ADVANCED CAD – PLM INTEGRATION IN A NAVAL SHIPBUILDING ENVIRONMENT
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SUMMARY
Military shipyards building surface ships and submarines are implementing PLM Systems as a global solution to the management of information through the life cycle of naval vessels, with the objectives of increasing productivity, reducing vessel design and manufacturing schedules, saving costs and improving the quality of the whole process.

A key factor in the success of the implementation is the integration between the shipbuilding CAD System and the PLM, as CAD provides advanced functionalities for vessels design and fabrication and CAD related data must be shared by all the shipyard departments from the early design stages until the commissioning of the vessel.

This paper presents an advanced architecture for CAD – PLM integration in a naval shipbuilding environment.

NOMENCLATURE

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1. INTRODUCTION

As a result of the increased pressure to reduce cost and delivery times of modern surface ships and submarines, many military shipyards are revising their processes and tools to manage and share information across all shipyard departments.

An important part of this process is in many cases the implementation of PLM Systems or an extended use of the PLM Systems to manage all the information that must be shared by the shipyard departments (engineering, purchasing, planning, operations, productions, etc.).

On the other hand, a specific shipbuilding CAD is another critical application in a military shipyard, to improve the design quality, to reduce design and production costs (by improving vessel manufacturability, operation and maintenance) and in general to provide relevant information to most of the shipyard departments during the vessel design and production stages.

Therefore, the integration of the shipbuilding CAD with the PLM is a key factor in the implementation of the new processes and tools.

The solution presented in this paper for an advanced integration between the CAD and the PLM intends to comply with the most demanding requirements of the military shipyards as well as to maintain the efficiency, the scalability and the performance of the shipbuilding CAD tool.

This paper presents in detail the architecture of the solution as well as the expected advantages and benefits for the military shipyard.

2. SHIPBUILDING CAD SYSTEMS IN NAVAL ENVIRONMENTS

The use of specialized shipbuilding CAD Systems in naval environments is crucial for the efficient design and manufacturing of surface ships and submarines.

The heart of a shipbuilding CAD System as FORAN is a relational database (ORACLE) where the vessel CAD product model is stored. The product model includes geometry, topology, specialized technological and manufacturing information for all vessel disciplines and many relationships between the vessel items.

Shipbuilding CAD Systems working in naval environments offer significant advantages over other generic CAD applications, some of which can be relevant for the purpose of this paper:

- Specifically developed for shipbuilding
- Availability of shipbuilding smart modelling tools
- Incorporation of many years of shipbuilding knowledge
- Outputs adapted to shipbuilding manufacturing processes
- Proven scalability
- Proven performance
- Adapted to military shipbuilding requirements [1]
- Reduction of design and manufacturing hours over generic CAD applications

The scalability refers to both the number of CAD users and to the number of vessel items to be handled.

Military vessels are very complex products that may be composed of millions of items, requiring a large number of designers, accessing concurrently to the vessel product model. (see figure 1). The design cycles of these vessels
are usually very long and there are many design changes along the whole vessel lifecycle.

Figure 1: Vessel Forward auxiliary engines module of S-80 submarine, courtesy of Navantia

Performance is another critical requirement, especially in the detail design and manufacturing stages, when the detail design is almost complete, there are hundreds of users working on the model, model changes are constant and information for the production processes must be provided continuously.

3. SOME KEY REQUIREMENTS FOR THE INTEGRATION

Until now, the most common requirements for integration between shipbuilding CAD systems and PLM’s were basically two:

- Management of all documents generated by the CAD in the PLM
- Transference of the vessel product structure from the CAD to the PLM, comprising both the geometry of the model items for visualization purposes and items attributes (metadata)

The result of these integrations can be considered as a low/medium level of integration.

On the other hand, and based on the lessons learned and on the issues identified in the military shipbuilding projects developed in the last years, other important additional requirements for the CAD – PLM integration have been raised by many military shipyards.

May be the most important requirement is the need for a continuous synchronization of the information managed by the CAD and by the PLM. This requirement leads to the need of a bi-directional integration between the CAD and the PLM and to the availability of publishing and synchronization processes automating the integration.

Another requirement derived from the previous one is the possibility of defining the most important standard components and model items of the vessel (e.g. equipment and main fitting items) in both the CAD and the PLM, depending on the project stage.

Among all these additional requirements it is also worth to mention some of them, especially relevant for the proposed integration:

- The integration should cover most of the phases of the vessel life-cycle (conceptual design, basic design, detail design, manufacturing, …)
- Sharing of attributes between the CAD and the PLM
- Handling of unique item identifications in both systems. Usually these identifications are generated in the PLM
- Access and locking control to the CAD items based on the maturity of the information and on security considerations. In many cases this information comes from the PLM but in other cases it is generated in the CAD system. The visualization of the model items based on their maturity and security considerations in both the CAD and the PLM is also a derived requirement
- Automatic generation of model (BOM) – drawing relationships in the PLM as a result of the publishing of model items and drawings from the CAD
- Transference of the vessel build strategy from the CAD to the PLM and vice versa.

Although many of the simulation processes to check the manufacturability of a design are currently done in the CAD in an automated and efficient way (e.g. piping fabrication sketches - spools manufacturability), in some cases it can be necessary to use more general simulation tools for digital manufacturing, closely integrated with PLM, especially to simulate some of the vessel assembly processes.

The results of the simulation could produce a different build strategy that would be transferred back from the PLM to the CAD.

The integration must also facilitate the collaborative work of different partners in the vessel project, as this is a normal scenario in the current shipbuilding military projects, especially in aspects such as the spatial integration and the cross manufacturing of the zones of the project developed by the different partners.

The CAD – PLM integration proposed in this paper try to comply at the maximum extent possible with all these requirements.

4. THE INTEGRATION SCOPE

The proposed integration considers all shipbuilding disciplines and areas covered by the FORAN System (Hull forms, Naval Architecture, Hull Structure,
Equipment, Piping, HVAC, Electrical, Supports, Outfitting Structures, etc.) as well as all the associated information for manufacturing or for other production processes.

The integration also covers all stages of the vessel lifecycle, from the conceptual and basic design to the maintenance of the ship.

That means, and as an example, in the basic design stage the information of the intelligent diagrams must be transferred to the PLM, including associated drawings in PDF format, and building automatically in the PLM the relationships between the diagrams and the related BOMS (equipment lists, piping fittings, electrical fittings, cables, etc.).

As the projects evolves and the 3D product model of the vessel is built in the CAD database, the 3D information of the routed systems must also be transferred to the PLM, but the product trees in the PLM must also evolve automatically, considering the project progress and building the connections between the diagrams and the 3D model.

To give an idea of the integration scope, next is included a list of the most relevant components and model items considered in the integration.

- Equipment
- Equipment components
- Piping fittings
- Piping components
- P&I Diagrams
- Piping lines
- Duct lines
- HVAC components
- Cable tray lines
- Hull structure items
- Outfitting structures
- Supports
- Cables
- Cable types
- Electrical fittings and instruments
- Components of electrical fittings
- Electrical diagrams
- Cable transits
- Types of cable transits
- Build strategy trees

5. THE ARCHITECTURE OF THE SOLUTION

5.1 GENERAL

The architecture of the solution for the CAD – PLM integration is based on the following components (see figure 2):

A vessel product structure in the PLM, referred as the Vessel Product Tree (VPTree), reflecting the CAD Product Structure at any time during the vessel project development.

The current PLM Classification Structure, referred as PLMCStr, that will support the management of standard parts between the CAD and the PLM.

A mechanism to transfer data from the CAD to the PLM. It will be referred as the Publishing Mechanism

A mechanism to transfer data from the PLM to the CAD. It will be referred as the Synchronization Mechanism

A set of relational tables in the CAD database, that will support the Publishing and Synchronization processes between the CAD and the PLM and vice versa. It will be referred as the CAD – PLM Synchronization Table

A neutral framework for the integration of the CAD (FORAN) with different PLM systems, referred as FPLM

Figure 2: Integration Components

5.2 THE VESSEL PRODUCT TREE

The Vessel Product Tree (VPTree) is a product tree created within the PLM where the CAD model items will be published.

The VPTree is automatically built and modified during the Publishing processes, so providing to the PLM users with an up to date view of the CAD product model during the project development.
The VPTree has a structure very similar to that of the CAD (FORAN) Product Model, so the position of the model items in the FPTree depends basically on the item type. See figure 3.

The VPTree is another view of the vessel model in the PLM that will be permanently synchronized with the CAD 3D model. These VPTree data will allow the PLM to control the CAD product model, through the model locks, as well as to add or modify all the necessary information required by the management of the vessel along the whole life-cycle.

5.3 STANDARD PARTS INTEGRATION

The integration of the standard parts (components) between the CAD and the PLM will use the current PLM Classification Structure. Both the Publishing and the Synchronization mechanisms will use this PLM structure.

The capacity of defining standard parts in the PLM, to be automatically transferred to the CAD by the Synchronization Mechanism, requires the assignment of some fixed attributes to these standard parts that will allow the Synchronization Mechanism to identify them as standard parts to be transferred to the CAD. These attributes will depend on the type of standard part. See figure 4 for equipment components.

5.4 THE PUBLISHING MECHANISM

5.4 (a) Publishing

Publishing is the process of sending the following information from the CAD to the PLM:

- Model items created or modified in the CAD
- Standard parts created or modified in the CAD
- Intelligent diagrams
- Plate and profile cutting information (nesting)
- Build strategy trees created or modified in the CAD
- Drawings or other files handled by the CAD

Deleted items are also handled by the Publishing Mechanism.

Some production assemblies defined in the CAD (e.g. spools) are also transferred to the VPTree in the PLM, creating, during the publishing process all the necessary relationships with the model items, so reorganizing the VPTree, so reflecting a more mature status of the model.

A CAD entity can only be published if it meets some specific conditions (see figure 5):

- The entity is marked as publishable
- The entity has not been deleted in the PLM
- The entity is not locked in the PLM
- The CAD entity’s date is later than the entity’s publishing date

5.4 (b) Publishing Modes

A specific Publishing process has been devised to facilitate all the publishing tasks. The Publishing process will provide tools to facilitate the selection of massive information to be published. Another relevant feature of this process will be the capability of being launched in a scheduled way.

The Publishing process will connect with the PLM through the FPLM (see chapter 5.8 below – The FPLM Neutral Framework), by means of some specific PLM web services.

The aim of this Publishing process is to facilitate and automate the publishing tasks, reducing the impact of these tasks in the normal operation of both the CAD and the PLM. See figure 6 below.

In addition to this standard Publishing process, it will also be possible to publish CAD information on demand.
That means a designer with sufficient rights will be able of publishing items created or modified by him.

5.4 (c) Information Published

The Publishing process will transfer attributes of the published items as well as the geometry of the items, if available.

Only a restricted number of attributes will be transferred from the CAD to the PLM, those shared by the CAD and the PLM and those CAD attributes selected for publishing but not editable in the PLM.

Concerning geometry, the Publishing process will automatically export to the PLM the geometry of the items, in the format more adequate for each PLM. Usually the geometry will be transferred at the level of elementary items (e.g. one part), but in some cases, it will also be possible to publish the geometry at a higher level (e.g. one spool).

5.5 THE SYNCHRONIZATION MECHANISM

5.5 (a) Synchronization

Synchronization is the process of getting from the PLM information of the CAD items or standard parts created, modified or deleted in the PLM and still pending of transference from the PLM to the CAD, through the Synchronization Table.

5.5 (b) The Synchronization process

A specific Synchronization process has been devised to facilitate all the synchronization tasks (see figure 7).

The Synchronization process will connect with the PLM through the FPLM (see chapter 5.8 below – The FPLM Neutral Framework), by means of some specific PLM web services.

5.5 (c) Synchronization Modes

The Synchronization process will be running permanently and will perform two types of synchronization:

- Urgent synchronization, asking continually to the PLM for entities requiring urgent synchronization, usually entities requiring locking
- Scheduled synchronization, asking every certain time to the PLM for entities requiring synchronization

Entities requiring synchronization of any type will be managed in the PLM through a Modification Register, permanently updated by the PLM with the entities requiring synchronization (model items, standard parts...). See figure 7 above.

The Synchronization process will also inform to the PLM of the entities successfully synchronized to allow removal of the entities from the Modification Register.

Model items can be locked by the PLM. The locking avoids the modification of the item in the CAD. Item locking can be temporal, due to updating needs, or can be permanent due to having reached a more mature status.

5.6 THE CAD – PLM SYNCHRONIZATION TABLE

The CAD – PLM Synchronization Table (SyncTab) is a set of relational tables in the FORAN/Oracle database that contain all the necessary information to manage the whole CAD – PLM Integration process.

The Synchronization Table contains information related to the entities participating in the CAD – PLM integration process, such as:

- Identification of the entity in the CAD and in the PLM
- Unique identification of each entity (provided by the PLM)
- Publishing process related information
- Synchronization process related information
- Entity maturity information
5.7 DEFINITION OF MODEL ITEMS IN THE PLM

The automatic management of the VPTree by the Publishing Mechanism makes possible the definition of new model items in the PLM, out of the VPTree, to be transferred automatically from the PLM to the CAD. The process is as follows:

- Model items are created in the PLM
- These model items must have the necessary attributes to uniquely identify the model item in the CAD (e.g. those indicated in figure 3 for equipment items)
- The Synchronization Mechanism will use these special attributes to identify the items to be transferred to the CAD and to transfer the model items to the set of relational tables in the CAD database supporting the integration
- The CAD reconciliation tools will allow to use these items in the CAD side, completing the item information (geometry, additional attributes, layout information, …)
- The Publishing Mechanism, when required, will publish these model items in the VPTree

5.8 DOCUMENT MANAGEMENT

5.8 (a) Main Functionalities

The CAD – PLM Integration includes a complete set of document management functionalities inside the CAD. Some relevant aspects of these Document Management functionalities are the following:

- Functionalities available in all FORAN modules (Document Manager)
- The most relevant document management functionalities are available
  - Download file content
  - Check-out of a document
  - Undo a previous check-out
  - Check-in of a document
  - Upload a new document
  - Create a new document version
  - Remove local file
  - ……
- Search documents in the PLM vault
- Editable XML template to configure document contents
- Dynamic documents attribute mapping between the CAD and the PLM

See figure 8 with a capture of the Document Manager

5.8 (b) Links CAD Drawings – PLM BOM’s

As indicated in Chapter 3 – Some Key Requirements for the Integration –, an important requirement for the publishing of drawings from the CAD side is the capability of creating and maintaining automatically in the PLM the relationships between CAD drawings and the items themselves (BOM lists), with the entities included in each drawing.

These links must be maintained for the most relevant types of drawings in all design stages (e.g. diagrams, layout drawings, manufacturing drawings, etc.).

The publishing of drawings has been designed in such a way that the process maintains automatically this connection, allowing the PLM users to get the items existent on a drawing or the drawings affected by the modification of an item.

The publishing process maintains these links using the items information contained in the FORAN/Oracle database, for the diagrams, and the items information contained in the FORAN drawing files for other types of drawings.
See in figure 9 above a capture of the FPLM schema manager showing the equipment units used in a diagram.

5.9 THE FPLM NEUTRAL FRAMEWORK

The FPLM (FORAN – PLM Neutral Framework) is a neutral framework developed by SENER [2] [3] with two main objectives:

- To facilitate and to simplify the integration of FORAN with different PLM systems
- To make the FORAN – PLM integration as independent as possible from the specific characteristics of each PLM system

The architecture of the FPLM can be seen in figure 10 below.

The FPLM is composed of several processes:

- FPLM Client: A set of utilities integrated in the FORAN modules to interact with the PLM Server, common to all PLM integrated systems
- FPLM Server: A Java process to manage FORAN business objects and their mapping to the PLM objects
- FPLM Plug-In: A set of PLM dependant libraries and tools, which map the FPLM objects and perform the communication with the PLM server. It consists of two parts:
  - A set of Java classes and methods embedded into the FPLM Server. They provide a specific PLM context and data model to the neutral FPLM object and data types
  - The PLM Adapter. It is a set of Web Services and PLM templates that are embedded and run into the PLM server. It provides the appropriate FORAN data environment for the PLM

Figure 10: The FPLM Diagram

The FPLM Plug-in usually relies on existing or to be developed PLM Web Services to allow the communication between the FPLM Server and the PLM (see chapter 5.10 – The PLM Integration Tools below).

5.10 THE PLM INTEGRATION TOOLS

5.10 (a) PLM Web Services

The bidirectional communication FPLM – PLM is done through the use of specific PLM Web Services. Many of these Web Services are standard PLM Web Services existing in most of the current advanced PLM systems. Generally speaking, the rest of required Web Services could be developed by using or specializing existing Web Services.

A non exhaustive list of required Web Services is included below:

- User Authentication
- Get User Attributes
- Check-Out Object
- Check-In Object
- Create New Object
- Create New Object Version
- Upload Content File
- Download Content File
- Get FORAN Data Types
- Get Attributes for Type
- Query Objects in the PLM
- Query Links in the PLM
- Synchronization Query
- Synchronization Acknowledgement
- Immediate Sync Required
- Publish Data
- Update BOM Links
- Transfer geometry Files
- Tree Synchronization
- Tree Publish
- Check VPTree Status

5.10 (b) Other PLM Tools

In addition to the previously indicated PLM Web Services, the integration will require the creation of specific configuration tools and data templates to facilitate the integration and to map items and attributes between the CAD and the PLM.

6. CONCLUSIONS

This paper presents a solution for the integration of a shipbuilding specific CAD System (FORAN) with an advanced PLM System in a Naval Shipbuilding environment.

The proposed integration presents several important advantages:

- Takes profit of the experience and results of previous integration of FORAN with different PLM Systems
• Incorporates the most outstanding requirements for the CAD – PLM integration coming from some relevant European shipbuilding companies, designing and manufacturing surface ships and submarines

• Improves predictability by providing a single point of truth for the whole organization

• The design of the integration has been done with the objective of limiting the degree of coupling between the CAD and the PLM, with several important aims in mind:
  − To reduce to a minimum the impact of the integration on the performance of both systems (the CAD and the PLM)
  − To produce a scalable solution able to work with hundred of designers in the CAD Engineering side and with thousand of PLM users in the whole shipbuilding organization

• It would allow the PLM to take benefit of all the vessel information handled by the CAD from the early stages of the design

The proposed integration is now under implementation for an important European Naval Shipbuilder.

7. REFERENCES


8. AUTHORS’ BIOGRAPHIES

Fernando Alonso holds the current position of Project Manager at SENER. He is responsible for all the FORAN projects in the UK military shipyards.

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