A plan to succeed

Because many different design and engineering applications are used in shipbuilding, the exchange of product information presents major challenges. The very nature of shipbuilding (one-off or small series) along with the involvement of a large number of systems integrators, subcontractors and suppliers requires an enormous exchange of technical, commercial and logistical information between all parties involved. The difficulty in proper digital communication between systems of different shipyards, sometimes inside the same shipyard, remains a serious hindrance to increased competitiveness.

Concurrent engineering and globalization have made it imperative to achieve efficient exchange of product and process information using the available infrastructure and bandwidth.

To overcome the challenges in data exchange between different software systems, many solutions have been proposed such as converters between CAD systems, using a standard exchange format like STEP. This paper proposes using the industry standard lightweight, neutral JT™ format as a data exchange standard in shipbuilding.
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Executive summary

In the shipbuilding industry, CAD/CAM systems have been a vital part of the design and construction process for many years. While several integrated 3D CAD/CAM systems are available and in use today for shipbuilding, many shipyards continue to use different CAD systems for different design stages and for different disciplines like structures and outfitting. Design results are usually delivered as paper drawings.

In addition to CAD/CAM, many other software tools are used by shipyards for activities such as production planning, project management and ERP. As a ship enters service, yet more software tools are used for applications such as operational performance and configuration management.

Each CAD system has its own data format optimized for its own functions. As a result, there are many kinds of data structures and data representation schemes. CAD geometric models are represented by different schemes including 2D graphic entities, 3D wireframes, 3D surface models or solid models. Some shipbuilding CAD systems store the design details of the ship in a database and generate 3D graphics for viewing “on the fly” as required.

The shipbuilding industry also has the involvement of a huge supply chain which includes design agents, marine equipment manufacturers, weapons manufacturers, other shipyards, block fabricators and system integrators. Each of these organizations uses its own design (CAD/CAM/CAE) systems which in many instances are different from the systems used by the shipyard. Every ship project also involves owners and classification society.

The many disparate software tools used in the ship design process do not communicate with each other which leads to proliferation of data and multiple representations of different aspects of the same design model, distributed within the shipyard, and more often outside and even globally. Managing a shipbuilding project with these disparate models is a critical and complicated task.

As in other industries, the worldwide collaboration network is rapidly changing in shipbuilding, with more design outsourcing, cross-enterprise engineering, contract manufacture and through-life support contracts. The OEM (shipyard) and entire supply chain has to manage the complexity of communication in a heterogeneous environment.

The challenge is to develop product representation methods to meet the demands of platform and application independence, support for the complete ship lifecycle, generation of viewpoint-specific representations, rapid information sharing between geographically distributed applications and users, and protection of corporate intellectual property or company know-how – i.e., what can be shared with whom? This paper proposes a product representation approach using the strengths of lightweight representation of a neutral 3D format (JT) and using a formalized markup language (PLM XML) to allow the association of product data throughout the lifecycle with the geometric form of the product. PLM XML provides a mechanism for transferring metadata and structure data.

A ship’s lifecycle can last more than 20 years for commercial ships and as long as 40 years or more for naval ships. This introduces important issues regarding organization and management of the ship product model. With continuous improvements in CAD technology and end-of-life for some of the CAD software traditionally used in shipbuilding, the reliability of old proprietary CAD formats has become a serious issue. There is a real danger that CAD models in which so much product data is encoded may become impossible to read in the future. The 3D JT format can also be used for the long-term data retention (LOTAR – LOng Term Archival & Retrieval) of ship product information.

By integrating the design data of shipbuilding CAD software with process planning and production management systems, shipbuilders can greatly benefit in workshop production and onsite construction. However, it is often not easy to extract data from many of these shipbuilding CAD systems because of complex internal database structure and licensing requirements. Extracting the ship design data from shipbuilding CAD systems into the JT format can provide the foundation for improving production and productivity in a number of areas in the shipyard.
Lightweight representation

Current CAD models are often too heavy and restrict information transmission between geographically distributed applications and users. Moreover, as these CAD models are increasingly embedded with corporate intellectual property and design standards, companies are often unwilling to share all the details of their product models directly with their partners, suppliers or customers. Also, since there are many CAD/CAE software systems with their own proprietary data formats, it is not feasible or economically viable for every user to install a copy of each CAD/CAE system to view or manipulate product models in their native formats. Even within design and engineering departments, users often do not know all the CAD/CAE tools being used. Also, for many applications (or use cases), full model fidelity is not required anyway, such as viewing of 3D models for reference by a procurement team.

In addition, current ship CAD models are largely limited to the design and construction phase. However, ship product information continues to develop throughout the lifecycle, and such lifecycle information should be reflected in the product model. Lightweight representations, combined with markup techniques, have the potential to address many of these product representation issues.

Lightweight representations are product model formats that are missing some of the richness of a “full” CAD model. The major characteristics of lightweight representations are reduced file size via compression techniques, platform/application independence, open source and support for protecting intellectual property. The aim of lightweight representations is to support users at different stages of the product lifecycle, enabling them to rapidly browse, retrieve and manipulate product information.

The benefits of lightweight representation visualization are many. It provides the ability to view, interrogate and mark up engineering data, allowing non-CAD users access to 2D and 3D graphical engineering data. This can be accomplished across the extended enterprise without requiring users to learn sophisticated CAD software. Most visualization tools are CAD-independent and allow users to view data originally created in different CAD systems. Lightweight representation allows visualization of large assemblies which is mandatory in shipbuilding, and provides the potential to reduce and/or eliminate the use of drawings. The large assemblies can be used for real-time interference checking, advanced visualization including virtual reality (VR), and early-validation and constructability analysis. Other applications of lightweight representation include creation of technical documentation for operations and service, advertisement for marketing, and bid preparation by sales.

A large number of “neutral 3D formats” are available for the transfer of 3D models. Each of these formats has different attributes, such as a high level of precision regarding the images being displayed, small file sizes, versatility and many others.

For selection of a particular 3D format, several important issues need to be considered:

Disclosure of the format specification: The disclosure and availability of a format specification within the framework of standardization can be seen as a good indication of the level of investment protection a 3D format offers and the extent to which the future of the format is guaranteed. Ratification of a format by a recognized standards organization is very important.

Widespread use of the format: How many industries have started using the 3D neutral format, and to what extent? What converters and software products exist that can produce and handle data in the format?

File size: The size of the file created as a result of converting data into a 3D format is very important for handling the data efficiently using the system resources and available network bandwidths.

Data security: Whether the data contains design know-how of the company which may compromise intellectual property.

Application in other future engineering activities: One key attribute of any neutral 3D format includes versatility, which allows development data to be used in departments outside of the engineering department. What software development kits (SDKs) and support mechanisms are available to extend the format to include future developments?

Long-term data archival: Long-term re-usability of the data. Will it be possible to view the data in 10, 20 or 40 years?
JT introduction/definition

JT (Jupiter Tessellation) is a format for describing 3D data that also supports object data and metadata.

The JT format was originally developed by Engineering Animation Inc., a company in the United States in the 1990s under the name Direct-Model toolkit. The data format was developed to create animation models for illustrating complex car accidents and other legal claims which needed to rapidly represent very large assemblies involving thousands of components.

This company was acquired by the Unigraphics Corporation in 1999 and the format developed further as JT. In 2007, Siemens acquired Unigraphics, which is now called Siemens PLM Software and is a business unit of the Siemens Industry Automation division.

JT is a binary format whose data model supports various representations of CAD geometry (Figure 1). The representations can be stored in a JT file individually or together. In addition to geometry, JT can be used to display product structure, attributes and product manufacturing information (PMI) like tolerances, dimensioning and surface properties.

Figure 1: What is JT?
**Geometry**

**Geometry primitives:** At one of the lowest levels, simple regular geometry such as cuboids, cylinders and pyramids are located in what is referred to as the bounding box.

**B-rep (boundary representation):** Offers the highest level of precision. B-rep data is compressed using different algorithms and stored without loss. In the current specification, two B-rep representations are permitted: the traditional JT-B-rep representation and XT-B-rep, which is based on the Parasolid® boundary representation.

**Tessellated geometry:** Representation of solids and surfaces as facets. Different levels of detail (LOD) can be defined within a JT file. A low LOD means a lower level of precision but a smaller volume of data, while a very high LOD means an almost exact geometry but a large volume of data. The JT file format is capable of storing an arbitrary number of faceted representations with varying LODs.

**ULP (ultra-lightweight precise):** The ULP compression method was released in 2008. The ULP format enables a lightweight, semi-precise representation of the 3D geometry. The level of precision that ULP offers is significantly higher than for tessellated geometry while the file size is significantly smaller – almost one hundredth the size of the original data (Figure 2). The ULP format makes it easier to share data across low bandwidth connections which are sometimes encountered as the shipbuilding collaboration network extends to countries with inadequate telecom infrastructure.

**Other information**

- Product structure (assembly, subassembly, part)
- Lighting (point light, infinite light, light set)
- Textures
- Material data
- Product manufacturing information (PMI) including dimensioning, 3D annotations, tolerances
- Attributes/properties (text, integer, float, date, layers)
- Metadata (property filters, transforms)

JT data can be contained in single or multiple files. Each file can contain any relevant JT information. By properly managing the allocation of information to a given physical file, if any source data changes, only the JT file corresponding to that information needs to be recreated or updated.

The product structure can be represented in a variety of JT file configurations:

- **Per part:** All assembly nodes in a product structure hierarchy are stored in a single JT file, and each part node in the hierarchy is stored in an individual JT file in a subdirectory that is of the same name as the assembly JT file.
- **Fully shattered:** Each product structure node in the hierarchy is stored in an individual JT file.
- **Monolithic:** All product structure is stored in a single JT file.

The JT data format has been approved by the International Organization for Standardization (ISO) as an international standard.

**Figure 2: File sizes with JT.**

<table>
<thead>
<tr>
<th>Relative file size</th>
<th>CAD Native (NX) part size</th>
<th>2,604 KB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enterprise JT (XT B-rep, 3 LODs)</td>
<td>320 KB</td>
</tr>
<tr>
<td></td>
<td>Remove PMI and low level LODs</td>
<td>50.9 KB</td>
</tr>
<tr>
<td></td>
<td>Using ULP (including PMI)</td>
<td>32.7 KB</td>
</tr>
</tbody>
</table>

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JT viewers and translators

**Viewers:** Several viewers are available for viewing and manipulating JT data regardless of the CAD system from which the data is generated. There are also many visualization tools which can handle JT data.

**Translators:** Translators are available to convert native CAD data to JT, JT into CAD, or by some converters, both. Some authoring systems also output data in JT format.

Some of these viewers/translators include JT2GO and Teamcenter® VisMockup software from Siemens PLM Software, CADverter from Theorem Solutions and ProductView from PTC. Translators available can convert data from CAD systems such as Pro/Engineer, CADDS5, CATIA, TRIBON M3, AVEVA Marine, AVEVA PDMS, Inventor, SolidWorks and data formats such as STEP AP203 and 3DXML.

Software based on ActiveX and Java can also visualize JT data. This allows the integration of JT data in Microsoft Office documents, for example.
PLM XML

PLM XML is an XML-based PLM format created and supported by Siemens PLM Software. PLM XML schema describes a model’s geometry, structure, features, ownership and visualization. It is designed to be interoperable between different tools from across the lifecycle of a product. The native schema for representing geometry can support 2D and 3D vector graphics, NURBS surfaces and features, although non-native representations can also be used or referenced in a PLM XML document. It also allows for a single logical product model to have several different geometric representations, tailored to different purposes. Metadata of several different types – mass, material, texture, product manufacturing information, dimensions and tolerances, user markup and application-specific data – can be attached to logical parts of the model or specific geometric representations. File sizes can be reduced using a reference-instance mechanism and by splitting out various sections of data into separate files, so data not needed for a particular purpose need not be transmitted. In addition to approximating and separating data, PLM XML also supports mechanisms for restricting access to parts of the model data on the basis of person, organization or place.

Figure 3: The JT pipeline.
Use cases

Visualization
This use case describes using JT for essential viewing purposes by any stakeholder (Figure 3). This can be for the presentation of product data, representation of 3D models for information purposes (design review, for example) and for realistic representation in virtual reality (VR) systems. Starting with simple geometry, product structure, product and manufacturing (PMI) information and metadata may need to be displayed. In shipbuilding in particular, high performance visualization of extremely large assemblies is an important requirement.

Once a ship model is converted to JT, a JT viewer can provide the following capabilities:

- Display product structure
- Select between exact geometry and different levels of detail for visualization
- View filters by selecting/deselecting nodes in the product structure or by selecting layers
- Define sections
- Perform measurements
- Create and store new views
- Display properties
- Export to JT storing new views and sections

JT can also be used for high-end visualization (photorealistic rendering), and the JT viewer can be coupled with a VR system. It is possible to create JT files that contain structure, metadata and geometry, or alternatively the material and metadata can be imported from a PLM system.

Digital mockup (DMU)
In digital mockup (DMU), the mechanical properties of a product are examined and checked. This can involve checking the overall geometry regarding dimensions and shape, interference checks, collision checks for assembly and disassembly and installation feasibility as well as design space checks.

The capabilities of JT here include further tessellation of the geometry based on the exact B-rep information to allow flexibility regarding necessary precision of the geometry created for collision detection.

If a kinematic simulation is run in the originating CAD system, the JT data can include the kinematic connections and the key frame animation sequence from the CAD system. In DMU, the assemblies and parts can be moved using the kinematic connections to correctly constrain the movement.

Documentation and archiving
For the purpose of documenting and archiving engineering data, it is normally necessary to factor in exact data representation, including all metadata and PMI. The latter is especially important with regard to product approval and product documentation if drawings and technical documents are being replaced by digital 3D models. There are also compliance requirements that often need to be satisfied.

The most important requirement relating to the documentation and archiving of engineering data is that all relevant information be stored in a standardized format that can be read irrespective of a specific IT infrastructure and after a long period of time.

JT can be extracted from CAD/PLM systems and used for archiving. Nongeometric data and structure information is covered by PLM metadata containers such as PLM XML.

Data exchange
Use of the JT format can facilitate data exchange between all stakeholders in a shipbuilding project, for example between the shipyard, design agency and suppliers. In some industries such as automotive, most OEMs and Tier 1 suppliers have standardized on JT as the design exchange medium. The structure, selected metadata and geometry are stored in the JT file and transferred to the data exchange tool.
Use in PLM

Product lifecycle management (PLM) is defined as the activity of managing a company’s products across the complete lifecycle, from the early stages of conception to the final disposal or recycling of the product. Important drivers for PLM in shipbuilding are the need to manage very long product lifecycles, demand for more complex products in terms of components and functionality, trends of globalization and outsourcing and consequently complex supply chains, the need for customization of products due to more demanding customers and increasing regulations such as safety, environmental and product reliability regulations.

PLM provides a shared platform for effectively capturing, representing, organizing, retrieving and re-using product-related lifecycle information across companies and to support the integration of the existing software systems including CAD/CAM/CAE and ERP/CRM/SCM.

PLM needs to support a collaborative environment in which information and knowledge is transmitted between geographically distributed applications and users. Conventional representations such as CAD models are not optimized for such environments.

While the STEP standard has been expanded from the product design phase to incorporate lifecycle phases such as maintenance and repair, it is not easy to implement because of extensive volume of software objects and consequent large file sizes. JT provides a very good format for use in PLM.

Replacement of 2D drawings

All information needed to process parts and assemblies can be included in the JT file. Dimensions, tolerances, work instructions, etc. are displayed in the JT file together with the 3D geometry. This provides an option to reduce the dependence on 2D drawings which has always been the mainstay in shipbuilding. A normal PC is sufficient for viewing; no CAD workstation or CAD licenses are necessary. For example, 2D drawings in many cases (such as complex outfitting assembly drawings and block assembly drawings for complex steel structures) require extended time for workers to understand the assembly situation, and increase the probability of misinterpretations. The use of JT can complement or be substituted for these drawings, and helps save time and reduce errors.
Conclusion

As shown in Figures 4 and 5, JT as a neutral lightweight format can handle several processes in design, construction and lifecycle support for the shipbuilding industry. The applications of JT go beyond visualization, so it is possible to optimize product engineering processes by integrating a JT-based solution into selected processes. Shipyards can use a combination of JT-supported processes along with processes which need the use of native CAD and/or STEP. With continuing developments of the JT format and adoption by industries, the percentage of JT-supported processes can be leveraged further. (Figure. 6).

Figure 6: Use of JT in downstream shipbuilding processes.
White paper | An approach to accessing product data across the shipbuilding ecosystem

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