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 up to 240-beam laser facility, at the CEA Laboratory CESTA near Bordeaux. It is a Megajoule class facility, designed to deliver a high energy to targets for high energy density physics experiments, including fusion experiments. LMJ technological choices were validated with the LIL, a scale 1 prototype of one LMJ bundle. The construction of the LMJ building itself is now achieved and the assembly of laser components is on-going.

The presentation gives an overview of the control system architecture and focuses on the way it was divided between the dozen of contractors involved in the LMJ design. We will discuss also how we tried to preserve system consistency by developing a common framework shared by the different contractors. This framework is based on the PANORAMA E^2 industrial SCADA and includes WCF technology for subsystems communication. It is intended to integrate all the common components and rules for configuring, controlling and operating a large facility, so that developers has only to concentrate on process specific tasks.

THE LMJ FACILITY

The Laser Megajoule facility (LMJ) is presently under construction at the CEA/CESTA site near Bordeaux (France). LMJ is an up to 240-beam laser system to study inertial confinement fusion (ICF) and the physics of extreme energy densities and pressures. LMJ is a Megajoule class facility capable of focusing its energy of 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. LMJ will 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). The four laser bays, 128 m long, are situated in pairs on each side of the target chamber. 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 building itself is now complete; the mechanical assembly of the bundles in the first laser bay is achieved. In the second laser bay the assembly of the bundles 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 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 eventually be coupled to LIL's quad.

THE LMJ CONTROL SYSTEM

The LMJ control system main functions are:

- 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: N0 layer corresponds to the basic control of a laser or target equipment, N1 layer to sub-systems (collection of equipments performing a specific function) supervisory control N2 layer to shot planning and operation and N3 layer to facility operation and planning. From an industrial point of view, LMJ is divided into a dozen of major contracts which correspond to the LMJ main functions (power conditioning, laser diagnostics, etc.).

Each of these contracts supplies the equipments hardware (e.g. Capacitor bank) and the associated controls. A high level supervisory control system coordinates these subsystems. For LIL, subsystem contracts supplied the N0 layer and another contract provided the upper layers (N1, N2, N3). 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 software and the insufficient specification of the subsystems behavior. Then, the integration of subsystems proved difficult and lengthy. Furthermore, the integration platform was not enough representative of the actual equipment hardware. For LMJ, the interface level was moved upwards, so that subsystem contracts now supply their own supervisory system (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 subsystems) imposed to every LMJ contractors were fully standardized: at the low level with the adoption of Web-Services and WCF, and at the upper level with a unique set of universal basic mechanisms.

DATA MODEL

The data model key concept is the resource. Resources represent equipments (motors, instrumentations, diagnostics…) or high level functions (alignment, laser diagnostics).The entire facility is described through trees of resources. Resources are linked together through different kinds of relationships (composition, dependency, incompatibility). Properties, functions, control points and alarms are attached to each resource. Resource life-cycle is described through states-charts.

Control-Points, alarms, states and functions standing for actions on equipments, are attached to each resource. Dedicated mechanisms manage the resource reservation and propagate properties updates into the tree of resources through relationships. There are about 200 000 resources in order to describe the entire LMJ.

COMMON COMPONENTS

It appeared during the design phase of the supervisory software that the N1 layer was actually composed of two sub-layers: the lower one which is subsystem specific and the upper one, common to every sub-system, which implements the data model and the interface protocol. This sub-layer named "Common Components" is developed independently by the N2 contractor, because N1 Common Components it is very similar to the N2 layer. It provides the following services:

- resources management,
- alarms management,
- lifecycle states management,
- sequencing,
- configuration management,
- event logging

Its use by every LMJ contractor is mandatory. We expect form this strategy less expensive and more reliable subsystems and consistency enhancements between N1 and N2 layers.

The high level supervisory software

The high level supervisory software developed for LMJ covers the N2 and N3 layers of the command control architecture. Few LIL components were reused, because we will have to take into account the LIL operation feedback and the interface protocol changes between subsystems.

The major high level supervisory software components are:

- GMC for maintenance and configuration management
- GTIR for the management of shot requirements files (expected characteristics of the beams involved in the shot)
- SVP for the shot sequence execution and high level supervisory controls. This software relies on a commercial product: Panorama E2 developed by the CODRA company.
- ADM for network administration.
- Common Components also rely on the commercial product Panorama E2.

Major contractors were chosen:

- The Sopra company is in charge of GMC and GTIR,
- The Codra company is in charge of SVP and Common Components
- For ADM, a call for tenders is on the way.

The contracts with Codra and Sopra were signed in 2007 and 2008. Successful requirements reviews carried out during summer 2008 for GTIR, GMC, and SVP. Then successful design reviews took place during summer 2009.

The priority was given to cost reduction and commercially available products. PC and Windows are imposed for the upper layers.

The design phase is now achieved and all major choices are made:

- SVP and Common components are specific ".Net" developments above the Panorama E^2 SCADA.
- Specific developments about LMJ sequencing will be integrated in the product Panorama E^2 in a future issue. GMC and GTIR are specific ".Net" developments above the Oracle 10g database.
- A mix of xml and HDF5 is used for shot data storage.

- The CMMS is based on the D7i product of Datastream.

The realization of these components is ongoing.

THE LMJ CONTROL SYSTEM ROAD MAP

The remaining contracts will be signed at the end of 2009 or in 2010.

The next milestone in 2011 is the commitment of the supervisory system on a dedicated platform, followed by the integration of subsystem controls.

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