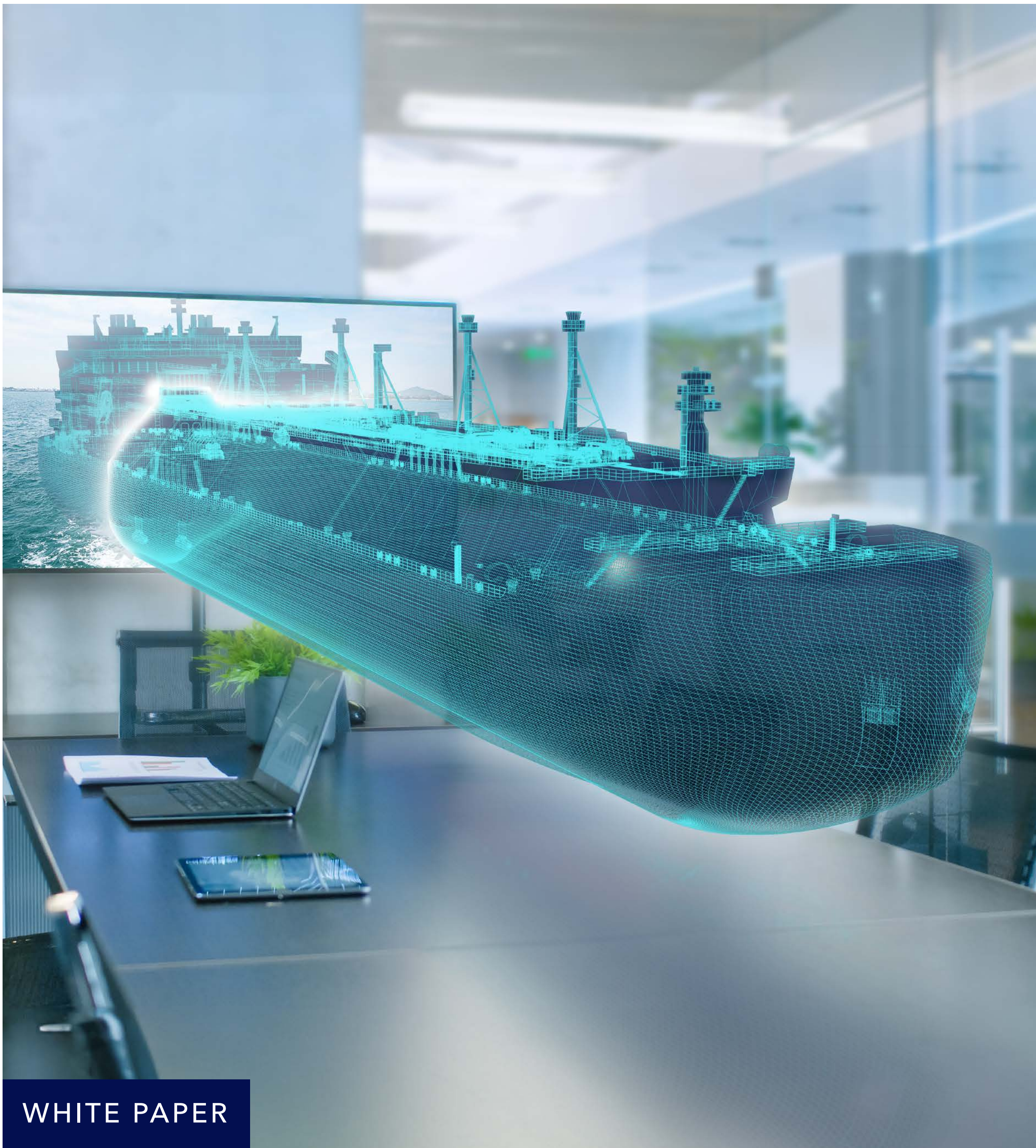
WHEN TRUST MATTERS

PAVING THE WAY FOR 3D MODEL-BASED CLASS APPROVAL

Streamlining and accelerating the use of 3D models in the approval process.



WHITE PAPER

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Introduction

As the shipping and shipbuilding industries make great strides in digitalization, there are more opportunities for classification to streamline and accelerate its approval processes where the use of 3D models instead of drawings has become a reality.

The result is a model-based class approval and verification scheme for newbuild projects, enabled by a cloud-hosted digital model-sharing platform. Cloud-based collaboration benefits from the "single source of truth" principle, eliminating media breaks, duplicated data entry, data quality issues and wasted work.

Ole Christian Astrup,
DNV, NORWAY

Executive Summary

Digital transformation – the integration of digital technology into all organizational areas, fundamentally changing how an organization operates and delivers value to customers or stakeholders – is increasingly prevalent in the shipping and shipbuilding industries. Since the dramatic global impact of the COVID-19 pandemic, this has accelerated, driven by necessity, technological advances, and expectations from consumers.

This digital transformation can be observed across many areas of the maritime industry and is expected to affect all aspects of the product lifecycle. Commercial ship design and production are steadily under pressure to reduce time to market and overall production costs as well as to improve product quality concerning multiple performance criteria that are to be met at the same time.

This paper focuses on how the digital transformation is being harnessed in the classification society's approval process using 3D models. While the use of 3D models has become a normal part of the production process in shipbuilding over the past 20 years, it is still relatively novel for designers to use 3D models at the early and basic design stage. However, the last few years has seen a shift towards a process where early and basic design is taking place on 3D models, with traditional 2D models then being extracted for the approval process. The obvious next step is to extract the information needed for design approvals directly from these 3D models and perform the entire review process digitally instead of the traditional drawing-based reviews.

The main barrier to achieving this is the lack of a standard format and process for submitting 3D design data to the classification society for approval. A wide variety of CAD software applications and digital engineering tools are used to support the design, procurement and manufacturing processes in the shipbuilding industry. This heterogeneity has created both technical and business challenges, including complex issues around point-to-point integration and data integrity, while there is no digital standard supporting the requirements and constraints of classification societies. The aim is, therefore, to standardize the format and process for submitting 3D design data to DNV as the classification society for approval.

In 2016, DNV established the joint industry project (JIP) APPROVED, bringing together CAD/CAM software providers, ship designers and builders, and 3D and PLM implementation specialists. This resulted in the development of the Open Class 3D Exchange (OCX) standard, an open standard exchange format which ensures interoperability with the classification societies across all the different CAD applications. It allows shipbuilders and class societies to review models and engage in a seamless digital workflow using a common specification for 3D models. In November 2022, DNV, Deltamarin and AVEVA were the first to announce a successful 3D approval of an engineering unit of the Höegh Autoliners' Aurora Class PCTCs utilizing the OCX standard.

OCX has unique features that distinguish this standard from existing formats. It incorporates the 3D model topology, a ship-specific taxonomy, and the spatial and logical structure of compartments and tanks – addressing the information needs of the classification society. The OCX standard has the necessary capabilities to transfer a full basic design model of the hull into a 3D model, which can be used as design documentation that can be submitted for verification. Effectively, OCX acts as a conduit between the design tools and class confirmation tools, highlighting the structural information the class society requires and idealizing and formatting it in an efficient way that can be easily processed.

Using OCX provides many benefits to yards, designers and classification societies. This includes reduced shipyard workload due to the need for fewer drawings; reduced time to market; reduced costs; improved quality and a common understanding of design and class comments; optimized calculation processes; and improved transparency.

DNV promotes the exchange of 3D OCX models with all customers who are using an OCX-enabled 3D design tool that can export the OCX file format. These customers can choose to submit a 3D OCX model as design documentation instead of traditional 2D structural drawings. Interactions with DNV can occur in three ways: efficient rule check using Nauticus Hull by the direct import of the 3D OCX model exported from the CAD system; early design review/pre-contract based on the review of an early 3D OCX model; or a full model-based approval process covering the hull discipline.

Extending OCX to support other disciplines and include new information items is straightforward, and the obvious next step on this journey. OCX can easily be extended to cover all functional zones relevant to ship design and regulatory requirements. This may include components like rudder, large shell-doors and ramps, which also require class approval.

The digitalization of shipping is gathering speed and it is up to all stakeholders in the industry – including shipowners, designers, yards, and classification societies – to ensure this takes place in a smooth and efficient way which optimizes resources and makes processes more seamless and efficient. The OCX standard represents a significant step forward in this process and is expected to become a central part of the approval process as shipping ramps up its digital transformation.

Digital transformation

Information technology, now increasingly leveraging the Cloud and global 24x7 access via mobile devices, is enabling the digital description and management of everything companies make and do, from the largest global organizations to small, start-up enterprises. Digital transformation is the integration of digital technology into all organizational areas, fundamentally changing how an organization operates and delivers value to customers and stakeholders.

Digitalization and digital transformation

UNIDO outlines that in a larger context, digital transformation is a broader term than digitalization (UNIDO, 2021). It is the integration of digital technology into all organizational areas, fundamentally changing how an organization operates and delivers value to customers or stakeholders. It is also about prioritizing organizational culture change, which requires organizations to continually challenge the status quo, experiment and get comfortable with failure. Digital transformation is a widely used term that, in practice, will look very different in each organization. In essence, it refers to the customer-driven strategic business transformation requiring organizational change and the implementation of digital technologies.

Digital transformation drivers

Three factors are driving the digital transformation. The first is necessity. Survival and adaptation to rapidly changing markets and circumstances challenge organizations to rethink how they execute their operations radically. The dramatic global impact of the COVID-19 pandemic advanced the adoption of digital technologies. Stresses such as supply chain disruptions, time to market pressures and rapidly changing needs in the health sector prompted more organizations, both commercial and governmental, to engage with digital transformation. The second driver of digital transformation is the technology itself. According to the OECD, mobility, cloud computing, Internet of Things (IoT), artificial intelliegence (AI) and big data analytics are among the most important technological drivers influencing industry today. The opportunities offered by digital technologies for innovation and efficiency drive change powered by rapid connectivity, exponential generation of data and affordability as time passes.

Necessity: The COVID-19 pandemic boosted the adoption of digital technologies

Expectations have been raised by digitalization and this heightened set of expectations is the third factor driving digital transformation. Citizens count on the same kind of experience in a professional setting as they experience with technology in their personal lives. Delivery of services and products that meet or go beyond stakeholder expectations for seamless integrated and efficient customer experience that meet their demands require businesses, governments and all organizations to transform their delivery models, embracing digital technologies and innovative approaches.

Technology: Mobility, cloud computing, IoT, AI and big data analytics are among the most important technological drivers

Industry 4.0

Industry 4.0 is characterized by the integration of digital technologies such as AI, IoT, and automation into the manufacturing and production processes. This integration allows for increased efficiency, customization, and innovation in the creation of goods and services. It also results in a significant demand for changes in workforce skills. This also calls for an increasing emphasis on data-driven decision-making.

Expectations: Customers and end users are demanding better user experiences and digital touchpoints

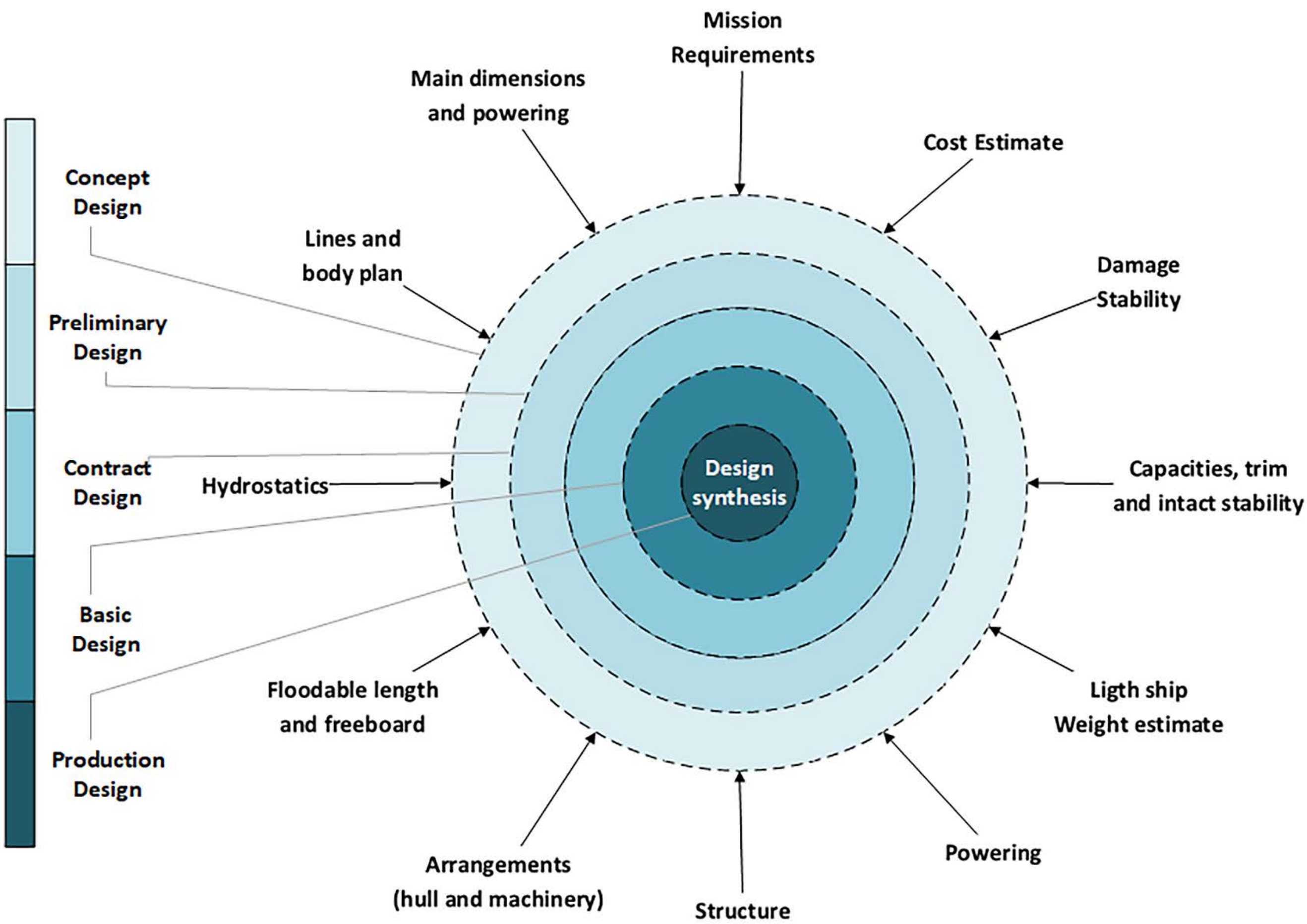
From a sequential to an integrated ship design process

Traditionally, 3D CAD systems have been used in the later design stages of projects, mainly in detail design. Nowadays, major ship designers and yards have realized the importance of using a 3D solution for basic (class) design, allowing for the review of previous decisions, and facilitating the re-work tasks.

A concurrent shipbuilding process
The consequence of the objective of reducing costs and delivery time but maintaining and even improving quality has produced changes in all aspects of shipbuilding, including construction, project management and design processes. As a result, ship design has moved towards an integrated process illustrated in Figure 1 where the 3D models have become the core of the design synthesis.

FIGURE 1

Integrated ship design process chart.



Reproduced from Pérez-Martinez (Pérez-Martinez and Pérez Fernández, 2021)

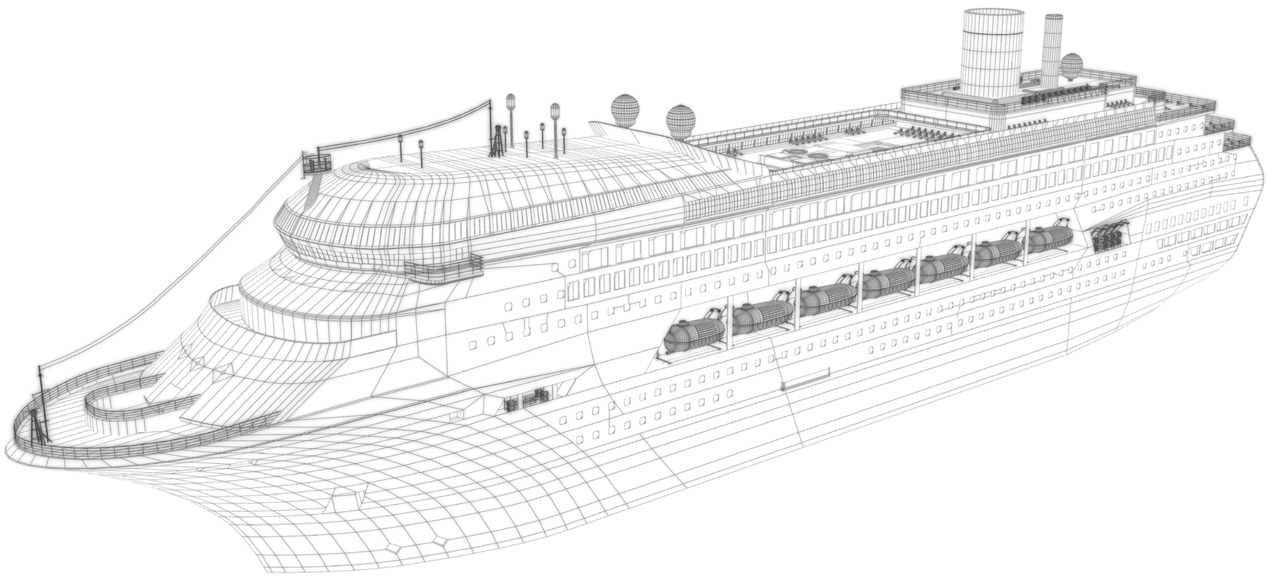
Digital modelling

While much of the digital product definition focus for the past 30 years has been on the development of detailed 3D CAD models for mechanical and electrical design and manufacturing, the next 5 to 10 years will see an increased emphasis on digital modelling of all key aspects of the product lifecycle (user needs, functional requirements, system architecture and interfaces, physical design, etc.) spanning all relevant domains making up the product (e.g., embedded software, hardware, electronics, controls, optics, chemical formulations, etc.). The use of robust digital models at the systems level and in all aspects of product development (i.e., model-based systems engineering) is creating a new paradigm for how manufacturing organizations and their global extended ecosystems must interact and collaborate to bring innovative products to market, as well as support them throughout their lifecycles (Astrup and Cabos, 2017).

Commercial ship design and production are steadily under pressure to reduce time to market and overall production costs as well as to improve product quality concerning multiple performance criteria that are to be met at the same time. Increased digitalization and automation within the shipbuilding industry have the potential to leverage the competition between high-cost and low-cost countries.

Simulation, virtual prototyping, and virtual testing combined with the introduction of advanced production and manufacturing robots are enabling technologies important also to the shipbuilding industry. Robotization and automation will be instrumental in increasing production efficiency and lowering production costs. Future yards will be based on a digital thread intervening all processes from design to production. In the future, a digital product definition from the design will be used in fully automated production processes (Schjølberg, 2016).

IoT will introduce capabilities to instrument the complete value chain in a cost-efficient way. It will be possible to quickly introduce design changes and simulate the impact on production. The production process can quickly be adapted and changed to reflect design changes. During production, vital production parameters can be monitored in real-time and modified to meet quality requirements. Companies mastering this shift into the age of Industry 4.0 will be the winners.



Use of 3D models in the design process

While 3D models are commonly used and an accepted way of designing highly complex ships, it is a relatively novel approach to use the 3D model throughout the entire shipbuilding process. The 3D model has become the single source of truth for the designer and the order of creation of the traditional 2D drawings has turned to the extraction from the 3D models.

3D models becoming the source of truth

This was not the case some 15 years ago when 2D drawings were the basis of ship design, approval, and production (Seppälä, 2021). In recent years, significant shifts have been enabled by new computing technology and comprehensive access to 3D manipulation. It has provided numerous possibilities to avoid 2D documents. Examples of these include direct interfaces with CNC machines, welding robots and cobots, new options to submit 3D models for class approvals, and more. Seppälä identifies three major use cases for 3D models in the ship design process at the yard (Seppälä, 2022a):

1. Boost for communication (project overview, handover, visualisation replacement of drawings)
2. Integration of information flows (Integration with ERP, PLM/PDM, planning systems and different stakeholders)
3. A platform for digital twins (consolidating ship management information with a 3D dashboard)

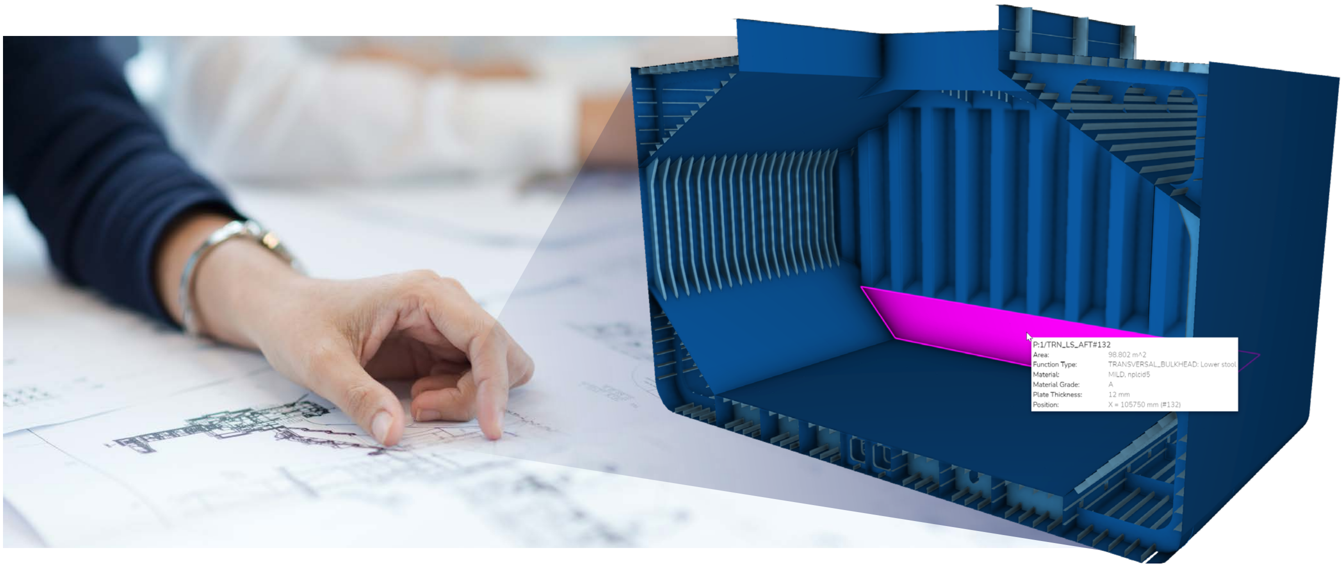
Seppälä further concludes that the reality at shipyards is still far from the ideal situation with a myriad of specialized systems, interfaces, and data storage methods used in different departments. A step that would provide unification is the expansion of the use of the 3D model and increased interoperability between systems, thereby ensuring support for the specific needs of each discipline and shipbuilding process stage.

The digital fabric of shipbuilding (Seppälä, 2022b) consists of data threads that originate from various specialized applications. There are commonly numerous different software solutions involved in a shipbuilding project, hundreds of engineers and designers, several companies located in different countries and continents, and even several building sites.

The data relating to the project is often based on a model-centric approach and serves all stages of the life cycle: from initial design to production, MRO, and operations. An incrementally built digital twin can be used for a wide range of purposes.

Can we replace traditional 2D Drawings with a 3D model?

To date, plan approvals for new-build projects have been based on conventional 2D drawings. Since most designers use 3D modelling software, the obvious next step is to extract the information needed for design approvals directly from these models and perform the entire review process digitally instead of manually. The challenge is to standardize the format and process for submitting 3D design data to the classification society for approval.



Engineering drawings are a universal language

Engineering drawing has stood as the universal method of translating design intent since the first standard was formalised in 1927 as BS308, (Garland et al., 2019). Traditionally, drawings are used for communication in the industry because they are the clearest way to tell someone what to make and how to make it. They are considered a graphic universal language. The fundamental purpose of an engineering drawing is to carry, control and maintain a product's definition in a precise and clear way with no risk of misinterpretation or assumption. Technical drawings provide a means to communicate product complexity in a comprehensible and effective manner thanks to visual abstraction.

Drawings are becoming the product of 3D CAD models

CAD models have traditionally been used in the design, evaluation, and manufacturing phases; up until the turn of the millennium, engineering software was used to support a paper-based workflow – CAD packages were used to create virtual models of designs, from which drawings and other design documentation could be produced. The manufacture or construction process was based on the resulting documentation. However, current digital environments necessitate an electronic flow of information between heterogeneous systems for Computer-Aided Design (CAD), Computer-Aided Engineering (CAE) and Computer-Aided Manufacture (CAM) as well as Enterprise Resource Planning (ERP), Customer Relationship Management (CRM) and Supply Chain Management (SCM). Thus, there is an increasingly greater reliance on CAD models. Many in the industry have moved away from a reliance on drawings to computer-based technology to design, price, and manufacture items in a world where digital information is king. Engineering drawings are no longer considered primary product definition sources or master representations of products, as the integration of CAD systems within the product development process has become the standard. Both the aviation and automotive industries are moving towards a drawing free product lifecycle. We can see several drivers in this development (Quintana et al., 2010):

- One master product definition
- Virtual prototyping and simulation
- Computer-aided manufacturing (CAM)
- Assembly automation
- Production of maintenance documentation

The above list is not exhaustive, but some common denominators are reduced time to market, reduced rework, reduced cost, and improved transparency for stakeholders throughout the product lifecycle.

From a business perspective, companies will benefit from reduced investment in piecemeal integration projects. The corresponding increase in data quality, based on data transfer versus data re-creation, will lower the cost resulting from rework. Ultimately, companies should see a significant reduction in application integration costs, as downstream processes and successive programs reuse the existing interoperability framework.

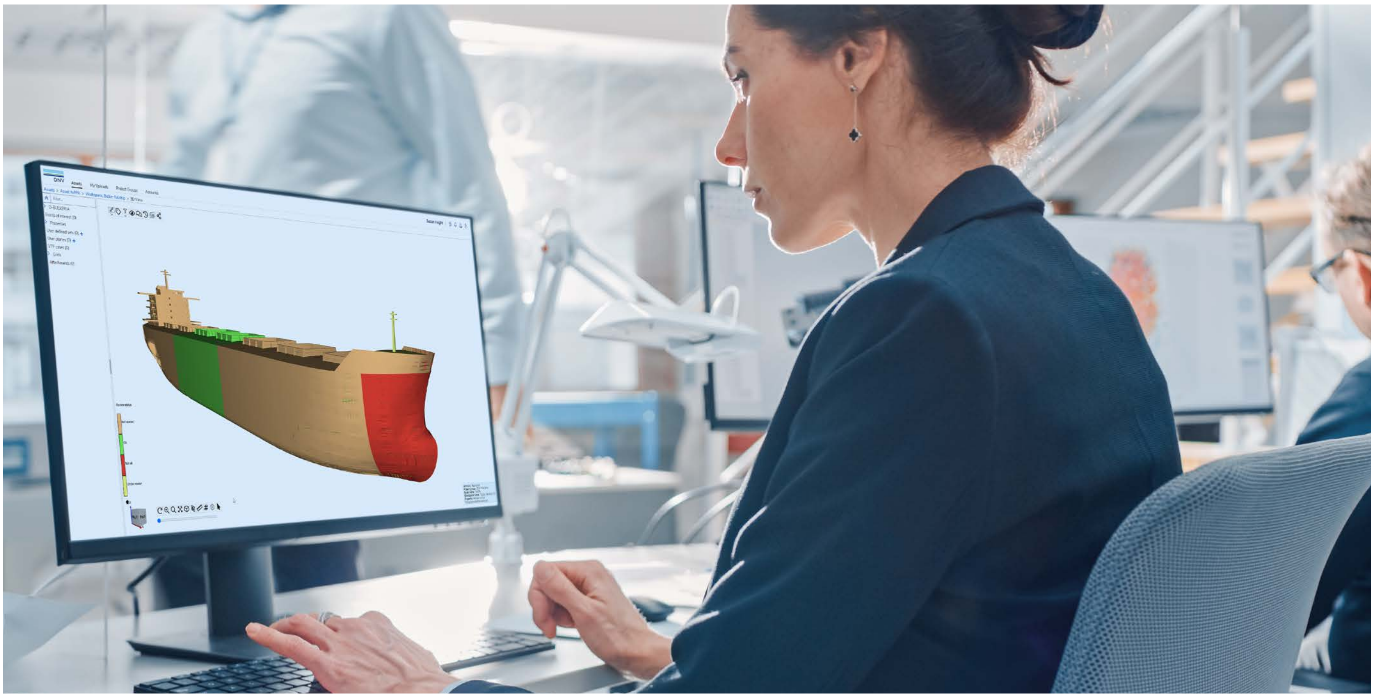
From a technical perspective, the standards-based approach can greatly simplify integration complexity, by largely eliminating the need to develop and maintain point-to-point integration solutions. The simpler integration model will make it feasible to add new applications as demands arise for new capabilities. The time required to deploy new applications and processes that are integrated with existing capabilities will be greatly reduced.

These benefits are predicated on several factors. The standards used must be comprehensive enough to support a complete business scenario, such as engineering design. They must be robust enough that they can support exchange between a wide variety of data models and applications. They must be feasible to implement, and the implementation itself should follow certain established patterns to derive maximum benefit (AIA, 2013; Astrup, 2017).

Further development of national and international standards has been informed by advances in CAD/CAM technology and the need for the transfer of complex yet unambiguous definitions between organizations. The emergence of model-based definition (MBD) has driven a new workflow where engineering drawing is no longer required in the manufacturing industries. Instead, the dataset includes semantic, machine-readable, tolerancing of surfaces and features for integration into manufacturing which are now being used as the method for recording definitive product data in several industries.

A model-based definition provides the core foundation of the product lifecycle. It is one of the first pieces of information that is created during product development. It then grows as the product matures, evolving it into the single authoritative source of product definition. But to be used by all the downstream users it must be delivered in a format that is truly CAD-neutral. The key to achieving interoperability across software applications is open standards, i.e., those developed by consensus either within a standards development organization or a consortium of stakeholders. No single software tool can perform all the engineering tasks needed to design and manufacture a product.

We would argue that the support for MBD in existing ISO standards (ISO, 2021) is not well suited for use in the shipbuilding industry. A complex product definition and CAD 3D model of a ship typically consists of hundreds of thousands of parts. A complex cruise ship's number of parts easily exceeds a million. A rich semantic and neutral model with parametric and topology information is a better solution for the shipbuilding industry.



The role of standards

Standards offer global, transnational, multidisciplinary and potentially rapid responses to the needs of the technology developments characterized by the Fourth Industrial Revolution (4IR).

Standards shape the digital transformation
Standards have an essential role in providing solutions to current and future technological and societal challenges derived from digital technologies because they set minimum requirements in terms of safety, security, reliability, efficiency, interoperability and trust. They also act as a precursor to regulations, voluntarily granting expertise and buy-in from private sector innovators, and leading to regulations that minimize risk and create an enabling environment for innovators and investors.

UNIDO lists the following benefits of standardization (UNIDO, 2021):

- Shape digital transformations
- Complement regulations
- Facilitate digitalization
- Promote Interoperability
- Set minimum levels of quality and safety
- Accelerate change
- Promote innovation

The timely and harmonized adoption of standards is likely to play a key role in the digital transformation. As a means of promoting interoperability, productivity and innovation, and of ensuring the successful scale-up of solutions to be implemented globally, standardization can offer a range of benefits and opportunities for digital technologies:

- Unifying technologies and specifying common technical features
- Promoting interoperability and compatibility
- Helping to eliminate technological silos
- Enhancing innovation and growth
- Accelerating technology adoption
- Building trustworthiness and describing governance frameworks
- Aiding user understanding, acceptance and confidence in new technologies
- Helping to minimize risks, improving safety, avoiding technological lock-ins and validating quality
- Collating best practices and use cases
- Supporting policy and legislation

Standards promote interoperability
Standards have an essential role in providing solutions to current and future technological and societal challenges derived from digital technologies because they set minimum requirements in terms of safety, security, reliability, efficiency, interoperability and trust. They also act as a precursor to regulations on a voluntary basis, granting expertise and buy-in from private sector innovators, and leading to regulations that minimize risk and create an enabling environment for innovators and investors. Consequently, several international organizations and professional bodies have developed considerable policy expertise regarding digital standards in recent years, not least the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the International Telecommunication Union (ITU), the United Nations Industrial Development Organization (UNIDO), the Institute of Electrical and Electronics Engineers (IEEE) and the G20.

Lack of standards is a barrier
The variety of engineering tools used to support design, procurement, and manufacturing in the shipbuilding industry are many. From company to company, tools and processes range from manual capture in 2D drawings to sophisticated 3D models that are tightly integrated with other enterprise systems. The challenge is further compounded by the growing need to provide engineering information for support extending beyond the life span of individual applications.

This heterogeneity has created both technical and business challenges. Data integrity across the applications and systems that author and consume engineering data is problematic. Point-to-point integration between systems is often so complex and costly that organizations opt for manual data re-entry when faced with program budget and schedule constraints. This decision has a lasting impact on information quality, supplier management, manufacturing integration, and in-service support.

Shipbuilding standards

Considerable effort has been spent in developing standard protocols for product definitions for the shipbuilding industry but none of these have been adopted by the industry.

Unsuccessful standardization attempts

A major standardization effort targeting the shipbuilding industry took place over a decennial starting in the mid-90s. Product data models meant to support the data exchange were developed and led to the ISO standards (STEP series) with the shipbuilding-specific STEP protocols: ISO 10303-215, ISO 10303-216, ISO 10303-218(ISO-AP216, 2003; ISO-AP215, 2004; ISO-AP218, 2004) which cover a broad range of different, sometimes overlapping scopes. Even though the implementation of these standards was supported by many development projects in the international community over the past 20 years, today there are only very few systems capable of exporting their internal data structures according to the standard definitions.

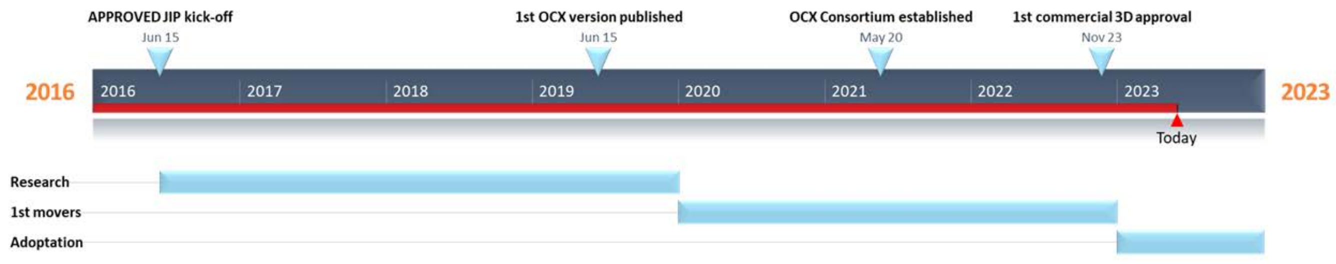
Due to its broad scope, the application protocol AP218 is a semantic standard to support the need for data exchange during the early stages of the design in a consistent manner. However, due to the generally limited support by software vendors, the shipbuilding protocols are not used in actual commercial ship design. The focus of the various ISO standardization initiatives has been to support product definitions with the primary aim to build and produce the asset, i.e. the ship. The product-oriented ISO standards are difficult to use as a basis for digital verification by the Classification Societies, as these (semantic) standards become too information rich and are not particularly adapted to the classification society's needs. There is no available digital standard supporting the requirements and constraints of the classification societies as of today. Attempts have been made to establish such standards in the past (Haenisch, J. and Langbecker, 1999), but nothing has materialized.

No ship-specific standard exists

The shipbuilding industry's lack of a ship-specific standard is a major problem. This has left a void that needed to be filled and resulted in a continuation of the development of "point-to-point" solutions based on a variety of ad hoc application programming interfaces (APIs) and XML-based interfaces. While these have been effective in terms of achieving the result, they have not been cost-effective from an industry perspective as the number of interfaces grows at a combinatorial rate as the number of applications increases (Polini, 2011).

The Journey of the Open Class 3D Model Exchange (OCX) standard

In 2016 DNV took the initiative to establish the joint industry project APPROVED. Developing an open-standard exchange format to ensure interoperability across all the different CAD software applications and allow the classification society to review models generated by many different CAD tools was a key activity of the JIP. The result is the Open Class 3D Model Exchange or OCX standard.



The APPROVED JIP

The APPROVED JIP brought together expertise (Halfhide, 2019) from CAD/CAM software providers Aveva, Hexagon (formerly Intergraph) and Siemens; along with ship designers and builders Kongsberg Maritime (formerly Rolls-Royce Marine), Ulstein Design and Solutions and Chantiers de l'Atlantique; as well as 3D and PLM implementation specialists CLEVR (formerly Digitread). During the project, NAPA joined as a full contributor. The result of the combined efforts is the development of an interoperability specification to allow shipbuilders and class societies to engage in a seamless digital workflow using a common specification for 3D models: The Open Class 3D Exchange standard (OCX) (Astrup and Cabos, 2017; Moser and Astrup, 2018; Astrup, 2019; Astrup et al., 2022).

"The vision of the APPROVED project is aligned with our ambitions as a design company to further reduce costs and time to market for our innovative design solutions. We see this can strengthen our competitiveness. The project also supports our goal to strengthen the interaction among stakeholders in the production and supply chain by utilizing the 3D model as an information carrier."

Bernt-Aage Ulstein
Director Design & Engineering Ulstein Design and Solutions AS

FIGURE 2

Deltamarin, DNV and AVEVA first to announce a successful 3D approval (November 24, 2022)

A 7 year long journey

The timeline illustrates a typical pattern for a standardization initiative with a 4 year research period focusing on development and implementation before the first version of the standard was published in 2019. The research and development phase was followed by the first movers utilizing the new capabilities of the standard. In November 2022, DNV, Deltamarin and AVEVA were the first to announce a successful 3D approval of an engineering unit of the Höegh Autoliners' Aurora Class PCTCs utilising the OCX standard (Deltamarin, 2022), see Figure 2. Soon after, BV, Damen and NAPA announced their first full 3D approval of a 2500 m3 dredger (Damen, 2023).

The result: OCX

Uniquely, OCX addresses the needs of the classification society and shipbuilders for fully digital information exchange. Effectively, OCX acts as a conduit between the design tools and class confirmation tools, highlighting the structural information the class society requires and idealizing and formatting it in an efficient way that can be easily processed. The APPROVED project has demonstrated the capabilities of the OCX providing seamless information exchange between the designer/yard and the classification society covering the hull structure definition of the design. The goal of the standard is to replace traditional 2D class drawings with a 3D model as the design documentation submitted to the classification society.

The joint consortium

To ensure neutrality and avoid the emergence of multiple incompatible exchange standards, an independent consortium was established in 2021 to industrialize, promote, and maintain the OCX standard (3docx.org, 2021). Several classification societies including nearly all the IACS members as well as major Computer-Aided Design (CAD) providers have joined. At the current time of writing 31 companies have joined the OCX Consortium.

The Consortium keeps the latest version of the exchange standard updated. The OCX exchange standard is public, which means that it can be downloaded by anybody and used under the terms of a public license.

The Consortium is a fully voluntary association between the members and is not a separate legal entity.

The uptake of the OCX by the industry is gradually expanding as classification societies are building on the OCX capabilities and changing the way they can interact with designers and shipyards.

For more detailed information please visit the OCX Consortium at **https://3docx.org**

"For the classification societies to succeed with 3D model-based approval and reap its benefits it is instrumental that OCX becomes a recognized industry standard. If this is to happen, the maritime industry must cooperate and work together to implement and use the standard. Therefore, DNV has taken the initiative and established a joint OCX consortium with the participation of the major classification societies and the maritime industry."

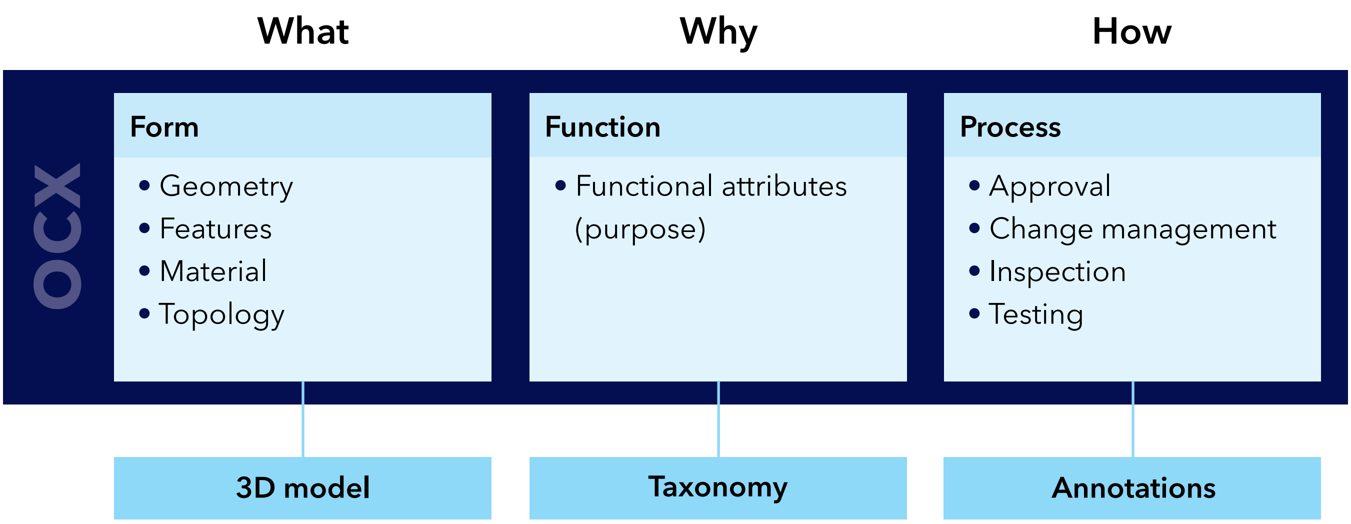
Geir Dugstad,
Director of Ship Classification & Technical Director at DNV Maritime

The OCX capabilities

The OCX has unique features that distinguish this format from existing standards. The OCX is a vessel-specific and feature-rich standard addressing the information needs of the classification society and is a key enabler to replace traditional 2D drawings with a 3D model as design documentation submitted for verification.

FIGURE 3

The OCX information structure



The What, Why and How

The OCX structure adapts concepts used by Product Lifecycle Management (PLM) and organises the information content into three major categories similar to Rachuri (Rachuri et al., 2008).

- **Form (What):** The vessel hull form is described by its geometry, features, materials, topology etc.
- **Function (Why):** The structure functions of the vessel are represented by a ship-specific taxonomy describing requirements, and the function to be performed.
- **Process (How):** Process and business-related life-cycle data represented by layered annotations describing process information e.g. approval, change management, inspection, testing etc.

We distinguish between Schema, Model and Annotation:

Schema, Model and Annotation

A Schema is a collection of entities (or classes), attributes, and relationships between entities. It defines the patterns or templates by which populations of these entities and relationships shall be represented. Such a schema is often called a Product (Data) Model (as opposed to a populated data model). The OCX specification is a schema.

A Model is a population of a schema, following the patterns, templates and constraints stipulated by the schema. It contains the actual instances of the entities (or classes). Such a model is often called a populated data model, a project data model, or a building information model (if the content is construction industry-specific). An OCX exchange file is a population of the OCX schema and represents a ship structure information model. The purpose of an OCX model is to form the basis for a model-based approval of the design by the Classification Society.

An Annotation is simply defined as adding any extra information for various purposes, such as further explanations, viewpoint interpretations, and extra descriptions of or comments on an existing entity in the model.

Design considerations

The main design considerations have been to incorporate the following features of the OCX schema:

- A concept-rich and vessel-specific domain model.
- A lightweight and CAD-neutral representation of the 3D geometry.
- The ability to grow the product definition information throughout the design lifecycle.
- The ability to describe the function and process-related information.
- The ability to reference functions and process information to the 3D model using multi-layered annotations.
- A referencing scheme or mechanism which is robust to 3D model design changes.
- An easily extendable scheme to cater for new functions and process-related data.

What can the OCX do

The scope of the current OCX schema definition is the hull structure. The developed schema has the following main capabilities:

- The ability to describe a vessel using typical shipbuilding concepts such as Panel, Plate, Stiffener, Pillar, Bracket, Lug, Cope, Cut-Outs, End Connections & Penetrations.
- Structure functions. Taxonomy for load-bearing structure functions (e.g. Deck, Girder, Bulkhead and sub-types).
- A unique identifier for each structure part.
- Physical spaces (compartments with content).
- All part geometry interrelationships (topology).
- A self-contained and parametric sheet geometry representation:
  a. 3D surface primitives (Plane, Cylinder, Cone, NURBS)
  b. 3D curve primitives (Line, CompositeCurve, Circle, Arc, NURBS).
- The ability to provide two different levels of details for the geometry representation:
  a. Gross geometry representation at the Panel level, see Figure 4.
  b. Detailed geometry representations at the Plate Bracket, Penetrations and EndConnection level for the true visual representation of the design model, see Figure 5.
- All parameters required by the classification society's Rules.
- Catalogues: Cross sections, materials and openings.
- Metadata: Scantling attributes, vessel particulars.
- Design views (a user-defined part or product structure).
- Full unit support.

See (Astrup et al., 2022) for a detailed overview of the OCX schema capabilities.

There are obvious benefits from the exchange of a feature-rich digital model:

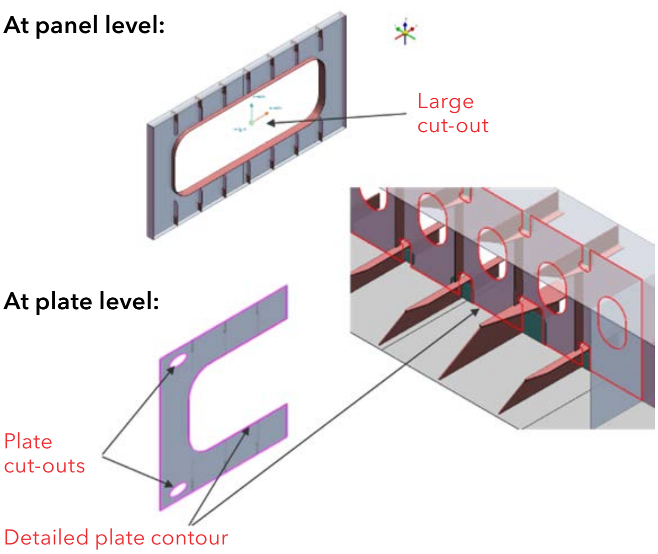
- The industry will benefit from a single neutral ship-specific 3D exchange format, avoiding costly point-to-point integrations.
- Engineering models can consistently be derived from one single 3D model source.
- CAD idealizations supporting several engineering analysis purposes can be covered: whole ship models to detailed fatigue models.
- Multi-layered annotations are independent of 3D model exchange and CAD formats.
- Annotations are loosely coupled to the correct entity in the model and can therefore be transferred between discipline-specific model representations.
- Annotations can be edited, circulated, and processed independently of the model, whilst the 3D model remains unchanged.
- Multiple independent annotation files can be safely applied to the same 3D model.
- Annotations are easily extendable and offer support for business-specific needs

The OCX exchange will

- **reduce shipyard workload** with fewer drawings to create,
- **improve quality** and achieve a common understanding of design and class comments by using a 3D design representation directly,
- **optimize the calculation process** by directly interfacing the 3D design model with calculation software such as structural and stability software,
- **improve the transparency and support** for automation and increased self-service.

FIGURE 4

The separation of detail level in the OCX schema



Improving collaboration and data exchange

The standard has the potential to significantly improve collaboration and data exchange in the shipbuilding industry (Bitomsky, Danetzky and Zerbst, 2022) making it easier to design and build ships more efficiently and with higher quality. It is designed to be flexible, vendor-neutral, and adaptable to different workflows, making it easier for shipyards, suppliers, and other stakeholders to collaborate on shipbuilding projects. The digital exchange of rich 3D data models supports the integrated design process with many parallel activities illustrated in Figure 1. This enables all stakeholders to have access to at any time updated design information from a single source of truth.

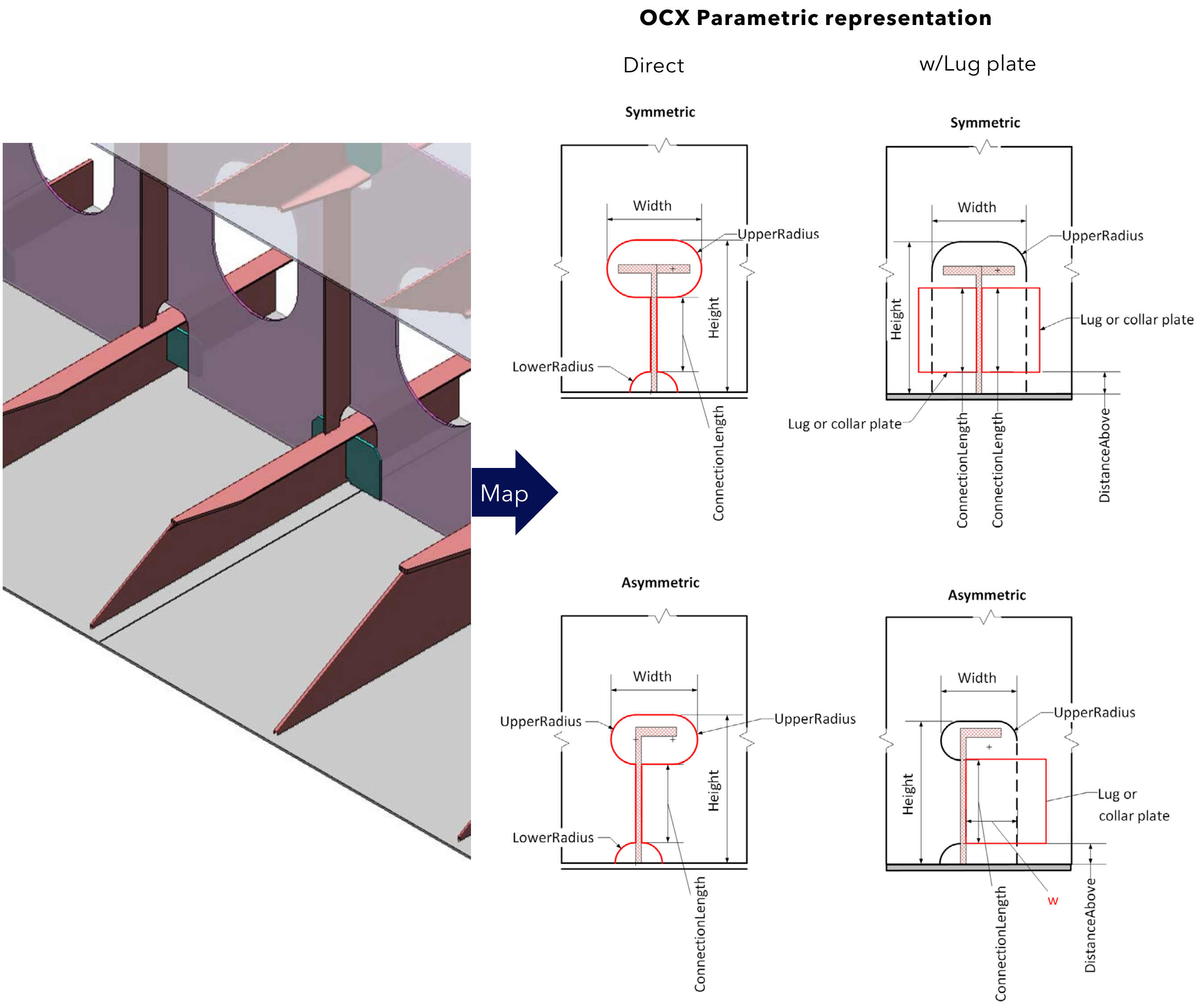
Shipyards and classification societies should therefore modify the traditional design documentation and review process and enable a direct 3D digital classification process to improve the exchange of information between the different stakeholders and ultimately accelerate the classification process.

To date, plan approvals for new-build projects have been based on conventional 2D drawings.

An obvious next step is to extract the information needed for design approvals directly from the CAD 3D models and perform the entire review process digitally instead of manually.

FIGURE 5

Mapping of a shipbuilding penetration to OCX parameters



Why is the OCX format unique?

The OCX standard incorporates the 3D model topology, a ship-specific taxonomy and the spatial and logical structure of compartments and tanks and has the necessary capabilities to transfer a full basic design model of the hull superseding previously available standards.

The OCX adds the missing pieces
Existing solutions and standards, such as STEP, for exchanging product information, are limited to the process of geometrical data, where semantics assigned to the product model are completely lost during the translation process (Abdul-Ghafour et al., 2014; Gusani, Radonic and Puurula, 2023). Moreover, STEP does not provide a sound basis to reason with knowledge where the OCX standard adds the missing pieces to achieve a seamless digital transfer of design information between designers/yards and the classification societies.

The typical use case for the exchange between the designer/shipyard and the classification society is illustrated in Diagram x.

FIGURE 6

The OCX exchange scenario

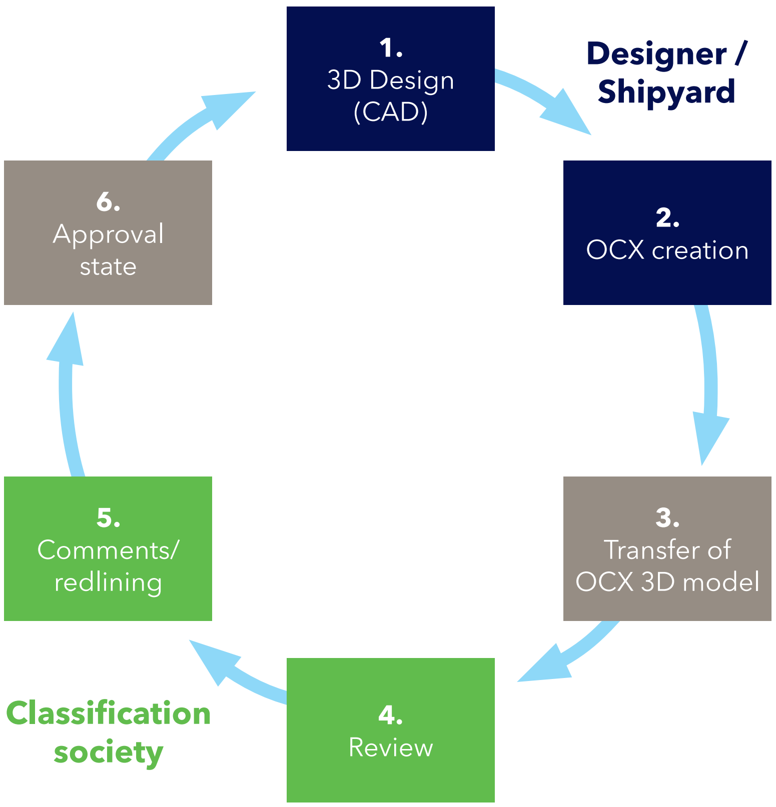
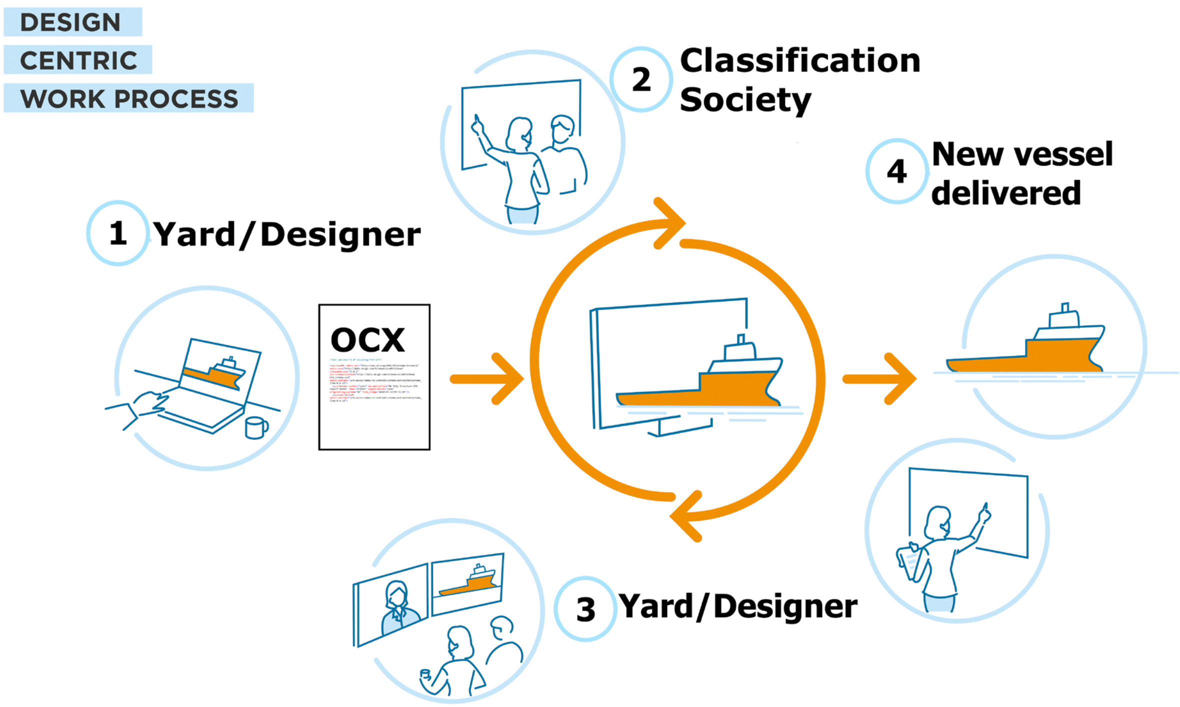


FIGURE 7

A digital information flow between the yard/designer and the classification society



A digital thread

Sharing a common OCX model enables a fully digital design-centric and iterative work process (the numbers refer to the steps displayed in Figure 7) between the designer/yard and the classification society illustrated by the following steps:

1: The Yard/Designer uploads the 3D OCX model to the classification society.

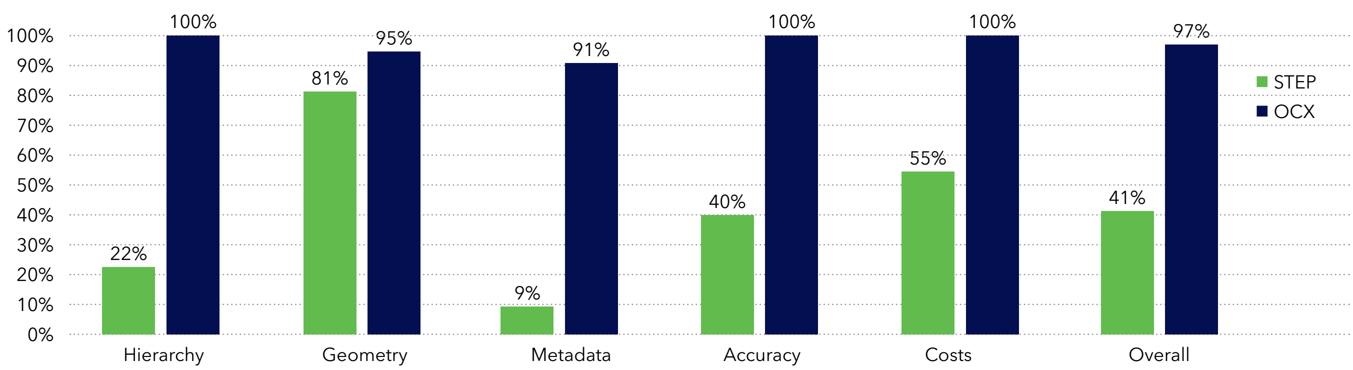
2: The classification society reviews the 3D model, performs rule calculations and provides comments and red marking directly on the design model giving immediate feedback to the designer.

3: The Yard/Designer makes the required design changes and engages in a model-centric dialogue with the classification society. A new design revision is uploaded documenting the changes.

4: At the end of the process, a new vessel is delivered with a shorter time to market, and improved traceability and quality.

FIGURE 8

OCX capabilities compared to STEP AP3142, reproduced from (Gusani 2023)



Unique features

Bitomsky (Bitomsky, Danetzky and Zerbst, 2022) states that they are confident that the OCX format is technically able to transfer vessel information needed on an initial design level. Their qualitative analysis demonstrates that the OCX covers 95% of the PROSTEP Ship XML attributes and adds the following unique features not found in other standards:

- Model topology
- A ship-specific taxonomy
- Spatial arrangement (compartments and tanks)

As the OCX contains the 3D model topology, namely the part interrelationships, this will allow the receiving party of the 3D OCX model to rebuild the full 3D model coming from the authoring system in their native CAD or CAE system. This capability is verified by Gusani (Gusani, Radonic and Puurula, 2023) from Meyer Turku in a thorough analysis of the capabilities of the OCX standard. Gusani investigated the transfer by OCX of a model designed in NAPA either as the basis for detailed design in Catia V6 or as the basis for calculations in FEMAP.

Gusani's analysis demonstrated that the OCX standard outperformed the generic STEP AP214 standard in most aspects as shown in Figure 8. Gusani's analysis demonstrates that the OCX format can transfer 97% of the design information from NAPA Designer to Catia V6. Not only are all features and geometry consistently transferred but the topology is also preserved, allowing the continuation of the detailing in Catia V6. When moving the deck, the stiffeners and bulkheads follow. The profiles can be moved on the plate and the endcuts can be added. It is also possible to move the bulkheads, which also contain the structure type transferred.

Gusani concludes that the OCX standard has shown great potential both in theory and practice. It already contains working implementations to transfer structural models to a sufficient extent for many practical use cases, such as scantling calculations, FE-analysis, plan approval and detail design (Son et al., 2022).

"Our teams see OCX as capable of managing all structural transfer needs for our whole basic design phase."

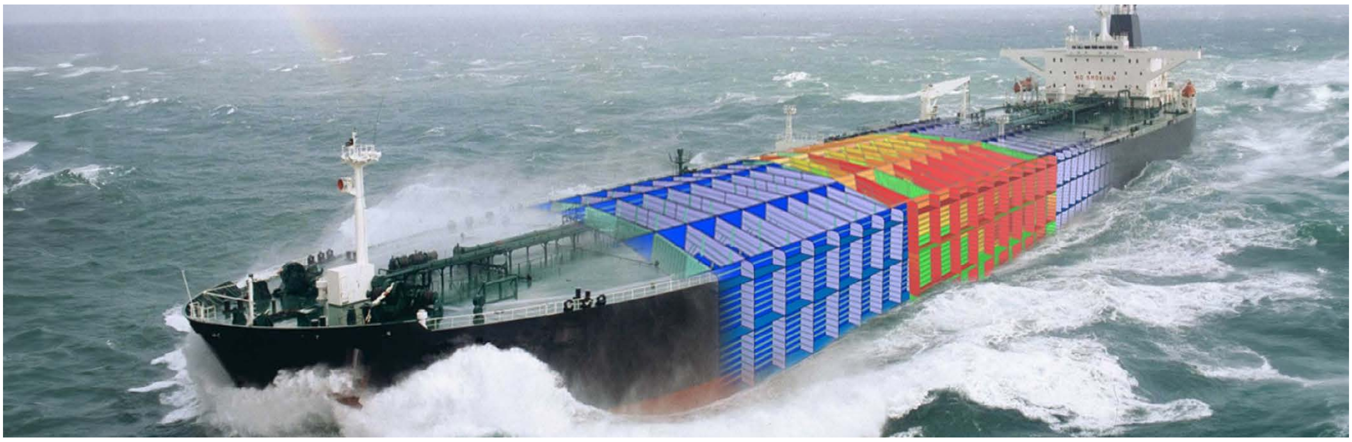
Sami Gusani,
Development Engineer - Shipbuilding Design
Meyer Turku

Gusani further concludes that the OCX standard offers a comprehensive set of objects that are necessary for transferring a typical basic design model. In addition to bare geometric representation, geometric definitions with related topology, hierarchy and structural metadata are included. Based on the evaluation conducted, it is evident that OCX can transfer structural information in the basic design context. Additionally, OCX can transfer a significant amount of structural information that is necessary for creating an initial detailed design model. However, certain structural details like notches and material sides are yet to be fully integrated into the OCX-schema. And for curved panels, it would be necessary to have information on the opening protrusion direction.

Model-based approval advantages

Compared to traditional drawing-based approval, the advantages of exchanging an OCX model give:

- **reducing shipyard workload** with fewer drawings to create,
- **improving quality** and a common understanding of design and class comments by directly using the 3D design representation,
- **optimizing the calculation process** by interfacing the 3D design model with all calculation software such as structural and stability software,
- **improved transparency and support** for automation and increased self-service.



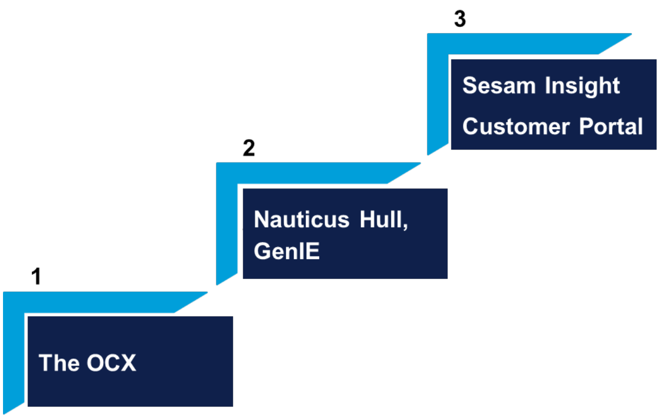
Model-based approval with DNV

DNV promotes the exchange of 3D OCX models with all customers who are using an OCX-enabled 3D design tool that enables the export of OCX file format. Customers who are using such design tools can choose in agreement with DNV to submit a 3D OCX model as design documentation replacing traditional 2D structural drawings.

An efficient model-based approval platform
DNV has built an efficient model-based approval platform utilizing the capabilities of the new OCX standard. The platform consists of three building blocks as illustrated in Figure 9:

FIGURE 9

DNV model-based approval platform



1. OCX as the standard exchange format
2. Reuse of the OCX for calculations in Nauticus Hull and GeniE
3. 3D model mark-up, comments and customer interaction based on Sesam Insight integrated in the Maritime customer portal.

Based on these capabilities, DNV can offer our customers three ways to interact with DNV for the hull model-based approval using the OCX format:

A. Efficient Rule Check
B. Early Design Review/Pre-contract
C. Model based approval process

A prerequisite for a designer/yard to engage with DNV and the model-based approval platform is the possibility to deliver a 3D design model on the OCX format in the basic design stage. At the current time of writing, the following CAD vendors have released an SW version supporting OCX export:

- NAPA designer
- Cadmatic Hull
- Hexagon S3D
- Siemens NX
- AVEVA E3D

Dassault Systémes is currently working to OCX enable Catia V6.

Efficient Rule Check
Use case
Traditional 2D design approval process where all design documentation is submitted and approved using 2D pdf. Provided a 3D design model exists it is possible to utilize the OCX file with the following benefits:

Benefit for the designer/yard
- Saving time to set up Nauticus Hull workspace and run prescriptive Rule check by using the OCX file exported from your 3D model to import structure and design parameters directly into Nauticus Hull.
- Reduce risk of error when transferring design information into Nauticus Hull.
- Efficient design iterations and optimization process confirming Rule compliant designs.

Benefit for DNV
- Saving time to set up Nauticus Hull workspace using the OCX file.
- Reduce risk of error when transferring 2D design information into Nauticus Hull.

Early Design Review

Use case

Early design development phase including pre-contract phase where it is time for designer to interact with DNV to confirm Rule compliant design solutions.

Provided a 3D design model exists it is possible to utilize the OCX file with the following benefits:

Benefit for the designer/yard

- All benefits from "A: Efficient Rule Check".
- Enable a more efficient communication with class as no time is needed to prepare 2D documentation for presenting the design.
- Receive quick feedback from class.

Benefit for DNV

- All benefits from "A: Efficient Rule Check".
- Enable efficient communication with designer as class can see, interact and review the design in the same format as designer.
- Ability to provide quick feedback to designer being an "integral" part of the design process (In-process approval).

Model-based approval

Use case:

The 3D design model is used to export an OCX file which is submitted to class for a partial or full design approval process of the hull structure.

Benefit for the designer/yard

- All benefits of "A – Efficient Rule Check" and "B – Early Design Review".
- Preparation of 2D class drawings based on the 3D design model is not needed to complete the hull structure class approval.
- Allowing designer and class to engage in a fully digital approval process.

Benefit for DNV

- All benefits of "A – Efficient Rule Check" and "B – Early Design Review".
- Approval of 2D class drawings are no longer required for hull structures.
- Allowing designer and class to engage in a fully digital approval process.

Working with customers to explore benefits

One way for customers to explore the benefits of model-based approval is to engage in a joint development project (JDP) with DNV. This is a low-risk and low-cost commitment which can demonstrate to customers the benefits of new technologies and new ways of working. For DNV, JDPs contribute valuable knowledge and help to improve both tools and processes.

JDP on 3D rudder approval with MARIC, China

In 2023, DNV and MARIC agreed to carry out a JDP with the objective of extending the OCX definition to cover 3D approval of rudders. The rudder is a complex component of the ship, requiring special manufacturing processes and specific rule requirements. Together, DNV and MARIC developed the OCX schema capabilities for defining the OCX 3D model of a semi-spade rudder. The parties successfully completed a pilot demonstrating the 3D model exchange and verified that the 3D model could carry the relevant information, fulfilling the DNV rule requirements. Based on the success of this pilot, MARIC and DNV have decided to extend the JDP to also pilot the 3D approval of the hull.

FIGURE 10

MARIC 3D rudder model displayed in Sesam Insight

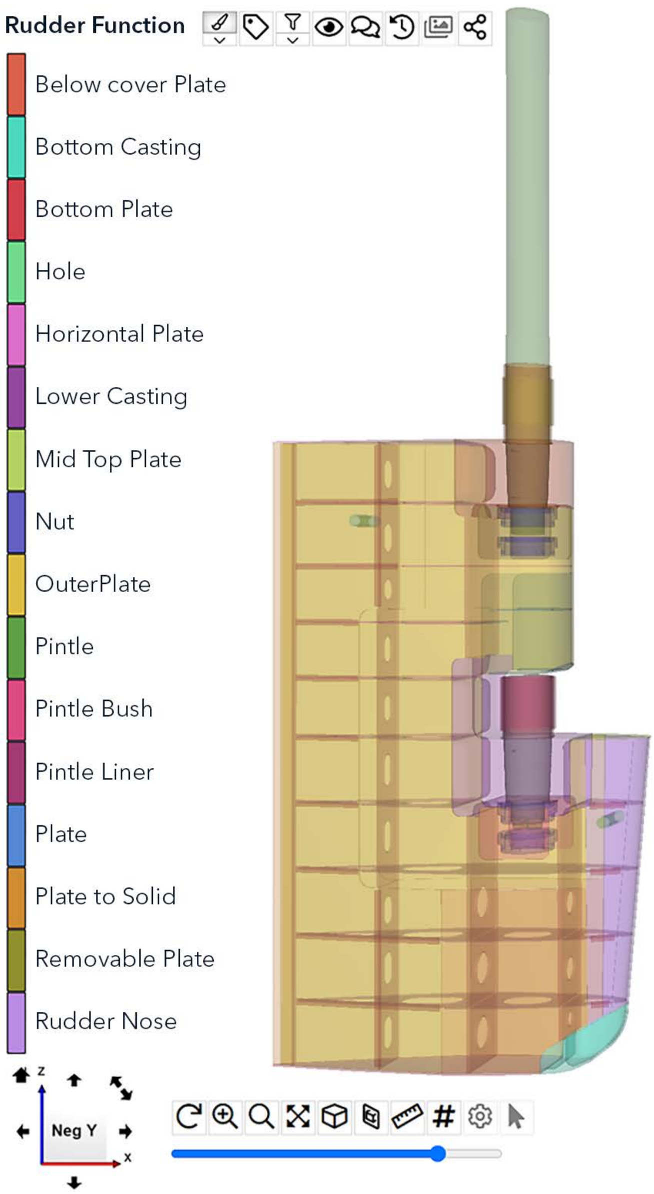
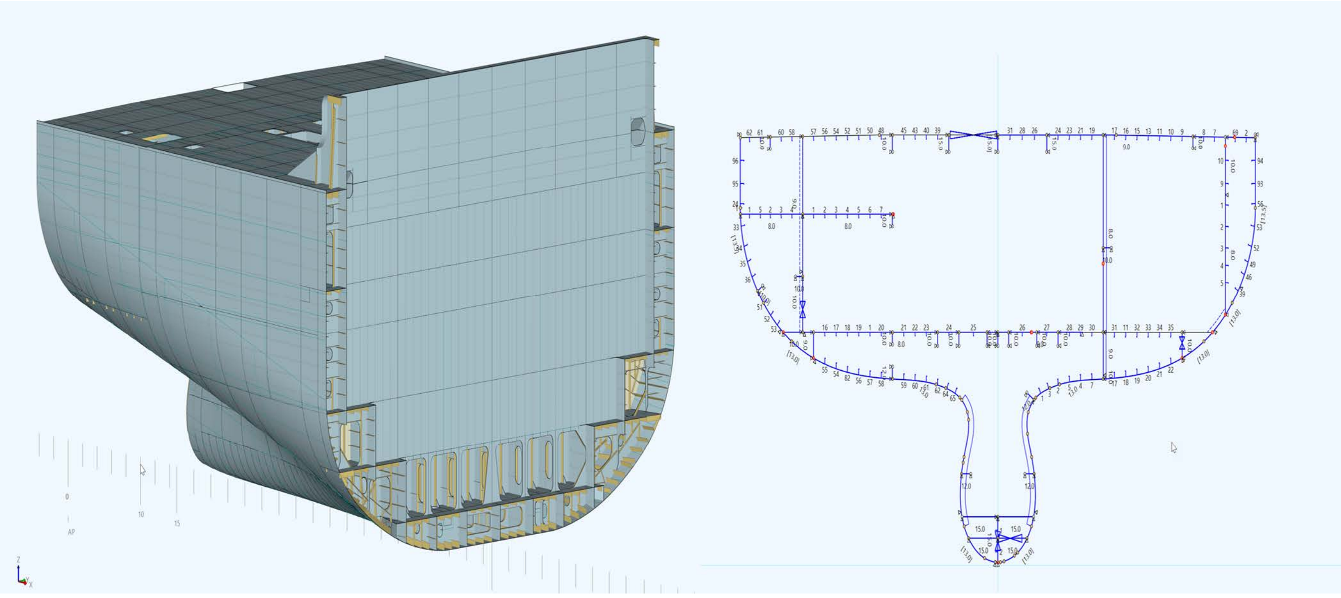


FIGURE 11

The SDARI 1800 TEU 3D engine room model in Nauticus Hull



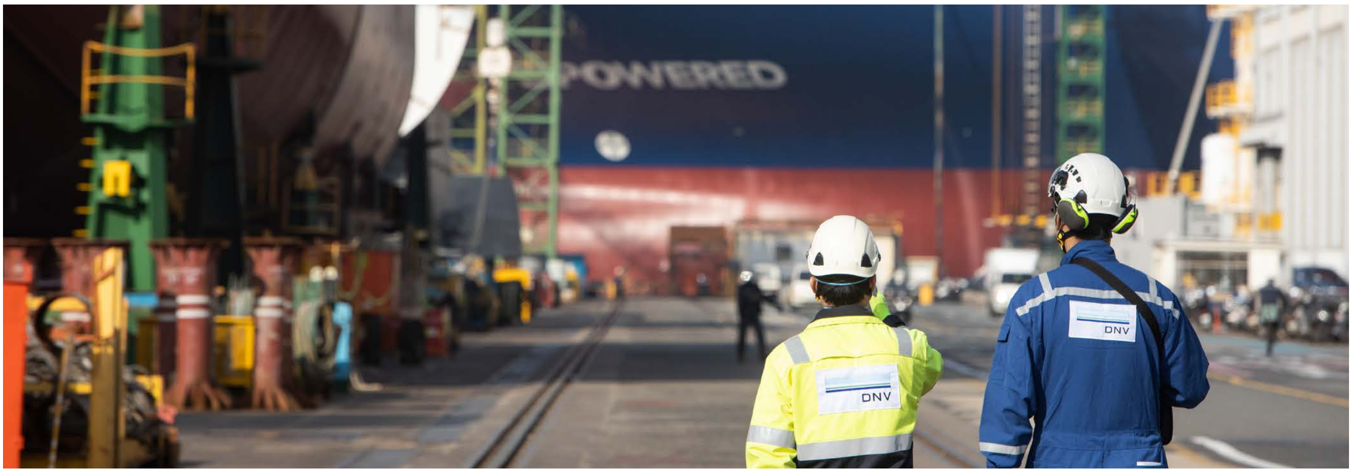
JDP on the 3D approval of a 1800 TEU container vessel with SDARI, China

In 2022, DNV and SDARI agreed to engage in a JDP with the objective of exploring the model-based approval of a 1800 TEU container vessel design by SDARI. The JDP was successfully completed in June 2023, demonstrating the 3D model exchange of the cargo area, fore and aft parts of the vessel. The scope of work included testing both calculations in Nauticus Hull and comment feedback in Sesam Insight. The JDP provided valuable experience to both SDARI and DNV and contributed to the improvement of DNV's 3D approval tools and services. The successful conclusion of the pilot led to a full 3D approval project for an Aframax oil tanker designed to DNV class. The 3D plan approval is planned to be completed by the end of 2023.

Site survey

When DNV has carried out a model-based approval of the hull in a project, there will not be any approved class drawings available on-site for construction surveys. DNV is developing a dedicated tool to be used during a block survey to equip the site surveyors with a toolset to follow the newbuild during the construction stage. The tool will have the following capabilities:

- **Enable the drawing-less block survey** using the approved 3D model from the designer/yard using a tailor-made 3D PDF document.
- **Support for offline 3D model** on a portable device.
- **Full 3D model** with additional supporting documentation (supporting documents such as additional 2D drawings, welding table etc.) bundled in one package.
- **Comments and 3D redmarks** from plan approval with 3D location (searchable by attributes).
- **Additional 3D focus areas** where relevant.



Extending the OCX Schema to new domains

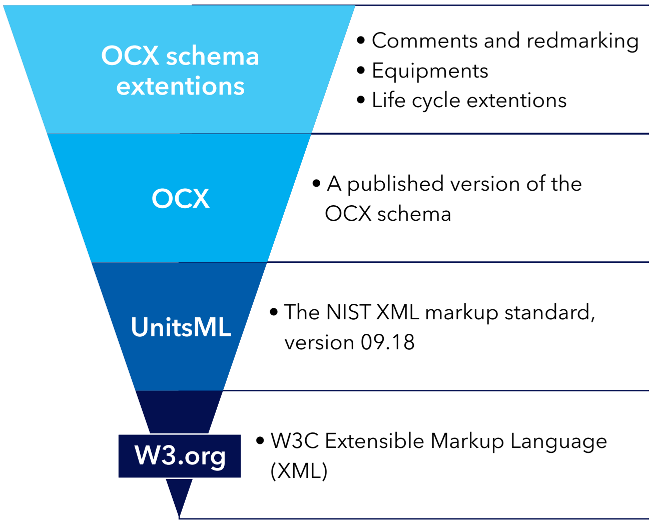
Extending the OCX schema to support other disciplines and include new information items is straightforward due to the modular design of the schema.

Easily extensible

Any OCX schema extension may be defined on top of the OCX schema by using the W3C XML xs:import construct. This allows for an easy way of adding any extension to the existing OCX schema as illustrated in Figure 12.

FIGURE 12

DNV model-based approval platform



DNV, Kongsberg Maritime and AVEVA has demonstrated how to extend the OCX schema to support the approval of opening and closing appliances regulated by the International Convention for Load Line, ICLL (Astrup et al., 2023).

Applied to load-line verification

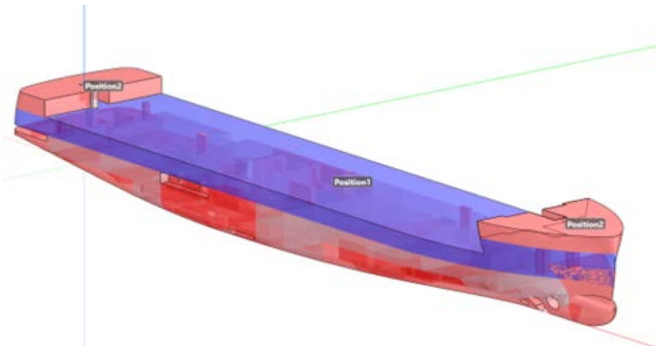
Moving from typical 2D drawings in Basic design, to a 3D model-centric design and engineering process, also in the early phases, enables the designers to work more closely across multiple disciplines and design the vessel with all its features in one common environment/model. It also allows the designers in the early phase to convey the design intentions /class requirements in the Basic Design model, making it easier for the engineers to follow those intentions in the later detail phase.

In an early phase, it may be critical for the designers to clarify in which areas of the vessel certain types of fittings are allowed/not allowed. This may be more relevant for prototypes, or vessels where the definition of the zones/areas is not clear based on definitions in ICLL or class/flag rules. Defining 3D spaces or 2D boundaries in the 3D model as illustrated in Figure 13 that can be verified by the classification society in an early phase, would help the designers to follow those requirements when detailing the model and laying out the components.

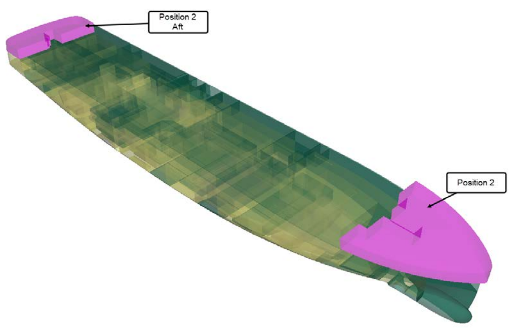
Utilising the OCX schema extension for load-line it was demonstrated that 3D ship modelling and model-based functional zone definitions can speed up the ship design process by enabling designers to identify and resolve regulatory requirements early on in the design phase, improving the design quality and reducing the likelihood of costly modifications during the construction phase.

FIGURE 13

ICLL Position 1 and 2 functional zones defined in the 3D model



Functional zones defined in the CAD system. ©AVEVA



The functional zones in Sesam Insight

The model-based approval process for loadline requirements outlined by Astrup (Astrup et al., 2023) demonstrates well that accompanying functional zones with specific design intents will enhance the approval process. Also, it will cut the time needed to prepare drawings where the model will contain all necessary information providing a "snapshot" of the status to the classification society. An additional benefit of working this way will enable the design to be more accurate and unintentional mistakes to be prevented on time via design intent checks of the models before any submission to class.

The full potential of a model-based loadline approval lies in the possibility to automate the verification of both the position and attributes of all opening and closing appliances. Figure 12 shows a mock-up of an automated loadline verification. Here, the received 3D model is used to create plan views with identification of the functional zones and the position of the opening and closing appliances shown with symbol marks. All attributes are available in tables and the result of the automated rule checks are displayed. Automation like this will to a large extent replace the time-consuming manual verification tasks today carried out by the approval experts. In the future, such automated services may also be available to the designer/yards and can be implemented directly in the design tools.

Applicable to many use cases

The loadline approval is just one example of the application of functional zones for model-based approval. There are several zonal ship design functions which will benefit from a model-based definition, such as:

- Gas outlet zones (hazard zones)
- Damage waterline boundaries
- Fire zones
- Escape routes

The proposed schema can easily be extended to cover all functional zones relevant to ship design and regulatory requirements.

It is also straightforward to extend the schema to include components like rudder, large shell-doors and ramps which also require approval by the classification society.

FIGURE 14

Mockup of future automatic load-line verification and reporting

Airpipes | Doors | Windows

	Id	Type	Mounting	Coaming height	Size	Closing appliance	Coaming thickness	Automatic	Brackets	Ok/Not ok
○	A1	Venthead	Deck	450	200	PV valve	8.5	Yes	No	Not Ok
○	A2	Gooseneck	Deck	2300	200	None	12	No	Yes	Ok
○	A3	Venthead	Ship side	450	200	Ball float	6	Yes	No	Not Ok

References

3docx.org (2021) OCX Consortium. Available at: https://3docx.org/ (Accessed: 1 February 2022).

Abdul-Ghafour, S. et al. (2014) 'Semantic interoperability of knowledge in feature-based CAD models', CAD Computer Aided Design, 56, pp. 45–57. Available at: https://doi.org/10.1016/j.cad.2014.06.001.

AIA (2013) Aerospace Industry Guidelines for Implementing Interoperability Standards for Engineering Data.

Arlington: Aerospace Industries Association.

Astrup, O. (2017) A Model Based Definition for Shipbuilding. 2017–0413, Rev 2. DNV, p. 66.

Astrup, O. et al. (2022) 'Moving towards model-based approval – the open class 3D exchange (OCX) standard', International Journal of Maritime Engineering, Part A. Available at: https://doi.org/10.5750/ijme.v164iA2.

Astrup, O. and Cabos, C. (2017) 'A model based approval process for basic hull design', in International Conference on Computer Applications in Shipbuilding, ICCAS 2017. Singapore: RINA, Royal Institution of Naval Architects, pp. 107–116.

Astrup, O.C. (2019) OCX-Open Class 3D Exchange. A digital specification of the hull structure for the Classification of Ships. Oslo, Norway: DNV, pp. 1–284.

Astrup, O.C. et al. (2023) 'Enhancing the 3D Approval Process using Functional Zones in Ship Design', in 22nd Conference on Computer and IT Applications in the Maritime Industries. COMPIT'23, Drübeck, Germany: Technische Universität Hamburg-Harburg.

Bitomsky, J., Danetzky, A. and Zerbst, C. (2022) 'OCX Revisited: The New Data Exchange Standard?', in COMPIT'22. 21st Conference on Computer and IT Applications in The Maritime Industries, Pontignano, Italy: Technische Universität Hamburg-Harburg, pp. 429–436.

Damen (2023) Damen, NAPA and Bureau Veritas successfully deploy 3D Classification approvals for first ship design, Marine & Offshore. Available at: https://marine-offshore.bureauveritas.com/newsroom/damen-napa-and-bureau-veritas-successfully-deploy-3d-classification-approvals-first-ship (Accessed: 6 April 2023).

Deltamarin (2022) Deltamarin receives 3D model-based DNV approval | Deltamarin, Deltamarin Ltd. Available at: https://deltamarin.com/2022/11/deltamarin-receives-3d-model-based-dnv-approval/ (Accessed: 6 April 2023).

DNV (2021) 'RULES FOR CLASSIFICATION Ships Part 3', in Rules For Classification Ships. DNV, pp. 1–29.

Garland, N. et al. (2019) 'Model based definition: Finally, the engineering drawing killer?', in Proceedings of the 21st International Conference on Engineering and Product Design Education: Towards a New Innovation Landscape, E and PDE 2019. Institution of Engineering Designers, The Design Society. Available at: https://doi.org/10.35199/epde2019.69.

Gusani, S., Radonic, M. and Puurula, J. (2023) 'OCX Standard and Structural Model Reuse in the Shipbuilding Design', in 22nd Conference on Computer and IT Applications in the Maritime Industries. COMPIT'23, Drübeck, Germany: Hamburg University of Technology, pp. 391–406.

Haenisch, J. and Langbecker, U. (1999) 'Exchange of Structural Design Data for Hull Cross Section Approval, EMSA Protocol', p. 53.

Halfhide, R. (2019) APPROVED redraws requirements for class verification, The Naval Architect, RINA. London. Available at: https://www.rina.org.uk/APPROVED_redraws_requirements_for_class_verification.html (Accessed: 16 January 2022).

IACS (2011) CLASSIFICATION SOCIETIES - their key role.
ISO-AP215 (2004) ISO 10303– Part 215: Application protocol: Ship arrangement. International Organization for Standardization.

ISO-AP216 (2003) ISO 10303– Part 216: Application protocol: Ship moulded forms. International Organization for Standardization.

ISO-AP218 (2004) ISO 10303– Part 218: Application protocol: Ship structures. International Organization for Standardization.

Moser, U. and Astrup, O. (2018) 'Approaching Design Review by Classification Society based on Digital Information Derived from the Customer's Design Models', in COMPIT'18. 17th Conference on Computer and IT Applications in the Maritime Industries, Pavone, Italy: TUHH, pp. 116–131.

Pérez-Martinez, J. and Pérez Fernández, R. (2021) 'Shipbuilding 3D CAD Tools as an Integrated Solution from Concept to Product', Ship Science & Technology, 15(29), pp. 45–57. Available at: https://doi.org/10.25043/19098642.220.

Polini, M.A. (2011) 'A Neutral XML Schema for Basic Design Stage Interface to Class Societies', in ICCAS 2011: International Conference on Computer Applications in Shipbuilding. Trieste: RINA, pp. 93–104. Available at: https://doi.org/10.3940/rina.iccas.2011.32.

Quintana, V. et al. (2010) 'Will Model-based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry', Computers in Industry, 61(5), pp. 497–508. Available at: https://doi.org/10.1016/j.compind.2010.01.005.

Rachuri, S. et al. (2008) 'Information sharing and exchange in the context of product lifecycle management : Role of standards', Computer-Aided Design, 40, pp. 789–800. Available at: https://doi.org/10.1016/j.cad.2007.06.012.

Schjølberg, I. (2016) Maritim21. En Helhetlig Maritim Strategi I. Lysaker: Norges Forskningsråd.

Seppälä, L. (2021) '3D Model – Technology Island in Ship Design or a Central Piece for Shipbuilding Project Data?', in COMPIT'21. 20th Conference on Computer and IT Applications in the Maritime Industries, Mülheim, GERMANY: Hamburg, Hamburg University of Technology.

Seppälä, L. (2022a) Information management in shipbuilding projects – Information flow from 3D design to production data. Cadmatic.

Seppälä, L. (2022b) White Paper - The Digital Fabric of Data-Driven Shipbuilding – 3D CAD data exchange in shipbuilding projects. Cadmatic, p. 18.

Son, M.-J. et al. (2022) 'Utilization of OCX as Part of 3D Model Based Approval in Ship Design Process', in 21st Conference on Computer and IT Applications in The Maritime Industries. COMPIT'21, Pontignano, Italy: Technische Universität Hamburg-Harbur.

UNIDO (2021) Standards & Digital Transformation Good Governance In A Digital Age. Vienna, Astria: United Nations Industrial Development Organization (UNIDO). Available at: www.unido.org.