# Utilizing a Single 3D Product Model throughout the Design Process

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**Abstract**

*A key to promoting efficiency and quality in shipbuilding, design and engineering is to have one "source of truth" for data throughout the entire process. By utilizing a single 3D product data model, both for subsequent design phases but also for interdepartmental communication, organizations can reduce errors and cost by maintaining information at various handoff stages. The information preserved is not only the obvious geometric and attribute data, but also the design intent that is incrementally built into the product model. This paper will show the advantages gained by various companies that have utilized this approach via the Marine Information Model from SSI's ShipConstructor software.*

## 1. Introduction

Ship design, engineering and construction have historically been somewhat linear processes with work proceeding in a step-by-step fashion though various stages. Along the way, different workers with different skillsets have performed isolated activities using specialized tools. However, in recent years due to time and cost pressures along with advances in software capabilities, there has been growing usage of concurrent work methods and an increasing recognition that designers, naval architects and engineers along with associated sub-disciplines should work together to achieve optimum results.

Despite this growing overlap, there is still much separation between individuals, departments and tools. There are many products and have been many papers that espouse the need for a continuation of the product model between each phase of design. However for activities like visualization, engineering review, owner operator review, analysis and more within those phases, the direct exploitation of a 3D product model is still disjointed and fragmented. The question therefore is how information should be shared and utilized. It is the contention of this paper that utilizing a single 3D product data model is the best way to increase clarity, quality, and speed.

## 2. Benefits of Concurrency

Before talking about the actual tool, the advantages of the integrated and concurrent method should be stressed. The naval architecture and engineering firm Vripack from the Netherlands has been a particularly vocal advocate of this philosophy, dubbing it the "holistic approach". For instance, in a recent paper for the 23rd International HISWA Symposium on Yacht Design and Construction, the company pointed out the inefficiency of operating in isolated silos, *Markov and Abma (2014)*. The focus of the paper was on the critical interrelationship between design, naval architecture and engineering. One of the key slogans of the paper was an almost word for word echo of a prominent point of another recent paper by British shipbuilder Mustang Marine related to the overlap of production and engineering, *Paine et al.(2013)*. Both papers said to adopt a "right the first time" or "first time right" approach since the wrong decisions at earlier parts of the process ripple through subsequent stages and are much more costly and time consuming to fix later on.

The fact that this holistic approach is the optimal methodology can be seen even at the very beginning of a project. Starting from the first few weeks of Concept Design, decisions are made regarding main dimensions, building materials, location of the engine room, propulsion concept, shape of the hull, and internal volume versus the length etc. Each of these decisions affects cost and performance and it is a delicate balance to make the right trade-offs. Thus, during the process of making these decisions it is important to have accurate information to check feasibility of certain approaches so various software tools are used to perform calculations and model various ideas. This back and forth interplay between different shipbuilding disciplines ideally continues throughout the entire project so that all stakeholders can give input to each other and work together for optimum results.

For instance, at project commencement, pure concept designers may be mainly concerned with the overall looks. However, very early on they should be getting input from the naval architect in regards to factors such as weight and center of gravity. Of course, you also have to consider engineering factors such as technical specifications and not long after that, as concept design fades into the basic design/engineering phase, you should also start thinking about more engineering factors such as where some primary systems might go.

The efficient overlapping relationship between each of these disciplines has been conveniently highlighted in the infographic from Vripack, Fig. 1.

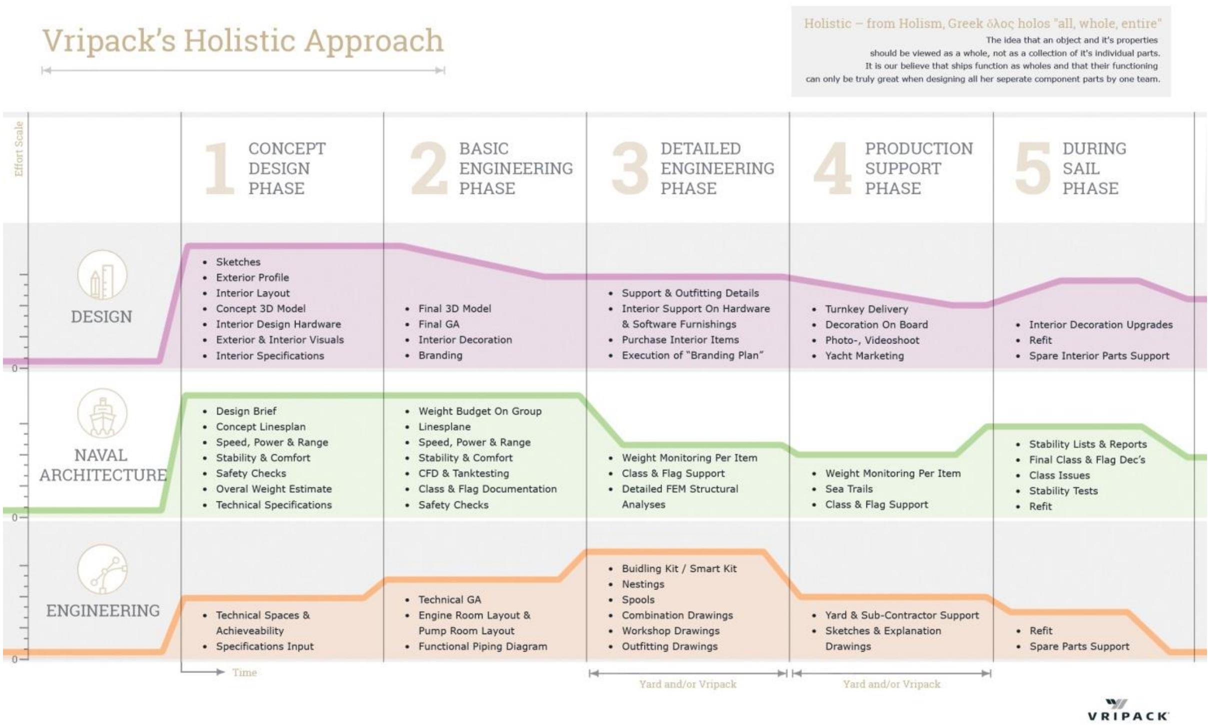

Fig. 1: Holistic Approach shows relationship between Design, Naval Architecture and Engineering

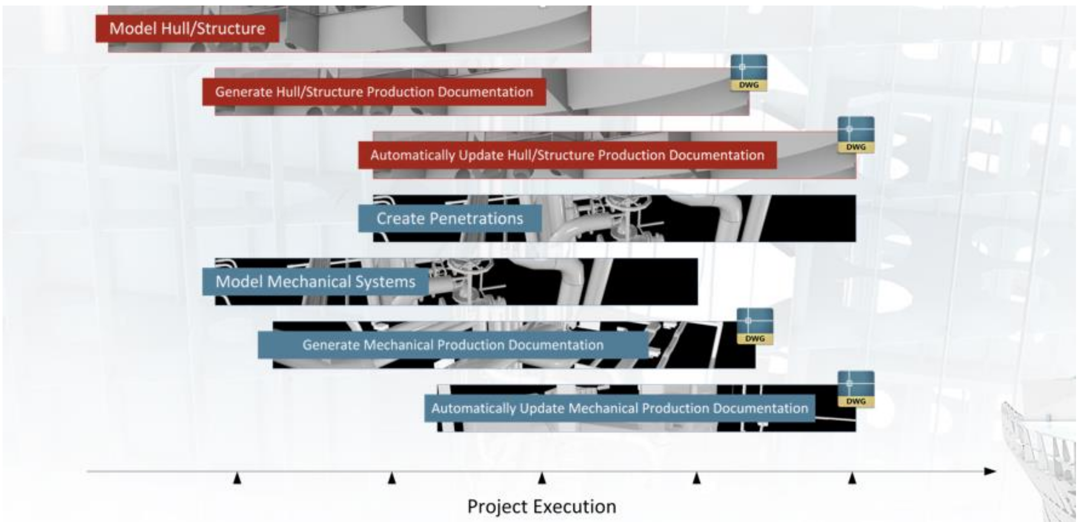

Fig. 2: Concurrent engineering

Fig. 2 shows the obvious logical time compression that occurs when different steps in engineering run at the same time. This is an additional driver of the growing recognition that a concurrent approach within engineering itself is desirable.

Then there is the fact that even when procedures were less connected and more linear, there was still inevitably a measure of overlap in various disciplines because companies simply could not afford to wait until, say, Class finally gave approval to move forward. Companies would always want to start doing something to make a project progress, even if some things had to change later on.

## 3. Typical Communication

With all this talk about different people and departments working together and interacting with each other, consideration of the means of communication comes to the forefront. Therefore, an analysis of how this is typically done is warranted.

### 3.1 Inefficient Method: Drawings

In this regard, the traditional method of choice has always been some kind of drawing. But these days, really, what is a drawing? Too often organizations act as if a drawing is a source of truth. This is wrong. Not only is a drawing not a source of truth, it is not truly a source at all. For anyone using a product data model (and these days, at a certain point, for any sizeable project, a vessel will be put into a PDM), a drawing is actually just a representation of a collection of information regarding a specific portion of the product model, usually for a specific purpose. For instance, an assembly drawing brings together standards, libraries, product hierarchies, part, spool or assembly attribute data relationships and other details. This provides enough information for production workers to perform certain tasks. Other drawings bring together other collections of information about the underlying product model for other purposes. However, no matter how much information a drawing contains, it only contains a tiny fraction of all the data contained in the vessel's product data model.

This point has practical consequences. Drawings are not going anywhere; they are great for many tasks, but they are not the right representation for many others. They are usually only ideal for the primary tasks for which they were originally created, not for the various other purposes that drawing-centric organizations use them for. The information on many drawings is either insufficient or not enough. One might ask why the shipbuilding industry uses drawings so much. One of the answers has to do with interoperability challenges when dealing with different software used for different purposes or by different companies or organizations. Sometimes this is a valid point; until there is a greater amount of standardization, drawings will be a natural method of communication with Class Societies and other organizations. However, a less significant, though perhaps more important reason is that for many companies, drawings are simply what they are used to. They know how to create, use, read, transmit and interact with them and do not believe it worth the efficiency and quality gains to do anything otherwise.

#### 3.1.1. Loss of Information during Copying

These organizations should consider more carefully the downsides of this approach. Every time you have to transfer information from one format to another, it takes more time and also inevitably leads to errors during the transmission process. When anything changes, someone has to remember to correctly update all the drawings and identify exactly what had been altered. With the thousands upon thousands of drawings generated during the ship design and building process, this is an extremely difficult undertaking and the source of an enormous amount of errors.

#### 3.1.2. Loss of Design Intent

A further reflection upon the issue shows an even deeper concern. When you transfer information to a static drawing, often the design intent is lost, thus increasing the chance of later errors yet again.

A non-shipbuilding example, albeit somewhat contrived, may perhaps make this point more clear. Consider Microsoft Word and the usage of various Style types, e.g. Heading 1, Heading 2, Heading 3 and Normal. The usage of these styles indicates the intent of the author, i.e. certain words do not just randomly change appearance; they are headings to group information and they are organized in a hierarchical fashion.

Now consider the case where Word is used to create a software manual. At the stage where the manual is to be provided to another department for the creation of help files, a PDF file is saved and sent. This secondary team has enough information to create the help file, but if they wish to convert, modify or otherwise reuse the information for anything other than a direct copy they need to infer the intent of a particular piece of text from the visual presentation of that text. The intent of the original author has been lost in translation.

On the other hand, if the help team was exploiting the Microsoft Word document itself, you would be able to simply look at the Navigation pane and go to the relevant section with full knowledge of how everything fit into the hierarchical outline of the manual.

A silly example? Perhaps. But the key point is that the source of the information incorporates relationships that are easily discoverable by the user and can be leveraged to provide other functionality (e.g. in this case, things such as an auto-generated table of contents if one desires.)

That is a simple illustration using a simple program with little in the way of relationships. Now consider shipbuilding, one of the most complex construction fields that exist, with part counts and interrelationships that dwarf even aircraft production. There are massive amounts of complicated relationships that are found in a product data model. Hopefully a drawing makes the relevant relationships clear to a particular user but real world experience at shipyards show that this is by no means always a warranted assumption.

## 4. Marine Information Modelling (MIM)

More and more, ship designers and builders are realising that the ideal method of communication is to work as much as possible by directly leveraging a unified 3D product data model. Similar to Building Information Modelling (BIM) in the architecture, engineering and construction industry, SSI calls this approach Marine Information Modelling (MIM).

To be clear, we are not proposing that all tools within and across phases of the ship design and construction process come from a single vendor. Quite the contrary as this does not lead to selection of a tool based on its own strengths and weaknesses but rather just based on the logo on the box (a dubious criteria for selection). We propose that the information in the product model (or more specifically in the source of truth for that information) be leveraged directly without conversion, or translation whenever feasible.

We are also not arguing that a single monolithic data store should be the source of truth for all information. As an example ERP systems should take engineering data from the product model and turn it into purchasing data to be stored within the ERP system. We are proposing that there should only be one source of truth for any particular piece of information. As an example, software used to perform final detailing and submittal of class drawings should not extract that information from the design and engineering product model to do so.

Section 5 outlines how several of SSI’s clients utilize this method to unite various disciplines: design, naval architecture, engineering and production. As much as possible, from the beginning to the end of a project, they construct and interact with the product data model in SSI’s ShipConstructor CAD/CAM software.

### 4.1 Requirements for Effective Use of a Product Model

This approach cannot be implemented with any and every product modelling software. The primary requirement of any product model to be used in this type of approach is that all information is available, in context, to other applications and processes as required. In general this requirement can be satisfied in many ways but this paper will focus on two ways in particular: neutral standards and platformization.

#### 4.1.1 Neutral Standards

One way to ensure other applications and processes can access information directly is to ensure that the native formats used by the product model are standards themselves. It isn't sufficient to simply export to a suitable standard as this disconnects the information from the product model and can lead to the challenges described earlier in the paper. While the Autodesk DWG and SQL behind ShipConstructor are not technically 'neutral' standards, they have become ubiquitous enough to satisfy this requirement fairly well in the real world.

#### 4.1.2 Platformization

A step beyond the use or application of standards is the move towards platform development, not product development. This trend, inelegantly referred to as 'platformization', opens the door for the type of direct use of product models being proposed earlier in the paper. Unfortunately this is not a trend that is as common in the shipbuilding industry as it is in other industries. A key pillar in SSI's approach to platformization of the Marine Information Model is the SSI EnterprisePlatform. This paper will not cover the details of the EnterprisePlatform which has been well documented in *Morais and Waldie (2013).*

## 5. Example MIM Implementations

A few example SSI clients who have adopted a MIM approach are the naval architecture firms Vripack from the Netherlands and Britain's BMT Nigel Gee. Both of these companies are well known for designing super yachts and innovative workboats. Another firm featured is the designer of many US Naval warships, Gibbs & Cox.

### 5.1 Concept Design

Design, Naval Architecture and Engineering functions overlap, Fig. 1, and naturally different people would be using different software to perform different tasks. However, as early as possible, companies want to get things into the ShipConstructor product data model so that they can start and keep using the data that incrementally gains more connections and depth. Of course, there are certain risks involved. A naval architect does not want to do too much work at the beginning if it is suspected that a project is not going to go forward. But if it's clear that it will become a build, the work in ShipConstructor could start as early as towards the end of the Concept Design Stage or what some companies might call the preliminary design phase.

The purpose here would be to start some basic modelling to help validate some design parameters such as weight and center of gravity. ShipConstructor is ideally suited for quickly building these types of models. You might just do a section or two to get a handle on things. Remember, this is a collaborative process that is being used to check various assumptions to optimize design and prevent expensive downstream changes.

### 5.2 Basic Design

Then, going forward into the Basic Design phase, the naval architects explained that they would use ShipConstructor to increase fidelity of modelling, primarily in structure. The goal, again, would be to ensure that things were correct. Gibbs & Cox explained that they might do some simple arrangement of machinery spaces and arrangement of other complex and congested areas such as an engine room of a navy ship. They would also look at using ShipConstructor for volumes for priority routing of distributed systems, i.e. planning where major piping and HVAC was going. Vripack emphasized that even at the very beginning you have to take this into account on a yacht. “In the end we all know that HVAC space requirements will happen, so why not better take this into account from day one,” is a quote from the recent paper by *Markov and Abma (2014).*

Of course though, one of biggest facets of Basic Design is a series of FEA calculations. There are methods for doing this in Autodesk based products such as AutoFEM which can directly take information from the ShipConstructor model. However, other programs such as NSC Nastran are known for particular strengths in this regard. No-one wants to duplicate work but which model to start in would depend on particular circumstances. Gibbs & Cox explained that if they were just doing a foundation they would put it in MSC Nastran first. On the other hand, if they were doing global analysis of hull/structure, they would put it in the ShipConstructor model first.

### 5.3 Detail Engineering

As you hit the detailed engineering phase, you need to generate drawings for Class Approval. Yes, they are 2D drawings, not 3D drawings, much less 3D fly-throughs of the model. But still, if the data is in ShipConstructor’s Product Data Model, ShipConstructor has a method of automatically creating this 2D documentation in native AutoCAD DWG format with appropriate symbology. Note that these drawings, despite being in the DWG format which is a common delivery format to the class societies, have not lost their design intent; they are still connected to the product model and know what portions of the product model they represent, even as they are delivered to class.

BMT Nigel Gee explained that on typical projects this literally cuts the time in half. There is no need to spend time creating 2D classification drawings and then copying them into a 3D model. You just put things directly into the ShipConstructor product data model and then not only can this be used for class drawings, this information can continue on and be leveraged for the rest of the ship design, engineering and building process. Furthermore, if any changes are required, because the AutoCAD based documents are interactively linked back to the model via ShipConstructor’s Associative DWG technology, notification can be provided and all relevant drawings automatically updated. Indeed, this associativity principle underlies the change management strengths that ShipConstructor provides throughout all aspects of a project. If something is linked to the single source of truth, if anything happens, change can be seamlessly managed efficiently and effectively.

### 5.4 Production Support (Production Design/Engineering)

In both Detail Engineering and Production Engineering, organizations typically use a program called Navisworks as a virtual reality collaboration tool. Navisworks is an Autodesk product, and therefore, part of SSI’s overall Autodesk based shipbuilding software solution. It is part of the solution because SSI’s ShipConstructor itself is built on top of an Autodesk platform and an AutoCAD foundation.

Navisworks is an ideal tool for interference checking. It is used for walkthroughs and analysis of design for production. In an SSI solution it is also typically the primary tool for collaboration between naval architects, shipyards and subcontractors because it allows everyone to see what is going on.

All of these strengths are delivered directly from the Marine Information Model. While a Navisworks model can be disconnected from the ShipConstructor product model, it can also be (and is typically) a real time dynamic view of the product model, complete with attributes and intelligence. Gibbs & Cox also highlighted how Navisworks is a common integrator of model information from other sources, including other computer programs, and even point clouds and as-built scans. You can process data in Autodesk ReCap and then use Navisworks to do the overlay between point cloud and model. Gibbs & Cox has found this works well.

## 10. Communication with Owner/Operator

Navisworks is a visualization tool for virtual reality but if one wants photo realistic renders and even animations, the tool that naval architects typically use is Autodesk 3D Studio Max, which, being a related Autodesk based product, SSI treats as part of its scalable software solution. As part of the integrated solution, it seamlessly leverages ShipConstructor's product data model to create movie quality images. Indeed, 3ds Max, as it is known, is the tool of choice for renderings in numerous Hollywood blockbusters such as the Harry Potter and X-Men series. When dealing with billionaire buyers of super yachts at any stage of the project, one can understand why the presentation of appealing images is critical for a firm such as Vripack. But Gibbs & Cox also notes that the same is true for a number of its projects as well.

## 11. During Sail Phase

During the final phase of Vripack's chart in Fig. 1, when a vessel is actually launched and at sail, the value of the product data model is still apparent. As an example, the US Coast Guard has recently recognized this and for its latest Offshore Patrol Cutters has required that an as-built model compatible with ShipConstructor be part of any shipyard's final deliverables. Gibbs & Cox is currently working with one of the bidding shipbuilders, Bollinger, to construct a ShipConstructor model of the ship which, upon completion of construction, would be handed over to the government should they be awarded the contract. There is so much information in the 3D product data model that it could be used for purchasing and in-service maintenance planning and there are ongoing talks regarding various possibilities.

An obvious advantage of having an as-built product data model would be for retrofit or repair. Gibbs & Cox already has used ShipConstructor on retrofit projects in the past such as a situation where the firm worked on an in-service modification project involving a model of an exhaust after treatment system for a commercial ship. Another time, the company used ShipConstructor to model a complex cofferdam to repair a vessel that had had a collision. Having a 3D model in those situations helped speed up the repair process, even though the models had to be created from scratch. If Gibbs & Cox already had had the model in place, the repairs would have gone even faster, thus, once again demonstrating that utilizing a single product data model has benefits from concept design, though to ship launch and even during in-service maintenance activities. In fact, the product data model could even help with decommissioning and the recycling requirements involved with scrapping. There is an enormous amount of information stored in the ShipConstructor product data model. Increasingly, organizations are learning how to harness its power.

## 12. Conclusion

Having workers in multiple disciplines collaborate and work concurrently increases quality and reduces costs. However, it is crucial that a tool exists to enhance communication and that there be one source of truth as a reference point. As much as possible, that reference point should be a single product data model. SSI's ShipConstructor software, due to its associativity with AutoCAD drawings and tight interconnection with other software provides tools to support the creation and interaction with a product data model. SSI's clients have proved that the model is capable of being used, to substantial benefit, at all stages of ship design, engineering, production, and beyond.

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