Standardising flexibility: Future-proofing designs and capabilities in complex warships

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As technological change accelerates and navies seek platforms built for longer service life, shipyards are blending – in their platform designs – capacity for extended operational service and adaptability to developments in technology. *Dr Lee Willett* explores Damen Naval Division as a case study in applying such thinking to surface ships in build, in design, and in concept

With some exceptions, most navies buy surface ships and submarines that are designed to remain operational for a relatively long time. A period of 25 years has commonly been the expected service-life baseline, though in practice many platforms operate for longer. In design and requirement today, navies need platforms that are able to operate for 30, 40, or even 50 years.

The operational requirements a platform must meet over an extended service life can change significantly, as can the technology available – either enabling new offensive capability and/or requiring a defensive response. Over the next half-century, the speed of technological change is likely to accelerate rapidly (although due to the range of technologies emerging, the speed and direction of the acceleration are unlikely to be linear).

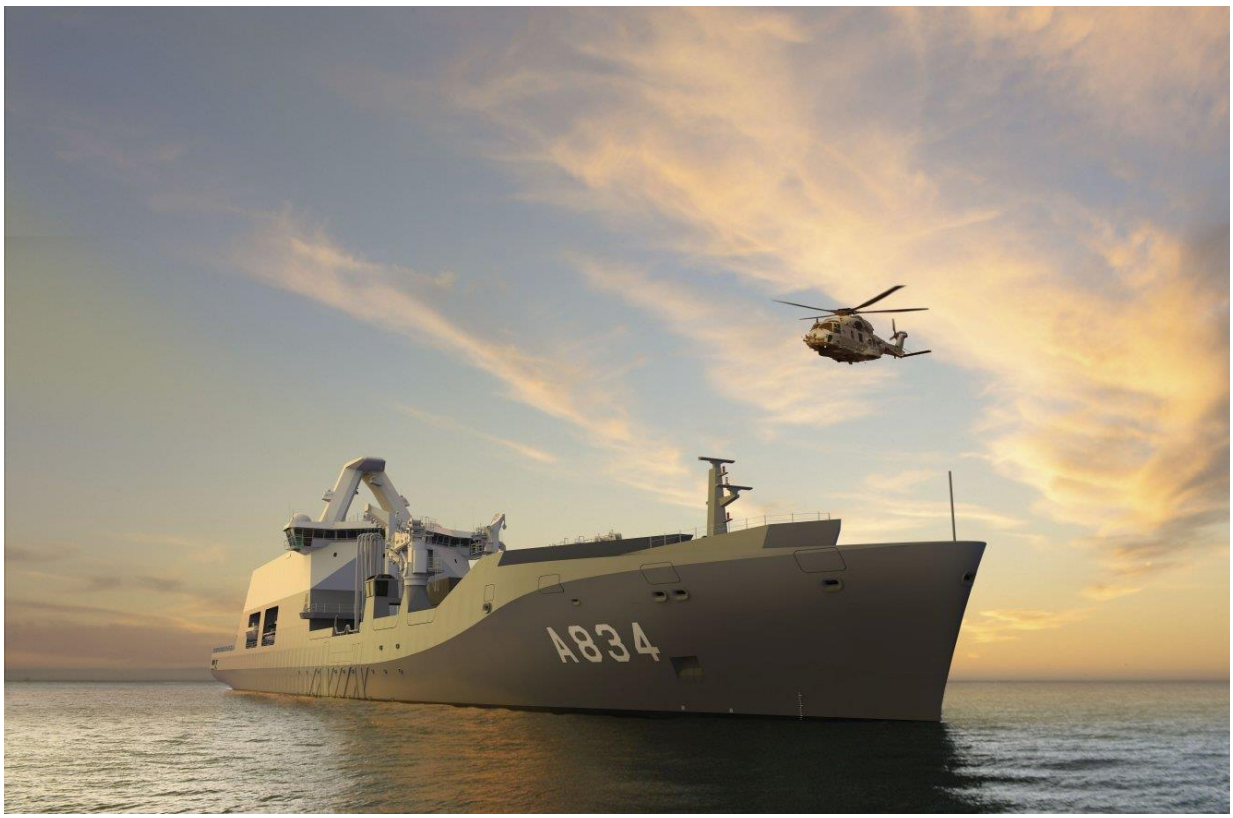
Double Dutch

The Netherlands' Damen Naval Division, part of Damen Shipbuilding Group, is one shipbuilder tackling the twin challenges of designing and building platforms with flexibility to adapt to technological change while also delivering a degree of standardisation to enable future upgrade integration.

The various ship types in build at Damen's naval shipyards underlines the broad range of platforms and capabilities navies need today. Alongside routine upgrades of Royal Netherlands Navy (RNLN) frigates and logistics ships, Damen is building a Combat Support Ship (CSS) for the RNLN and an ice-capable Antarctic Survey and Resupply Vessel for Australia.

Emerging programmes include Damen leading on a Belgium/Netherlands bilateral programme to replace the two navies' M-frigates with anti-submarine warfare (ASW)-focused frigates (ASW-Fs); Damen is also working in partnership with Lürssen Group's Blohm+Voss and Thales Deutschland (through Thales Nederland) to build the German Navy's future F-126/MKS-180 frigate. At a strategic partnering level, in December 2020 Germany and the Netherlands exchanged letters of intent (LOI) to co-operate on other potential frigate replacement programmes, such as for the

Deutsche Marine's Type 124 Sachsen-class frigate and the RNLN's De Zeven Provinciën-class air-defence and command (luchtverdedigings en commandofregatten [LCF]) frigate.



An artist's impression of the RNLN's new CSS, the future HNLMS Den Helder . Following contract signing in February 2020, the ship is in build. Damen Naval Division is using emerging programmes like CSS as a testbed for new technology and design approaches. (Royal Netherlands Navy)

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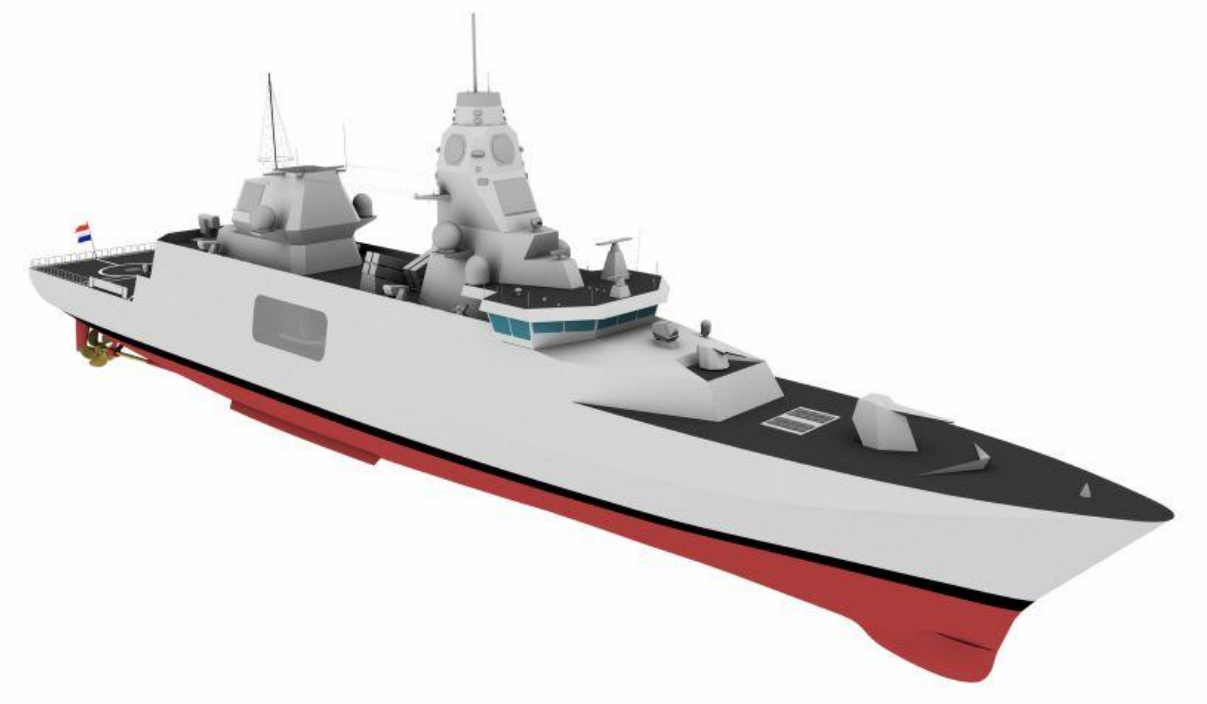
The combination of intricacies in the naval operating environment and the evolving pace and direction of technological change is driving increased complexity in naval platforms. This 'complexity' challenge is especially evident in higher-end platforms – traditionally termed 'complex warships'. The challenge for shipbuilders is blending a degree of platform standardisation to facilitate future upgrades, with the capacity to be rapidly adaptable. However, blending such approaches can deliver capability and operational benefits, senior industry experts argue.

"The basic idea of how you think about standardisation, is actually [how to give] you some advantages," Richard Keulen, Damen Naval Division's director naval sales support, told *Janes* . "I think the focus we have to look for in complex combatants is that they have to be flexible, [and] they have to be future-proofed." However, he added, "They have to answer the development that, [in] the innovation of a lot of subsystems that present the functionalities of the combatant, such innovation comes much faster than [in previous] decades. That's not a linear process anymore."

Keulen – a former RNLN commander and frigate commanding officer – continued, "The standardisation idea in the military portfolio should translate into very flexible platforms that can

serve as a ‘system of systems’ and that can offer a higher pace of innovation, upgrading, and addition of new functionalities.”



An artist’s impression of the ASW-F design being developed for the Belgium/Netherlands M-frigate replacement programme. The ship’s data management set-up could include an integrated mission management construct overlaying their platform and bridge management systems. (Defence Materiel Organisation, Netherlands)

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Damen has a tradition of building standardised ship designs, for commercial ships and complex warships. In the latter context, Keulen pointed to the export-focused SIGMA surface ship family. “SIGMAs are corvettes and frigates of various sizes and lengths, but they have a number of common features, like the hull shape: the whole design is standard, and it [can be] enlarged in a very standardised and modular way.

“The way you can apply standardisation varies a little bit per segment and per portfolio,” Keulen continued. “Complex combatants, [as] more a ‘system of systems’, encompass more variables like different sensors, weapons, and communications fits [with] different operational concepts they have to support.”

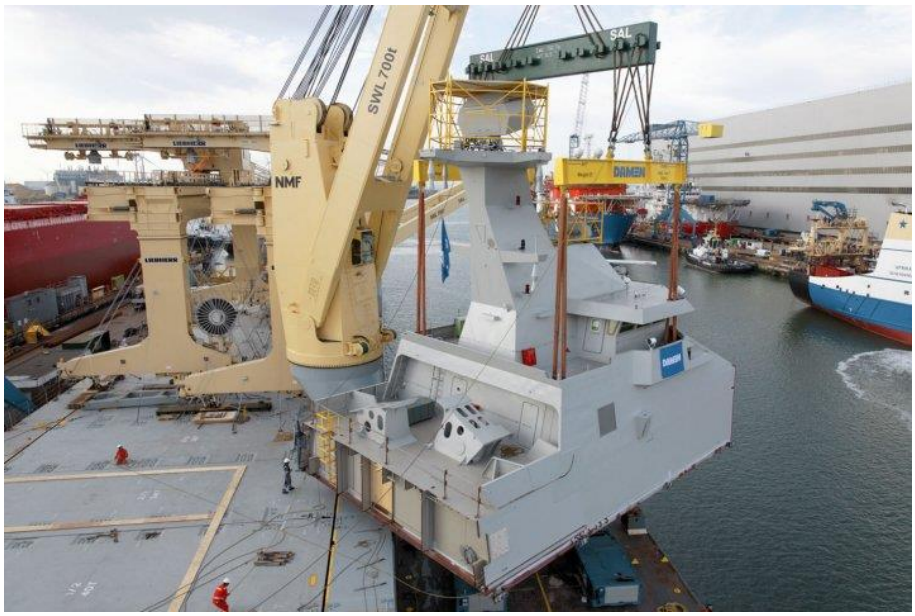
Industry’s aim is to develop complex warships that are standardised but also sufficiently flexible to embrace emerging technologies to provide future-proofed naval operating concepts. Blending and balancing standardisation and flexibility is “the interesting question, … it’s the Holy Grail all naval ship designers are looking for,” Joep Broekhuijsen, a project manager for research at Damen Naval Division, told *Janes* .

Broekhuijsen, a naval architect focused on surface combatant research and development (R&D), said, “Technology developments [move] rather quickly at the moment, the pace is still increasing,

and we see that a future platform will have systems on board that have a much shorter life-cycle than the core platform. So, that means we intend to design the core platform with characteristics that allow for future development of the subsystems."

Broekhuijsen pointed to two approaches, one being applied by Damen and one being applied across the Netherlands' naval shipbuilding community. At Damen, he explained, "We implement mission- and model-based systems engineering methodology. That means we go from the missions – the operations – of the ship, derive functional requirements related to these operations, and then make a full functional decomposition of the systems we need on board to fulfil these operations…. We minimise the interfaces and make sure these interfaces are standardised [so] we can introduce 'plug-and-play' solutions for these functions. That is the concept that we are working for at the moment."

At the national level, in 2020 the Netherlands Ministry of Defence (MoD) established the 'Dutch Naval Design' initiative, to enable greater integration of technologies and design visions developed across the customer base (including the MoD, RNLN, and Defence Materiel Organisation [DMO]), R&D institutes, and the naval industry. This navy-focused initiative emanated from the Netherlands' original, defence-wide 'Golden Triangle' concept.



Damen builds its SIGMA corvette/frigate family to a standardised design that can be enlarged in a modular manner to meet different requirements. Pictured here at Damen is a pre-outfitted module for an Indonesian Navy SIGMA 10514 Martadinata-class frigate being delivered under Indonesia's Perusak Kawal Rudal (PKR) programme. (Damen Shipbuilding Group)

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Through this new initiative, Broekhuijsen explained, "We try to 'catch' the vision in narratives that describe the future operational capability.… We are in the process of detailing the roadmaps and technology steps we need to take to introduce this as a future operational concept for the RNLN." The initiative's early phases will explore in a multidisciplinary setting how emerging trends in technology may influence platform designs or RNLN operations, Broekhuijsen added. The

initiative is designed to ensure all stakeholder perspectives are considered, that an open-minded approach is taken to how technologies may shape future operations, and that RNLN doctrine and concepts of operation are adaptable. As the next step, he continued, "We should really prioritise and select the direction we want to pursue."

Steps like 'Dutch Naval Design' are essential to building stakeholder partnership at a national level. Effective and early partnering between customer and supplier is key in delivering flexible capability, said Keulen. "Part of the solution to meeting the non-linear speed of development in a lot of subsystems starts with how you team up from day one with your customer and how you approach the project," he continued. "You should already, upfront, be in a deep dialogue – we sometimes call it common design, where you design in the same room, and in the same environment, with your customer – to fully understand what new developments could be anticipated and how can they be accommodated in the design.

"If you want to go for the best overall solutions – so, not only the investment, but also the operations and the life-cycle cost management – you need to approach from day one, together with the customer and the R&D community, co-development of that project," Keulen explained. "Then, in an open and transparent setting, you can share information and think about future developments.

"You have to be able to understand how an operational concept of tomorrow relates to technological requirements and then to construction of a ship," said Keulen. Recognising how trends in technology translate into operational concepts is the basis for delivering future-proofed projects, he added. "It also impacts how you approach these future-proofed projects, given the fact that trends will speed up, they will accelerate, they will change over time."

Keulen pointed to automation and unmanned systems as primary examples. "You can see already the contours of the development: they will influence the actual platforms in a growing manner."

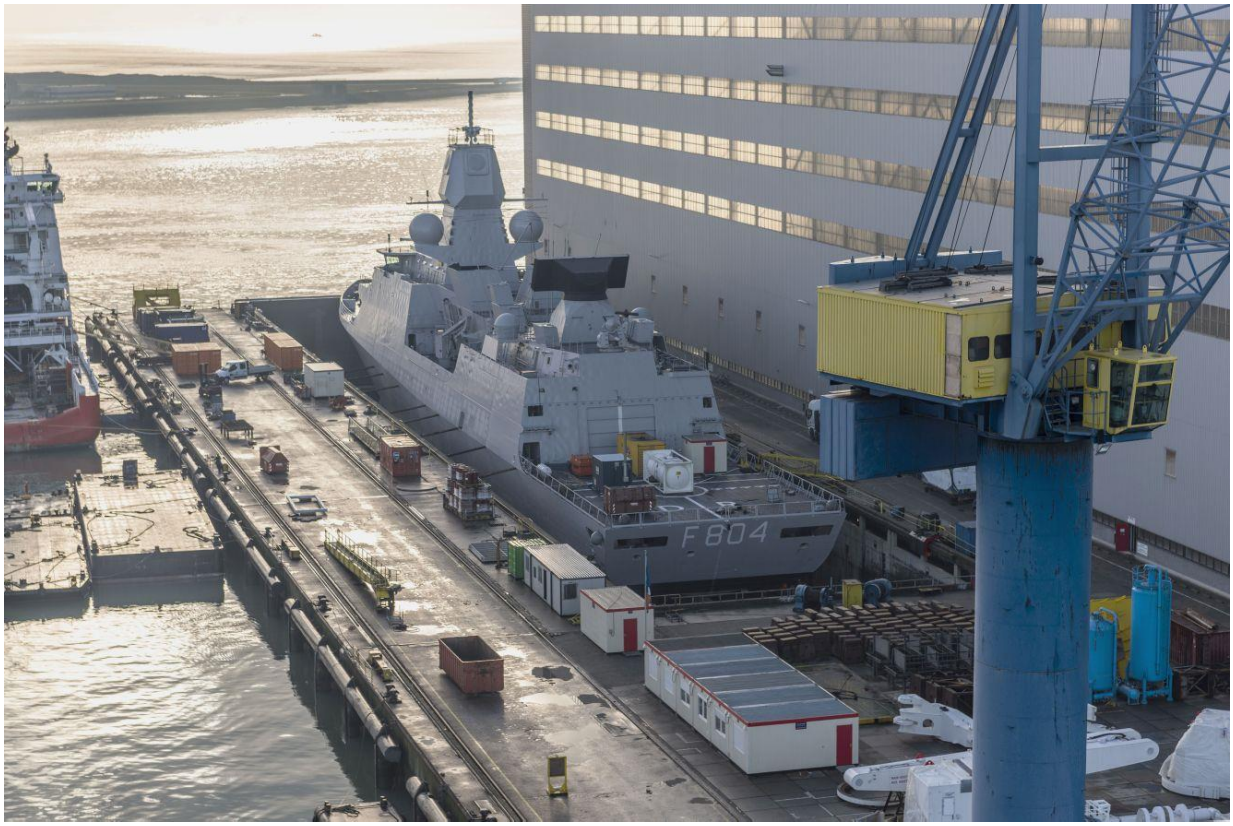
System of systems of systems

Discussing technological trends more broadly, Keulen said "We think future naval ships will be, more than now, 'system of systems of systems'. They will have a growing degree of layers of system dependability."

While automation and unmanned systems will be central in the future capability picture, Damen is open-minded about other system and subsystem capability areas that could have an impact. Nonetheless, the 'system of systems of systems' concept – what the company refers to as 'S3' – encapsulates the overall vision, Broekhuijsen explained. "Future operations will be more a network-type operation, where a 'mothership' operates with 'satellite' [offboard] systems that are manned or unmanned. Together, in the network type of operation, they fulfil the command aim."

In this emerging operational context, Broekhuijsen continued, "The way we see traditional systems engineering could help in figuring out what mix of systems you need for certain types of operations…. We are in the process of deriving the requirements for the subsystems, the unmanned subsystems, that we need in this type of operation and to see what is the best balance between functionalities you have integrated on board a 'mothership' and functionalities you have in a more stand-off situation.

"[The 'S3' approach] is the next level of systems engineering," said Broekhuijsen. In traditional 'system of systems' concepts, the focus fell largely on the ship as a single platform, he explained. "In the future, the ship will not be one ship anymore. It's a networked operation that has all kinds of 'satellite' assets – unmanned and manned systems – surrounding the vessel, in the air, on the water, below the surface.



The RNLN's De Zeven Provinciën-class air-defence and command frigate (LCF) HNLMS De Ruyter in refit at Damen's Vlissingen shipyard. Damen is already assessing how new approaches to matching future technologies to future requirements could apply to a potential replacement platform for LCF. (Damen Shipbuilding Group)

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"The architecture we are developing and implementing for this is called 'model-based systems engineering', when you look at the front end [concept design] of the design cycle," said Broekhuijsen. "Then we introduce 'mission- and model-based systems engineering'. [Here], we try to derive from mission scenarios and wargaming … the functional requirements for such a 'system of systems of systems'.

"The full implementation of this model-based systems engineering, that we are also supporting with software architecture provided by Dassault, allows us to design and apply systems engineering that is supported by models," Broekhuijsen continued. With the models providing a basis for technology and capability evaluation against operational requirements over the platform's predicted life-cycle, such modelling provides the basis for developing platform digital twinning concepts designed to enable programme management and decision support functions, he added.

"So, this is a software-supported architecture that we are currently developing to try to find a good answer to the difficult question – the optimum mix between standardisation and flexibility and the ability to continuously upgrade your asset over its life-cycle," said Broekhuijsen. "You need a good digital representation of it to be able to assess the impact of new technologies and how you can best integrate them. This is a very important innovation direction for us.

"I don't have the full answers yet, but this is an approach we are implementing and is an approach we see as the backbone of future naval ship design," Broekhuijsen added.

Innovation impact

Such thinking is already moving beyond the theoretical, being applied in practice in Damen's yards to ships that are in build, in design, and in planning.

For example, Damen is introducing an integrated approach for optimising the outputs of ship platform and bridge management systems, Broekhuijsen said. In the context of using automation to support improved data processing, Damen has been looking at integrating the traditional data management stovepipes on board warships, namely the platform management, bridge management, and combat management systems. "We will put in an overlay across those stovepipes that allows integration of all the information; we call it an integrated mission management system," Broekhuijsen explained. "On this system, we can introduce new functionalities, so all kinds of decision support functionality in terms of signature management, maintenance management, improved support for the battle damage repair organisation, and other functions." Such an overlay is enabled by increased sensor and computer processing capacity on board. This approach is being introduced in current RNLN programmes, alongside a system for condition monitoring of onboard systems. These approaches help to build a baseline from which future requirements to expand capacity during ship life-cycles can be measured, said Broekhuijsen.

The German Navy's Type 124 Sachsen-class frigate FGS Hessen . Germany and the Netherlands have put in place a strategic partnering agreement to co-operate on future frigate replacement programmes, including for the Type 124 and the Dutch De Zeven Provinciën-class LCF frigate. (Michael Nitz, Naval Press Service)

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Versions of these systems are being designed for the Belgium/Netherlands ASW-F frigate, said Broekhuijsen, and potentially for Germany's F-126 frigate.

Damen is building the future HNLMS *Den Helder* as the RNLN's next CSS, with a build contract signed in February 2020. The CSS programme is acting as a testbed for how Damen enhances the utility of the models it uses for platform design development. Damen uses several different model types: physics-based models of the ship design, data-driven models, and what it terms 'grey box' models – where the physical and data-driven models can be integrated to enhance each other. "This is a continuous cycle, especially when we start collecting data from ships at sea," said Broekhuijsen. "We are starting this process with CSS."

As regards future frigates, following the LOI exchange Germany and the Netherlands have committed to exploring commonality in requirements, concepts, and other areas that may emerge in their future frigate plans. Such strategic-level co-operation could see an industrial partnering arrangement emerge to deliver the platforms. With the Deutsche Marine looking to replace its Type 124 frigates and the RNLN its LCFs, Damen has already begun to assess how new approaches to meeting future requirements and integrating future technologies could be applied.

"We took the approach to think, along with the RNLN, about future air warfare capability and how unmanned systems could influence this, and how we can make such a platform more future-proofed by using the line of thinking of a core platform that has a longer lifetime, and a lot of functionality on board that should be able to be upgraded at a much quicker pace with much shorter system life-cycles," said Broekhuijsen.

"When you look at current [air warfare] capability and some shortfalls we see in effectiveness, and we look at the technological trends that could contribute to the future capability – like unmanned aerial vehicles that carry sensors, giving an over-the-horizon [OTH] capability and much quicker reaction time against an incoming air threat – that is a very important aspect of this future design," Broekhuijsen said. "We are currently investigating what this mix of unmanned systems should look like to be able to give 24/7 OTH coverage." Such thinking includes numbers of systems, and whether such capabilities could support, enable, or even replace manned helicopters as organic aviation.

New technologies can be considered in terms of either their proactive or reactive contributions to operational requirements. In the latter context, anti-air warfare (AAW) warning time and range is likely to be critical in a future complex warship's capability due to emerging air threats like hypersonic weapons, Broekhuijsen said. "We see a new threat of hypervelocity weapons that needs to be countered…. We need earlier reaction time and systems that can provide for that – so, more early detection especially for low-flying incoming missiles that you would detect too late with current systems…. That's something that will change quite drastically the way of operation for AAW."

An artist's impression of a future Royal Swedish Navy (RSwN) A26 diesel-electric submarine at periscope depth. Saab Kockums is building two A26 boats for the RSwN and, in partnership with Damen Naval Division, is bidding a derivative of the A26 design into the competitive tendering process for the Netherlands' future submarine programme. (Saab Kockums)

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Comment

The impact of increasing operational complexity and accelerating technological change over the next half-century is likely to be particularly pronounced in the underwater domain. The Netherlands and Sweden are both procuring new submarines that are planned to be in service across that timeframe. For the Netherlands' future submarine requirement, a downselection from the three bidders – Saab Kockums/Damen, France's Naval Group, and Germany's TKMS – is expected by the end of 2022.

Partnering for future capability

In industrial terms, partnering at national and international levels will be key for Damen in delivering some future capabilities, like unmanned systems. While Damen Naval Division is an original equipment manufacturer (OEM) for complex warships, it is likely that it would seek other OEMs to develop and acquire the unmanned systems required to provide capabilities such as those to be delivered in future complex surface combatants.

"In future naval warship design, part of the functions of the combatant are not on board the 'mothership' but are fulfilled by the unmanned 'satellites' that interoperate with the 'mothership' in the networked operations," said Broekhuijsen. "There are other functionalities you could probably place on board unmanned 'satellite' systems. [One] example would be that they could play a role in providing decoys in AAW scenarios: you don't put the decoy systems on board [the 'mothership']; they are on board unmanned systems." Unmanned systems "could also try to mimic other ships' signatures or could help assess their own ship's signature," he added.

From Damen's perspective, said Broekhuijsen, "We can help set the requirements by understanding the operations. Then, we need partners that have the capabilities we think are needed for the type of operations we foresee…. In terms of range, speed, payloads et cetera, if you use the 'mission/model-based systems engineering' approach, I'm quite sure we will come up with requirements for which there will not be off-the-shelf autonomous systems already on the market," he continued. "So, we will try to find partners and push the development in the direction we think would have the largest operational effect."

The next step in such partnering would be to develop the capability as an 'S3', Broekhuijsen said, assessing the unmanned system's interaction with the 'mothership', including power, spare parts, launch-and-recovery, and other requirements, and then incorporating such requirements into 'mothership' designs.

Saab Kockums' evolutionary approach to standardisation

Other European OEMs are thinking along similar lines to Damen about how to tackle the rapid, non-linear pace of technological change to ensure flexibility and future-proofing in complex warships. One is Sweden's Saab Kockums, which is responsible for delivering the RSwN's future complex warships, including the Visby second-generation (G2) corvettes and the A26 Blekinge-class diesel-electric submarines (SSKs). In the case of submarines, Saab Kockums is partnered with Damen Naval Division in bidding a derivative of the A26 design into the competitive tender process delivering the Netherlands' future submarine.

Like Damen, Saab Kockums views the speed of technological development as driving a degree of flexibility in the long-term projects that deliver complex warships, with such flexibility enabled by modular development and production philosophies. In this context, Saab Kockums sees three factors as enabling its effective introduction of technology into future programmes, Lars Brännström, deputy head and chief marketing officer for Saab Kockums, told *Janes* .

First, he explained, Swedish national naval partnering is based around the 'Triple Helix' concept, with the customer, academic and R&D communities, and industry all "harmonised and working together". Here, established and integrated relationships between stakeholders (including Swedish defence procurement agency FMV) helps, in mid- and long-term projects, "ensure most logical implementation of new technologies, with few surprises" in the process, said Brännström.

Second, he continued, "The constant evolutionary steps taken in enhancing existing [surface vessels and submarines] and new-build platforms using modular designs facilitates future upgrades." Third, to tackle constantly evolving requirements, Saab positions itself as a small but adaptable OEM bringing in-house technological competence relating to critical areas like hull design, sensors, command and control (C2), and particular weapons systems.

Another element of Saab's approach is partnering with like-minded and similar-sized OEMs, including when trying to anticipate and introduce fast-changing technology into current and future designs. "Technical breakthroughs are more and more the result of international synergies," said Brännström. "With Damen, we have common goals and comparable ways of thinking, while at the same time each company has unique core competencies. Combining this expertise in an equal, balanced partnership can improve future designs."

For Saab Kockums, addressing the twin issues of designing and building platforms with flexibility to adapt to technological change while maintaining design standardisation to enable easier technology integration "is definitely a balance, but one does not need to exclude the other", Brännström explained. "We do not disconnect the design part from the building/maintaining part. Effective through-life support is an essential element when we design."

Underlining too the importance of constant evolution, Brännström used the example of the mid-life upgrade (MLU) on the RSwN's A19 Gotland-class SSKs. The first two boats in the three-boat class, HSwMS *Gotland* and HSwMS *Uppland* , have finished MLU work; following Sweden's latest defence bill (announced in December 2020, and covering the 2021–25 period), boat three HSwMS *Halland* will be upgraded. "The engineers working on the original design had secured on the drawing board where major extensions and modifications could be performed, and sourced steel plates for the hull that could sustain treatment such as cutting the boat in two," said Brännström.

In addition, he explained, the Gotland boats were fitted from build with the Mk 3 version of the Stirling air-independent propulsion (AIP) system, a version also retrofitted during MLU to the earlier A17/Södermanland class: the Gotland boats received an improved variant during their own MLU. In turn, the A26s will receive the improved Mk 4 Stirling AIP. The continued evolutionary development of the RSwN's submarine capability demonstrates this theme more broadly, with technologies intended for the A26s being fitted into the A19s, including in the MLU work. "The use of new capabilities in the Gotland class will lead to some early adopted developments for the Blekinge class going forward," Brännström said.

Brännström also pointed to the RSwN's corvette capability. The in-service Visby-class corvettes have been constantly upgraded throughout their service lives, and the product definition phase for their MLU – also announced in the December defence bill, and contracted to Saab Kockums in late January 2021 – "aims to continue that development and make the five ships-in-class operationally relevant beyond 2040", Brännström said. "The same upgradability will be a prerequisite for Visby G2," he said, adding, "The product definition phase begins in 2021." Visby MLU work will be synchronised with Visby G2 development, with lessons learned incorporated in the new design,

said Brännström.