ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-MOPV003

LASER MEGAJOULE FACILITY OPERATING SOFTWARE OVERVIEW

J.-P. Airiau, V. Denis, H. Durandeau, P. Fourtillan, N. Loustalet, P. Torrent
CEA, Le Barp, France

Abstract

The Laser MegaJoule (LMJ), the French 176-beam laser facility, is located at the CEA CESTA Laboratory near Bordeaux (France). It is designed to deliver about 1.4 MJ of energy on targets, for high energy density physics experiments, including fusion experiments. The first bundle of 8-beams was commissioned in October 2014. By the end of 2021, ten bundles of 8-beams are expected to be fully operational.

Operating software are used to automate, secure and optimize the operations on the LMJ facility. They contribute to the smooth running of the experiment process (from the setup to the results). They are integrated in the maintenance process (from the supply chain to the asset management). They are linked together in order to exchange data and they interact with the control command system. This paper gives an overview of the existing operating software and the lessons learned. It finally explains the incoming works to automate the lifecycle management of elements included in the final optic assembly (replacement, repair, etc.).

INTRODUCTION

The LMJ facility is still in construction. We are currently mixing assembly, operating and maintenance activities at the same time. The progressive increase of operating activities concerns the laser bundles (10 of 22 expected) and the target chamber diagnostics (14 of 33 expected) (see Fig. 1).

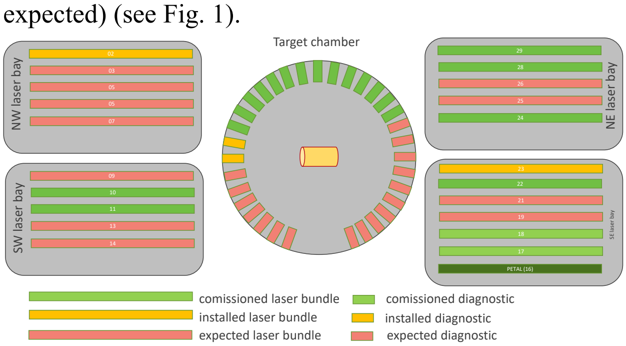

Figure 1: Laser bundles and target diagnostics status.

Laser bundles assembly started in early 2013; the first physics experiment on the facility has been done at the end of 2014 with one laser bundle and two target chamber diagnostics. The end of laser bundle assembly operations is expected for 2025. The full set of target chamber diagnostics is expected later.

Operating software are used to automate, secure and optimize the operations on the LMJ facility. They contribute to the smooth running of the experiment process (from the setup to the results). They are integrated in the maintenance process (from the supply chain to the asset management).

OPERATIONS VS MAINTENANCE

Operating the facility must be still possible while doing assembly and maintenance activities avoiding coactivity issues. These activities must respect safety and security instructions.

Operating such a facility needs to manage many different technical skills (mechanics, electronics, automation, computing and physics). The LMJ is composed of many components. Some of them could be « on the shelves » parts (ex.: pump or motor), others could be specifically designed for the facility and be made of innovative technologies in order to meet the extreme requirements (temperature, pressure and radiation). The supply chain could be very complex for some parts (exclusive know-how, small manufacturing capacity).

The main goal is to fully operate the facility with all the laser bundles and target diagnostic available. But like all complex system, there is sometimes issues on the components (failure, malfunction, etc.). The impact of these issues could be transparent (fault tolerance managed by redundancy), moderated (fault could be bypassed), serious (one laser bundle or one target diagnostic is unavailable) or critical (experiment failure/facility shutdown).

Everything is done to avoid a critical failure and optimize the operation availability. This availability is measure with a Key Performance Indicator (KPI). For example, an availability of 75 % means that quarter of the time the facility could not operate in a nominal way. The time wasted in unplanned maintenance (replacement of faulty parts) downgrade the availability. This KPI is used to measure the technical management of the facility and the ability to anticipate the failures. It is also used for long and mid-term planning.

In order to maximize the availability, it is important to identify all the parts with a Mean Time To Failure (MTTF) lower that the facility’s operating life time. It is important to characterize some indicators used to check the “health” status of these parts. By monitoring these indicators, you can anticipate the replacements before the

ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-MOPV003

occurrence of failures. The stock management is based on the MTTF in order to plan the supply of spare parts.

Some of the issues related to the human factor cannot be predicted. It is possible to limit these issues by constantly updating the operating procedure with the feedback (to avoid doing the same error twice). However, it is hard to eliminate totally these kinds of issues.

Despite substantial efforts to reduce unplanned event, you have to deal with operations and maintenance activities. In order to ensure the highest availability KPI, these two activities must be closely linked and complementary. You can't oppose them: operating the facility need maintenance to run and maintenance is useful only if the facility is running (see Fig. 2).

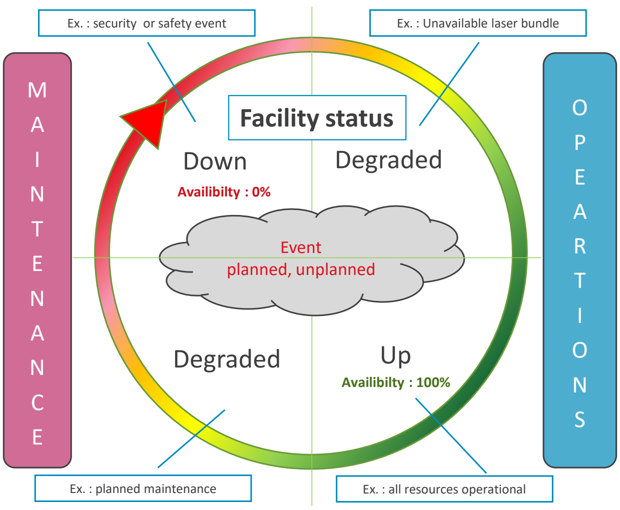

Figure 2: Operations and maintenance duality.

A set of operating software are used for each activity and interfaces between them provide the link.

OPERATING SOFTWARE

Operating software tools are used to control and automate operation and maintenance. These high level tools manage process made of complex tasks in order to reduce the processing time and avoid risk linked to the human factor. Human actions are limited to control critical step in the process (monitoring). The control is made by an operator (technician, contactor) and can be helped by an expert (engineer) if necessary. The idea is to avoid wasting time in low value-added actions and save resources. The tools are used to build dedicated reports to ease the analysis of an issue. The results of the analysis can be re-integrated in the tools and be used to identify a known degraded behavior.

Operating software are used for experiment and maintenance processes.

Operating Software for Experiment

The operating software are developed internally, they are linked with the command control system (see Fig. 3). The shot manager tools (GTIR) is the input and output point of an experiment. The experiment setup is described in GTIR. The results are stored and displayed in this tool. Computing tools are used to:

- predict the control command setup (PARC),
- compute the results and check security and performance during the different step of the shot sequence (rod shot, power shot, etc.),
- calibrate equipment and CC setup with calibration sequence,
- validate experiment results for laser bundles and target diagnostics (PARC + OVID).
- Equipment setup and characteristics are stored in the command control configuration tool (GCI).

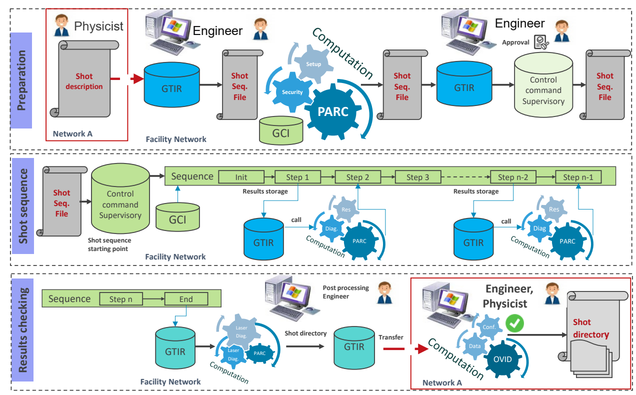

Figure 3: Operating software for experiment.

Operating Software for Maintenance

The facility is composed of more than 200 000 mounting points (registered in the Enterprise Asset Management (EAM) tool). Each mounting point could have an equipment mounted on it. The equipment can be composed of sub parts. Most of the times you have spare parts in the stock. It represents a huge quantity of part and is not humanly possible to identify, check and follow-up the status of every ones. Like for experiment, a set of tools are used for the maintenance activities.

The main tool called GMAO is based on Infor EAM software. It provides a parametrable asset management environment. Every work order is registered in the software in order to follow the facility configuration set-up. Each equipment is identified by a barcode number.

The Electronic Document Management (EDM) called SIROCO is based on Dassault Systems ENOVIA software. Every information related to the lifecycle of equipment (manufacturing, control file, characteristics, etc.) is registered in SIROCO.

The command control configuration tool (GCI) manages the current setup and characteristics used to conduct an experiment.

ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-MOPV003

The software used to manage the lifecycle of equipment are described on Figure 4. Each new mounting or replacement of equipment is initiated in GMAO as a work order. The planification and the authorization workflow are managed by other operating tools. Once the work permit is authorized and planned, the equipment replacement can be done by an operator helped with the procedure extracted from SIROCO. GMAO and GCI are notified of the part replacement (part with barcode xxx has been replaced with part with barcode yyy). In the case of complex equipment composed of subparts, all the replaceable sub parts are updated in each tool.

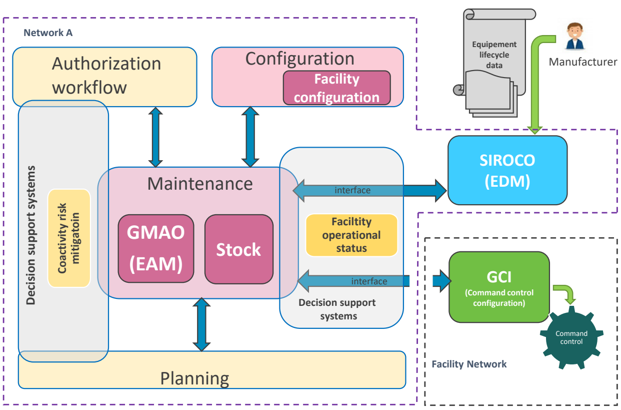

Figure 4: Operating software for maintenance.

A closed link between these three operating software (GMAO/SIROCO/GCI) is necessary.

Interface Between Experiment and Maintenance Software

Characteristics of equipment are supplied by the manufacturer and manage by the EDM tool SIROCO. The facility installed configuration set-up is managed by the EAM tool: GMAO (i.e.: the equipment identified with its barcode is installed and operational). The command control configuration tool GCI registers all the information of all equipment driven by the command control (setup values, characteristics and lifecycle attributes).

The consistency between these 3 tools is critical for two reasons:

- Characteristics from GCI are used for simulation computation (ex. Optics transmission) and equipment calibration (sensibility for an energy sensor). If there is a mismatch in the characteristics associated to equipment (wrong barcode number), you can have biased simulation computation and an important variance on diagnostic results.
- The lifecycle attributes are used to monitor the behavior of equipment during its life in the facility environment and stored in the GCI. These indicators are set by the command control (ex. working time of a pump in hour) or by operating software like PARC [1] and SCIBORG [2] (ex. cumulated energy seen by optics). They are returned to the manufacturer (via SIROCO) when the equipment is down to provide feedback analysis. If there is a mismatch in the indicator associated to equipment, data returned to the manufacturer can be wrong and might bias the results of analysis.

A consistency rule has been specified between tools and software interfaces has been developed to manage the consistency.

LESSONS LEARNED

Network Issues

Maintenance and experiment operating tools are deployed on two physically separated networks. For cybersecurity reasons, the software link is not possible between GMAO/SIROCO and GCI (see Fig. 4). The interface cannot use a synchronous and dedicated protocol to exchange data. The link is done by file exchange between the two networks; each application can load the file in a shared directory and interpret the content.

This one way asynchronous exchange may break the consistency rule. A late update of GMAO data (data transfer issue) can lead to wrong notification of GCI.

The project to move GMAO and SIROCO applications on a network with less cybersecurity constraint has started. The main goal is to update the interface in order to communicate in a synchronous way with web services.

Complex Consistency Rule

The old consistency rule between GMAO and GCI was based on the mounting point key. Equipment and its sub parts (structured as a tree) are referenced in GMAO and geographically positioned with the mounting information. This same information is reported in GCI when the work order to replace the equipment is done. The consistency rule (GMAO vs GCI) works for the equipment only if the tree structure of the equipment and its sub parts are the same in both of the tools.

This hypothesis is not always respected and creates some consistency error.

A new simple consistency rule has been introduced. GCI structure tree uses a Functional Code Number (FCN) as a unique identifier of an element in the tree structure. The FCN information will be added in GMAO and updated after the replacement of the equipment by notification. This rule covers all the use cases.

Identifying Parts on the Facility

Field inventories are conducted to control the “real“ consistency between what is mounted (barcode read on the part by the operator) and the information of GMAO. Sometimes errors are found during these inventories.

The main reason of these errors is due to the difficulty of identifying the right part. The same equipment or part may be found at many places in the laser bay (ex.: autom-

ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-MOPV003

aton). We have optical scanner to identify the part with its barcode but these scanners are not yet connected on mobile devices and the GMAO is not connected to these devices.

A project of deploying local WIFI network in the facility has been initiated. The mobile Infor EAM application will be installed on these devices and provides a direct link to the information of the work order by scanning the bar code.

Spare Parts Inventory

Some parts needs to be replaced or maintained regularly (ex.: pump). After a few year of use, some equipment can be deprecated and the new production series is not compatible with the current setup (ex.: control command hardware). The know-how of a manufacturer can disappear because the product has no more customer (ex.: neodymium doped laser glass for amplifier) so you need to manage a strategical stock for the lifetime of the facility.

The spare parts inventory is about to be completed. For each part, it is important to evaluate the stock size, the maintenance frequency and the maintenance procedure (resources, tools and time expected).

Health Indicators

Some equipment had sensors to monitor their status or performance. These data are processed and stored by the control command supervisory system. Operating tools like PARC [3] manage high level indicator related to laser, alignment and synchronization performances. These health indicators are used to detect degraded operating mode and anticipate maintenance before breakdown.

An exhaustive survey of health indicators is about to start. The main goal is to identify the missing health indicators and the way to implement them.

Global Monitoring System

Each field of activity in the facility has a monitoring system (control command hardware, computing hardware, network, supervision system, software). This could be legacy software (ex. Nagios), logging system or specific software. The monitoring is limited to a specific perimeter and you can't do cross perimeter analysis. In an issue is detected on one of this system, you can't know the impact on the parent systems. Conversely, if you can't run a root causes analysis to find an issue on the child systems.

The project to deploy a global monitoring system on the facility (LMJ Dr.) has been initiated. This system will extract, load and transform data from the different existing monitoring subsystem including health indicators. The data will be stored in a standardized format (data + metadata) as time series.

The primary goal of this system is to be able to manage multipurpose monitoring. For example, it will be possible to correlate the malfunction of a diagnostics with the loss of a network link between this diagnostic and the associated computer.

The secondary goal is to use the time series to detect health indicator decrease and/or predict equipment failure (AI tools based on knowledge database).

USE CASE (FINAL OPTIC ASSEMBLY LIFE CYCLE)

To illustrate how closed is the link between operating tools mentioned before, this use case (see Fig. 5) shows the different steps to manage the lifecycle of an element (vacuum window) of the final optic assembly

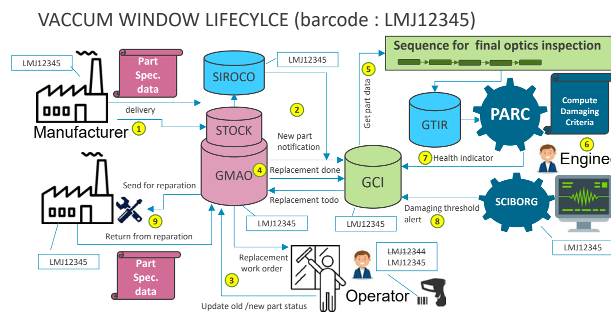

Figure 5: Vacuum window use case.

CONCLUSION

To perform ignition experiments on the facility, the energy expected on target chamber will be very high. The vacuum windows damaging will be important and this part will need to be replaced and repaired several times. The rate of maintenance on this particular optic element will be intensive. The operating software used for experiment and maintenance activities must be perfectly coordinated to ensure this rate of replacement. All the improvements based on the lesson learned needs to be deployed in order to achieve these ambitious goals.

REFERENCES

[1] S. Vermersch, "The Laser Megajoule Facility: The Computational System PARC", in *Proc. 15th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'15)*, Melbourne, Australia, Oct. 2015, pp. 38-41. doi:10.18429/JACoW-ICALEPCS2015-MOC3006

[2] J-P. Airiau, V. Denis, P. Fourtillan, C. Lacombe, and S. Vermersch, "SCIBORG: Analyzing and Monitoring LMJ Facility Health and Performance Indicators", presented at the 17th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'19), New York, NY, USA, Oct. 2019, paper THCPL04.

[3] J-P. Airiau *et al.*, "PARC: A Computational System in Support of Laser Megajoule Facility Operations", in *Proc. 16th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'17)*, Barcelona, Spain, Oct. 2017, pp. 1034-1037. doi:10.18429/JACoW-ICALEPCS2017-WEAPL05