CONTRIBUTION OF CAD AND PLM FOR RESEARCH REACTOR DESIGN AND CONSTRUCTION

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ABSTRACT

As with all reactors, the principal issue in the engineering of the design and construction of research reactors is the management and sharing of the technical data, together with the functional, physical and contractual interfaces data between the various contributors to the entire design and construction cycle project.

For 40 years, AREVA TA has designed and built reactors. Computer Aided Design (CAD) tools were introduced 30 years ago into the engineering processes of AREVA TA, supplemented for 15 years by Product Lifecycle Management (PLM) tools. For 15 years, AREVA TA has implemented the integration of these tools for the benefit of its most recent projects. The Jules Horowitz Reactor (JHR) is the first research reactor to apply these most recent information technology (IT) tools.

In the first part, the paper presents the synthesis activities applied by AREVA TA on the JHR project and introduces the associated tools.

In the second part, the paper presents how the schematics and CAD tools were used to support the engineering processes during the different phases of the project. CAD was used throughout the design phase and now supports the management of the layout and design studies, including interfaces between suppliers, up to the creation of the as-built CAD mock-up.

In the third part, the paper presents the relationship between the various tools and the PLM solution implemented by AREVA TA to ensure consistency between all the tools and data for the benefit of the project.

1. Issues to be addressed

The Jules Horowitz Reactor (JHR) is the largest new experimental platform dedicated to irradiation experiments in support of Generation II and III reactors, Generation IV technologies, and radioisotope production.

This facility consists of 250 systems comprising roughly 45 000 PBS leaves (the reactor itself comprises only 40 systems i.e. less than one fifth of the total number of the systems). For the construction phase, the procurement allocation defined with the customer (CEA) has resulted in 21 contracts covering 44 procurement packages. Most of them include the detailed design studies, fabrication, on site installation and commissioning tests. The limited number of contracts and the fact that they include an important part of the design implies that the maturity of the design is not complete and that most of the interfaces cannot be defined without stringent constraints for the future. Therefore, special attention has to be paid to address this issue.

The main issue to be addressed by the engineering team in charge of the EPCM contract is ensuring the consistency of the design among the different contributors and maintaining it accurate and up-to-date through robust configuration management.

To address this issue, AREVA TA has benefited from its experience gained through 40 years of engineering associated with naval propulsion reactors, the test reactor RES and research reactors. These projects were opportunities to develop and tailor the methods and tools with the aim of improving the technical control of the projects.

The major progress steps were the introduction of CAD tools for the mechanical engineering, instrumentation and control, fluid systems and the layout and installation studies during the early 1980s and the establishment of the current engineering processes set driven by a set of CAD tools and a PLM in the mid 1990s.

As a result of our experience, these 2 steps have been identified as the key success factors and AREVA TA had the opportunity to successfully apply the implementation of these methods outside its historical field of activities for the Laser MejaJoule (LMJ) project and for the ITER project within the System Engineering Support contract.

The main items consisting of the synthesis cell, the CAD tools and the management of data, documentation and CAD models by the PLM are developed hereafter.

2. Synthesis activities

Inside the engineering team, the synthesis cell is a dedicated team responsible for the control of interfaces between all the project contributors (i.e. CEA, engineering team, suppliers). The geometrical interfaces are controlled by means of the virtual mock-up and the functional interfaces are controlled by means of interface files. The synthesis cell activities cover the preparation, the integration and consistency follow up of the detailed design studies carried out by the suppliers.

Its purpose consists of integration and interface management studies dealing with the buildings and their ancillary systems, the process systems, the cabling by the means of interface management process and virtual mock-up management. The synthesis cell defines the approach to be implemented, prepares its procurement specification items, provides suppliers with inputs, verifies supplier work, integrates supplier work and provides updated data, in the event of difficulties, to aid in the management and addressing of the issue.

For each of the interfaces identified among the 21 supplier contracts, the team in charge of interface management ensures the clear definition of responsibilities and schedule and manages the interfaces definition.

The process and tools used to perform these activities are the interface management process and the CAD system CATIA used for the digital mock-up, both supported by the PLM.

The main principles implemented within the interface management process consist of definition of a process defining the “rules of the game” to be applied by the engineering team and the suppliers to define the correct information items on time. This process defines, in detail, the approach, the content of interface files, the organisation and the respective responsibilities (e.g. establishment of data, review, validation, criteria to be met at milestones etc.), the communication and the tools.

The process addresses the following:

- Planning (identification and planning) : identification of the interface files and interface milestones.
- Interface definition: definition of the interface information items to be included in the interface files.
- Process monitoring and control.
- Treatment of non-conformances.

In addition to these items, the process manages the interfaces following on from configuration management processes after they have been frozen.

The success factors arising from our experience which are to be applied are:

- To define an interface management process.
- To consider each interface as a product with its own engineering life cycle.
- To implement a unique source of information for each interface.
- To implement an interface definition process in which all the participants are involved throughout the project at the relevant level.
- To include this interface definition process in the contracts.

AREVA TA integrates this approach into the engineering of all its facilities. In addition to being an essential skill, it is a valuable service provided to the LMJ project as part of our support role. For the JHR project, there are roughly 150 interface files covering the 21 procurement contracts.

3. CAD tools and digital mock-up management

3.1 Diagrams

The disciplines supported by the CAD tool with regard to diagrams and the associated bills of materials (BOM) are the fluid systems engineering including HVAC engineering, the electrical power supply and instrumentation and control engineering and mechanical engineering.

The diagrams are driven by the SeeVisio package (SeeSystemDesign) edited by IGE-XAO including a database.

This application is interfaced with the PLM in order to manage, through configuration control, the diagrams and their content (functional and component characteristics), to guarantee the uniqueness of the data, to generate and manage the BOMs and, finally, to provide 3D studies with functional inputs.

3.2 3D CAD systems

The CAD system implemented within the engineering team is CATIA V5 (Dassault Systèmes) associated with SmarTeam for the management of CAD models.

The engineering disciplines are covered by the following modules: assembly design, piping design, HVAC design, equipment arrangement, structural design, system space reservation, electrical cable routing.

A 3D viewer (CreoView PTC) provides each participant to the project with the viewing capability of the current status of the digital mock up even from a simple PC.

The main benefit is the entire coverage of all engineering disciplines by a single set of tools. This approach results from previous difficult experiences of previous reactor design and construction projects in which different CAD tools were used for different disciplines.

3.3 Digital mock-up

Since the decision was made to give up the use of wood mock-ups for the installation of nuclear propulsion reactor compartments in 1987, the use of a virtual mock-up within AREVA TA has become a very common practice for the design and engineering of complex systems. However, one of the main problems is to keep the mock-up current and up-to-date. A major step forward was achieved when AREVA TA was selected in 1998 for the LMJ project, specifically to implement a concurrent engineering process for the many project participants and partners, each of which used different CAD systems. The 10 gigabyte mock-up for LMJ consists of more than 30,000 data files and more than 50,000 objects. AREVA TA drew on the considerable experience acquired in the early 1990s to ensure the success of this activity. The JHR project benefits from the practices developed for the LMJ project. They are implemented by the engineering team and by the customer, CEA. The JHR mock-up will integrate more than 1 million items for a total size estimated at 340 gigabytes of data.

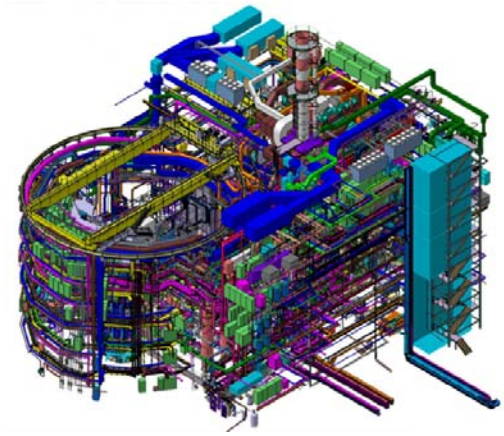

Figure 1: View of the Nuclear Island CAD Mock-up Without Building

The digital mock-up aims at ensuring that all the components are integrated in the building in a consistent way.

The main uses of the mock-up are at the engineering team level:

- To provide a global view or exhaustive view of the entire content of a defined area.
- To support the project communication and at synthesis cell level.
- To provide the right support to geometrical interface management activities.
- To define (at supplier level) all the boundary and close environment information suitable for the studies.

AREVA TA's method couples configuration management to mock-up management by implementing the following approach. Two main concepts were extrapolated: the baseline for component development (tree structure) and the choice of configuration items (leaves). The tree structure is commonly used for technical baseline purposes, but it can only describe items without making a distinction as to how they are used. For the mock-up, a topo-functional tree is built. Because a large mock-up may consist of several thousand items, configuration management must limit monitoring to specific configuration items called mock-up items, which are treated as unique entities.

Even if the item has is own tree structure, it will be represented by one mock-up object i.e. the leaf on the tree. Creating a mock-up object consists of creating a simplified representation of the CAD design. Managing the configuration of the entire mock-up essentially consists of changing or revising the leaves. A customised PLM is used to maintain consistency. The PLM thus provides the guarantee required before distributing the mock-up to the different partners. The mock-up is kept up-to-date throughout the design and development phase and as-built drawings are delivered thereafter for troubleshooting during construction, for example for physical interferences during the installation of the different systems.

All these activities are regulated by a formalised process and the exchanges with the suppliers are made by means of a Sharepoint allowing easy external communication.

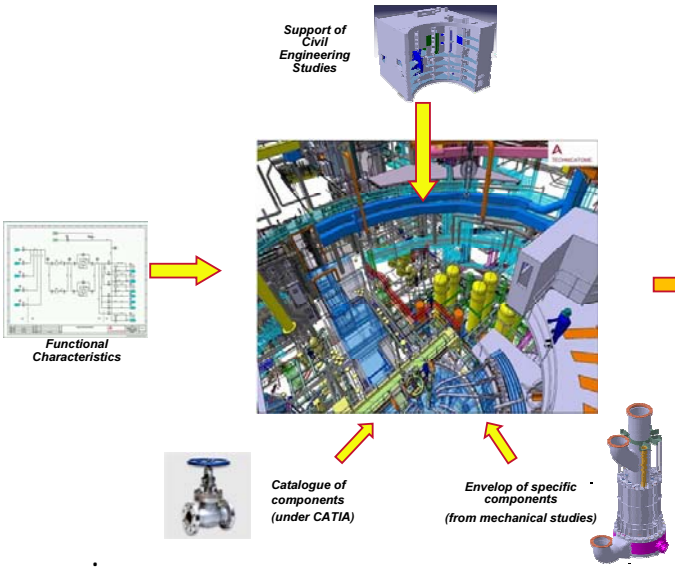

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Figure 2: CAD Mock-up Inputs

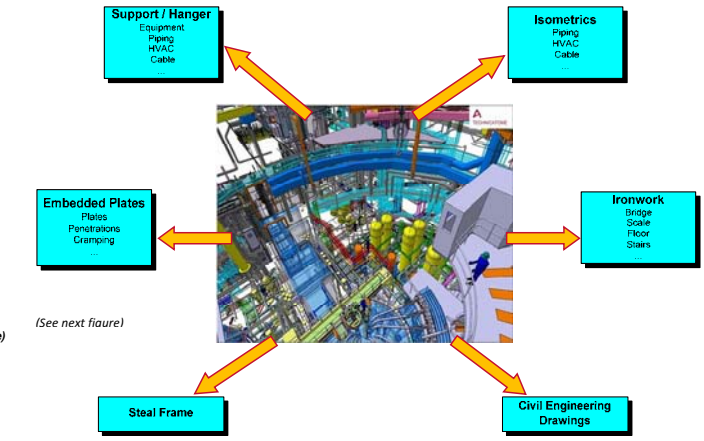

Figure 3: CAD Mock-up Outputs

3.4 Towards virtual reality

There is an ongoing development towards virtual reality. Recently as regards our CAD history, AREVA TA has implemented a dedicated laboratory aimed at developing the activities dealing with the design of paths (i.e. people traffic, installation/removal of components, maintenance activities, potential interferences), validation of complex tooling kinematics and validation of on site intervention. The purpose of this laboratory are the technological survey or observation of human machine interface, the implementation of hardware and software tools and the demonstration of performance improvement in the field of interfacing and affected activities .

The investigations are conducted by the mean of case studies dealing with nuclear propulsion, test reactors and the JHR projects. As an example, the system allows introducing dummy operators into the CAD mock-up opening so as to model a wide field of validation activities.

The main benefit of virtual reality is to extend the capability of reviewing the design outside the core of the engineering team.

This field of new approaches is highly promising and should provide new methods for tomorrow's engineering activities.

4. Integrated data management

The management of all the data is ensured by the PLM ENOVIA Matrix One which has been customised to meet our needs. The PLM allows us to:

- Support our engineering processes.
- Constitute the unique source of consistent data.
- Manage, under configuration control, many different objects such as CAD models, drawings, diagrams, breakdown structures, occurrences (PBS leaves), data, work packages, milestones, component and parts libraries, documents, engineering and client files etc. and their links and associated characteristics and properties e.g. the link occurrence, type, individual and their respective information items.
- Provide the project contributor with data access ensuring their protection according to project policy.
- Guarantee the consistency of diagrams and CAD model information.
- Provide each project member with viewing capabilities of the digital mock-up.
- Provide the I&C emulator (used for test purpose) with functional data issued from diagrams.

The PLM is the backbone of data management and exchange within the JHR project.

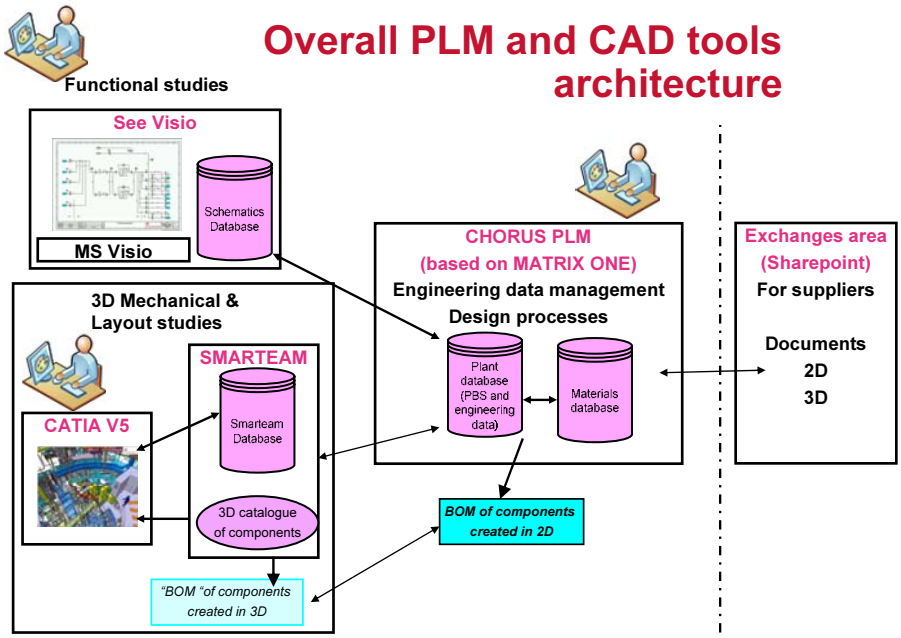

Figure 4: Overall PLM and CAD Tools Architecture

5. Concluding remarks

The JHR project has benefited from 40 years experience of using integrated CAD and PLM tools on previous reactors and other major projects engineered by AREVA TA.

The CAD mock-up and PLM are based on well-known tools available from the market and have been tailored to support nuclear reactor engineering processes. These engineering methods and tools guarantee the consistency of all technical data that are exchanged between all teams and contractors. The same evolving tools and engineering methods are used, and are being improved for future projects.

In our opinion, this feature will be a key success factor for the technical control of major and complex projects.