

THE FUTURE REALITY OF THE DIGITAL TWIN AS A CROSS-ENTERPRISE MARINE ASSET

D Morais and **G Goulanian**, SSI, Canada

N Danese, NDAR, France

SUMMARY

This paper aims to define the Digital Twin in a general context, explore the current role of the Digital Twin within shipbuilding, and demonstrate the benefits of and path towards an integrated, cross-enterprise Digital Twin. Shipbuilding, as an industry with unique challenges and structures, requires a shipbuilding specific approach to technology implementation, integration, and utilization. This factor has been considered within this paper and is one of the main drivers behind the developments SSI has made to further the integration of platforms and improve the information available within a shipbuilder.

1. INTRODUCTION

In recent years, across our industry, the Digital Twin has become a buzz word or concept. Complete with claims of a solution for all of shipbuilding's problems. In reality, the promised organizational benefits of a Digital Twin for shipbuilders are only just emerging. Part of this comes down to the fact that our industry is in the business of shipbuilding, not technology. As more shipbuilders become technologically savvy, ship owners continue to demand more information, and the benefits of a complete, cross-enterprise Digital Twin come to light, the shift will rapidly emerge.

1.1 DEFINITION OF A DIGITAL TWIN

At its core, a Digital Twin is just the digital representation of a physical object [1]. Right now, we're increasingly seeing 'as-built' Digital Twins delivered with newly built vessels. These models contain engineering data and attributes pulled from the CAD tool in use but fail to tie in all of the data that is already being captured throughout the shipbuilding process and beyond. Fully incorporating that data into a Digital Twin that is organization wide will require taking small steps to reach that goal.

This paper aims to outline what the current reality is, how and why shipbuilders need to pursue the implementation of a cross-organizational Digital Twin, and some practical examples of the steps being made.

2. CURRENT DIGITAL TWIN REALITY

Considering the Digital Twin as a complete digital representation of a physical asset (a ship), we see that in reality, only some sub-assets are represented in the Digital Twins currently in use. With hundreds of thousands of sub-assets (engines, steel, valves, pumps, propulsion, scrubbers, etc.) in a modern ship, representing their inherent properties and how they interact with the rest of the vessel, within a single Digital Twin, is a huge undertaking.

Currently, industry observation indicates that portions of an overall organizational Digital Twin are in place. Digital

Twin solutions are in place for specific sub-assets but are not effectively being utilized for the entire ship as a whole, complete with all the information necessary to feed the rest of the organization.

Typically, when the Digital Twin is restricted to a simple engineering or operational asset, the benefits are similarly restricted. Despite the fact that increased digitization is supposed to reduce silos within our organizations, the narrow usage of a Digital Twin is an ineffective way to tackle that challenge.

Work from one team cannot be leveraged by other teams and similar problems must be solved several times and differently when information silos are present within a shipbuilder. It's clear that minimizing this factor can lead to significant process improvements.

3. WHY SHIPBUILDING IS DIFFERENT

3.1 THE COMPLEXITY OF SHIPBUILDING

Shipbuilders realize that they are experts in building ships, not implementing software or integrating technologies. It's understood across the industry that IT expertise is necessary to remain competitive going forward. Despite this, the scale of the challenge and complexity of implementing software within shipbuilding is often misjudged [1].

One of the inherent factors influencing this complexity is the sheer number of parts involved with building a ship (significantly more than in airplane or vehicle manufacturing), another factor are the silos of information that are present within a shipyard. Connecting and integrating these silos while capturing all of the associated information within a single Digital Twin is exponentially more complex within shipbuilding because of the sheer number of connections required. This number of connections arises because, unlike in other industries, shipbuilders design, engineer, construct, and procure their projects at the same time.

Looking at the data reality of a completed ship, the complexity requirements do not decrease. This is despite the

fact that standards are beginning to emerge [2]. As onboard systems are replaced throughout the life of a vessel, changes to compatibility or the addition of new technologies add to the complexity of the systems on board [2]. Being able to include the data and information captured from these sources, no matter whether they are legacy or future systems, allows a Digital Twin to remain relevant throughout a vessel's operational life.

The scale inherent to shipbuilding increases the complexity of the organizations involved. Operations, environments, and stakeholders are characterized by complexity and multitude [3]. Managing this reality requires shipbuilding specific solutions.

3.2 STRUCTURAL REALITIES

Ship owners have historically been the party determining payment structure within our industry. That structure is one of the reasons why the implementation of digital technologies within shipbuilding has lagged behind other industries. Unlike other large-scale manufacturing industries, such as aerospace or automotive, shipbuilding is cost-driven [4]. Payment from owners is tied to milestones surrounding the physical construction of a ship [1]. Historically, this has left little room for the implementation of new technologies, as shipbuilders race to achieve the next milestone. Despite understanding that a new technology will help a shipbuilder speed up a significant part of their workflow going forward, risking the next milestone on the current project being built is not acceptable. As a result, traditionally, the latest technologies available to shipbuilders remain on the sidelines until they have been proven.

Going forward, as outlined in section 5.3, ship owners will be one of the main benefactors of a cross-enterprise Digital Twin, and they are starting to realize it. This is causing those ordering ships to request a complete Digital Twin alongside the delivered vessel. As noted in [1], "Bourbon is so serious about Digital Twins that it is selling off 41 old "non-smart" ships that do not have IoT Sensors." This appetite for more digital data is closing the return on investment (ROI) gap for shipbuilders and minimizing the risk of implementing new technologies.

4. THE ORGANIZATIONAL DIGITAL TWIN PROBLEM

The convergence of two vectors, with very different requirements, has driven a wedge between the traditional requirements of a Digital Twin and what is required going forward. From the shipbuilding and new construction perspective, the traditional need to utilize and visualize 3D CAD data and use the Digital Twin to improve engineering, design, and manufacturing persists. However, the increasing need for owners (operators) to access up-to-date data analytics, as they relate to specific aspects of an in-operation ship has altered the expectation of a delivered Digital Twin.

Combining these two disparate requirements within a single informational vehicle allows the Digital Twin to service enterprise goals across the entire spectrum of a ship's lifecycle. However, shipbuilders and other players within our industry will have to overcome key organizational hurdles to achieve that vision.

4.1 CULTURAL CHALLENGES

At the end of the day, no matter what the incentives and benefits of a cross-enterprise Digital Twin is, it will be up to each individual organization to start the process of making it a reality. Currently, the culture among many shipyards is hindering progress towards this Digital Twin vision, rather than helping it.

Creating a culture that is focused on achieving that vision will require a business and cultural transformation within the organization. The changes that come out of this transformation will be organization-wide and not directed at a specific department. It's important to look at the problem holistically, and at a high level, as the new Digital Twin world will result in processes that are different from those in the past.

A successful *digital* transformation, more narrowly the implementation of the underlying technologies required by a cross-organizational Digital Twin, requires a *business* transformation to really take advantage of the latest technology. To illustrate this point, consider how one might go about digitizing a map. You could take a picture of a fold-out paper map and convert it into a pdf. It would now be digital, and there would be some benefits, but it would be nothing compared to using a GPS system that gives you turn by turn directions as you drive [5].

With a unified goal to create, expand and leverage a company's Digital Twin, there is a united push throughout the organization to build on the Digital Twin. As a result, before undertaking a new initiative, every conversation will start with:

How can we leverage what is in the Digital Twin already or add to it to achieve our goals?

It is a huge undertaking to incorporate the hundreds of thousands of assets (and the data and relationships associated with each one) into a single unified representation. One of the key business decisions that will allow that to happen is an understanding of the small steps needed to make this a reality.

5. BENEFITS OF CROSS-ENTERPRISE DIGITAL TWIN

For the overall organization, the cross-enterprise Digital Twin removes silos of information, allows for more effective re-use and discovery of information, promotes global

collaboration, and drives the implementation of new technologies. The benefits of a cross-enterprise Digital Twin touch every part of a shipbuilding organization throughout each stage of a vessel's lifecycle, allowing for better, more informed, decisions to be made in the design, build, and maintain stages.

5.1 DESIGN

Almost every aspect of initial, basic, and detail design can be captured within a comprehensive Digital Twin. Capturing requirements, hull designs, supplier information, workflows, standards, simulations, etc. and threading that information throughout the project and across departments allows for more informed design decisions to be made.

Apart from the obvious consideration that vessel design is moving towards taking place entirely in a 3D digital space, making it easier to construct a Digital Twin from design information than ever before, with a completely integrated Digital Twin that spans the entire lifecycle of a ship, it becomes possible to rapidly improve on previous designs.

In general, the requirements of every newly constructed vessel will capture several improvements over previous vessels [6]. For example:

- Improved performance.
- Lower lifetime costs.
- Reduced expected downtime.
- Compliance with the latest regulatory requirements.
- Reduced construction costs.
- Improved role-specific capabilities.

A Digital Twin that has been continuously updated, managed, and utilized throughout the lifecycle of a ship becomes the ideal starting point for future improvements. Because each aspect of a previous ship's design that is being considered in that moment has relevant information and data points that can be pulled from, the existing design is able to feed the improvements of the next.

5.2 BUILD

The production floor will be reaping the benefits of the cross-enterprise Digital Twin. When fully implemented, there will be zero need for 2D paper documents. It's impossible to say with confidence whether paper documents will be completely removed from a shipbuilder's workflow. However, it is extremely likely that a digital representation of the ship will be used on every production floor once implemented. With automated machines on the shop floor directly leveraging the information found in a Digital Twin, keeping that information up-to-date and one hundred percent accurate will be necessary as it feeds sources downstream. This additional benefit will encourage shipyards to invest more in maintaining an accurate Digital

Twin model and push towards further adoption throughout the organization.

The key to ensuring a Digital Twin is relevant to the build stage lies in the data being leveraged. By threading in information from previously disparate sources, like global supply chains, machinery data, and part and project status, as well as essential engineering information, a Digital Twin can become a cohesive hub for everything related to the construction of a ship [7].

5.3 MAINTAIN

Perhaps the biggest benefactor of a cross-enterprise Digital Twin are shipowners. As shipowners and operators continue to focus on operational excellence, the drive to obtain a better understanding of their ships, both the vessels already in-service and the ones not yet built, continues to increase.

As ship service lives continue to increase, the need to perform mid-life retrofits will continue to increase. The current status quo workflow is hugely inefficient: for example, using laser scanning to obtain the 'as-is' structure and condition of a vessel, using the laser scanning data to help remodel the area to be retrofitted, manually pulling information to get material data, and then managing supplier information for the assets/material that was purchased. While all of this can be done digitally, it remains disparate, with nothing linking all of that information together. In this situation, there would be five different silos of new digital information that remains disconnected.

It is not fully understood if shipowners are aware of the effective gains that could be achieved when that new digital data (generated as a result of Maintenance, Repair, and Operation (MRO) activities) was fully integrated into a unified picture of the vessel [8]. Within Defense, it's clear that the need to understand the underlying connections between and within knowledge assets (such as a Digital Twin) is becoming top of mind [9].

The existing belief is that, for a shipowner, a future significant use case will only be achieved when a critical mass of ship sensor information, (such as that required for increased levels of ship automation and remote vessel operation) is achieved. At that point, we will certainly see ownership and maintenance of a Digital Twin data set as being a future mandatory requirement to obtain class approval permission for remote vessel operation (even with human on board supervision) [8]. However, even as things stand now, implementing small, incremental steps towards achieving a unified representation of a ship being operated can have huge implications towards the bottom line.

However, despite the fact that many shipbuilders still provide disparate pdfs as deliverables alongside the ship, some are looking towards new ways of adding value. For

example, Ulstein saw that ship operators were expecting an increased amount of data to go alongside their ship. By creating the ULSTEIN IAS® control system to provide a seamless integration between control systems, power management systems and energy management systems, they were able to use the Digital Twin data they already had to deliver additional value [10]. Companies who can continue to provide such value will thrive as operators and navies demand access to an increasing amount of data.

6. ACHIEVING THE CROSS-ENTERPRISE DIGITAL TWIN

6.1 PLATFORM OF PLATFORMS ECOSYSTEM

The technological reality that will allow a cross-enterprise Digital Twin to be effectively achieved will be known as a platform of platforms infrastructure. When such a strategy is utilized, the applications in each of the platforms leverage the data, processes, and workflows stored in the other platforms. This can happen in one of two ways. Either through the linking of those platforms together, or through a mutual sharing of data. This reduces errors and leads to deeper and more seamless integration which translates to a better experience for the user. As a result, bridging platforms together is an effective integration strategy [11].

A connected and networked Digital Twin of platforms is the same concept but applied to Digital Twins. There will be several Digital Twin platforms (nodes), each performing some, if not all, of the functions we require of a specific asset. A complete Digital Twin of an entire ship will need to be a connected collection of these platforms. Each integrated together to represent the whole ship.

If successfully implemented, an end user will not feel as though they are navigating across multiple platforms. The user experience will be one where information from various systems will be pulled together for your task, without manual configuration. While a solution like this is more complex than a single platform complete with all the information and features a cross-enterprise Digital Twin would require, it is extremely unlikely that one platform will ever be able to satisfy everything required across an organization.

Just as our industry and others have realized, there are many systems & platforms from different vendors and partners that are required to run our businesses. This strategy we are implementing for our enterprise systems will be the same we implement for our Digital Twin vision.

Some concern about this future has naturally arisen. Multiple times within our industry, past experiences dealing with, exchanging, and integrating across systems have either failed or not achieved the benefit that we wanted or needed.

However, as shipbuilding has changed over the years, so has the business of a technology provider. It is understood across technology providers that to be successful you will have to be capable of connecting to systems from other vendors, even if they are your competitor in some areas. Doing so effectively removes the burden placed on the end user to connect the systems. Eliminating the root cause of previous integration issues in the past.

The connecting of these systems will need to be the technology partner's responsibility, allowing the users of their system to focus on their business and not on creating a custom integration. This is not a reality today. Despite the fact that most technology partners message that they are "open" in their marketing material. Their solutions have not caught up to their messaging. Simply put, if a technology partner has a closed system, it will not exist in the future. Within our industry there have already been huge losses in the last few years from some major software vendors who forced their closed solution on their clients, who in turn found alternate technology providers. This is motivating everyone to embrace the new open digital world.

6.2 AGILE IMPLEMENTATION STRATEGIES

Achieving the above will be impossible all at once, and it will require a cultural shift as discussed in section 4. The need to progress to a cross-enterprise Digital Twin goal using small, incremental, value-adding steps is crucial. In other words, it will become crucial to implement an agile methodology.

The best practice in software and IT is to do things in the following Agile way. In agile, rapidly, incrementally, and consistently adding value requires picking a short time period and then, within that period, complete something which you believe, in and of itself will be of immediate benefit [10].

Such an approach heavily contrasts with an 'all-at-once' approach where you work on a project for a long time and only deliver value at the very end, all at once. Within the Digital Twin context, a key advantage of the Agile approach is that the incremental benefits of part of a Digital Twin are available sooner. At any point, after each increment is completed, the process can be stopped with confidence that something of value has been accomplished. All along the way in Agile, you are learning. Indeed, certain Agile frameworks have mandatory regular ceremonies where work is carefully analyzed.

The Agile approach is quite different from how shipbuilders have historically worked. Both in terms of their internal structure and from how they build ships. However, because it is based on proof, in and of itself an Agile approach can empower shipbuilders who are ready to embrace change.

7. THE DIGITAL THREAD

The Digital Thread is the connective tissue that makes a cross-enterprise Digital Twin a reality. Taking the definition used by Roberts, David, and Franca [8], "The Digital Thread is the full traceability of a ... product lifecycle from concept design through manufacturing, commissioning, and service." From this definition, it becomes clear that the Digital Thread is what allows for a Digital Twin to contain relational information, be updated throughout the lifecycle of a vessel, and manage product development structure.

The traceability provided by the Digital Thread allows the huge amount of data generated from modern shipbuilding to remain within their native platform while simultaneously contributing to the overall Digital Twin goal. [8] All of the digital information generated from various digital solutions will essentially become digital assets within the Digital Thread as it relates to the Digital Twin [8].

In essence, the Digital Thread is what provides enterprise context for the Digital Twin and allows data from disparate sources to become information that is relational, contextual, and present throughout every aspect of a Digital Twin.

8. IMPLEMENTATION THROUGH A SHIPBUILDING PLM

As expanded upon throughout this paper, currently, shipbuilders are beginning to capture an increasing amount of data throughout the shipbuilding process. However, in many cases, that data is not being effectively being fed out of the Digital Twin and into the organization. And while the Digital Thread attaches context and traceability to the information within the Digital Twin, it does not facilitate the flow of a data set.

In order for the Digital Twin to effectively feed the organization, particularly within the design and build phases of a project, the underlying processes within a shipyard must be able to leverage the Digital Twin. Perhaps the most effective way to leverage that information is through the implementation of a shipbuilding specific PLM system [8].

The most significant benefit of PLM for shipbuilders is the connection of all departments and disciplines through a single hub [5]. With the Digital Twin at the center of that hub, everyone can now access the most up-to-date data and information required, and that information can flow directly to production machinery.

As shipowners continue to invest in obtaining increased levels of information, from both on-board a vessel and from its construction process, both shipbuilders and shipowners will be pulled into the benefits of a shipbuilding PLM [8]. Throughout the design, build, and maintain processes, the vast informational data sets housed within the

Digital Twin will increasingly be leveraged through the implementation of a PLM, effectively connecting each aspect of an organization with the right information, at the right time.

9. CONCLUSIONS

As shipbuilding specific solutions for the implementation and integration of a cross-enterprise Digital Twin continue to be developed, it will become easier for shipbuilders to solve the unique challenges they face.

This external factor, combined with shipbuilders who continue to become more technologically savvy and ship owners and operators who demand an increasingly detailed amount of data, a clear return on investment for these new technologies becomes clearer. The benefits for all parties are tangible and timely as indicated throughout this paper; as a result, the cross-enterprise Digital Twin vision will become increasingly top of mind and attainable.

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- grated information and process fields, with special attention to practical implementation in the design, production and operation environments.

11. AUTHORS BIOGRAPHY

Denis Morais is the co-CEO of SSI where he is responsible for developing and directing the strategic product vision for SSI's software and services. This involves analyzing industry needs and technological trends to prioritize SSI product creation and enhancement. Denis oversees SSI's development team and consults with clients directly to implement optimized solutions that address their unique constraints and business requirements. Denis is a world authority regarding the future of shipbuilding and technology. He is an award-winning author, writes a popular blog, and is a sought-out presenter at international conferences. He is an active participant in several shipbuilding and technology organizations such as RINA, SNAME, the Autodesk Developer Network, VIATeC, and Autodesk University.

Greg Goulanian is the PR Writer for SSI where he is responsible for promoting SSI's innovative software solutions and global success stories through various forms of media. Prior to SSI, Greg has written for and worked in the renewable energy, technology, and marketing sectors.

Nick Danese is Managing Director of NDAR (Naval Architecture, Marine Engineering, Shipbuilding) and Syrrkle (IIoT&S). Involved first-hand in the design and production of large yachts since 1986, management duties sub-tend an active R&D engagement, specifically in the inte-