level supervisory system. For LMJ, CEA will have this responsibility.

The high level supervisory software developed for LIL covered the N1, N2 and N3 layers. The LMJ software covers only N2 and N3 and thus allows the reuse of LIL components. They will however have to evolve to take into account the LIL operation feedback and the change of the interface protocol with the subsystems.

The major high level supervisory software components are:

- GMC for the management of the configuration of laser and target characteristics and their settings
- GTIR for the management of shot goals files (expected characteristics of the beams when they arrive on the target, depending on the type of experiment)
- SVP for the shot sequence execution (command and control of subsystems). This software relies on a

SCADA type commercial product: Panorama E^2 developed by the French company CODRA.

- ADM for network administration

THE LMJ CONTROL SYSTEM ROAD MAP

The challenge of CEA now acting as a prime contractor is to coordinate a dozen contracts and to integrate their software deliveries.

The first milestone is to have common software requirements included in every subsystem contract. These contracts will be signed in 2007 and 2008. The next milestone is represented by contract reviews that will allow a close management of each contractor during the development phase. The third milestone concerns the qualification of the system supervisory on the integration platform which will occur in winter 2010. Then come the integrations of each subsystem control. They will spread out over the year 2011. The supervisory and control of the first laser bay is expected for winter 2011, followed at mid 2012 by the target bay supervisory and control.

REFERENCES

[1] Michel L. André, "The French Megajoule Laser Project (LMJ)", Fusion Engineering and Design, Volume 44, February 1999 (p.43-49).