# How digital engineering is revolutionising naval vessel design and support

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# Introduction

## Harnessing the benefits – how digital engineering is revolutionising naval vessel design and support

Digital twin, augmented reality, virtual reality, robotics, automation, additive manufacturing, artificial intelligence… The list of new technologies that have emerged over the past decade to bring digitalisation to shipyards as well as on board surface combatants and submarines grows every year.

Their introduction across all phases of these platforms' lifecycles is intended to bring an equally long list of benefits. From design and production though to maintenance, digital technologies hold the promise of facilitating the development of 'incredibly complex systems of systems', as many interviewed for this exclusive report referred to surface ships and submarines today.

Digital technologies also have the potential to improve the production process, thus increasing efficiency while reducing costs.

Nonetheless, the speed at which such technologies are appearing can at times bring its own challenges. From hiring and training skilled personnel to the wider perspectives of overhauling organisational culture, 'digital transformation is a matter of strategy, not only a question of available IT systems', Massimo Debenedetti, Research and Innovation Director of the Military Ships Unit at Fincantieri, told *Shephard*.

What, then, are the principal benefits and challenges of introducing digital technologies throughout a vessel's lifecycle, and how is this managed across the industry?

**Digital transformation is a matter of strategy, not only a question of available IT systems.**

**Massimo Debenedetti,**
Research and Innovation Director of the Military ShipsUnit at Fincantieri



# In the beginning

**In the first part of this exclusive technology report, Dr Alix Valenti investigates how digital engineering can bake innovation and future-proofing into a ship or submarine long before any metal has been cut.**

'Submarines and surface ships are highly technological platforms whose design, construction, update and maintenance are complex,' a Naval Group spokesperson told *Shephard*. Yet this ever-increasing complexity is being met with the necessity to reduce time to market and reduce costs.

The paradox stems from navies around the world facing a growing number of threats that are driving demand for complex, interdependent systems, while resources to acquire these platforms remain finite.

FIRST PRINCIPLES

# Taming complexity

Against this background, as James Gladman, Chief Naval Architect at Expleo, told *Shephard*: 'The surge in technology development and the desire to incorporate enhanced or new capability increases the probability of late changes in the design, leading to increased complexity, cost and programme delays.'

This is not only evident in ship design, but in the production phase as well. Constructing complex and interconnected systems of systems requires a well-orchestrated approach.

Success is not only reliant on detailed planning at the shipyard, but also demands that subcontractor activities and warehouse management are carefully built into the planning process.

Beyond the need to skilfully orchestrate multiple actors across different phases of design and construction of ever-more-complex platforms, shipyards also face another critical challenge: future-proofing.

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>
> **James Gladman,** Chief Naval Architect at Expleo

'Innovation in weapon technologies means platforms will need to integrate a large variety of new equipment, with significant changes for both platform and systems,' Ana Moya, Engineering Director at Navantia, told *Shephard*.

It is not only weapon systems that will continue to evolve. A Naval Group spokesperson pointed out that multiple factors will continue to affect the design of a platform, including protecting the seabed, operating in colder waters, emerging threats, increasing needs for autonomy and environmental requirements such as alternative fuels.

Last but not least, Moya also commented on the importance of designing and building platforms that will be able to accommodate future autonomous systems, be they aerial (UAVs), surface (USVs) or sub-surface (UUVs).

'The increasing presence of these vehicles on board is affecting platform design, communication and command and control systems, and will trigger a quick evolution in the remote and autonomous recoverability of this kind of vehicle,' she said.

In such complex, interconnected, forward-looking environments, digital technologies have a significant role to play in facilitating design and production of surface ships and submarines.

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>
> **Ana Moya**, Engineering Director at Navantia

## THE POWER OF DATA

# Tools for transformation

According to the Gartner IT glossary, digital technologies are the tools used to change a business model and provide new revenue and value-producing opportunities. In other words, 'it is the process of moving to a digital business'. The shift to digitalisation was a pervasive theme among industry leaders interviewed for this report.

This is evident, first and foremost, in the use of the digital twin. The virtual representation of a physical object is undoubtedly the most common reference point used for discussing the digitalisation of the naval industry.

However, while it is so far mainly associated with maintenance and upgrade cycles, the digital twin has revealed significant added value for design and build.

As a representative from BMT commented, the latter aspect is primarily rooted in the fact that 'the data feed can take the guesswork out of many of the engineering decisions'.

More specifically, naval experts from BAE Systems told *Shephard*: 'In design and build, digital twins can be used to test concepts and designs rapidly before anything is physically built.'

This allows engineers to agree more quickly on (potentially innovative) design solutions that ensure a platform and/or an industrial process's performance optimisation, the Naval Group spokesperson noted.

> **In design and build, digital twins can be used to test concepts and designs rapidly before anything is physically built.**
>
> **Naval Experts from BAE Systems**

Similarly, Jon Wines, Senior Solution Architect at Expleo's marine business unit, said: 'Our experience shows that designing in a configured digital toolset means that the teams can fully understand the context in which they are working and make quicker and more informed decisions.'

Interestingly, while the concept of digital twinning mostly evokes the image of a ship's virtual replica, for Navantia this goes further.

'A digital replica of the factory, such as Navantia's engine factory, allows the simulation, monitoring and optimisation of production processes, thus improving efficiency and productivity and, ultimately, reducing production time and cost,' Moya said.

In fact, beyond the use of the digital twin, as Debenedetti told *Shephard*, a pervasive digital approach helps avoid unnecessary delays and optimise cooperation in all the phases of the product's lifecycle, from concept design to decommissioning.

> **Designing in a configured digital toolset means that the teams can fully understand the context in which they are working and make quicker and more informed decisions.**
>
> **Jon Wines,** Senior Solution Architect at Expleo's marine business

More specifically, he added: 'A digital approach will help the interaction with systems and component providers and maximise information availability, avoiding misunderstandings and lack of clear indications.'

In this sense, BMT added that collaboration and configuration tools are key: 'Digital collaboration tools have been hugely important to enable the sharing of information and concurrent working by geographically disparate teams, as has been the case in many industries.'

As for configuration tools, they are central to the quality assurance process as they increase confidence in the consistency of the data being used.

Exepleo added that design intent is only part of the story, to enable a digital twin to add maximum value the 'as built' configuration must be captured and incorporated to support the transition from manufacturing to in-service, allowing the support organisation to have full visibility of the delivered configuration.

More generally, Naval Group noted that data sharing through the Internet of Things (IoT) facilitates production process monitoring. Debenedetti also commented on the fact that the IoT allows for better management of the warehouse as well as improving coordination among subcontractors, who benefit from direct access to production information.

Just as importantly, tools like AI can significantly increase the efficiency of digital technologies.




## SKILLS SETS

# Attracting, honing and retaining

'There is a current volume and skills challenge in the sector,' Neil Young, Babcock Marine's Engineering and Technology Director, told *Shephard*. The volume issue is driven by the growth in demand for surface ships and submarines, on top of maintenance and upgrades for existing fleets.

The skills challenge, on the other hand, is a result of the new capabilities required to efficiently deliver design, build and maintenance of vessels.

While the need for a highly skilled workforce continues to grow following platform demand trends, interviewees noted that attracting enough suitably qualified and experienced personnel remains difficult.

This means that digital technologies can play a significant role in addressing this issue.

**There is a current volume and skills challenge in the sector**

**Neil Young**, Babcock Marine's Engineering and Technology Director

For instance, Naval Group pointed to automation and robotisation as critical tools to carry out difficult tasks or jobs without added value for the workforce: 'At Naval Group, robotic process automation is the technology addressing this issue', the spokesperson added. This is particularly interesting for tasks such as welding where robotisation improves working conditions.

Similarly, Babcock Marine has implemented a new panel line at its Rosyth site that is turning shipbuilding from a labour-intensive process into an automated production sequence. 'The facility incorporates a high level of automation and robotics, which provides a safer working environment, high quality and high throughput,' Young pointed out.



Another important element of attracting and retaining a skilled workforce is the ability to train teams and individuals in a way that is efficient and intuitive. This is particularly true for new generations of employees arriving at shipyards now.

As noted by Magnus Olsson, head of surface ship design and engineering at Saab Kockums: 'Employees today have more experience meeting digital transformation.'

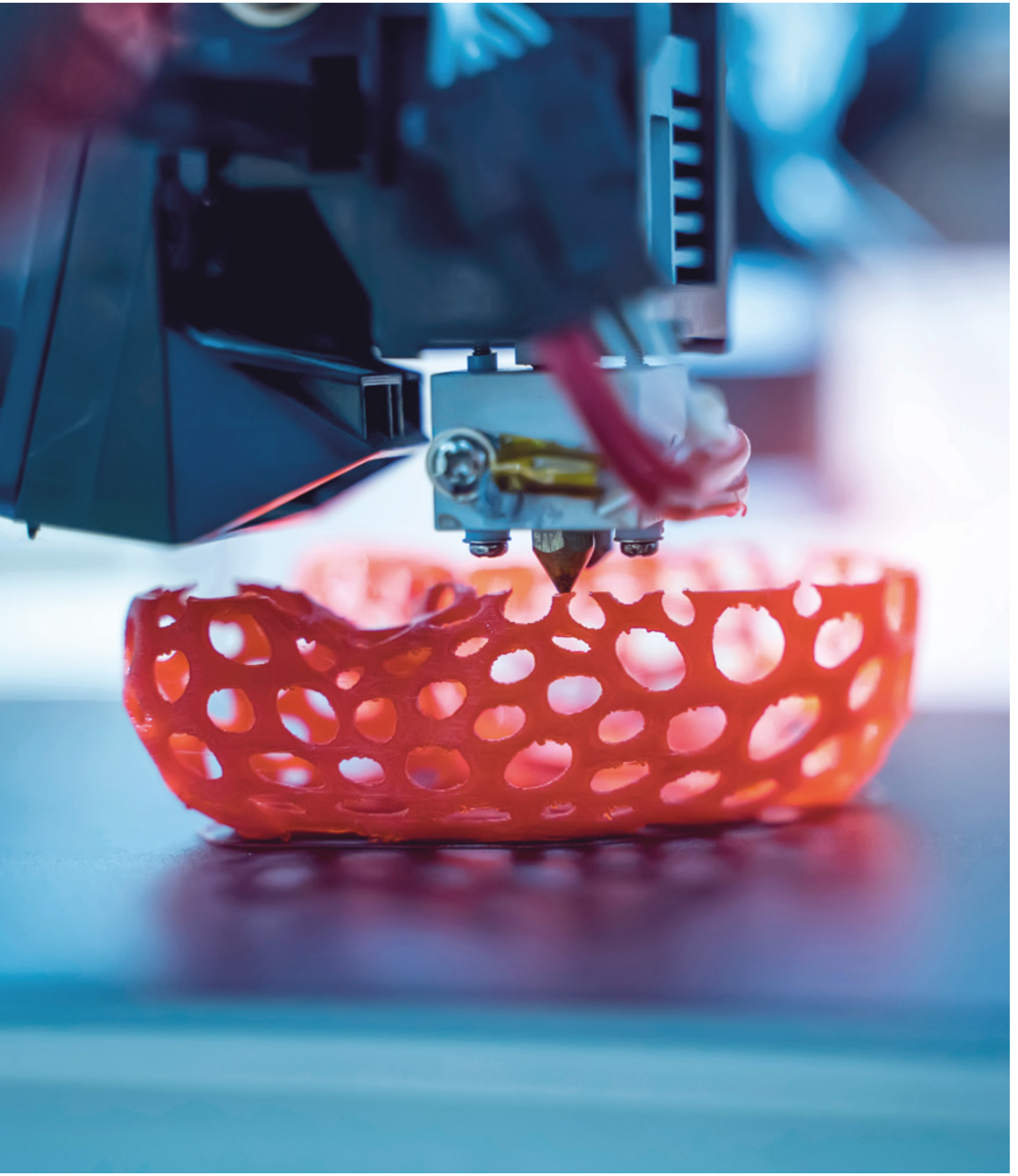
In this context, augmented reality (AR) and virtual reality (VR) are the digital tools of choice for both Naval Group and Navantia. As Moya explained: 'VR/AR allow the efficient training of workers, reducing the risk of errors, and support the construction and assembly operations.'

This technology can also be used to enable design and production processes. For example, BAE Systems is putting digital technology toolsets directly in the hands of production engineers.

'In the future, digital models will provide a single point of truth across the ship, but these must be easily accessible for shipbuilders who often wear gloves and other deliberate safety equipment,' the company emphasised.

**Employees today have more experience meeting digital transformation.**

**Magnus Olsson,** Head of Surface Ship Design and Engineering at Saab Kockums



## FOSTERING INNOVATION
# Printing ahead

Much like digital twinning, additive manufacturing – also known as 3D printing – is more commonly associated with maintenance operations. Yet this holds significant potential for the design and build phases of surface ships and submarines.

Similarly, Naval Group sees additive manufacturing as an opportunity to facilitate innovation for certain parts of a platform. In 2019, for instance, the company, together with French engineering school Centrale Nantes, developed the first ever propeller using the wire arc additive manufacturing (WAAC) method. The propeller, built for the French Navy tripartite-class *Andromede* minehunter, spanned 2.5m and weighted 200kg.

According to Naval Group, 'the key advantage of additive manufacturing in the manufacturing process is that it allows the development of certain shapes that could not be built with other processes.'

One example is the possibility of creating hollow components, potentially for propellers, that would make the part much lighter and therefore increase overall ship efficiency.

Additive manufacturing also opens up new possibilities in relation to materials. For instance, designers and builders currently have to make compromises on parts such as propellers: they must remain relatively light without being subject to corrosion.

Additive manufacturing offers the possibility of selecting a lighter material for the core of the part and then applying a non-corrosive layer on top.

Finally, and much more pragmatically, this technology reduces the scrap factor. Where current production inevitably leads to high levels of wastage for some materials, additive manufacturing uses only what is necessary. This is not to say that there is no waste at all, as some parts may still need smoothing out, but less material is being used to begin with, therefore reducing costs.

# Life after launch

**In the second part of this exclusive technology report, Harry Lye examines how digital engineering technologies are improving maritime maintenance for the better and future-proofing vessels to be ready for new equipment fits and training crews how to use them.**



Confronted by the rapid pace of technological change in fields such as sensing and shooting, navies are increasingly struggling to keep up with news threats. This is manifesting itself across industry and government, with a demand for ships to be built faster, and a need for maintenance times to be reduced, keeping hulls in the water on operations for longer.

Jon Wines, Lead Solution Architect at Expleo's marine business unit, told *Shephard* that increasing the availability of fleets is one of the key challenges facing the naval sector, and a digital twin represents a significant opportunity to improve the effectiveness of maintenance programmes.

Digital technologies are beginning to play a more significant role in supporting naval vessels post-delivery, with solutions such as modular designs, embedded sensors on equipment and a digital twin being deployed to tackle challenges in maintenance and deliver efficiencies.

Shipbuilders and vessel designers from across Europe made it clear to *Shephard* that they were embedding a digital twin into their processes to support maintenance, training and other aspects of a ship's in-service life.

# Context is key

'The creation and configuration control of a digital twin throughout the life of a vessel provides the opportunity for a step change in the way in which we operate them,' Chief Naval Architect at Expleo James Gladman told *Shephard*.

'The collation and transmission of near real-time information could enable more effective decision-making. For example, the life of a ship's structure is normally dominated by cyclic fatigue. But could we use the digital thread to monitor and analyse the effects of that fatigue and increase the life of a vessel?'

Despite the clear benefits, interviewees told *Shephard* that the implementation of a digital twin had so far been limited due to the expensive upfront costs associated with their deployment and differing commercial arrangements that divide the life cycle of a ship.

It is not uncommon in defence for one company to build a platform, another to be given a contract to support it, and then another to conduct any future significant upgrades, all creating barriers between data.

Babcock Marine's engineering and technology director Neil Young echoed these sentiments, telling *Shephard* that using a digital twin was important for improving a vessel's design, availability and performance.

He explained: 'Newly designed vessels are being delivered fully digitally enabled, through the design and build process to the operational and maintenance life of the vessel, where operating data can be pulled directly from the ship.'

Babcock has already used a digital twin to improve the availability of a naval gun system, improving the processes and outputs from traditional troubleshooting techniques.

Marine experts from BAE Systems said that a digital twin had different definitions and use cases in different businesses and sectors, adding that the company saw one of the main benefits as connecting physical and virtual systems to 'close the circle of in-service learnings'.

In service, BAE's capabilities are designed to enable the company to have a near-real-time set of ship data and performance figures which informs maintenance planning and therefore has benefits for platform availability.

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BAE's experts detailed two tools they use: System Information Exploitation (SIE), which gathers, stores and processes data on a ship; and Prognostics and Health Management (PHM) algorithms which use machine learning to monitor system and equipment health.

'This is all available on board for the user as well as allowing for the near-real-time transfer of this data to the shore, enabling us to feed shoreside digital twins,' BAE's experts added.

A representative for Fincantieri told *Shephard* that the digital twin approach would be applied to its future new builds, describing it as a 'digital thread' among all the product life cycle phases.

The Italian shipbuilder believes that the use of the technology maximises the end user's experience and offers a better understanding of the product.

As soon as the physical twin – in this case, the finished ship – is available, Fincantieri said the digital counterpart was used to support decision-making in various areas, from predictive maintenance to safety enhancements and remote assistance.

'What-if' analysis, the company said, can be performed on the digital twin and fed back directly to a crew to optimise performance of propulsion, energy and other mission-critical aspects of a ship or submarine.

It added that such solutions also offered better training, using augmented reality or virtual reality environments to enhance the proper use of onboard systems and devices, increasing a crew's knowledge of their ship and making them more confident operators.

Spain's Navantia echoed Fincantieri's views on training, saying, 'virtual and augmented reality (VR/AR) allows immersion in the natural environment in NAVANTIS – the NAVANtia Training Integrated System.

'Through the use of NAVANTIS and thanks to the digital training, the entire crew can go directly on board from the training centre and navigate safely.'

French shipbuilder Naval Group also told *Shephard* that the digital twin was an interesting solution for controlling the configuration management of ships over time.

With a robust digital model, much of the design work that goes into upgrading a platform can be done on shore, meaning a vessel does not necessarily need to be in port for engineers to inspect it before planning commences.

Saab Kockums' Magnus Olsson, head of surface ship design and engineering, explained: 'Take an example from the Swedish Navy; we have few vessels in each area. There can be one or two ships in each ship class.

'To be able to perform upgrades, updates, modifications, you can do more of the design work without having the vessel in harbour. That is when you have a good digital twin of the vessel.'

Expleo's Marine VP Jonathan Taylor explained that the biggest value of digital tools is connecting data into a 'single source of truth'. Therefore maintenance and configuration control of the digital asset are as important as the physical asset.



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In this vein, a spokesperson for Navantia told *Shephard*: 'A ship's digital twin, such as the one that will be on board the future [Spanish Navy] F110 class frigate, is the key to safe and optimised operation and sustainment throughout the ship's life.'

Navantia is using a digital twin to enable 'smart sustainment'. Like the other examples, this employs machine learning and information gathering to extract insights from operational data collection to support decision-making and offer diagnostic and predictive maintenance.

The spokesperson for the Spanish shipbuilder added: 'Digital continuous monitoring of all systems, including [a vessel's] structure, allows the early detection and prediction of maintenance needs, reducing failures and improving the ship's safety.

'Digital twinning is reshaping the lifetime of vessels by improving reliability, safety and efficiency, reducing maintenance costs, and extending the life of the ship's systems and equipment.'

With the importance of a digital twin now clear, they open up some interesting possibilities for maintenance procedures.

## HOLISTIC MAINTENANCE
# Scanners, printers and sensors

Olsson said: 'The next step is also in maintenance, training, etc, and how it can be used by the crew. We are then into how to implement the 3D model into the ILS [integrated logistics support] documentation as well.'

The Saab expert said that a good 3D model and database of the vessel, combined with 3D printing, can allow navies to produce spare parts on board, speeding up maintenance processes significantly.

By allowing crews to produce parts while under way, 3D printing in conjunction with a digital twin offers potential cost reductions and ensures operational availability in several ways. By not having to go into port or fly out replacements, navies can fix issues on the water – within reason.

This could also offer exciting benefits in a task force scenario in which a larger ship, such as an aircraft carrier with abundant space, could, in theory, be used as a floating factory to replenish its escorts with self-produced parts.

**The next step is also in maintenance, training, etc, and how it can be used by the crew.**

**Magnus Olsson,** Head of Surface Ship Design and Engineering at Saab Kockums

3D printing is increasingly being used across the naval supply chain, from the fabrication of components used to build ships to experiments with deployable systems on board vessels for the purposes described above. For example, liquid metal printers have already been deployed on US Navy ships.

Young said: 'We [Babcock] are applying additive manufacturing to address the issue of obsolete parts, which can no longer be sourced through the supply chain.

'This involves scanning the part and making a 3D model of it, engineering checks to confirm it is safe for the design intent and then having it additively printed and delivered to the platform.'

This is a specific example of the benefits of digital technologies when supporting older vessels. With naval programmes often facing delays or nations with less funding having to keep ageing platforms in operation for longer, 3D printing, laser scanning and digital modelling could pay dividends.

Young added: 'In the maintenance area, we are using laser scanning to quickly scan ships and submarines to produce a known material state, and then produce quicker design solutions and a fit first-time solution. We can do this using hand scanners, via drones in the air or ROVs in the water.

'We have also produced a holistic maintenance solution, which can take real-time or buffered data from an asset and work out what maintenance needs to be completed (and by inference what maintenance does not need to be done).

'This provides a risk-based predictive maintenance capability instead of a checklist approach as traditionally seen.'

Olsson noted that Saab also employed laser scanning to support older ship types.

Moving beyond predictive maintenance, Expleo sees the digital twin as being the key enabler for improved availability, with systems usage data and critical parameters being captured in near-real time.

This allows asset-specific analysis and simulation to be conducted for the purpose of optimising operations and maintenance planning directly based on the data.

This approach also extends into future maintenance periods but furthermore offers navies insights into how their platforms perform in different conditions.

For example, in the Royal Navy, it is not uncommon for two ships of the same class to be operating concurrently in two very different climates. By collecting data on the performance of subsystems, navies will be able to generate an understanding of how conditions affect parts and then tailor their deployment schedules with that knowledge in mind.

So a component may have wildly differing operational limits in the freezing cold of the Arctic than it would in the sweltering heat of the Gulf or humidity of the tropics. This could become increasingly beneficial as European navies, in particular, seek to operate more frequently in the Indo-Pacific.

Sensors can also be deployed across the supply chain to track vendors, which information can then be fed into digital tools to understand better how equipment flows from factory to ship.

Fincantieri cited the use of RFID tags to track how components move through a plant, how long they stay in a warehouse, when they are placed on board a vessel, and then hold information about when a part needs replacing.

The Royal Navy has also conducted an Internet-of-Things tracking trial at HMNB Devonport with Smarter Technologies to keep tabs on mission-critical government-furnished equipment.

The UK MoD used the trial to see how technology c ould be used to improve efficiency at large naval bases. While this may seem tangential to maintenance, support and availability, the exercise significantly reduced the time to find specific objects.

Using digital technologies to make onshore facilities more efficient could have more knock-on benefits. In an availability scenario, every little helps, reducing the time it takes to ready a ship for a deployment or cycle through a maintenance period.

## DESIGNING FOR UPGRADES

# Modules and power

Digital tools and modelling also allow shipbuilders and designers to keep one eye on the future when developing platform designs.

Fincantieri explained: 'Now we can try and define what is product innovation for a shipbuilder: it is the ability to deliver an innovative platform able to grow during time with a plug-and-play, and not plug-and-pray, approach all along the life cycle.

'While we might not know the exact specifications for future combat systems, we must design ships with margins in known areas, like electrical power, for example. Rarely do technological advances in weapons and sensors require less energy to operate and maintain.'

In a more concrete example of how vessel design is changing to support modernisation and through-life support, Denmark is at the forefront with SH Defence's The Cube and a new company Cubedin, designing interfaces to support modular shipbuilding.

The Cube containerises capabilities for various naval missions, allowing navies to interchange them when required quickly and builds on the STANFLEX concept.

This could also allow forces to potentially keep up with technological change more efficiently, as the capability of a ship is not tied to mid-life upgrades or lengthy overhaul procedures.

Cubedin offers physical and software solutions for plug-and-play modules, allowing navies to quickly re-role ships at a national, task group or alliance level.

However, these approaches are not without challenges, as many naval missions can be exceptionally specialist. Re-roling vessels will also require a multi-skilled crew or the rotation of sailors between platforms depending on the task assigned.

# Conclusion: The human side of digitalisation

**While digital technologies have the power to revolutionise vessel design and sustainment, there are a number of complex background factors that must be tackled to ensure success.**

The benefits added by digital technologies to the whole lifecycle of surface ships and submarines, from design and production all the way through to routine maintenance, are significant.

They not only contribute to considerably reducing costs – be that in terms of materials, optimisation of processes or training of personnel – but they also represent a key enabler for innovation.



Expleo's VP Marine Jonathan Taylor was clear that 'we must not forget that people are a key part of the transformation and must be considered central to the strategy to embrace digital technology. As well as attracting the new skills into the Naval Enterprise we must invest in developing our existing teams to keep pace with the opportunity that digital technology brings.'

And this is just the beginning, as these technologies continue evolving and, just as importantly, will become ubiquitous to the next generation of engineers. BAE Systems' experts noted: 'These "digital natives" bring with them the expectation around the use of technology and data [and] this transition cannot be underestimated – think transition from sail to steam!'

Yet even the technologies that help the industry address a number of key challenges present their own implementation issues. Chief among those, as with all industries that depend heavily on datasets and data transfer, the naval sector will have to contend with issues of cybersecurity and data management.

**We must not forget that people are a key part of the transformation and must be considered central to the strategy to embrace digital technology.**

**Jonathan Taylor**, VP marine at Expleo

As Naval Group's spokesperson explained: 'Before implementing a digital solution, a complete analysis of potential risks and an evaluation of the countermeasures to be put in place is absolutely necessary.'

Similarly, as many different actors in the value chain gain access to data sets, data management will play a significant role in the successful implementation of digital solutions.

This also includes intellectual property issues, as Moya pointed out, 'to prevent unauthorised use [of the data sets]'. Such issues were also raised by Debenedetti, who added that, for example, a different business model should be implemented where industry and an MoD are part of the same environment.

Additionally, 'appropriate legal and contractual models should be put in place for treating these aspects', he explained.

Ultimately, as new technologies such as cloud computing, AI and quantum computing enter the realm of ship design, build and maintenance, one of the key challenges will be organisational culture transformation to enable digitalisation.

Because as Debenedetti told *Shephard*, if digitalisation is not ubiquitous to an organisation, or if training does not sufficiently address skills gaps, the whole process might be hampered. 'If you no longer feel that the digital environment will help you, why lose time understanding and using it?' he pointed out.

# Navigating tomorrow, delivering today

**Accelerating our marine clients to the forefront of their industries with cross-sector engineering and technical expertise to deliver intelligent solutions to complex problems, creating a smarter, safer world.**



# About Expleo

Expleo is a global engineering, technology and consulting service provider that partners with leading organisations to guide them through their business transformation, helping them achieve operational excellence and future-proof their businesses. Expleo benefits from more than 40 years of experience developing complex products, optimising manufacturing processes, and ensuring the quality of information systems. Leveraging its deep sector knowledge and wide-ranging expertise in fields including AI engineering, digitalisation, hyper-automation, cybersecurity and data science, the group's mission is to fast-track innovation through each step of the value chain. As a responsible and diverse organisation, Expleo is committed to doing business with integrity and working towards a more sustainable and secure society. Expleo boasts an extensive global footprint, powered by 17,000 highly-skilled experts delivering value in 30 countries.


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