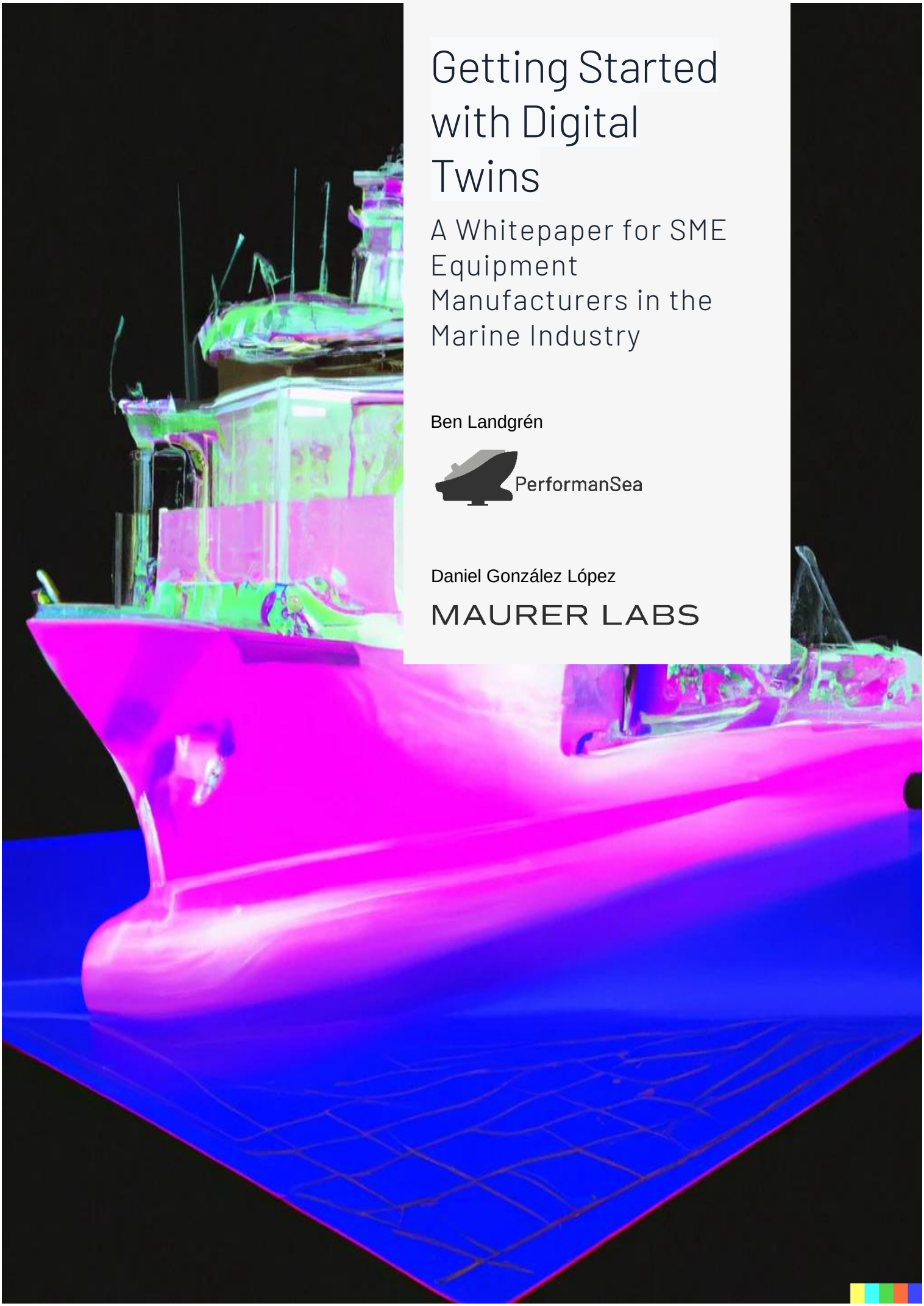

Getting Started with Digital Twins

A Whitepaper for SME Equipment Manufacturers in the Marine Industry

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Executive Summary

Today, several off-the-shelf digital twin software are available, some of which are specifically targeted to the marine industry. However, the market is still in need of clarity, as there is a lack of standards relating to the digital twin concept and best practices are not yet fully established. This has led to technical solutions that are both complex and expensive and therefore out of reach for the average SME.

Although most SMEs operating in the marine sector are working towards digitalisation, many are still transitioning from basic to advanced levels of digital engagement. This, combined with the increasing complexity of integration in today's marine systems will limit the flow of information between stakeholders, which translates to higher costs due to rectifying mistakes. Some elements of the digital twin concept are strongly related to the product development stage, meaning that OEMs can easily begin its partial implementation and start enjoying its benefits.

SMEs are struggling to adapt and take full advantage of advanced digital tools such as digital twins. SMEs face barriers and limitations in making the digital transition, such as lack of knowledge regarding digitalisation, concerns about data, cybersecurity, and costs. However, advanced digital engagement has been estimated to bring many appealing opportunities to SMEs.

Large companies in other industries, such as automotive and healthcare, have been taking advantage of digital twins for some time now. It has had a significant impact on businesses, providing savings to customers worth billions of USD. Compelling and innovative examples can be found across different industries.

Implementing a digital twin concept can happen gradually but the benefits are felt instantly. For an OEM, a logical place to start implementation is at the product development stage. Physics based modelling, model exchange and visualisation of large amounts of data enables a simple, cost-effective, and future-proof starting point. These steps however require special knowledge in the fields of data management, visualisation, and time-domain modelling. External consultancies with expertise in these areas play a critical role in helping companies to accelerate the implementation of the digital twin concept.

Today's Challenges

The fourth industrial revolution aims to lower the boundary between digital and physical assets. Implementing a digital twin concept is a key element of this revolution, combining technologies such as machine learning, big data, simulation, visualisation, and global connectivity. Today the technology is becoming more widely available, less expensive and is already being implemented by OEMs in marine equipment.

The digital twin industry fulfills many of the criteria of a fragmented and emerging industry (Porter, 1998). No clear rules exist and there is no clear market leader in the new, emerging industry. Customers require customised solutions and market needs are diverse. The industry lacks standardisation and general practices which has led to customer confusion and high costs for off-the-shelf products, slowing the adaptation of the technology in SMEs.

Today's boats are becoming more complex, requiring large amounts of data from multiple sources in their design. Carrying out engineering work and product development tasks in silos remains common practice of the industry today. However, a report by DNV states that this practice heavily restricts the flow of data, which combined with the increasing system complexity will result in increased costs, inefficiency, uncertainty and wasted time and resources (DNV-GL, 2018).

Across industries, SMEs seem to have a very hard time making a full digital transition. A study by Deloitte on Australian SMEs shows that 87% of SMEs are not taking full advantage of digital tools available. The major barriers to these enterprises making the transition were: privacy concerns, cost of digital tools and a lack of resources to learn to use them. The report estimates that SMEs with advanced levels of digital engagement are 50% more likely to increase revenue, have the potential to earn 60% more revenue per employee and are 14 times more innovative in terms of product and service offerings (Deloitte, 2017).

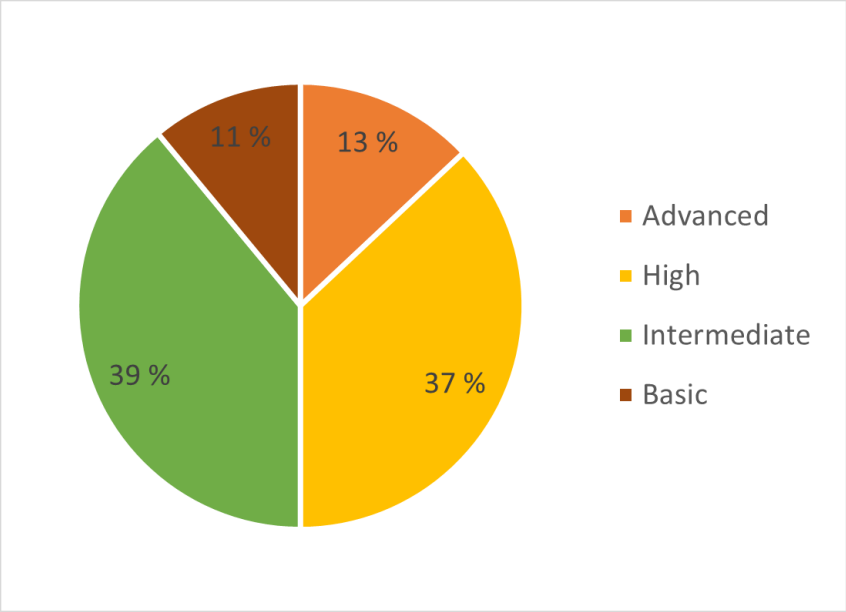

Figure 1. SMEs distribution of level of digital engagement (Deloitte, 2017)

Digital Twin Starts in Product Development

Regarding the lifecycle of a product, the design and development stage is naturally very important for an equipment manufacturer. It is also the first stage of a product's lifecycle where digital twin tools can be implemented.

Digital twins contain data from many sources. These include time-domain models, sensor and geometry data and 3D visualisation. The concept also includes methods and standards to facilitate flow of data such as digital model exchange. (DNV-GL, 2018).

If the digital twin concept is implemented for the first time, many of the elements, such as sensor data, might not be available. However, elements like time-domain models, model exchange and visualisation are easy to implement at the beginning of product development.

Time-domain models	**Model exchange**	**Visualisation**
Time-domain models are not only used in all stages of product development but also after commissioning. They are used to assess performance and to make data-driven decisions (ABS, 2022).	In digital twin concept, model exchange falls under the category of improved flow of data. It allows sharing, connecting and simulation of time-domain models developed in different tools. Hence improving flow of data, cooperation and security in joint projects.	Visualisation technology is advancing rapidly, and it is already changing how we interact with and learn about systems (ABS, 2022). On top of product development and marketing, visualization can be applied, for example, in operational planning and product training (DNV-GL, 2018)

When time-domain models, model exchange and visualisation are combined, any number of stakeholders with different levels of technical knowledge can interact with and gain knowledge from the product development model. Interestingly this allows complete flexibility in the product development process, such as by enabling the customer and external partners to gain understanding of the equipment's performance during the design stage (Eskola, 2022).

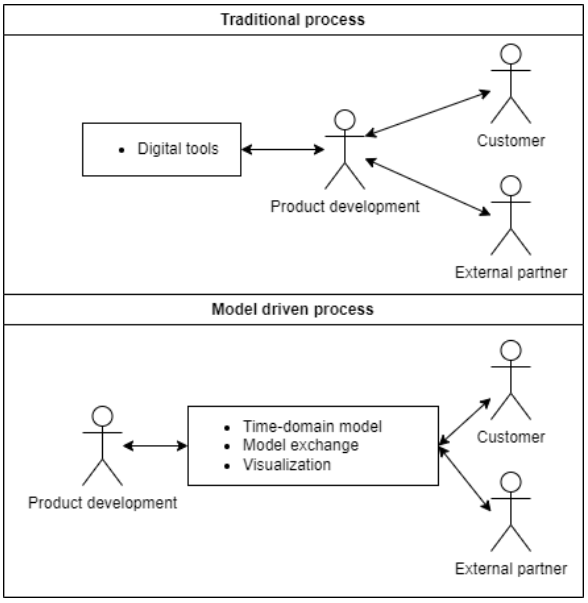

Figure 2. Product development process

Time-domain models, visualisation and model exchange also make the following possible: virtual commissioning, improved system integration, virtual demonstration of product performance, quality assurance checks and development of additional services specifically linked to product maintenance (DNV-GL, 2018).

By implementing the above-mentioned elements alone, the definition for a digital twin concept is not fully met, as, for example, data from the physical counterpart does not yet exist. However, some of the key elements of the concept are already present, which directly benefits the product development process. Also, a solid base for future development of the concept has been established.

Leading Examples in Other Industries

In other manufacturing industries, companies like Tesla, General Electric and Rolls Royce have taken significant advantage of the digital twin concept. Tesla creates a digital twin for each car it sells, which it then uses to further improve and design software updates. GE claims that digital twins have significantly reduced maintenance and risk while adding value to its customers. As a result of digital twin capabilities alone, GE claims to have saved customers 1.6 billion USD (Yasin, et al., 2021).

Many OEM industries are benefitting from digital twins by monitoring their equipment's performance on the cloud. This has allowed the OEMs to have better understanding of their equipment's performance, use and health. Thanks to this, for example, handling warranty claims and user experience has improved.

Some interesting examples of digital twin applications in other industries include voice processing used in a chicken farm to detect illness based on chickens' clucks (Khaled, et al., 2020). In another example a pump manufacturer in the biomedical industry monitored and optimized product performance 'on the fly' based on the fluid properties. This is done using mathematical models of the pump that calculate the optimal operational parameters using cloud computing based on the user's inputs.

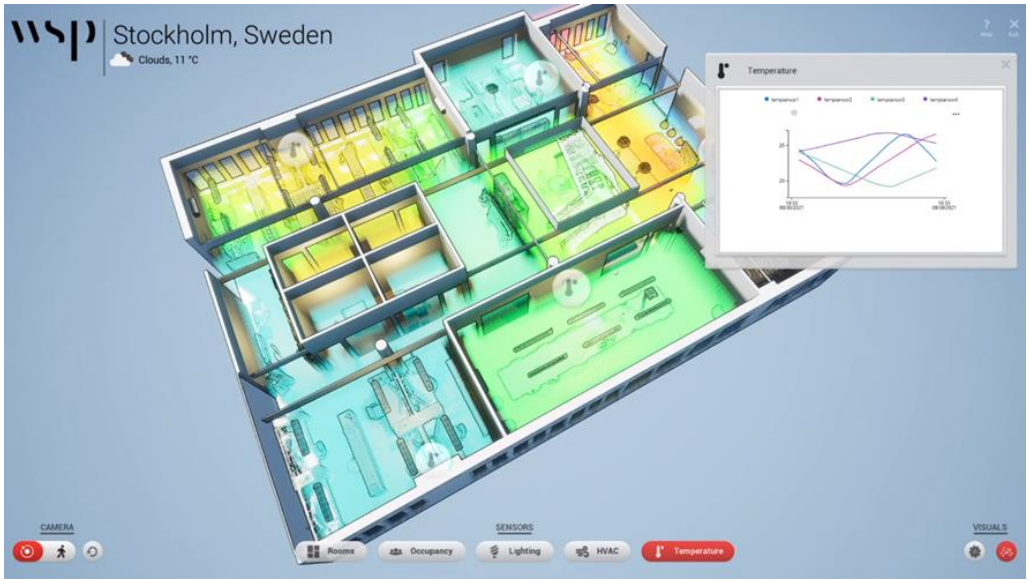

Figure 3. Visualisation example of the monitorisation of ambient conditions in an office (Unreal Engine, 2022)

Overcoming the Barrier

The product lifecycle concerning digital twin can be divided into design, production and use phases (Qi, et al., 2021). The core of a digital twin is the data collected from the physical counterpart which only becomes available during the use phase of the equipment. However, time-domain models, model exchange and visualisation are already needed in the design phase which makes it the perfect starting point for implementing a digital twin concept.

To bridge the knowledge gap required to start implementing a digital twin concept, involvement of consultancies is deemed necessary by DNV (DNV-GL, 2018). This is especially true in specialised areas such as time-domain modelling, model sharing and visualisation in which the equipment manufacturer might not have the necessary expertise.

Time-domain models

Time-domain models are developed by domain experts using programming languages and simulation tools. Traditionally, spreadsheets and datasheets have been used to communicate technical information in the form of performance graphs. However, building a digital twin using hundreds of spreadsheets would be unimaginable.

Modelica is a widely used open language which develops multi-physics time-domain models. It has significant advantages over spreadsheets such as: time-domain simulation, optimisation tools and elimination of modelling errors.

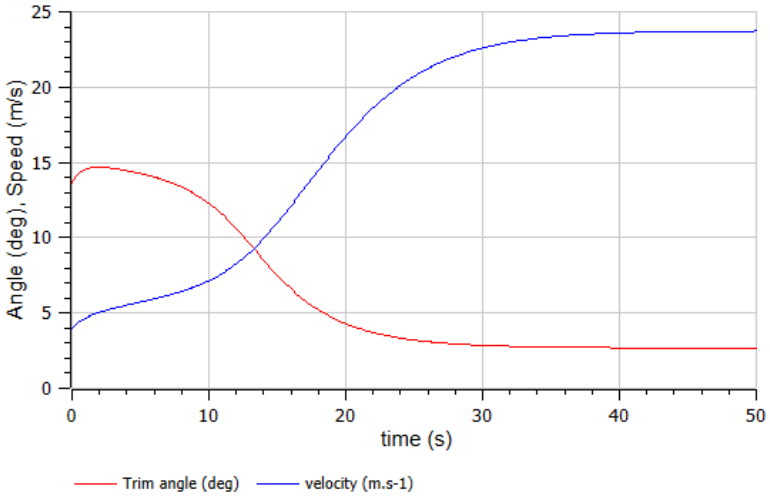

Figure 4. Time-domain simulation of boat's trim angle vs speed

Model Exchange

An open standard, Functional Mockup Interface (FMI), was developed to standardise time-domain model exchange between stakeholders and different tools. This way engineers across departments and companies can easily build and analyse complex systems in parallel. FMI allows safe model exchange without exposing sensitive IP data by using black-box executables. This means that the simulation practitioner can only see the inputs and outputs of a model. The FMI has become the industry standard with 170+ compatible software tools (FMI, 2022).

The FMI standard is embraced across the marine industry. Companies such as Damen, Kongsberg Maritime, Vard, Corvus Energy and DNV are already implementing it in the Open Simulation Platform (OSP) model exchange ecosystem. OSP is another open tool which is an addition to the FMI standard and allows easy connection of models from different suppliers and tools (Open Simulation Platform, 2022).

Visualisation

SME equipment manufacturers often think of CAD and rendered marketing images when they hear the word visualisation. These are so called static visualisations. However, the recent advancements in technology have made the dynamic visualization of performance predictions and historic data possible in real-time. This accelerates understanding and comparison of design alternatives and communicate them to all stakeholders involved in the product development process (DNV-GL, 2018).

Current challenges in visualisation of digital twin data are related to its large quantity and high dimensionality. Also, the required level of data visualisation varies greatly between applications (Qi, et al., 2021). This calls for careful extraction of useful data and its visualisation in an easily understandable format.

Some of the technologies that leverage the interaction with data are Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). They allow for the replication of routine tasks and training environments, as well as aiding the monitoring of autonomous processes and systems, all of them pivoting in the final goal of building a useful and rich user experience around the product (ABS, 2022).

Conclusions

This whitepaper proposes a starting point for implementation of digital twin concept for SME equipment manufacturers in the marine industry. The earliest stage where digital twin can be implemented is product design. This can be done by visualization of data, development of time-domain models and establishing methods to exchange them safely. These actions will allow a product development environment where engineering teams and external partners are no longer working in silos, improving product knowledge, extraction and visualisation of valuable data to support decision making.

Digital transformation has been slow and difficult for SMEs. However, it unlocks many benefits such as new business models and opportunities that translate into higher revenues. Therefore, an SME equipment manufacturer should seek the assistance of consultants' to accelerate the adaptation of digital tools such as time-domain models, model exchange and visualisation.

PerformanSea

PerformanSea is a marine engineering office specialising in system design, analysis and integration using time-domain models and model exchange. PerformanSea has been helping SME companies in the marine industry to take full advantage of digital tools in their product development process.

To find out more about how to get started with time-domain models in product development, visit www.performansea.com or contact me directly at ben.landgren@performansea.com.

Maurer Labs

Maurer Labs is a software engineering company that focuses on visualization, 3D modelling and 3D algorithms. Currently Maurer Labs is centred in enabling digitalised pipelines and workflows for companies that wish to incorporate digital twin related technologies into their ecosystem.

If you want to dig deeper into how visualisation can boost your business, please contact dglopez@maurerlabs.com

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