THE
NAVAL ARCHITECT

NOVEMBER/DECEMBER 2025

Gone with the wind

Wind-assisted propulsion enters the next phase

SEA DAGGER DRAWN

Leidos responds to UKCF call for more "lethal, dispersed capability"

ROC STARS

The role of the remote operator comes under academic scrutiny

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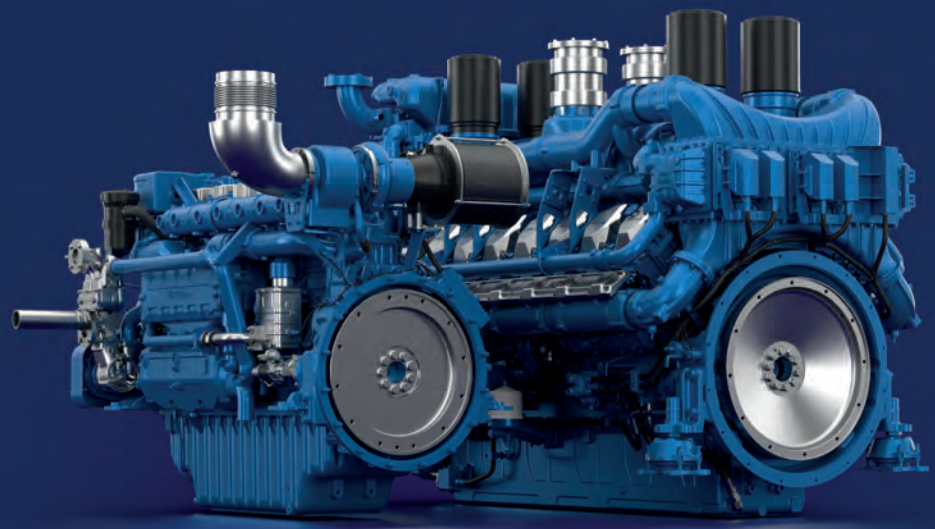

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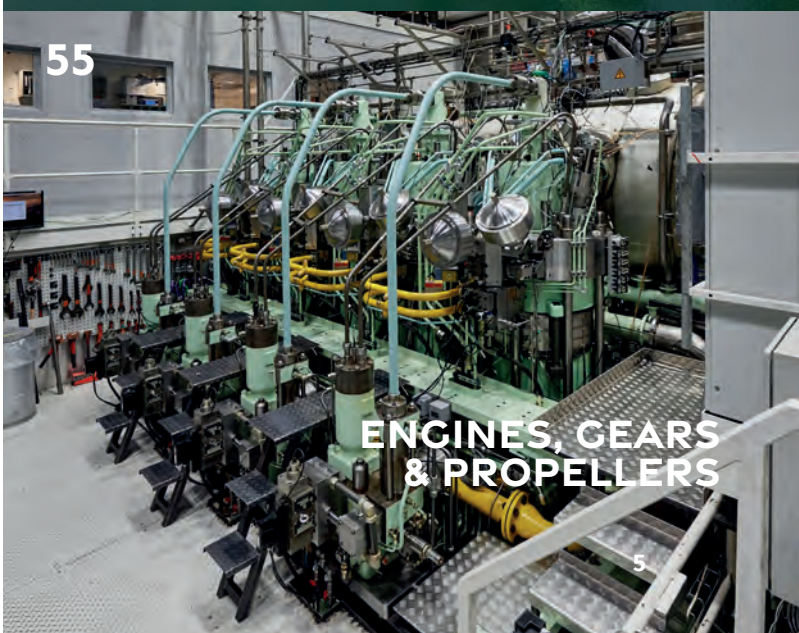

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Wind-assisted propulsion systems came to the fore as a maritime decarb solution this year

2025: GONE WITH THE WIND

There was a fair amount of upheaval in 2025, especially in the offshore wind sector, where a combination of supply-chain bottlenecks, high interest rates and escalating costs – plus the US Government's retreat from new offshore wind leasing – scared off some investors.

However, as the fixed offshore wind segment rolls with the blows, the floating wind turbine has been slowly but steadily evolving, with new floating platforms and substructures tailored for 15MW+ turbines now advancing to the next stage of deployment. As our feature on pages 44-47 highlights, the fixed-wind sector may not be mobbed by investors quite yet, but is certainly making a good business case for itself. The ability to deploy floating wind turbines in deeper waters, further offshore, means access to higher average wind speeds (potentially 30-50% higher at good sites); much less seabed disturbance (only using mooring lines and anchors, not massive monopiles and jackets); and reduced visual impact from shore (something that famously irked the current POTUS, as well as more than a few coastal communities).

In terms of leaps and bounds, nuclear power, as enabled by small modular reactors, and wind-assisted propulsion systems (WAPS) really came to the fore this year, making it into most panel debates and roundtables focused on maritime decarbonisation. While partly down to the pioneering, dogged work of groups like the International Windship Association (IWSA) and the many advocates of wind-capture technology, Norsepower's Ville Paakkari hits the nail on the head (see pages 48-49) when he points out that these advances take time, and that now, with more vessels adopting WAPS, "shipowners are becoming more used to the concept and understanding it better, which is building up their confidence in this technology". One doesn't just develop a new technology and apply it to everyday operations: the first applications are usually an integral part of the development process, shaping the further evolution and refinement of the technology.

There's also the fact that WAPS doesn't preclude vessels from switching to (currently expensive) green fuels later, making them something of an ideal 'drop in' solution until alt-fuel prices come down and availability increases. Which bring us to another key benefit of WAPS (and possibly a growing trend for 2026?): by putting wind sails on just a few ships, a company can create extra green credits and share them with its other ships through FuelEU Maritime pooling, enabling the whole fleet to meet the rules without fines, and without the need for wind sail installations or green fuel storage on every ship. ■

Martin Conway,
Managing Editor

TUGS

SANMAR SISTERS BOUND FOR BAHRAIN

Turkish shipbuilder Sanmar has delivered a pair of azimuth tractor tugs to global operator Svitzer, with both vessels intended for operations in Bahrain. The duo, christened *Svitzer Manama* and *Svitzer Awal*, has been based on the TRAktor-Z 2500SX design, supplied exclusively to Sanmar by Canadian naval architect Robert Allan Ltd (RAL).

Each sister features an overall length of 25.3m, a moulded beam of 12m, a moulded depth of 4.45m and an extreme draught of approximately 6.55m. The sisters are equipped with twin Z-drive propellers, chosen to facilitate harbour shiphandling work and towing duties, and each tug has a minimum bollard pull of 80tonnes and a free-running speed of 12.5knots.

Sanmar states: "Both vessels are also equipped with FiFi 1 systems, further enhancing their operational capabilities and safety performance. They benefit from being efficient, highly controllable and manoeuvrable due to a modern hullform and appendage configuration, which is the result of significant effort in model testing and computer-based CFD optimisation during the design process."

The pair are not the only recent Sanmar deliveries to Svitzer; in September, Queen Mary of Denmark named the 25.4m x 12.7m electric tug *Svitzer Ingrid*, which was built by to the specs of RAL's ElectRA 2500SX design – featuring a 1,808kWh onboard battery system and a bollard pull of 70tonnes. ■

TRAktor-Z 2500SX tugs *Svitzer Manama* and *Svitzer Awal* were designed exclusively for Sanmar by Robert Allan Ltd

PATROL AND RESCUE BOATS

GAVILÁN I IN LINE TO FIGHT CRIME

The Rodman Polyboats yard in Spain has delivered a new coastal patrol boat to the State Tax Administration Agency, the body responsible for countering organised crime, money laundering and drug trafficking both on land and in Spanish waters.

The newbuild, *Gavilán I*, is a Rodman 33-class patrol boat constructed by Rodman's facility in Moaña, and now stationed in Muros Bay, in the province of A Coruña. Fashioned from a mix of glass-reinforced plastic (GRP) and composites, the vessel features a length of 11.4m (overall), a maximum beam of 3.4m and a maximum draught of 0.75m. The boat has been designed for up to four crew members, and particularly for missions in bays and river mouths.

Gavilán I is equipped with two Mercury F350 four-stroke outboards, each delivering an output of 350hp (261kW), and this set-up permits a maximum speed surpassing 40knots. The Rodman 33 also features an onboard fuel capacity of 800litres and a fresh water capacity of 50litres, and its range exceeds 150nm, Rodman Polyships adds. ■

***Gavilán I* is equipped with two Mercury F350 four-stroke outboards, enabling a top speed of more than 40knots**

CONTAINER VESSELS

DNV GREEN LIGHTS NUCLEAR CONTAINER CARRIER

Geir Dugstad, DNV technical director (left) and Sungkon Han, senior VP, HD KSOE, pictured at the nuclear containership AiP ceremony

A nuclear container vessel concept developed by HD Korea Shipbuilding & Offshore Engineering (HD KSOE) has secured approval in principle (AiP) from classification society DNV. The 15,000teu vessel is intended to run on small modular reactor (SMR) technology, combined with a supercritical CO_2-based power generation system – the latter selected for higher thermal efficiency and a more compact equipment footprint compared with conventional steam-based systems, DNV says.

With this set-up, the containership would be able to operate at 24knots. The vessel design was unveiled in Q1 this year, offering more space for the carriage of containers by removing traditional engine room gear, and securing AiP from US class society ABS.

In May this year, DNV jointly conducted a hazard identification (HAZID) workshop with HD KSOE to assess accident scenarios and potential risks for nuclear-powered ships. DNV says it has also reviewed the ship concept in line with the requirements specified by SOLAS Chapter VIII and the IMO Code of Safety for Nuclear Merchant Ships.

Dr Kwangpil Chang, CTO of HD KSOE, says: "In addition, we have developed a novel shielding and containment system, designed to maintain reactor safety and vessel survivability even in the event of collisions, groundings or sinking accidents." Geir Dugstad, DNV technical director, adds: "With little recent experience in utilising nuclear power for cargo vessels, this AiP represents an important first step in building the technical verification process for nuclear-powered vessels." ■

PATROL AND RESCUE BOATS

FOUR FAST-RESPONSE BOATS FOR NORWEGIAN CUSTOMS

Viking Life-Saving Equipment has been contracted to supply four Norsafe-branded patrol and fast-response craft to the Norwegian Customs Service (aka Tolletaten), for law enforcement and inspection duties within Norwegian waters.

The order includes three Munin S-1400 units, each featuring a maximum length of 15.42m and a height of 3.48m, and powered by triple 500hp (373kW) Mercury outboards. The fourth boat is a Marathon S-900 craft, measuring 9.66m in max length and powered by twin 350hp (261kW) Mercury outboards. Both the Marathon and Munin types feature shock-mitigation technology and flexible deck layouts for personnel protection, as well as a lightship weight of 10.5tonnes, a fully-laden weight of 14tonnes and the capacity to carry up to 14 persons.

All four boats will be constructed at Viking's production facilities in Arendal, Norway, with deliveries scheduled to run between 2026 and 2027. The contract has been valued at NOK 43 million (US$4.3 million) and includes an option for additional vessels. ■

Tolletaten's Viking Life-Saving Equipment order includes three Munin S-1400 patrol/response boats (image: Tolletaten)

SAFETY

ENCLOSED-SPACE SAFETY SURVEY OPEN TO SEAFARERS

InterManager, the international trade association for ship managers, has invited seafarers to complete an online survey focused on enclosed-space safety, as part of a broader effort to understand how related incidents, injuries and fatalities continue to occur in these onboard tight spots "despite decades of safety campaigns and regulatory updates", the association says.

Captain Kuba Szymanski, InterManager: "Despite the rules, people are still dying in confined spaces at sea"

The survey was developed in partnership with The Nautical Institute and IMarEST. InterManager notes that, despite IMO attempts to beef up safety measures – including the mandating of space-specific registers for trained crew – 34 enclosed-space incident-related deaths were recorded in 2023 alone, "almost double the number recorded in 2022", InterManager says. The leading cause of death remains oxygen depletion, usually caused by poor ventilation, and most fatalities continue to occur in cargo holds or access areas. "Bulk carriers account for around 41% of all enclosed-space incidents," the association adds.

Captain Kuba Szymanski, InterManager secretary general, says: "Despite the rules, people are still dying in confined spaces at sea. IMO has now strengthened its rulings, but we need to hear from those on the frontline to understand what's really happening on board." The anonymous survey can be accessed at https://www.surveymonkey.com/r/enclosed_space and will be open to seafarer respondents until the end of 2025.

SUPERYACHTS AND MEGAYACHTS

'ELF' AND EFFICIENCY

German Naval Yards, a subsidiary of CMN Naval, reports that it has signed an agreement to complete the construction of the megayacht 'Project ELF'. The 4,950gt vessel was designed by Netherlands-headquartered Azure Yacht Design & Naval Architecture, with US design studio Pindaros handling the exterior and interior design, assisted by Andy Waugh Yacht Design and architect Laurent Champeau respectively.

'Project ELF' measures 114m in length and 15.8m in beam, and has been designed to draw 3.85m. The vessel can accommodate up to 18 guests, housed across seven staterooms, plus up to 39 crew members. The vessel's signature features include a 20m pool on the main aft deck, German Naval Yards says, plus a gym, a spa and a helipad capable of landing an H135 helicopter.

More bespoke design elements will be announced as construction progresses at the company's facility in Kiel, the builder adds.

Upon handover, scheduled for 2028, the megayacht is expected to deliver a range of 5,000nm at 12knots.

The 114m 'Project ELF' is scheduled for delivery in 2028

OBITUARY

JONATHAN DAVID MORLEY: 10 AUGUST 1958 – 15 SEPTEMBER 2025

Jonathan David Morley, a fellow of RINA, CILT, IMarEST, CIWEM and SNAME, passed away suddenly on 15 September when he was just about to complete another cross-country walk from West to East coast, UK – a pastime that gave him great joy.

After graduating with a BSc (Hons) in Naval Architecture and Shipbuilding from the University of Newcastle upon Tyne, Jonathan joined Lloyd's Register (LR) on a UK graduate training scheme in 1981. He spent time on new construction and existing ship work in Liverpool, Newcastle and Sunderland, and later surveys based from London.

He joined the LR Pollution Section in London one week before MARPOL 73/78 Annex I came into force in September 1983, and the

Jonathan David Morley served as president of the RINA London Branch

LR Chemical Section in May 1987 just after MARPOL 73/78 Annex II came into force. He became the lead specialist working on MARPOL, chemical and gas codes at LR and worked continually for LR throughout his career for 43 years until retirement in 2023. His vast experience with MARPOL led to many sessions at the IMO on various pollution aspects.

From 2000-2005, he was the honorary secretary of the RINA London Branch; then, from 2005-2011, president of the RINA London Branch; and then, since 2011, vice president. From 2017, Jonathan was a member of the RINA Maritime Environment Committee, and, from 2019, vice chairman of the RINA Maritime Environment Committee.

Jonathan is survived by his wife Christine, daughters Heather and Sarah, and a recently added grandchild. ■

WATERJETS

WATERJET RETROFITS FOR KUWAIT COAST GUARD

Kongsberg Maritime has been contracted to upgrade the waterjet propulsion systems aboard 13 vessels operated by the Kuwait Coast Guard, working in partnership with shipbuilding and repair specialist Abu Dhabi Ship Building (ADSB).

The contract will see ADSB install Kongsberg Kamewa waterjets across the fleet, replacing existing third-party systems on 10 vessels and retrofitting three others. The 13 shipsets will comprise stainless-steel S63-4 waterjets, jet control systems and powerpacks. The systems will be installed between Q1 2026 and Q1 2027.

ADSB will install 13 shipsets for the Kuwait Coast Guard, including Kongsberg Kamewa S63-4 waterjets

Kongsberg Maritime says that the order was placed as part of the Kuwait Coast Guard fleet's "mid-life upgrade", currently taking place at ADSB, adding: "This project is expected to unlock new opportunities for Kongsberg Maritime in the Gulf Cooperation Council [GCC] defence market, particularly as ADSB expands its footprint in naval newbuilds and strategic partnerships." Jouni Raatikainen, EVP for global customer support, Kongsberg Maritime, comments: "By working closely with both ADSB and the end customer from the outset, we were able to present a compelling solution that goes beyond equipment supply, offering long-term value, performance enhancement and full lifecycle support." ■

CAMERAS AND IMAGING

NEW LONG-RANGE MODELS FROM FLIR

FLIR has launched its M460 and M560 AI-powered, multi-spectral camera systems for ships and boats. The 4k cameras incorporate FLIR's AI Target Tracking technology, developed to automatically identify and classify objects in the water, including human casualties, buoys and other vessels.

"Once an object is selected, the camera intelligently tracks the target with dynamic pan and tilt control, maintaining precision even in rough seas [and] crowded waterways or during high-speed manoeuvres," FLIR says. The M460 and M560 also feature a three-axis gyrostabilisation system, which compensates for pitch, roll and yaw to produce smooth, long-range image quality.

The M460 uses a long-wave infrared thermal sensor, equipped with a 5x optical zoom lens, while the M560 uses a mid-wave infrared thermal sensor with a 14x optical zoom lens. Both models also come with an integrated tight-beam laser spotlight, capable of illuminating objects up to 1km away, and an ITAR-free (meaning it can be exported from the US without a special licence) laser rangefinder. "Models with the rangefinder will offer an effective range up to 6.5nm," FLIR says. ■

The FLIR M460 and M560 both feature a three-axis gyrostabilisation system

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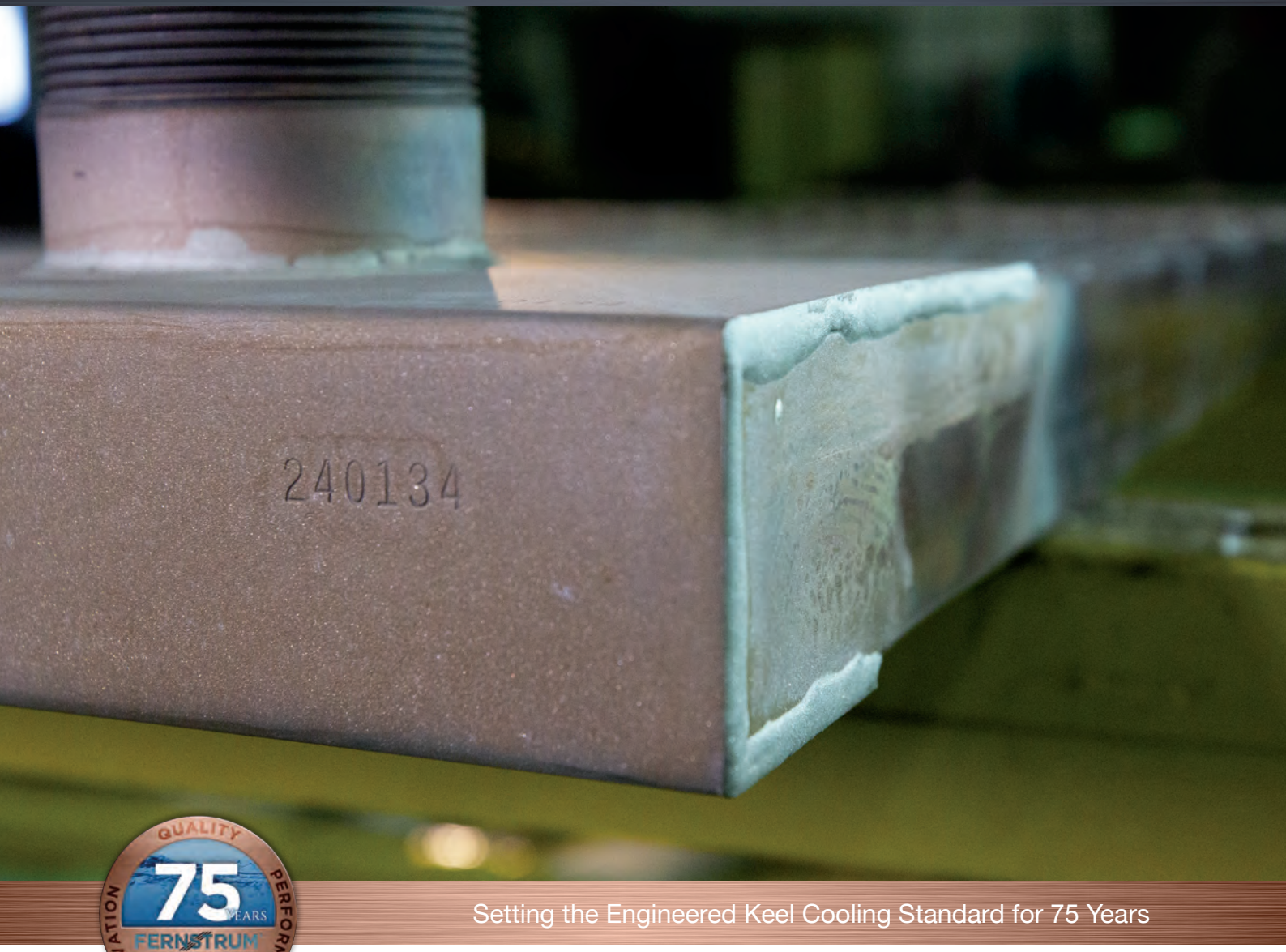

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SAFETY AND SECURITY

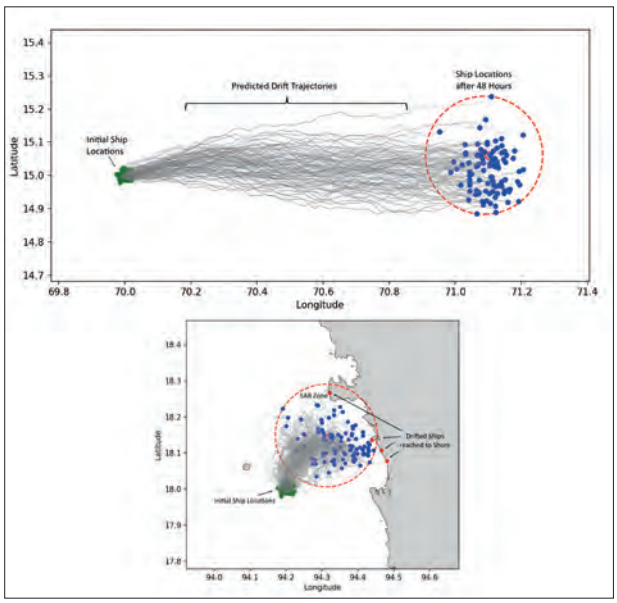
IRS PREDICTIVE TOOL GETS THE DRIFT

The Indian Register of Shipping (IRS) has launched its Ship Drift Trajectory Prediction Service, a computer program-backed tool designed to predict the drift of vessels that have lost propulsive power.

The solution uses the computer program to simulate vessel trajectories based on real-time environmental data, such as wind, current and waves. The idea is that these forecasts then enable emergency response teams and maritime authorities to plan their response with greater precision and speed, and that the system helps to prevent groundings and collision with coastal (or offshore) infrastructures and other vessels by allowing rerouting and proactive interventions.

The programme was developed in partnership with the Indian Institute of Technology Bombay (IIT Bombay). P.K. Mishra, MD of IRS, comments: "As maritime traffic and offshore developments continue to grow, accurate drift trajectory prediction becomes essential for safeguarding lives, assets and infrastructure. This new service empowers response teams to forecast vessel drift based on real-time environmental conditions."

Reported features include a simple, intuitive dashboard for extraction of simulation results, plus built-in post-processing tools that generate visualisation videos of drift paths for analysis. ■



IRS' Ship Drift Trajectory Prediction Service is designed to help prevent groundings and collisions for ships that have lost power

WIND-ASSISTED PROPULSION

WIND-ASSIST UPGRADE FOR BULKER COLOSSUS

Anemoi Marine Technologies has installed five of its Rotor Sails on the very large ore carrier *NSU TUBARAO*, owned by NS United (NSU) Kaiun Kaisha, Ltd of Japan, and chartered by mining company Vale International. The vessel, delivered in September 2020, is one of the largest bulkers in the world, featuring a length of 361m, a beam of 65m and a deadweight tonnage of just under 400,000dwt.

The five Rotor Sails, each of which measures 35m in height and 5m in diameter, are expected to help reduce *NSU TUBARAO*'s annual fuel consumption by approximately 6-12%. The Rotor Sails were also installed with a tilting mechanism, for greater flexibility during cargo handling. Installation was completed during scheduled drydocking at Zhousan Xinya Shipyard, China, where the ship also received a new shaft generator, subsequently integrated with the Rotor Sails through an advanced control system.

Five Anemoi Rotor Sails were installed on the five-year-old *NSU TUBARAO*

Toru Fukita, director and managing executive officer of NSU, says: "We aim to support our stakeholders with the world's most efficient ships. The Rotor Sails on *NSU TUBARAO*, and the advanced systems that will help maximise its fuel-saving potential, are a perfect example of those efforts." ■

ROVS AND AUVS

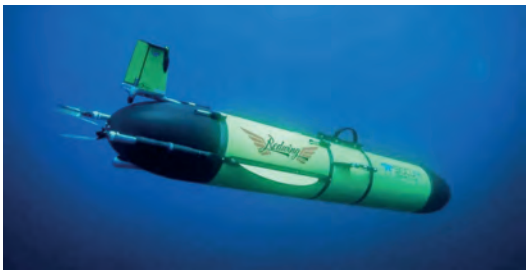
SENTINEL REDWING EMBARKS ON ROUND THE WORLD TRIP

AUV developer Teledyne Marine and Rutgers University, New Jersey have deployed a next-gen version of Teledyne's Slocum Sentinel Glider, rebranded the Sentinel Redwing, on a mission to circumnavigate the globe. The Sentinel Mission, hailed as a "world first", will see the drone undertake the 73,000km journey over the course of five years, starting and ending in Massachusetts and incorporating several legs.

During its trip, the Sentinel Redwing will gather data related to ocean currents and sea temperature. When the glider surfaces every eight to 12 hours, it will send this data, via satellite and in real time, over the National Oceanic and Atmospheric Administration's (NOAA's) global monitoring system. "This data is intended to help refine weather models, improve hurricane intensity forecasting and inform ocean policy and conservation efforts," Teledyne says.

The Sentinel Redwing measures 2.57m in length and 330mm in diameter, and has a sensor payload capacity of up to 3.5kg. The AUV can dive down to 1,000m and uses gravity and buoyancy to propel itself forwards at an average speed of 0.75-1knots. Rutgers University students helped to programme the Sentinel Redwing's navigation software.

The 'Redwing' is an acronym for 'Research & Education Doug Webb Inter-National Glider', so named in honour of Teledyne Webb Research glider inventor Doug Webb, who died last year. ■



The Sentinel Redwing will circumnavigate the globe over the course of five years

NAVAL AND DEFENCE

CRY HAVOC AND LET SLIP THE DRONES OF WAR

Louisiana-based boatbuilder Metal Shark has agreed a strategic partnership with HavocAI, a Rhode Island-based defence technology start-up specialising in AI-driven maritime autonomy solutions, previously deployed with both the US Navy and US Army. The deal will see Metal Shark integrate these solutions across its existing fleet of high-speed manoeuvrable USVs, to enable "unprecedented interoperability and lethality through autonomous, intelligent boat swarms that overwhelm adversaries", the builder states.

Metal Shark adds that it has secured contracts worth "hundreds of millions of dollars" to construct patrol boats for the US Navy, the US Coast Guard and the US Marine Corps, as well as for non-US militaries and first responder organisations. The builder is currently working on the US Navy's next-gen 40' Patrol Boat (40 PB) combatant craft – a twin-screw model with a sprint speed of more than 35knots – plus 26m-long, near-coastal patrol vessels for the same client.

HavocAI CEO Paul Lwin comments: "We're demonstrating that real autonomy is available right now for existing warfighting platforms. Metal Shark's track record of delivering thousands of reliable vessels to military and commercial operators worldwide makes them the ideal partner." ■

Metal Shark will integrate HavocAI's solutions across its fleet of high-speed manoeuvrable USVs

THE ROLE OF THE REMOTE OPERATOR

Remote vessel operations still require regulatory clarity, but also an assessment of the remote operator's education and nautical experience

This is a significantly edited version of the paper 'The Role Of The Remote Operator', presented at the RINA Autonomous Ships 2024 conference in Copenhagen, and authored by C. Plawenn-Salvini, University of Applied Sciences Emden-Leer, Germany, and O. T. Gudmestad, Western Norway University of Applied Science, Haugesund Branch, and UiT, The Arctic University of Norway, Tromsø, Norway.

In the last decade, numerous Maritime Autonomous Surface Ship (MASS) concepts have emerged. However, the maritime industry is heavily regulated, and the different players designing the rules do not follow a unified approach to defining autonomy and the degrees thereof. Table 1 gives an overview of some noteworthy definitions regarding maritime autonomy.

In 2017, IMO initiated a regulatory scoping exercise, as there was a complete lack of a regulatory framework for MASS. In 2021, the results were presented to the Maritime Safety Committee at its 103rd session. Four degrees of autonomy were defined:

- Degree One: a fully manned ship with systems supporting the mariner with automated processes
- Degree Two: a ship with seafarers on board who are ready to take over the remote-controlled operation
- Degree Three: a fully remotely controlled ship with no seafarers aboard
- Degree Four: a completely autonomous ship that does not require human intervention (IMO, 2021)

This definition of autonomy is vague and imprecise. For example, there is no further description of remote control and what this entails.

Class definitions of autonomy

Even before IMO's efforts, Lloyd's Register came up with a designation of seven autonomy levels (ALs) for cyber-enabled ships (Lloyd's Register, 2016):

AL 0 Manual; describes full manual control of the ship;
AL 1 On-ship decision support. The ship is still considered to be fully manned, but with a designated support tool available;
AL 2 On and off-ship decision support, including a decision support tool that offers decision options to the seafarer on board;
AL 3 'Active' human in the loop, describes a system of mere human supervision, critical situations are presented in a manner that provides easy intervention. There is no mention of whether the human is on board or ashore;
AL 4 Human in the loop still describes a system with human supervision and the possibility for intervention in critical situations;
AL 5 Fully autonomous; describes a non- or seldom-supervised operation where the system can make decisions independently;
AL 6 Fully autonomous, is a completely unsupervised system that makes autonomous decisions.

Table 1: Definitions and foci of autonomy levels

Body	Levels	Focus
IMO	4	Manning level
Lloyd's Register	7	Human involvement depends on the technical system
DNV GL	5	Human involvement in the decision process
Bureau Veritas	4+4+4	Degrees of automation, direct -, and remote control
ClassNK	4+3+2	Extent of tasks a computerised system is taking on, the means of operation, and the location of the operator
ABS	3	Smart-to-autonomy
ISO	4	Operator control modes centred around the operational envelope
NFAS	4+4	Definition of the manning level and the operational approach. Goes on to fragment aspects of automatic and manual operation
Rødseth and Wennersberg	3	Cooperation modes between the operator and automation

Co-author Ove T. Gudmestad: "Legislative issues restrict the full potential of autonomous shipping"

DNV, on the other hand, based its first attempt to describe levels of autonomy on the automotive industry. The description ranges from manual operation via decision support functionalities, with or without the option of the system executing the decision by itself, to a system that operates with an operator in the loop but can act independently. Further, it mentions the possibility of the system acting by itself without human interference (DNV GL, 2018).

Bureau Veritas focuses its description of degrees of automation (A) more on humans. This ranges from human operated (A0), human directed (A1), human delegated (A2) and human supervised (A3), to an automated system that requires intervention only in emergencies (A4). Further, Bureau Veritas describes four levels of direct control (DC), from DC0 (no direct control) via DC1 (available direct control) and DC2 (discontinuous direct control), to DC3 (full direct control) where the crew on board does not rely on external intervention (Bureau Veritas, 2019).

ABS describes three levels:

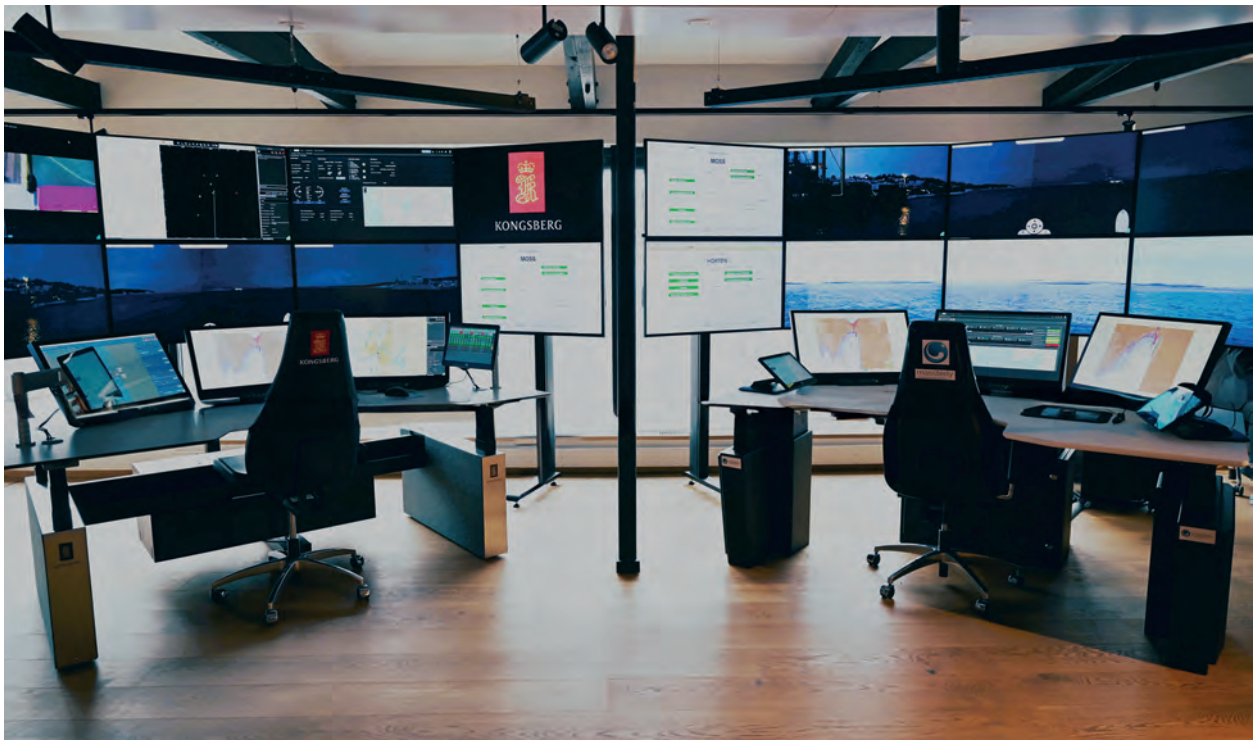
- Smart: a human carries out all functions and is augmented by the system;
- Semi-autonomy: the system carries out functions but is augmented by a human;
- Full autonomy: the system carries out all functions by itself, and the human only takes a supervisory role with the option of interference (ABS, 2024).

Academic criticisms

The International Organization for Standardization's (ISO) definition for autonomous ships goes from 'operator exclusive', where the operator is not further defined as being on board or ashore, to 'operator and automation combined', explicitly mentioning the crew but not detailing whether this is meant for crew ashore or on board. Further, it mentions autonomous control and full autonomy (ISO, 2021).

Another noteworthy approach was presented by the Norwegian Forum for Autonomous Ships (NFAS), which made a clear distinction between the MASS and the operational autonomy levels. Regarding autonomous systems, the NFAS describes four MASS classes: a continuously manned bridge; a periodically unmanned bridge; a periodically unmanned ship; and a continuously unmanned ship. In the operational approach, a differentiation is made between decision support,

"The RO and the OOW must conduct a detailed handover before the controls may be passed between the ROC and the shipboard crew" (image: Kongsberg Maritime)



Co-author Clemens Plawenn-Salvini: "Nautical experience is needed" in the ROC

automatic, constrained autonomous, and fully autonomous (Rødseth & Nordahl, 2017).

Both the NFAS and the ISO mention the operational envelope (OE). The ISO brings forth the idea of the OE, which may be tied to individual phases of a ship's transit, as the operation of a vessel differs significantly throughout a voyage (eg, manoeuvring in port vs sailing in open waters). However, instead of making the approach goal-based, the document ISO/TS 23860:2021 (E) states a need for defining control tasks; both the ones performed by a human and the ones performed by the system (ISO, 2021). Rødseth and Wennersberg (2023) try to define "areas of responsibility" of humans and the automation being in control of a ship, and thereby disagree with the IMO's and class societies' approach of defining autonomy through manning levels and system requirements. Instead, they discuss three cooperation modes between the operator and the vessel:

- OE (operator exclusive): the vessel is operating outside its operational design domain (ODD), and the system functions may support the human in control.
- OA (operator-assisted): a state where the vessel is within its ODD, but the system cannot operate in its constrained autonomy domain, so the human's continuous attention is required.
- CA (constrained autonomous): the system is fully in control, and the human will be alerted if required.

It is important to stress that Rødseth and Wennersberg do not consider it relevant whether the human is on board the vessel or ashore in the ROC, as they deem it secondary to the definition of autonomy.

Remote operations modes

To reduce the dependence of humans on the bridge, much research on ship collision avoidance systems has been conducted. These systems are being developed for application both on board by the ship's crew and in the ROC. The adoption of these systems will, however, significantly differ whether used during direct control or when monitoring. Considering the cooperation of humans and automation, Endsley describes the difference between parallel and serial systems (Endsley, 2016). When the operator or the officer of the watch (OOW) is in charge, working with automation, both evaluate the situation and identify a risk of collision or other situations requiring action, making the final decision jointly. But when an RO monitors multiple vessels, the automation makes decisions that may be reviewed and revised by humans, making it a serial system. There is a big difference between the direct control of a ship, be it onboard or from ashore, working with a collision avoidance system, and an RO in the ROC making use of the automation.

Instead of describing theoretical approaches, a series of qualitative interviews was conducted with some of the leading players in certification, training personnel and management of remotely operated/potentially autonomous vehicles. The goal was to get a clear picture of the role of the RO, as we understand it today. When considering the RO's role, it turns out that regardless of the definition of the levels or degrees of autonomy of a system, one of the following three modes of remote operations will apply:

- Supervision of autonomous systems
- Remote control of vessels
- Remote navigation support

The RO must be able to quickly go from one mode to another, as the situation requires.

Differences in RO modes

Table 2 gives a short overview of the responsibilities in the different modes of remote operations.

a) Supervision of autonomous systems

Vessels departing, transiting and docking by themselves is an intriguing idea, but for the

Table 2: Modes of remote operations

Mode of operation	RO's role	Ship's role	Responsibility
Supervision of autonomous systems	Observing one or more ships	System operating autonomously	RO
Remote control of vessels	Manoeuvring the ship from afar	Executing commands from the ROC	RO
Remote navigation support	Supplementing the bridge team	Manual navigation	OOW

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THE ROYAL INSTITUTION OF NAVAL ARCHITECTS

time being, someone will have to monitor and control them. These supervised vessels are supposed to run on routes defined by the RO, be capable of acting according to the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) (Lazarowska, 2024), and manoeuvre in port.

The RO must keep an eye on multiple vessels simultaneously. One company is talking about one operator supervising five vessels; another would like to go up to as many as eight. However, they agree that only time and the level and reliability of the autonomy will give a clear picture of the true capabilities.

It is the RO's duty to recognise situations that require human interference and to troubleshoot in case of failure or breakdown. Correctly identifying situations when intervention is required demands focus and immersion into different situations simultaneously. Therefore, time in the chair while observing a number, n, of vessels, must be heavily limited. Supervision of autonomous systems is always done in teams; for now, it is assumed that a team consists of two ROs and one remote engineer (RE). Repeatedly rotating the two ROs in a shift ensures that the immersion-heavy nautical situational awareness is limited in time; otherwise, the attention will degrade quickly (Endsley, 2016). If a situation requires more focus from the RO, there will always be a second person who can supervise the n-1 remaining vessels.

b) Remote control of vessels

Remote control of vessels is the direct control over a ship from a ROC. This kind of operation is common practice for USVs, primarily used for underwater surveys. Operation of such vessels falls under national legislation, which is easier to change and adapt compared to IMO rules. The same applies to inland waterways, where cargo vessels are already being remotely controlled.

In recent years, this method has seen expansion in Europe. One operator exclusively handles one vessel at a time. This approach may also be used at sea temporarily, when in low-traffic areas, to reduce work hours for the onboard crew, or when there are not sufficient navigators onboard to operate on a 24/7 basis, but there is no sophisticated autonomous system in place. The RO and the OOW must conduct a detailed handover before the controls may be passed between the ROC and the shipboard crew. Remote control of vessels might also be used when the bridge crew is engaged with other duties.

c) Remote navigation support

Remote navigation support refers to operations with a manned bridge, where the RO assists the OOW remotely from ashore. This person logs onto a bridge, accesses relevant navigation instruments and uses cameras and sensors. A company following this remote navigation support approach stated that these duties are still fulfilled mostly by senior nautical officers. The reason is that the technology may be updated, and processes and features can be optimised; thus, nautical experience is needed. Another benefit is that they are using the captains of their fleet in the ROC – they will spend some time in the operator's chair and then return to their deployment at sea. This approach builds trust in the ROC and the RO but also allows the mariner to see both sides of the operation – and this knowledge can, in turn, be used to update the system.

Commonalities

Presently, companies operate in one mode or another, but there is potential to vary a vessel's mode of operation repeatedly. An example may be a ship departing under manual control, and an OOW taking the navigational watch alone on the bridge. Due to darkness, restricted visibility or density of traffic, he may ask for remote navigation support. When the lookout is no longer needed, he relieves the remote support navigator of his duties. Later, during the deep-sea passage, he switches the system to autonomous with appropriate supervision. When active intervention is needed, the RO can switch from supervision to remote control immediately.

One challenge for the RO is the flow of information. Modern vessels are equipped with sensors that produce a quantity of alarms, which is difficult to manage. The flood of alarms is already an issue on conventionally crewed vessels (Nepal & Gudmestad, 2022); if the same continues in the ROCs, it will be almost impossible to maintain situational awareness for a remote-controlled ship, not to mention several supervised autonomous vessels.

As we are moving away from IMO's rigid four degrees of MASS definition and are looking at more flexible and individual solutions, familiarisation with the vessels needs to remain a high priority. This can be done by spending time on board, if there is still crew accommodation available, by just visiting the vessel or with virtual reality (VR), which offers a complete walk-through of vessels, including the lifesaving appliances.

Expectations regarding the RO

When the vessels are behaving as they should during autonomous operations, one person in the RO team will have time available apart from their main task (ie, monitoring the vessel's safe transit).

Operating a vessel entails much more than just bringing her from A to B. Routes must be planned thoroughly and may need adjusting according to meteorological conditions. Passage-planning duties can be managed by the RO, not necessarily only for the vessel under one's immediate care, but also for any vessel within the fleet.

Further, the responsibilities of the RO entail planning and conducting maintenance, scheduling services, organising the renewal of certificates and ensuring that the vessel is in good working condition. The advantage of the RO taking over these duties is that they are in a hybrid position of ship and shore, effectively making the interaction between the officer and the vessel manager or superintendent obsolete and challenging the classical hierarchy of a shipping company.

RO requirements

Summarising the competencies required for the RO, according to the result of the conducted interviews, provides us with the following list:

- A basic understanding of vessels can be accomplished through familiarisation in conjunction with onboard experience. The practical training will help to build trust with the crew still on board, and will avoid detachment from the vessel when making manoeuvres. The first author has frequently observed nautical students, without previous bridge experience, making unnecessarily hard manoeuvres in simulator training. In real life, this is not only uncomfortable for persons on board but may be dangerous to the ship and cargo.
- Shiphandling, at least to a limited extent, as the amount of direct control will be limited. Whether the current approach of only dedicating waypoints prevails remains to be seen. Alternative solutions could be joystick control or a limited range of emergency manoeuvre options.
- Sensor fusion is performed by autonomous systems, meaning that the information from different sensors is overlaid and combined. A thorough understanding of the different systems and their limitations is key to a correct interpretation of the displayed data.
- Situational awareness is the cornerstone of making autonomous shipping work, requiring an understanding of the abovementioned sensor fusion and extensive simulator-based training.
- Coordination of traffic situations is essential for maintaining situational awareness of multiple vessels simultaneously.
- Familiarisation with the trading area needs to be addressed, including knowledge of local navigational hazards, expected traffic and surrounding conditions.
- COLREGs and national rules must be adhered to.
- Route planning may be conducted by ROs when not directly engaged in navigation or supervision.
- Resilience and emergency response training must be part of both the education and regular contingency training.
- Cybersecurity threat recognition and response need to be schooled, trained and updated regularly.
- Radio operator training will enable the RO to correctly convey information and intentions. Knowing and applying correct radio procedures is the foundation for many of the abovementioned points.
- Stability is essential for any vessel of any size.

Challenges

Remote control of vessels works well inland. However, traffic is busy in coastal areas, which makes it more difficult to achieve full situational awareness, while in the open ocean, connectivity might be more of an issue. An increase in data traffic is also expected, once the non-mandatory MASS Code is completed (Liberia, Republic of Korea, and UAE, 2024).

The fact that there is a need to transport data between the ship and the ROC inherently poses one of the major challenges concerning remote operations. Tusher *et al*. (2022) identify navigational systems to be far more vulnerable to cyberattacks than, for example, the domain of the RE. Satellite-based navigational systems, both global and regional, are the most susceptible to cyber threats.

The maritime sector is moving away from the rigid four degrees of MASS as defined by IMO, and looking at more flexible, individual solutions (image: BMT)

Legislative issues restrict the full potential of autonomous shipping. This ranges from terminologies such as crew and master of a ship and their inherent responsibilities, across a range of international conventions, such as the UN Convention on the Law of the Sea, SOLAS, the International Convention on Standards of Training, Certification and Watchkeeping, and more, to the engagement in search and rescue activities (Ahmed *et al*., 2024). Currently, national solutions are being sought and found, and as soon as

there is sufficient proof of concept, these national solutions can grow into bilateral and multilateral agreements before being implemented by IMO.

A considerable issue in training is to achieve the situational awareness that is inherently adopted by mariners when looking outside the bridge windows. Concurrently, the introduction of technology makes it easier to identify objects, judge distances and receive suggestions for positive action. We do not know yet whether generically trained personnel might work more efficiently when using these systems, compared to conventionally educated mariners with an extra RO's training on top. Kennard, Zhang & Rajagopal (2022) indicate in their research that practical seafaring experience is the basis for several skills required as an RO. But another study of VTS staff, who did hold a CoC and had seafaring experience, indicated that they tended to intervene and take earlier action than automation (Baldauf & Rostek, 2024). Presently, using conventionally trained maritime professionals with additional qualifications as an RO is the only viable approach to staffing the ROCs.

Globalisation and the COVID-19 pandemic have made cooperation between teams spanning different continents commonplace. When connectivity is ensured, this is also possible for shipboard operations. However, cooperation on board ships is very different from many other sectors. The shipboard crew is putting their lives into the hands of the person or the system in charge of the navigational watch. A level of trust is required, which must be built within the bridge team.

By dedicating ROs to work along the three modes of remote operations traditional watchkeeping duties are updated to keep pace with the technological advances. Introducing a designated and internationally recognised education for the RO will eliminate the prerequisite of being a mariner first and ensures that the future personnel demand, in this emerging sector, can be met. ■

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DON'T STOP THE ROC

The ROC + DOCK project aims to bring together remote-controlled USV operations, a modified, dual-function simulator and a 'hands-off' USV docking station, to encourage force multiplication of USVs in ports and harbours

A UK-based collaboration between USV developer HydroSurv, naval architect and designer BMT and South Devon College is nearing completion of a project assessing the benefits of electric USV operations in ports and harbours.

The 'ROC + DOCK' initiative has involved shoreside pilots remotely controlling South Devon College's unmanned training vessel *USV Dart* – a 1.58m-long HydroSurv REAV-16 model, deployed on the River Dart – from a remote operations centre (ROC) on college grounds. Additionally, the partners have been trialling a remotely monitored docking station, fitted with solar panels, developed to recharge the USV with pure renewable energy – and all without manual intervention.

The chief goals of the project, which has been funded through the Innovate UK Marine & Maritime Launchpad, are to enable "true force multiplication of resident USVs operating across geographically separated coastal sites" while demonstrating "an integrated, end-to-end workflow that could transform how short-range environmental monitoring, inspection and surveillance missions are planned and executed – all from a centralised facility", HydroSurv says.

Docking station

ROC + DOCK commenced in early September, when the prototype docking station was deployed on the river. This station, designed by HydroSurv's in-house naval architect and chief electrical design engineer, is fitted with an automated mooring latch, and has been designed to enable fully hands-off recovery of the USV and recharging of its lithium-ion batteries.

HydroSurv tells *The Naval Architect*: "The docking station's power system is capable of charging [our] latest [2.5m-long] REAV-25 USV at up to 50A, to enable rapid replenishment. However, in practice, the USV will be recharged over longer periods when the vessel remains in the docking station for a few days at a time."

At present, the docking station is designed for single-vessel support. HydroSurv adds: "The docking station control software is accessible to the vessel operator, providing the latching and unlatching system, monitored through a proximity sensor system. Charging is enabled through a contact charging system."

ROC layout

Back at the ROC, pilots remotely launched and navigated *USV Dart* by integrating HydroSurv's vessel control software with BMT's Rembrandt simulator – the latter tool more traditionally used for crewed vessel training.

HydroSurv elaborates: "This capability – enabling operator training in a virtual environment that precisely replicates the vessel's handling characteristics, before transitioning to live control

The prototype docking station, deployed on the River Dart in September, enables docking and recharging of South Devon College's *USV Dart* without manual intervention

– represents a significant advance in ROC design. It supports both the modernisation of maritime training syllabuses and the technical evolution of uncrewed operations facilities, with enhanced human factors and situational awareness at their core.

"Being a conventional vessel simulator, the spread is relational to the layout of a commercial vessel or workboat bridge, as opposed to more conventional screen layouts seen with remotely operated, uncrewed vessel spreads."

The River Dart trials have so far included water quality assessment missions involving pre-planned

BMT's Rembrandt simulator was integrated with HydroSurv's vessel control software, enabling both remote operator training and direct control of the USV

routes of up to 10km in line length from the docking station, HydroSurv explains. These runs were based on standardised tasks from HydroSurv's parallel 'Smart Waters, Clean Ports' project, launched last year, in which REAV-16 USVs have transited rivers and estuaries around the ports of Dartmouth, Falmouth and Plymouth to assess local water pollution levels.

Summing up the *USV Dart* trials so far, HydroSurv states: "A two-person team can now execute multiple missions from a single facility, across dispersed coastal sites, without the need for local on-water support."

Further integration

HydroSurv reveals that it is now looking to further develop the integration between the USV and the Rembrandt simulator. This will likely include "enhancing the live view capabilities from an improved situational awareness spread, possibly with larger seagoing systems; and [evaluating] human factors for one-to-many USV supervision approaches", the group says.

The docking station, meanwhile, will be honed to handle HydroSurv's larger, seagoing USVs, "as part of an onward development roadmap, in close cooperation with [our] commercial customers", HydroSurv adds. In November, as the project enters its final phase, the group also aims to identify potential savings to be made, in terms of both reduced crewing/support vessel costs and reduced emissions, through using the ROC, USV and docking station compared with typical manned vessel set-ups. ■

DATA TO THE FORE

Decarbonising shipping will require focus, collaboration and a significant chunk of onboard data if these efforts are to succeed, naval architecture firm Foreship explains

The past three years have been transformational for Foreship, involving new global offices, internship programmes and diversification, all culminating in the company's full acquisition by a leading multinational engineering consultancy, inspection and certification company over the summer.

Established in Finland in 2002, Foreship has grown to employ more than 100 professionals across eight international offices, specialising in marine consultancy services, energy-efficiency solutions and naval architecture – primarily, but not exclusively, for the cruise ship and ferry sectors. Foreship's UK branch was opened in 2022 and established itself in Southampton, granting the company access to cruise and ferry operator clients.

June 2025 saw Foreship's entire share capital acquired by Italy's RINA, which clearly spotted some attractive synergies between its own engineering consulting activities and Foreship's business. Shaun White, MD of Foreship UK, tells *The Naval Architect*: "RINA didn't have a strong presence in the UK for its marine consulting work, so we're aiming to grow a UK marine centre of excellence, to compete with the centres established by the other players." For Foreship, increased access to an expanded market is a welcome benefit – as is the opportunity to export its current services portfolio into other vessel segments, including superyachts, offshore, containerships and LNG carriers. "We're excited about the potential to go beyond cruise and ferry, and to compete against people we haven't competed against before," White says.

Foreship has also built up a sizeable customer base in ship repair and conversion, which, White says, "has been a big focus area for us this year, with conversion projects returning to pre-COVID levels". This is especially the case for environmental retrofits, he adds, where the pressure is on to both attract eco-conscious passengers and appease the regulators. "Cruise brands have significant plans, fleet-wide, to push down their energy consumption through innovative technologies and operational changes," he says.

Shaun White, Foreship UK: "Most shipowners are very well informed about alternative fuels, and a lot are setting up their own teams to look into energy and decarbonisation"

'Supply and demand'

Inevitably, realising these plans means scrutinising onboard energy consumption. "Now, cruising's very much about adding exciting features and activities on board, focusing on the journey as the destination, while changing the onboard configuration to keep the customer active on the ship," says white.

These activities tend to create a significant drain on the shipboard power plant. In turn, Foreship is working with its cruise line customers to anticipate and accurately judge periods of onboard energy 'supply and demand'. In this way, rather than running the vessel at a certain energy level 24/7, the operator can use smart tech, including sensor arrays, to immediately respond to fluctuations in demand.

For example, White explains: "Power demand peaks during the evenings, when the passengers are in their cabins and preparing for their dinner and/or shows. In the midday period, though, when the passengers are on their shoreside excursions, we can change the supply to meet the demand.

"We're much more intelligent now with our system design, augmenting sensors to turn systems off, and to ramp things down, when they're not needed. If most cabins are unoccupied during a certain period, we don't need to be cooling them all – so we can throttle back on the air-con." This 'supply and demand' strategy "translates from the hotel side down to the engine room", White adds.

Drive for data

Obtaining an accurate overview of these onboard activities, and making informed decisions related to peak periods and power allocation, requires data – and plenty of it. White identifies an increased reliance on energy-saving data as one of the biggest recent trends among cruise and ferry operators eager to reduce their carbon footprints.

"A lot of owners started from a point where the data never left the ship," he explains. "This information was left to the chief engineer or the technical team on board. Now, though, we're seeing data coming off the ships and data centres being set up by all the major cruise brands, and even by some ferry

Foreship has been creating new skilled positions as it builds up its workforce

operators. The challenge then is augmenting the data from the ship and doing something meaningful with it.

"You can have a really nice graphical display, but what is it actually telling you? And how can you interpret it to make operational and technology investment decisions? This is where we help customers: we can analyse the data and produce an energy-efficiency assessment for the customer, which gives them numbers on the return on investment, the potential savings, the energy reduction and so on. It's not just a manufacturer's claim; we're independent and agnostic of any particular technology."

Ideally, White says, an effective assessment would draw on a year's worth of data, though the process can become incredibly complex depending on how deep you dive. "With one client, we took about 90 million data points", he recalls. "To process that, and to present it in a way that a CEO or CFO can understand, is a real challenge."

Data hurdles

Another challenge, White highlights, is that the typical cruise ship does not have a set itinerary. "You can build up data covering a year's itinerary, but then the cruise line chooses to reposition the vessel," he says. "She might go from cruising the world one year to just cruising in the Med the next, so you're often dealing with a different operational profile reflecting changing climate and different speeds."

For vessels with more regular, fixed itineraries – including many ferries, for instance – this data can prove valuable in predicting Carbon Intensity Indicator (CII) and Energy Efficiency eXisting Ship Index (EEXI) ratings – which, in turn, can help an owner to decide whether the best strategy for themselves is to carry on as usual, opt for an equipment overhaul or "invest in more modern, energy-efficient ships, future-ready for a number of fuel scenarios", he says. This is particularly relevant as most owners now demand "a menu of options, particularly on the retrofit market", and often involving a return on investment in "as little as three years", rather than the more conventionally accepted five-year period, he adds.

This emphasis on data has inspired Foreship to seek capability for the roles of 'computer scientist' or 'data engineer' in addition to the more traditional 'naval architect' and 'marine engineer' job descriptions on its internships and training courses (see Box).

Alt-fuel considerations

As mentioned, Foreship takes a largely fuel-agnostic approach when helping its clients to produce the most energy-efficient but operationally effective vessels and fuel systems for the job at hand.

Refreshingly, White sees a healthy amount of collaboration taking place in the industry. "We need those on the port infrastructure side to

WIDENING THE INTERN NET

Foreship's forward-looking moves include providing placements to graduates and interns across its sites in Finland, Estonia, the UK and US, and the company typically takes in anywhere between 10-20 interns over each summer. All of these interns get the chance to work on real-life projects: "We don't make up work for them," says White. "We pepper their training with ship visits, drydockings and surveys, to give them first-hand experience in the field." Many graduates are sourced from the "talent pipeline" of UK universities, such as Southampton and Strathclyde, and White is pleased to note a high level of retention once these interns complete their degrees.

More recently, the traditional roles of 'naval architect' and 'marine engineer' have been supplemented by new skilled positions. "We need data engineers and computer scientists too because, when we flip over to data, most naval architects and marine engineers haven't necessarily had that exposure to IT and data," says White. "Equally, most digital engineers and computer scientists won't know much about the end application, so bringing all of these categories together is really important, whether in front-end or back-end roles."

Foreship provided technical and strategic support for Wasaline's *Aurora Botnia* (pictured) battery retrofit

come and join us in that debate," he opines. "I do think there's a lot of dialogue between operators and the ports, even though it's easy to suggest that there's not – we're very busy participating in roundtables and discussions.

"The challenge is: is the capex forthcoming? Is the investment coming? The challenge is well known and understood, it's a case of – where is the money coming from, and who pays? Does the owner of the shore infrastructure stump up the money, or should the operator pass on an emissions trading scheme [ETS] charge to their customers, like the levies some airlines charge when we fly?"

It is similarly refreshing to hear White confirm that, in his opinion, "most shipowners are very well informed about alternative fuels, and a lot are setting up their own teams to look into energy and decarbonisation" – a good anecdotal antidote to gloomier reports of a shipping sector besieged by uncertainty and doubt.

Foreship has collaborated with various battery and fuel cell manufacturers, helping them to achieve the relevant class notations for their offerings and assessing their suitability for different ship designs. "So, if a company has developed a battery pack or fuel cell solution for buses and trains, we can help them comply with ship rules and regulations," says White. "We consider factors like safety, fuel storage, bunkering, fuel processing – and, from that, we produce a concept design or feasibility study, to secure approval in principle.

Contenders and risks

White sees one of the biggest risks as being linked to low-flashpoint fuels – understood when bunkered as cargoes but posing new challenges as fuels – and especially when it comes to training crew to handle them. In terms of the available alt-fuel options, he continues: "We're still waiting for that pivotal moment in fuel cell technology that really unlocks its potential – there have been start-ups and promises, but very few big applications so far."

As for batteries, he says: "We've undertaken well over 50-60 battery-related projects, but the battery market stagnated for a few years during the COVID pandemic – battery prices just didn't come down in line with the industry's projections. It didn't mean there wasn't a return on investment; it just wasn't in the range that customers were prepared to tolerate.

"Lithium-ion batteries also had a bit of an image problem in the early 2020s, with reports of electric car fires and things not going very well, but we're now seeing a renaissance in battery technologies, with prices dropping and a shift in the preferred chemistries.

"We know that ships degrade over time, but electrical systems degrade too. We should be modifying and maintaining these electric systems constantly. We see ships that need a lot of intervention for the upkeep of their electrical plant: hull degradation and electrical plant degradation are now a very important joint consideration."

Now, working in close cooperation with RINA Marine Consulting, Foreship's future plans include "a good schedule of drydocks coming up next year", as owners look to retrofit energy-saving technologies aboard their vessels. The sooner Foreship can engage with this process, the better, White says: "Some of this equipment can take up to 12 months to build and the lead times need to be taken into account, so we need to be planning today to finish a project by the end of 2026." ■

The Sea Dagger concept is designed to be fast and stealthy and to embark personnel and their vehicles

LEIDOS DRAWS SEA DAGGER

Leidos has responded to the UK Commando Force's call for a high-speed, low-signature, well-protected craft that can insert UKCF strike teams and their vehicles, writes **David Foxwell**

A requirement for a new type of vessel to deliver commandos from amphibious assault ships to the shore and replace ageing assets the design of which dates back to World War II has drawn an innovative response from defence contractor Leidos.

Sea Dagger is Leidos' response to a UK Commando Force (UKCF) programme designed to transform the Royal Marines into what it described as "a more agile, lethal, dispersed capability". To do so, a new high-speed, low-signature, well-protected craft is being sought that can insert UKCF strike teams and their vehicles.

Currently, such a vessel does not exist and the commando insertion craft (CIC) will need to be far more capable than the ageing landing craft it will replace. The CIC requirement calls for a fast craft capable of operating successfully in open seas and the environment close to shore.

In addition to Royal Marine commandos, the new craft will have to carry vehicles, defensive and offensive payloads, be armoured in order to withstand enemy action and be far more stealthy than existing assets used by British commandos.

It will have to be interoperable with NATO amphibious ships, and of operating from their well decks and from davits, where possible, and be able to operate for long periods independently or in groups of other landing craft, acting as a 'forward operating base' afloat. In contrast to this very demanding requirement, today, the UKCF still uses venerable landing craft vehicle personnels (LCVPs), the smallest vessels, which can carry troops and vehicles. As with all NATO landing craft, LCVPs are in large part based on World War II designs. They are also expected to be withdrawn from service in 2027 and their use would be challenged in a 'post-Ukrainian' world of high-tech warfare. Existing Special Forces craft do go fast and far, but do not carry vehicles.

CIC requirement

The requirement for the CIC was first communicated at a UKCF Industry Day in June 2024, with updated requirements issued in September 2025, shortly after which Leidos unveiled its response, the Sea Dagger, at the DSEI conference and exhibition at the end of September.

Asked how the Sea Dagger responds to the CIC requirement for a next-generation CIC, a Leidos

spokesperson told *The Naval Architect*: "Sea Dagger is the first craft of its size to combine high-speed, long-range vehicle delivery and modular mission systems into a single platform. It also sets a new standard in maritime autonomy and operational agility. The modular design enables rapid reconfiguration across a wide mission set – from commando insertion to intelligence, surveillance and reconnaissance, to anti-submarine warfare and remote strike."

Leidos says the Sea Dagger meets and exceeds the CIC requirement through a number of key design features. With a length of around 20m, and a speed in excess of 40knots in sea state 2 – an average wave height of 0.1m to 0.5m – it is also engineered to withstand sea state 7, with wave weights typically between 6m and 9m, giving crews confidence in challenging operating environments.

With a range in excess of 400nm, Sea Dagger is a true oceangoing craft, is survivable in high seas, offensively and defensively weaponised for 'hardkill,' 'softkill' and strike, and is stealthy and armoured. Interestingly, the Sea Dagger concept also includes the use of modular 'SeaPods,' which can house a range of weapons and sensor system payloads to significantly enhance operational flexibility, availability and upgradeability.

"Uniquely," said Leidos, "Sea Dagger also delivers a modular 6tonne payload direct to the beach, including light vehicles. This is all fully integrated into the StrikeNet concept – an initiative aimed at advancing communications, data sharing and uncrewed systems integration in maritime operations – and it operates in the most demanding of environments."

Full-rate production

Sea Dagger can be a crewed craft or operate in fully autonomous mode. "Sea Dagger is optionally crewed, using Leidos Autonomous Vessel Architecture [LAVA], a proven autonomy system applied on the US Navy's Sea Hunter, Seahawk, Mariner and Ranger large uncrewed vessels," the company said, "This capability complements a very lean crew when the vessel is manned, which we believe gives best of both worlds flexibility as tech iterates and operations dictate."

Asked what kind of hullform it has adopted for the new craft, Leidos told *The Naval Architect* that the current Sea Dagger design is a planing V-form monohull.

Asked what kind of propulsion it would employ, the company said: "We have the customer requirement at the forefront of our design, alongside fitting into the customer budget envelope, and various priorities from the customer such as speed, range, power, human factors, maintainability and reliability. We have a mature solution." It said it is also appraising a number of options for the construction of Sea Dagger, including composites, specialist composites and aluminium, to ensure they fit with its current design, the customer requirement and the supply chain.

Leidos told *The Naval Architect* that, if selected by UKCF to meet the CIC requirement, Sea Dagger could move quickly into full-rate production. Initial discussions have suggested a delivery rate of four vessels per year, although Leidos has the capacity to increase production beyond this level to meet evolving customer requirements.

The company said the unveiling of Sea Dagger in September 2025 has also attracted significant attention from other markets, including the US and Australia, and other allied partners seeking to enhance their expeditionary warfare capabilities.

The procurement process for the CIC is being led by Defence Equipment and Support, a central government public authority located at the Ministry of Defence facility at Abbey Wood in Bristol. It is planning a procurement process for the design, manufacture and support of the CIC. At the time of writing, this process was approaching the completion of the planning stage, with key dates including a future notice publication on 1 December 2025, and a contract period set from 31 December 2026 to 31 December 2033. ■

GRIFFON DECLARES ITS HAND

Apart from Leidos, few potential contractors have declared their hand with regard to the CIC programme, but one that has is Griffon Marine Solutions. Its response is based on an air-assisted catamaran assault craft with twin catamaran hulls, which will deliver directional stability and high-speed manoeuvrability, allied to a forward-mounted air cushion module that enhances trim and enables soft landings on unprepared or unstable shores.

It has proposed a unit with a low-profile, open-deck architecture that allows fast ingress and egress for personnel and light equipment. The hullform supports a dry-landing capability in surf zones or marshy areas. Built from marine-grade aluminium, the craft is lightweight, corrosion-resistant and optimised for modular armament or mission-specific outfitting. Construction would make use of marine-grade aluminium.

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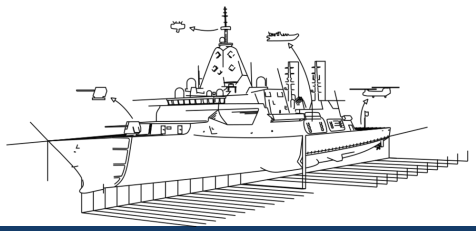

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THE LAUNCH AND RECOVERY 'MISSING LINK'

David Foxwell speaks to Sealartec about its ALR-S technology, developed to convert a conventional stern ramp to a fully autonomous recovery system for USVs

Military and paramilitary vessels have long used stern-based launch and recovery systems for manned vessels, but how do you launch and recover a USV, and enable multiple USVs deployed in 'swarms' to operate truly independently of manned vessels?

These are some of the challenges Israel-based Sealartec and its founder Amitai Peleg set out to solve, as he tells *The Naval Architect* in an exclusive interview. Peleg and Sealartec business development director Dov Raz describe launch and recovery as the 'missing piece' in USV technology development, one that USV designers and builders – and manufacturers of recovery systems, such as stern ramps and davits – have failed to address.

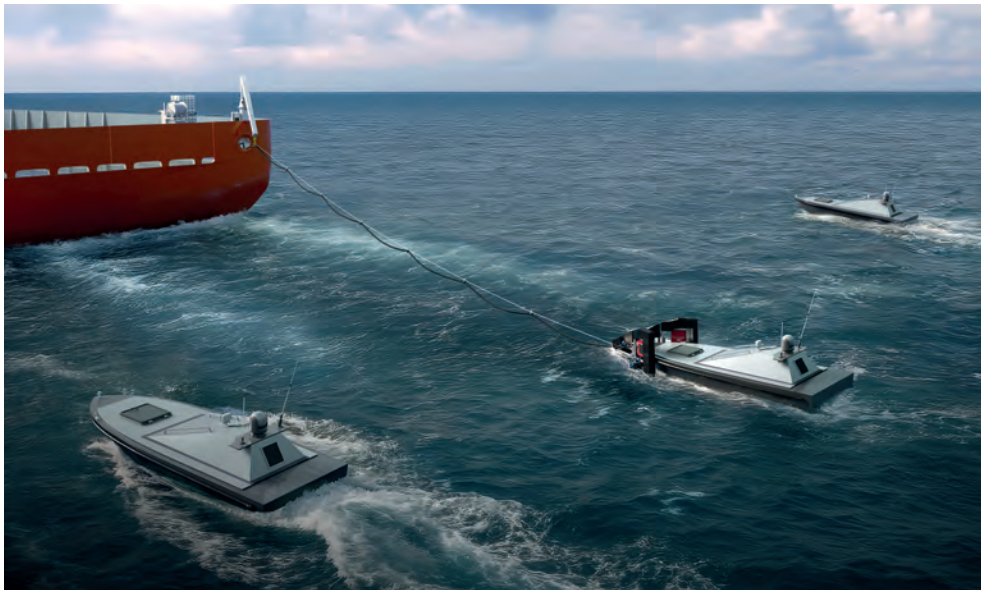
Whilst working for a well-known company that designed and built high-end USVs, Peleg recognised that no-one was addressing launch and recovery. He began working on an autonomous solution, subsequently raising funds for an incubator programme. The launch and recovery concept he developed has now reached the point where Sealartec is collaborating with the US Navy, Israeli Navy and leading contractors such as BAE Systems, Huntington Ingalls Industries, IAI and MARTAC among others, and its technology has been successfully tested in the US and elsewhere, most recently in June 2025 by the Naval Surface Warfare Center, using the Stiletto, a vessel that serves as a modular testbed for emerging technology.

"Phase mismatch"

"Without safe, reliable launch and recovery systems that can handle USVs in adverse conditions, use of USVs is going to be severely constrained," says Peleg. Raz adds: "We knew there was a need for a system that would remove human operators from the process, that was fully autonomous. A conventional stern ramp used to launch and recover manned rigid-hull inflatable boats is heavily dependent on a human operator's skill and is a risky, challenging process, but when used for USVs, their design limits quickly become a critical obstacle."

Raz continues: "Dependence on direct hull-to-ramp contact exposes manned craft to relative motion effects, impact loads and control difficulties, especially in moderate to high sea states. When a large host vessel and a small craft interact in waves, their heave and pitch motions are out of phase. Fleets using conventional or extended stern ramps report increasing risk to boat and ship beyond sea state 3.

Sealartec's ALR-S converts a standard ramp at the stern of a vessel into a fully autonomous recovery system



The A-RAS enables USV refuelling to take place with minimal impact on a mothership

"At that point, the difference in vertical displacement between the mothership's stern and the daughter craft's bow often exceeds 2m, with relative pitch angles of over 10°. The result is an unpredictable recovery window and an increased likelihood of impact or loss of control.

"As vessel size increases, this phase mismatch worsens. Larger ship hulls have longer natural pitch periods, which means their stern moves differently than a smaller USV. In such cases, extending the ramp's length or depth provides little improvement, and relative motion, not geometry, becomes the limiting factor."

Impact risk

As Peleg and Raz note, when recovering unmanned units, the consequences of these constraints become potentially serious, not least because of the impact forces from a USV on the hull of a mothership. Without any form of motion compensation, they say, a 10,000kg USV re-entering a launch platform at 5-10knots can generate vertical relative motion of over 2m/s, releasing enormous impact energy, sufficient to cause structural damage and damage sensors and electronics.

One of the most recent demos of Sealartec's technology took place on the US Navy's Stiletto platform

"Impact load increases exponentially with approach speed, and even small deviations in timing or wave phase translate into large energy spikes," says Raz. "This risk grows considerably when an operator cannot directly sense vessel motion, when the craft being recovered is in autonomous mode or is being remotely piloted."

Sealartec's solution to these challenges, ALR-S, uses innovative technology the company developed that can convert a conventional stern ramp to a fully autonomous recovery system that can safely recover USVs in up to sea state 6. At its heart are three processes: the first is to identify when a boat is in the 'capture zone' and is ready to be captured; the second is to safely capture it while it is still aft of the stern of the host vessel; and the third is to control the motion of the boat/USV as it enters the host platform, restraining bow motion, so that it can be 'landed' softly, in a controlled manner.

A new process

As Peleg points out, this is completely the opposite of the process used to recover manned boats, where an operator has to be extremely skilful and, quite often, "a little bit lucky" if he is to get the timing right to manage the effects of sloshing and turbulence as he drives a craft onto and up a stern ramp.

"In contrast to this old-style way to recover a boat – in which a boat effectively 'rams' into the ramp in the mothercraft – Sealartec's solution sees a USV driven into a relatively wide capture zone aft of the stern ramp, at which point speed of the boat and the ship are matched," says Peleg. "The USV loosely maintains position, the ALR-S 'identifies' and captures the boat autonomously and the system sends a 'captured' verification to the boat to reduce throttle to zero and for the ALR-S to initiate the process of hauling it onto stern ramp under controlled tension."

At the heart of this process is a 'local positioning system' or LPS that Sealartec developed that, rather than relying on GPS, uses a number of different sensors and beacons on the USV and the host vessel to identify exactly where the USV is in relation to the mothership. The data provided by this form of 'near-range sensor fusion' provides precise relative 6° of freedom positioning and is seamlessly integrated with onboard control systems.

The LPS has undergone extensive testing in extreme environments to ensure that it delivers reliable solutions. Using it enables the recovery process to be automated. "Using the LPS also ensures that a USV can be recovered more quickly than would otherwise be possible," Peleg says.

Future swarms

Looking further ahead, Raz says Sealartec's technology could play an important role enabling the use of USV 'swarms' – that is, large numbers of USVs deployed to operate independently of manned forces.

"Swarms of USVs need power," says Raz. "Refuelling multiple USVs at sea using our replenishment system removes the need for them to be repeatedly launched and recovered from a host vessel, and extends endurance and mission flexibility. Responding to this need, we have developed A-RAS, a system providing autonomous replenishment at sea that also enables real-time data transfer with minimal impact on USVs and motherships.

"A-RAS can refuel a USV, swap sensor pods on it and offload mission data while both vessels remain in motion. Alternatively, a buoy-mounted refuel and recharge station can be positioned offshore, eliminating the need for a high-cost, operationally important asset to attend to a swarm of USVs. In this way, large numbers of uncrewed vessels can remain on station for weeks without a port call." This enables what Sealartec calls 'a distributed sustainment network' that, Peleg believes, can transform how navies operate USVs and project presence. ■

PREPPING FOR GREEN-FUEL RISKS

Alternative fuels may be good for the environment, but the maritime sector must remain mindful of associated risks to crew safety and vessel and equipment integrity

Making the transition from traditional to alternative marine fuels introduces an entirely new range of uncertainties – and not just for naval architects, shipbuilders and vessel operators.

Ammonia, hydrogen and biofuels come with their own spread of risks – including fuel instability, toxicity and engine damage – that have the potential to strain the resources and expertise of ship operators, crew and protection and indemnity (P&I) clubs. Many mutual insurers are bracing for a future wave of complex, alt-fuel-related claims and unprecedented liabilities, forcing them to rethink their risk assessments and "consider the risk for entered tonnage in liaison with loss prevention", Mark Smith, loss prevention director for decarbonisation at global mutual NorthStandard, tells *The Naval Architect*.

Rather than waiting for this 'wave' to materialise, however, P&I clubs are being proactive and helping members prepare early. As Smith puts it: "It's about keeping our eyes open and our ears to the ground to stay up to date with developments, so that we and our members are prepared for these new fuels.

"The International Group has identified that there is a gap in existing liability and compensation regimes when it comes to the carriage of alternative fuels as bunkers and has supported a paper to IMO's Legal Committee to review these gaps and identify solutions. This work is now on the Legal Committee's agenda."

The fuel overview

Describing NorthStandard's approach as "fuel-agnostic, meaning we don't favour one alternative fuel" Smith emphasises the need for the club to understand the implications of adopting each alt-fuel type, to educate both its in-house personnel and its members, who currently account for approximately 20% of all tonnage insured by the International Group of P&I Clubs – "totalling about 150 million gt", he explains.

For instance, nuclear power, enabled on board some commercial vessels by small modular reactors, hasn't escaped NorthStandard's attention. "We need to understand nuclear-related risks," says Smith. "A lot will depend on the type of reactor installed on board the ship and the emergency planning zone [EPZ], as well as the intended trade and operating model". The EPZ is a reference to the immediate area around the reactor (typically, the vessel itself) where measures to manage a nuclear accident are in place.

"Modern reactors have a smaller EPZ," Smith continues. "The larger the EPZ, the more of a problem operators will have finding an insurer to insure the nuclear risks and ports willing to accept the ship. It won't be long until floating nuclear powerplants come to the forefront, and NorthStandard are involved in this research, and it may be the case that they're treated in a similar way to an FPSO, for example – but we don't know that now. That's why we need to prepare proper risk assessments to stay on top of the evolving risks." Smith reveals that he is also heading up an STCW training task force for nuclear-powered vessels for the Nuclear Energy Maritime Organisation (NEMO).

At the other end of the alt-fuel scale, risk assessments are also necessary for wind-assisted propulsion systems (WAPS). Smith suggests considerations such as: "What if you can't put down the sails when you're entering or leaving port? What if the crew encounters mechanical problems? The WAPS may create manoeuvrability issues and require extra crew training, extra spares on board and additional maintenance." As another alt-fuel example, Smith highlights hydrogen's "big flammability risk and wide flammability range", adding: "There are still lots of unknown issues developing all the time. This is why we need to work closely with the class societies, fuel experts, industry experts and technology manufacturers.

"When there's a danger, there's always a way to mitigate it – but there is also a risk that, four or five years down the line, the crew aboard the ship become complacent and critical maintenance or procedures are not followed – and that's when incidents could happen."

To this end, NorthStandard offers its members several live webinars each year, to keep them updated on regulatory changes and potential risks as they evolve – with the "Achilles heel" of crew training remaining a primary, ongoing concern, Smith adds.

The rise of biofuels

Despite the options available, one fuel type looks set to lead in commercial vessel adoption – and, consequently, in potential P&I claims.

"We're going to see a huge rise in biofuels," says Smith. "These are essentially drop-in fuels, directly replacing fossil fuels – so, if you are running the ship on a modern slow-speed marine diesel engine, you don't need to make any major modifications or conversions to use the biofuel. That lends itself well to older tonnage that is coming to the end of its lifecycle; operators won't want to spend huge amounts of money on new propulsion systems for these ageing ships."

Mark Smith, NorthStandard: "We anticipate some problems with biofuels"

Another factor driving biofuel adoption is the introduction, in January 2025, of the FuelEU Maritime regulation, and especially the surplus/deficit pooling option that can be generated using biofuels on vessels operating in Europe.

Put simply, the regulation recognises that biofuels may be easier to access in certain areas (such as Amsterdam and Rotterdam, Smith says) than others (like Nordic and Mediterranean ports), depending on the available bunkering infrastructure, and its level of advancement, at each location.

Under the terms of FuelEU Maritime, each ship will report its fuel use annually, relevant to emissions and GHG intensity. Ships using biofuels (or other low-carbon fuels) accrue a 'surplus', while those using fossil fuels accrue a 'deficit' – so, ships with greater access to biofuels may pay less in FuelEU costs than ships without.

Now, though, by entering a collaborative pool – comprising, for example, Ship A, operating in surplus, and Ship B, operating in deficit – the respective owners can work together to trade surplus and deficit. "The pooling system only applies to the EU at the moment but a similar system is up for adoption at the IMO, subject to adjournment for at least one year following the MEPC 2nd extraordinary session in October 2025," Smith adds. NorthStandard offers its members a discount to access a surplus/deficit trading platform called BetterSea; the discount could equate to a saving of "around €42,000 per containership, or more for a cruise ship", plus free expert consultation, Smith says.

Fuel quality analysis

"We anticipate some problems with biofuels," Smith continues. "Perhaps not so much with the big mainstream suppliers and ports around the world, but somebody will always be looking to make money somewhere in the supply chain, which becomes a problem if they take cheap, poor-quality fuel, mix additives into it and sell it for a profit with no concern for the consequences. That is very hard to control without, say, fingerprint analysis and blockchain technology to provide full visibility."

Fingerprint analysis may involve assigning unique 'markers' to fuel batches, to make it easier to spot whether contaminants have been added at a later stage, while blockchain technology would log and timestamp all transactions on a decentralised ledger, making it more difficult, if not impossible, for bad actors to tamper with results and records.

NorthStandard also offers its members free-of-charge access to its Fuel Insights platform, which provides real-time fuel quality statistics, obtained from partner VPS and sourced from all major global bunkering ports. This data can help operators to make informed decisions on whether to bunker at a certain port, or to take on fuel from a certain supplier, and can even provide the tested calorific value, which is relevant to energy content.

Smith recalls a case where one NorthStandard member who had bunkered poor-quality fuel complained to the supplier, who in turn denied there being any quality issues with the fuel. Using Fuel Insights, Smith says, the customer managed to pinpoint the exact barge that had supplied their ship with the off-spec fuel, and discovered that the barge had also suppled off-spec fuel to other vessels.

"The VPS fuel testing analysis allowed the customer to debunker that fuel, which saved them significant sums in legal charges," Smith adds. "The more our members use Fuel Insights as a loss prevention tool, the higher the chance of them avoiding high-value claims." The platform also sends out alerts to customers as situations develop; for example, should a region detect and immediately report an increase in the presence of cat fines, for example.

Early days for claims

So far, NorthStandard has managed several biofuel-related claims, representing unchartered territory for most insurance mutuals.

Smith says: "We have run two webinars on biofuels. In one, for example, we pointed out that fatty acid methyl ester [FAME] content can lead to microbial activity when it is stored long-term. The industry doesn't have much experience of that yet, because we have only seen the results of short-term trials so far...but longer-term trials may highlight more problematic issues.

"The biofuel-related claims so far are similar to those we've seen for low-sulphur fuel oil, with the main problems being blocked filters and purifiers."

And herein lies the dilemma that P&I clubs must assess. "High-value fuel disputes are based on the question, 'Is the problem with the fuel, or with how it was managed on board?'," says Smith. "The shipowner thinks they have handled the fuel perfectly and the supplier thinks the fuel is perfect – whereas the truth usually lies somewhere between the two. This is why keeping records and maintenance logs is so important."

Smith adds that NorthStandard is developing a platform to assist members in in understanding the risks of alt-fuels. "Working together as an industry and staying on top of developments is how we'll all get there," he concludes. ■

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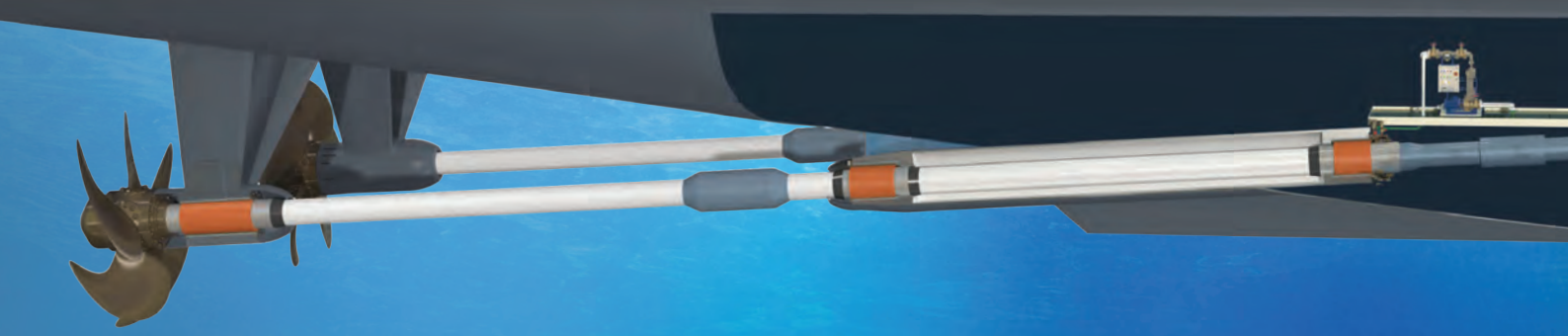

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DECADES OF DESIGN DEVELOPMENT

Founded in 1993, Macduff Ship Design has grown from its roots in the fishing and aquaculture sector to engage in a wide range of vessel design, engineering and consultancy services, taking in multiple vessel segments, writes **Duncan Boag** CEng MRINA, project naval architect at Macduff

Macduff Ship Design is delighted to be celebrating 20 years as corporate partners to RINA. The company was formed in the fishing town of Macduff in the Northeast of Scotland in March 1993 by Donald Cameron, with the backing of a group of local businessmen. Donald had previously been the senior naval architect at the James N Miller shipyard in Fife, Scotland – a yard with a long shipbuilding heritage and involvement in small commercial and fishing vessel building.

Macduff was established to perform bureau consultancy services to the large Northeast Scotland fishing fleet with the major ports of Buckie, Macduff, Fraserburgh, Peterhead and Aberdeen all within an hour's drive. The company also quickly built a strong working relationship with its neighbours, Macduff Shipyards and James M Joiner Marine Engineers, providing naval architectural services for both newbuild and refit work.

The company quickly built a reputation for providing high-quality consultancy services for statutory Maritime & Coastguard Agency (MCA) requirements, stability testing and analysis and advice to the fishing fleet. This expanded to cover similar services for the Orkney and Shetland Islands council-run ferries, local harbour boats and the growing aquaculture industry. With this growth, the company soon added two graduate naval architects to its staff, starting a company policy of employing and growing young professionals.

Early days and evolution

Following the formation of the company, Macduff was pleased to receive its first commission for a new vessel design in late 1993 from the local Macduff Shipyards. The first design, *Johanna* – an 11.8m monohull workboat for the aquaculture industry – was a resounding success. This was followed in 1995 with a bespoke design for a fishing stern trawler, *Andromeda III*.

The next step in the company's evolution was the development of the design for a larger 40m stern trawler, *Solstice II*, which led to two further sister builds for the UK and Ireland, named *Atlantic Challenge* and *Avro Warrior*. All these vessels are still operational, with the fishing vessels now operating in the South Atlantic and around Southern Africa. It is interesting to look back at these designs, which were completed traditionally, utilising pencil, paper and drawing boards, before the company moved into developing designs on CAD systems.

The large-scale decommissioning of the fishing fleet in the early 2000s led to a reduction in fleet size and newbuilds into the sector. This directly affected the core business of Macduff Ship Design and created a need to diversify further into other marine sectors, which led to small harbour tugs and workboat designs becoming a major new area of development. A growing recognition of the quality of the company's designs and the growth of the internet meant the company gained exposure on a global stage, with commissions for new designs being received from around the world.

Project diversification

Key projects within this diversification included a 2003 contract for a fisheries research vessel for the University of London. The vessel, *Aora*, was based on proven fishing vessel hullforms, with development

The 13m *Fair Maid of Perth*, completed in 2005, was Macduff Ship Design's first tug

for specific operations and crewing demands. This was quickly followed by a preliminary design and assistance for Shetland Islands Council in developing a new inter-island ferry, *Filla*. The design had to meet stringent operational requirements, and the work completed at this time has led to a strong relationship between Macduff and the Shetland council operations team. Following this, Macduff was contracted to develop a new fishing vessel for the east coast of Canada, *Lery Charles*. The design was to be a synergy of Canadian and Scottish design and fishing technologies, and led to the introduction of new ideas and approaches to design being introduced on both sides of the Atlantic.

The company's first tug, *Fair Maid of Perth*, was completed in 2005, and this 13m design proved itself a versatile harbour workhorse, quickly becoming a popular design. Seven similar designs have been completed since, all bespoke to owners' requirements and built by yards in the UK and globally, from the same basis. It also led to the order for a 16m tug, *Sally McLoughlin*, in 2009, which has become an equally prolific design.

The company has expanded steadily and consolidated to become one of the most prolific marine consultancies in the commercial, fishing vessel and aquaculture sectors. The growth of the company through these changes has been accompanied by a slow increase in staff, all the time looking to employ the best young talent available, and bringing the new recruits into the company with in-house training. All naval architects are either members and chartered engineers or working towards this accreditation with RINA. Macduff Ship Design sees as an important stamp of approval that its staff are properly trained and able to provide the high levels of support to their customers.

A decade of change

While continuing to provide bureau consultancy services to the fishing and aquaculture fleets alongside the new design operation, Macduff Ship Design identified an opportunity to expand its services to include more dedicated survey services. A survey division was set up in 2015 and has developed a full range of services, generally for vessels under 24m, including conducting workboat code surveys on behalf of the MCA and ultrasonic thickness measurements.

In recent years, further diversification has included the development of ASD tugs and high-speed vessels. A series of ASD tugs, developed from 19-30m, has been built and operates globally. The tug portfolio is constantly evolving, with Macduff Ship Design recently working within a UK consortium to deliver a fully electric harbour tug. High-speed vessels include a series of pilot vessels from 12-27m and a 45m patrol vessel (*Atco Noura*), again built and operated globally. These projects have allowed the design team to expand expertise, and showcase the company's versatility.

The last 10 years have seen significant changes within the aquaculture industry, where commercialisation, professionalism and efficiency have seen rapid expansion in farm set-ups, both in physical size and technology. Macduff Ship Design has been at the forefront of this change, designing new, highly capable and versatile vessels to provide safe and efficient solutions to the management and maintenance of the sites. The sector has also seen investment in lower-carbon technology. Macduff's first diesel-electric battery-hybrid vessel design, *AQS Trym*, is operating within the Norwegian aquaculture sector.

Macduff Ship Design continue to see fishing, aquaculture and small commercial vessels as key sectors for the company's future development. The team is also looking forward to working on the integration of low- and zero-emission solutions, plus developments towards automated and unmanned vessels. ■

The fishing vessel *Lery Charles* represented a synergy of Canadian and Scottish design and fishing technologies

STANDARD TERMS AND CONDITIONS: THE UNSUNG SHIELD OF NAVAL ARCHITECTS

Robert Hodge, director and general manager of ITIC, addresses standard terms and conditions as a means of managing risk and clarifying responsibilities

Naval architects are entrusted with the design of ships and offshore structures that must be safe, economic and seaworthy. The profession is broad, with specialists in everything from yachts to ferries, merchant ships to military vessels. Regardless of the area of expertise, one constant remains: the need to manage risk and clarify responsibilities. Standard terms and conditions are the foundation for achieving this.

It is not unusual for a naval architect to be appointed as the owner's representative, overseeing a project and ensuring that contractors and sub-contractors perform their roles correctly. However, the most vital responsibility is to deliver a design that meets the client's requirements and stands up to scrutiny. When things go wrong, the contract is the first place everyone looks.

Whenever a naval architect is appointed by a client, the terms of the appointment should be recorded in a contract. This contract typically consists of standard terms and conditions, a scope of work, and sometimes a general agreement. The standard terms and conditions are the backbone, setting out the rights and obligations of both parties.

A well-drafted set of terms and conditions will clarify the scope of services, define what is and is not included, and allocate risk appropriately. For example, if the naval architect is not responsible for selecting propulsion units, this should be stated explicitly. Clients may assume that certain tasks are included unless told otherwise. Clear terms prevent misunderstandings and disputes.

Robert Hodge, ITIC: "Having robust terms is only effective if they are properly incorporated into dealings with clients"

Limiting liability

One of the most important functions of standard terms and conditions is to limit liability. The ITIC standard terms cap the consultant's liability at the lesser of 10 times the consultant's charges or £100,000, and specifically exclude consequential loss, such as loss of profit. This means that even if a mistake is made, the exposure is limited and the business is protected.

The contract should also set out the standard of care expected. The usual legal standard is that of a 'reasonable' naval architect. It is important not to agree to a higher standard, such as "best endeavours," as this can increase exposure unnecessarily.

A frequently overlooked but vital clause is the time bar provision. Under the ITIC standard terms, the consultant is discharged of all liability unless, within 12 months from the date of the final report (or, if no report is issued, the date of the final invoice), formal arbitration proceedings are commenced by the client. This ensures that claims are brought promptly, while evidence is still available and memories are fresh. Without a clear time bar, a naval architect could face

claims years after a project has concluded, with all the uncertainty that entails.

Claims examples

Claims against naval architects can arise in many ways, sometimes even when no mistake has been made. The following examples illustrate the value of robust terms and conditions.

A naval architect was engaged to design a new class of workboat. Several months after delivery, the owner alleged that the vessel's fuel consumption was higher than expected and claimed damages for additional operating costs. The contract included a clear limitation of liability and a time bar provision. The owner had not commenced arbitration within the 12-month period specified. As a result, the claim was time-barred, and the naval architect avoided a lengthy dispute.

In another case, a naval architect provided stability calculations for a refit project. The client later alleged that the calculations were incorrect and sought to recover the costs of remedial work. The limitation of liability clause capped the architect's exposure at £100,000, well below the amount claimed. The dispute was resolved quickly, with both parties able to move on.

A further example involved a disagreement over intellectual property. A client sought to use a set of drawings for a new project, arguing that they had paid for the work and therefore owned the rights. The standard terms made it clear that all intellectual property created by the consultant remained with the consultant, with the client receiving only a non-exclusive, royalty-free licence for the agreed purposes. This clarity prevented a potentially costly dispute.

Key points

Having robust terms is only effective if they are properly incorporated into dealings with clients. ITIC's guidance highlights the following key points:

Terms must be provided before or at the time the contract is made. Reference them in proposals, engagement letters and all communications. The safest route is to have the client sign or acknowledge receipt of the terms. If not practical, ensure proof of provision. Make terms available on the company website and include a statement in email footers (for example, "All work is undertaken in accordance with our Terms and Conditions, available on request or at [link]"). Reference terms on invoices to help establish a course of dealing for future engagements. Under English law, the last set of terms exchanged before work commences usually prevails. If a client responds with their own terms, clarify before starting work which terms apply.

Provide standard terms and conditions at the outset of any engagement. Ensure that the client acknowledges receipt, ideally by signing or confirming in writing. Make terms easily accessible, both in print and online. Review terms regularly to ensure they remain up to date and reflect current best practice. Seek legal advice if unsure about any aspect of the terms or their incorporation.

Standard terms and conditions are not just a legal formality. They are a practical tool for managing risk, protecting intellectual property, and ensuring that payment is received on time. By taking the time to draft clear terms and making sure they are properly incorporated, naval architects can focus on what they do best: delivering safe, innovative and seaworthy designs. ■

ITIC's guidance on incorporating standard terms and conditions: *https://www.itic-insure.com/knowledge/guidelines-on-incorporating-standard-terms-and-conditions-129819/*

ITIC's members can use our standard terms and conditions drafted for naval architects: *https://www.itic-insure.com/our-publications/the-wire/standard-trading-conditions-for-naval-architects-3699/*

The 89.6m CSOV *Windea Clausius* was "built to operate in strong currents and is less limited by weather conditions", Ulstein says

CLAUSIUS, THE SECOND

The latest addition to Bernhard Schulte Offshore's CSOV fleet, *Windea Clausius*, combines a methanol-ready hybrid propulsion plant with Ulstein's TWIN X-STERN design. **Patrik Wheater** reports

Ulstein Verft has delivered *Windea Clausius*, the second in Bernhard Schulte Offshore's new series of commissioning service operation vessels (CSOVs), consolidating the company's role in Europe's offshore-wind service market.

Windea Clausius and her sister *Windea Curie*, delivered in June, form part of an extensive newbuild programme that began in 2023. Hulls three and four are on schedule for delivery next year and will also enter service under the Windea Offshore joint venture, established to provide integrated logistics and operations support to major wind farm developers in the North Sea and Baltic.

Built to Ulstein's SX222 platform, first unveiled in early 2021, the 2,200dwt *Windea Clausius* combines a methanol-ready hybrid diesel-electric propulsion plant with Ulstein's hallmark TWIN X-STERN design, which allows the vessel to operate either bow- or stern-first. Ulstein says the novel hullform improves operability, lowers energy use and enhances comfort by reducing slamming and spray loads when holding position.

Hydrodynamic refinements

The TWIN X-STERN – which evolved from Ulstein's earlier X-STERN family introduced in 2015, and leverages on the success of its X-BOW design from 2004 – is awash with hydrodynamic refinements that include optimised propeller inflow to reduce underwater noise and vibration.

Speaking in 2021, Kolbjørn Moldskred, sales manager at Ulstein Design & Solutions, said: "It's a completely different experience to be on board. It's built to operate in strong currents and is less limited by weather conditions. TWIN X-STERN is in

A DUAL-ENDED DESIGN REVOLUTION

The July 2024 delivery of *Olympic Boreas* marked the first real-world application of Ulstein's TWIN X-STERN concept – a dual-ended hull form that combines superior seakeeping with fuel-saving propulsion efficiency. Developed from Ulstein's X-BOW and X-STERN hull series, the TWIN X-STERN introduces symmetrical sterns at both ends of the vessel, each equipped with main propeller units and rudders. This dual configuration allows the ship to manoeuvre and operate efficiently in either direction, maintaining heading in heavy seas without the need to turn to face weather or current.

With a balanced flow around both hull ends and reduced wave impact, motion and vibration levels are dramatically lower than on conventional single-ended designs. DP performance improves significantly, with enhanced control and stability across a wider range of sea states.

During sea trials in June 2024, *Olympic Boreas* is reported to have demonstrated fuel consumption reductions approaching 50% while on DP compared with existing CSOVs. Beyond its technical achievements, the TWIN X-STERN concept prioritises crew well-being through lower noise and vibration levels.

MASTERING WALK-TO-WORK OPERATIONS

Ulstein has now completed 22 walk-to-work (W2W) vessel designs and redesigns, with 16 currently in operation. Together, these vessels service more than 5,000 wind turbines each year. Walk-to-work operations have become an indispensable solution across the offshore wind sector, with Ulstein widely recognised as a pioneer of the concept.

The company delivered its first W2W vessel, *Seaway Moxie*, in 2014, in what many consider a milestone that helped redefine offshore service logistics. Before the introduction of active motion-compensated gangways, technicians were transferred to turbines in small craft, climbing ladders to reach the platforms; operations often limited by sea conditions. The adoption of W2W systems has revolutionised this process, allowing transfers in rougher seas and extending operational windows by weeks, or even months, each year.

Walk-to-work operations have become an indispensable solution in offshore wind

the same family as our other two revolutionary hulls, X-BOW and X-STERN, and provides similar benefits, just in a different set-up optimised for the offshore wind segment."

With an overall length of 89.6m, a 19.2m beam and a draught of 5.9m, *Windea Clausius*' hull was built at the Crist Shipyard before being towed to Ulstein Verft in Norway for the final phase, which included outfitting, paint work, electrical installation, equipment integration, commissioning and sea trial.

The vessel is built for a service speed of about 10knots with propulsion provided by way of a Kongsberg Maritime package that integrates two main US 205 azimuth propellers fore and aft with a K-Power DC Hybrid solution, K-Chief EMS/IAS and K-Line control systems for smart energy management, fuel efficiency and optimal performance in dynamic positioning (DP) operations.

Electrical power to these and other consumers is through a hybrid battery-propulsion system supplied by Everllence (formerly MAN Energy Solutions), which features a trio of methanol-ready MAN 175D-MEV (variable-speed) gensets, each of which is rated 2.2MW and equipped with an integrated MAN closed-loop selective catalytic reduction (SCR) system to optimise emissions abatement. Indeed, Matthias Müller, Bernhard Schulte Offshore MD, said the engine design "is notable for its flexible use of various fuel grades, including biofuel, and its suitability for dual-fuel methanol retrofits".

Fuel savings

First-in-class *Windea Curie*, named after the famous physicist and chemist Marie Curie, represented the first reference for the engine which, when running on methanol, can cut CO_2 emissions by up to 95%, NOx by up to 80% and SOx and particulate matter completely.

Complying with IMO Tier III NOx-emission standards, the hybrid arrangement is also claimed to deliver up to 10% fuel savings in typical North Sea service and to reduce generator operating hours, cutting maintenance costs.

Øyvind Gjerde Kamsvåg, chief designer at Ulstein, said in 2021: "The key advantage of the hull is its ability to stay in position. The secret lies below the waterline. TWIN X-STERN has main propeller units at each end, which provide maximum manoeuvrability. The hull also provides major fuel savings; we have findings from the sister patent X-STERN, which show a reduction in power consumption of up to 60% when manoeuvring stern-first compared to flat transom stern."

Equipped with a large, height-adjustable, centrally located walk-to-work gangway and elevator tower for personnel and cargo transfers, the vessel includes a 3D motion-compensated crane for offshore lifts of up to 5tonnes. Onboard logistics are optimised with spacious storage areas and stepless access to offshore installations.

While the hull's symmetry and twin-ended propulsion allow the ship to weather-vane naturally, maintaining heading with minimal thrust and energy demand, the bridge layout follows Ulstein's Insight Bridge concept, combining navigation, DP, crane and gangway operations in an ergonomic, 360° workspace that improves situational awareness during complex offshore manoeuvres.

Following delivery, *Windea Clausius* sailed from Ulsteinvik on 10 September 2025. It is thought the vessel will support the development of Ørsted's Borkum Riffgrund 3 offshore wind farm. Sister *Windea Curie* has been deployed on long-term charter in the North Sea. All four vessels are built to DNV class and certified to the latest standards for hybrid electric systems, redundancy and DP performance. ■

New platforms ands substructures designed for floating turbines exceeding 15MW are now entering the next phase

NO FIXED PLANS

While 2025 battered the ambitions of the fixed offshore wind sector, the floating offshore wind segment is undergoing a flurry of activity, writes **Patrik Wheater**

After a decade of growth, the fixed offshore wind sector is entering a period of adjustment, with developers facing rising costs and higher interest rates and supply-chain bottlenecks prompting investment rethink. This, combined with the January 2025 US Government decision to withdraw from new offshore wind leasing, has added to concerns that the fixed offshore wind sector is entering a phase of strategic recalculation and constrained momentum.

One of the clearest signals of slowdown is the recent drop in new awards and contracts. According to a recent report by offshore renewables analyst TGS 4C, global awards of new offshore wind sites and offtake contracts fell by more than 70%. Reuters also reported in February that Denmark's Ørsted had cut its 2030 investment programme by around 25%. Equinor, a leading project developer, is also reported to have reduced its renewable-energy capacity target for 2030 in light of the changing market dynamics.

Indeed, a review by Boston Consulting Group reports that raw materials, labour and component costs have surged by up to 50% since 2021, while elevated interest rates have reduced project margins to such an extent that analysts now see a growing gap between what the market needs and what the economics allow.

Nevertheless, despite the more measured pace, the long-term ambition for offshore wind remains as governments continue to meet albeit less ambitious decarbonisation goals. The UK, for instance, is expected to fall short of its 43GW offshore wind target by about 10GW.

US decarbonisation could also falter following the White House decision to review its wind energy policy. The January 2025 Memorandum stated that no new or renewed approvals, permits, leases or loans for on- or offshore wind projects will be issued pending a "comprehensive assessment and review" of the sector. Analysts believe the freeze will affect some 21GW of planned US offshore wind capacity, but the decision could be the first domino to fall in a chain of stalled renewable energy projects.

FOW sector

That all said, the less mature floating offshore wind (FOW) sector has recorded substantial progress in technological development and supply-chain readiness, even though investors remain wary of the costs and risks involved in scaling gigawatt levels. New platforms and substructures designed for floating turbines exceeding 15MW are now entering the next phase.

In September, for example, Korean Register (KR) and Lloyd's Register (LR) granted approval in principle (AiP) to Samsung Heavy Industries' (SHI's) SnapWind Float, a novel floating offshore wind substructure capable of supporting 15MW turbines.

The SnapWind Float design incorporates lightweight, modular features for easier construction and installation. It is stabilised by a minimum of three mooring lines fixed to the seabed, ensuring safety and stability even under slightly inclined conditions.

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KR EVP Lee Yongsok says that "floating offshore wind at the 15MW level represents a new frontier for the industry," emphasising the role of classification societies in accelerating deployment of innovative substructures that will underpin the next wave of offshore wind projects.

Parallel developments

This is indicative from parallel developments in Italy, where Saipem launched a proprietary floating foundation, Star1: a steel semisubmersible foundation shaped like a three-armed star that converges at a central tower base, capable of supporting turbines exceeding 20MW.

The geometry is designed to minimise turbine movement and stress, distribute loads evenly across mooring lines and ensure high stability in deep water. Saipem announced that Star1 technology is ready for front-end engineering and detailed design, paving the way for industrial-scale deployment. The company also signed a strategic agreement with Divento for the application of Star1 in two major Italian floating wind projects: the 7 Seas Med development, off Sicily, and the Ichnusa Wind Power project, off Sardinia.

According to Saipem, a technical and commercial viability review conducted by DNV confirmed the

NOTABLE FLOATING OFFSHORE WIND (FOW) PROJECTS

UK & IRELAND

- Green Volt (INTOG, Scotland) – JV Flotation Energy/Vårgrønn. All planning approvals secured; CfD awarded 2024; up to 560MW; grid + O&G platform power
- Cenos (INTOG, Scotland) – Flotation Energy/Vårgrønn. Offshore consent application submitted Feb 2025; up to 1.4-1.9GW
- Salamander (NE Scotland) – Simply Blue Group/Odfjell Oceanwind. Section 36 marine licences granted 2025; 100 MW
- Pentland Floating Offshore Wind Farm (PFOWF) (Caithness) – Highland Wind. Floating demo/transition project in permitting
- TwinHub (Cornwall, England) – Hexicon. UK CfD secured (first UK floating CfD); 32-40MW demo

FRANCE & SPAIN

- Provence Grand Large (PGL) (Provence) - EDF R/Enbridge. Full commissioning announced June 2025; 25MW (3 × TLP floaters)
- Éoliennes Flottantes du Golfe du Lion (EFGL) (Occitanie) – Ocean Winds/Qair. Offshore installation completed September 2025; 30MW pilot
- EFLO 250 MW (Occitanie) - Ocean Winds/Banque des Territoires. Commercial project awarded late 2024; in development 2025
- WHEEL (Spain) – Esteyco with partners incl. J-POWER. Demonstration participation announced Jun 2025; hybrid barge/spar concept

NORWAY

- METCentre technology campaigns (Karmøy) – multiple developers. New floaters signed to test at Norway's national floating test centre (2024–25 agreements)
- Hywind Tampen: A commercial-scale FOW farm owned by Equinor off the Norwegian continental shelf; it's cited as the world's largest floating offshore wind farm at commissioning
- Utsira Nord: Norway's upcoming FOW site for commercial projects – the government has opened tenders and accepted applications from consortia for floating wind farms

JAPAN

- Fukushima, Goto, Kitakyushu demos - multiple consortia with ClassNK involvement in certification FLOWRA–ClassNK collaboration – sector-wide technical standardisation to accelerate deployment (MoU Oct 2025)

SOUTH KOREA

- KF Wind (Ulsan 1.1–1.2 GW) – Ocean Winds/Mainstream RP. EIA and licences progressed; 2025 onshore transmission design contract
- MunmuBaram (Ulsan 1.2–1.5GW) – Hexicon JV. LOI with Ulsan City, Sept 2025; local cooperation and fisheries surveys underway
- Bandibuli (Equinor, 750MW) – SK fixed-price PPA offer (Dec 2024); progressing toward FID (developer/government process)

PORTUGAL

- WindFloat Atlantic (Viana do Castelo) – Ocean Winds/Principle Power

US (WEST COAST)

- California & Oregon floating pipeline – lease areas and state plans exist, but federal policy shifts in 2025 affected new leasing; California advancing port/supply-chain investments to enable future floating build-out

JAPAN STRENGTHENS COLLABORATION ON FOW

The Floating Offshore Wind Power Technology Research Association (FLOWRA) and classification society ClassNK have signed an MoU to collaborate on the development and standardisation of floating offshore wind technologies in Japan.

FLOWRA, a national research consortium, works with international partners to advance common technical foundations for floating wind, aiming to reduce both costs and development risks. Masakatsu Terazaki, chairperson of FLOWRA's board of directors, said: "Since FLOWRA was founded, we have built a strong working relationship with ClassNK through technical exchanges and expert advice."

ClassNK president and CEO Hayato Suga added that ClassNK's previous involvement in Japan's early floating wind projects off Fukushima, Goto and Kitakyushu – and its cooperation with the government on standards and certification – provides a solid basis for this new partnership. "Leveraging the knowledge and experience we have accumulated, we will work together with FLOWRA to contribute to technological development, standardisation and the accelerated social implementation of floating offshore wind power," Suga said.

platform was at an advanced stage of technical maturity, stating that full-scale prototype testing was not required and had reached a "sufficient level of readiness to proceed" directly to commercial deployment.

FOW pipelines

Several flagship projects underline how the FOW sector is gaining traction. In the UK, for instance, Stockholm-based Hexicon's 32MW TwinHub floating foundation demonstrator, 16km off Cornwall, is nearing completion, marking the first FOW project in England and Wales.

The floating foundation, which allows two turbines to be placed on a single foundation, is expected to be completed by 2027. The platforms will be anchored to the seabed at depths down to 60m using a catenary mooring system – a free-hanging chain that forms a 'U' shape, between a floating structure and a seabed anchor.

Another FWO project gaining momentum follows agreement between the UK's Crown Estate and Equinor and Gwynt Glas – a joint venture between EDF power solutions and ESB. Following an auction in June, the developers were selected as preferred bidders to deliver two sites through Offshore Wind Leasing Round 5. The sites, which lie off the coasts of South Wales and South West England, each have a capacity of up to 1.5GW and hold the potential to generate clean energy for millions of homes.

Saipem's Star1 semisubmersible foundation can support turbines exceeding 20MW

The Crown Estate, which aims to ensure delivery of the full potential capacity of 4.5GW, said the agreement "represents a major vote of confidence in the UK's offshore wind industry as a place to invest, at a time when global energy markets are being disrupted by geopolitical volatility and pressure on supply chains". Once Equinor and Gwynt Glas have delivered project designs and site surveys, they will be invited to apply to obtain a full lease to build and operate the new wind farms, which could be operational by the mid-2030s.

20MW and beyond

While various reports forecast a total FOW-generated capacity of 266GW worldwide, the UK, Norway, France, Japan and South Korea are the five most active national markets. Indeed, the International Renewable Energy Agency (IRENA) predicted in 2024 that the technology needed for the sector to advance could achieve commercial parity with fixed offshore wind by the mid-2030s. Turbine ratings are expected to continue to grow beyond 20MW. But, at that scale, there are challenges in terms of hydrodynamics, mooring systems, installation logistics and farm layout optimisation.

Despite this, floating wind represents an extension of established competencies in shipbuilding, mooring, subsea installation and marine warranty surveying. And, as more designs receive AiP, demand for specialist vessels, dynamic cabling systems and large-component logistics is expected to accelerate. Market analysts believe that floating wind platforms will soon rival oil and gas structures in scale and complexity, reshaping global marine supply chains. ■

FROM OUTSIDERS TO FRONTRUNNERS

Wind-assisted propulsion systems may have been viewed as fringe curiosities in the previous decade, but their guaranteed fuel savings, relative simplicity to install and data-enhanced options are seeing them rapidly grow in adoption, Norsepower's Ville Paakkari tells **Martin Conway**

Norsepower's NPRS units (pictured aboard 230m LPG tanker *Oceanus Aurora*) can help deliver emissions savings up to 25%, and beyond in some cases

As with small modular nuclear reactor technology, the past five years have seen wind-assisted propulsion systems (WAPS) go from outside bets to serious contenders in the race to decarbonise the maritime sector. Class societies have expressed their confidence in WAPS to deliver, accompanied by a surge of installations aboard both new and existing tonnage – doubling in adoption each year, a recent presentation by Lloyd's Register highlighted.

So, why are WAPS gaining traction now? Ville Paakkari, head of R&D at WAPS manufacturer Norsepower, tells *The Naval Architect*: "We are gaining experience and gaining a reference fleet, and shipowners are becoming more used to the concept and understanding it better, which is building up their confidence in this product. It takes time: you need a few years of operation to prove the technology side. Norsepower's first WAPS installation was more than 10 years ago, so we now have a wealth of experience on our side."

Environmental regulations are the other big driver of change over the past five years, Paakkari opines. "Prevously, ships had to meet Energy Efficiency Existing Ship Index [EEXI] requirements, but these rarely influenced commercial decisions – once a vessel was certified, operations continued largely unaffected," he says. "But now, with Carbon Intensity Indicator [CII] ratings, the European Union Emissions Trading System [EU ETS], FuelEU Maritime penalties and evolving IMO requirements, we see these regulations becoming much more commercially oriented, which makes a strong business case for installing wind propulsion."

Paakkari continues: "WAPS are the most cost-efficient way to support compliance with these instruments. Some of the alternatives to traditional marine fuels, especially the more exotic options like hydrogen, have rather low energy density, which means you need a lot of onboard space to store these alt-fuels. With WAPS, you don't have to disassemble a wheelhouse to put in a scrubber; you're just installing a sail on the deck, like you would a crane – so, reducing fuel consumption by means of wind propulsion is a more attractive option."

Scope of supply

The past few years have seen Norsepower surf "an exponential growth curve, doubling our installation base every year or so", Paakkari says. So far in 2025, Norsepower has sold a dozen of its Norsepower Rotor Sail (NPRS) units, with another 44 or so on order, contributing to a grand total of 84 unit sales since the company's inception in 2012 – equating to more than 36,000tonnes of CO_2 saved to date.

About 40 of these units have been manufactured in Norsepower's dedicated rotor sail factory in Dafeng, China, which came online last year. This facility is currently staffed by a team of 40 engineers and wind propulsion experts, though Norsepower plans to boost the workforce as it raises its rotor sail production targets – from 50 to 60 units annually, initially, before scaling up production to 100 NPRS units per year.

The sails can be installed on newbuilds or retrofitted on existing ships, typically starting with a minimum length of 100m for single-hull vessels right up to LNG carriers, tankers, ro-ro/ro-pax vessels, bulkers, cruise ships, large ferries and VLCCs – "no limitations for maximum ship length apply", says Paakkari. Typically, he explains, the only limiting factors to NPRS installations are available deck space, stability and buoyancy, plus cargo capacity/deadweight.

That's not to say, though, that NPRS units could not be applied to smaller, sub-100m vessels. "I don't see why not, if the business case and scalability are there," says Paakkari. "It just happens to be that the first WAPS movers are the oceangoing vessels." The owners of small-to-medium-sized vessels would have to consider access to wind and wind strengths, especially as a fair number of these smaller

ships would comprise coastal and inland craft. In all, Norsepower estimates that its NPRS have the potential to help decarbonise at least 30,000 vessels currently in operation.

Sails opportunities

The NPRS range includes 20m-tall, 4m-diameter sails and 35m-tall, 5m-diameter units, all automated and deployable from the wheelhouse. The cylinder-shaped sail is described as a modernised version of the old Flettner rotor concept, which uses electric power to actively rotate the sails on the deck. "These rotating sails use the wind to produce powerful thrust, reducing fuel consumption, lowering emissions and costs," says Norsepower.

In 2021, Norsepower installed what it describes as "the world's first tiltable rotor sail" aboard Sea-Cargo's 1997-built, 154.5m ro-ro cargo vessel *SC Connector*, shortly followed by the installation of five tiltable sails aboard Pan Ocean Ship Management's 340m newbuild bulk carrier *Sea Zhoushan*. Tiltable sail mechanisms have become an obvious requirement for WAPS-assisted vessels calling at port for loading /discharging operations, or travelling on coastal routes flanked by bridges.

One of the group's biggest contracts to date was the signing of a 2024 deal to install NPRS units on a series of hybrid MDO/e-methanol-fuelled ro-ro vessels owned by French shipowner Louis Dreyfus Armateurs, for charter to Airbus – an order including six 35m-tall NPRS units per shipset. And, in March 2025, Norsepower secured a contract to supply two 28m-tall, 4m-diamater NPRS to a 147m Stena RoRo newbuild, under construction at Jinling Weihai Shipyard, China: the sails are expected to deliver up to 9% fuel savings on the vessel's planned trade route on the Irish Sea.

Other NPRS customers include TotalEnergies, Oldendorff Carriers and Scandlines, to name just three, and, depending on the vessel's route, main operational area(s) and access to wind, emissions reductions of 5-25% – and, in some cases, even more – can be achieved using the rotor sails, Norsepower confirms.

Data accuracy

The rise of WAPS technology has gone hand-in-hand with greater use of data to optimise performance. "Every ship fitted with NPRS provides us with about 1,000 real-time data streams, which we can feed back into the controls," says Paakkari. Combining wind propulsion and weather prediction data "is a match made in heaven", he adds, helping crew to plot the route most likely to result in low fuel consumption and suitable access to wind.

All the same, Paakkari cautions, it's not just about continually chasing wind: "Winds come with waves, and waves increase your resistance," he says. "It's why you need a holistic assessment of the onboard propulsion as a whole, and not just of the sail, so that you don't end up using more fuel than you need."

In Q2 this year, the company officially launched its Norsepower True Performance system, designed to measure the thrust force from both the sails and the vessel's propeller(s), to provide owners, charterers and regulators with precise and verifiable data regarding the actual impact that NPRS units are having in the field. As Norsepower put it at the time: "Measuring the effectiveness of wind propulsion has traditionally been challenging due to highly variable operating conditions. By directly measuring the real-life thrust produced by Norsepower Rotor Sails in real-time, Norsepower True Performance delivers clear, science-backed insights into fuel savings and emission reductions, setting a new benchmark for transparency in wind propulsion. This strengthens not only the business case for wind propulsion but also its role in regulatory frameworks."

In turn, Paakkari notes, the granular thrust measurements captured by the system, which were previously unavailable, can support R&D efforts and predictive maintenance regimes.

Holistic approach

When it comes to overseeing all onboard propulsive systems as a unified whole, one question is whether WAPS developers work on this technology themselves, or utilise systems such as Kongsberg Maritime's K-Sail – which was devised, for instance, to adjust the vessel's steering system to accommodate the additional thrust generated by the sails, and to ensure that the propeller operates efficiently with the added wind propulsion (see *The Naval Architect* September 2025).

Paakkari says: "Without wanting to sound arrogant, there are certain things that external system providers are unable to do, simply because they do not have access to the data we have, nor to the WAPS devices themselves. Then again, there are also areas where we don't have the insight that these providers do. Holistic system optimisation is a task for which all the providers must work in concert to achieve the best outcome." ■

The sails are easy to install; "you don't have to disassemble a wheelhouse to put in a scrubber", Paakkari explains

NAVAL BLOW

The New Generation Maritime Affairs Patrol Vessel could be the first application of wind-assisted propulsion technology aboard an active patrol boat

Until now, aside from some short-sea/coastal shipping applications, wind-assisted propulsion systems (WAPS) have tended to be the domain of 100m+, oceangoing vessels, including tankers and large cargo ships. So, it is something of a surprise to see WAPS technology being applied to a patrol boat, as is the case with the New Generation Maritime Affairs Patrol Vessel (PAMNG) project unveiled by naval architecture and marine engineering firm MAURIC. The PAMNG project aims to slash carbon emissions amid tightening EU maritime regulations and France's commitment to net-zero shipping by 2050.

Officially announced in January 2025, the PAMNG's first steel was cut in September at Socarenam's shipyard in Boulogne-Sur-Mer, France. The concept is for a 53.7m-long boat with a steel hull and an aluminium superstructure, powered by a diesel-electric hybrid system and a deck-mounted Wisamo wingsail, manufactured and supplied by Michelin and featuring a surface area of 170m^2.

Delivery to the owner, the French Directorate General for Maritime Affairs, Fisheries and Aquaculture (DGAMPA), is earmarked for the second half of 2027, and the vessel will operate primarily in the Bay of Biscay, undertaking missions ranging from maritime fisheries surveillance, pollution monitoring and enforcing compliance with environmental regulations to search and rescue operations, anti-trafficking activities and protection of French national interests. The Bay's challenging winds and waves should make it an ideal proving ground for wind-assisted propulsion tech in real-world enforcement scenarios.

Smart automation

Combined with the diesel-electric powertrain, the wingsail will help the PAMNG to achieve a maximum speed of 17knots at 85% MCR – reduced to 10knots when the vessel operates on electric alone – and overall fuel savings in the region of 15%. The PAMNG will also feature an endurance of 3,600nm at a speed of 12knots, MAURIC says.

The Wisamo includes a telescopic and retractable carbon-fibre mast, which can be lowered when the vessel enters port or passes under bridges. The wingsail is made of a light but strong fabric like a conventional boat's sail, and fills with air at low pressure when the mast extends.

A small fan blows in air to keep the wing's shape smooth and even, while built-in sensors enable the wing to autonomously adjust its angle to capture the right amount of wind, providing more speed and saving fuel. This smart automation will also reduce crew workload during long patrols. The PAMNG will also incorporate solar panels for auxiliary power, as well as an active trim control system to minimise energy consumption, further enhancing sustainability.

For this project, MAURIC conducted a detailed arrangement study for the vessel, including an 'optimisation loop' – an iterative computational process, used to simulate wind, speed, fuel use and stability to inform the best positioning for the sails for optimal performance. This kind of work is common in green maritime projects where sails are introduced to reduce emissions. MAURIC says: "This phase also enabled the finalisation of active and passive stabilisation systems development, through seakeeping calculations carried out to optimise the anti-roll tank with free surface effects and active fin stabilisers."

Using computational fluid dynamics (CFD) simulations, MAURIC then designed the boat's bulbous bow to refine the hull's hydrodynamic performance. "These CFD studies have optimised resistance through the water and defined the vessel's active trim control system underway, confirming a hybrid cruising speed of 10knots and maximum speed exceeding 18knots," the company says. "This configuration ensures the energy efficiency sought for this vessel with reduced environmental footprint." Advanced modelling also predicted reduced drag in moderate seas.

Long-range missions

The PAMNG has been arranged for a crew of 16 and four special forces personnel, and has an autonomy of 12 days – sufficient, MAURIC says, to guarantee sea patrols for up to 200 days annually, plus offshore capability for extended missions. In addition to its crew complement, the vessel will carry a pair of 6.5m-long, semi-rigid boats, capable of 35knot intercepts.

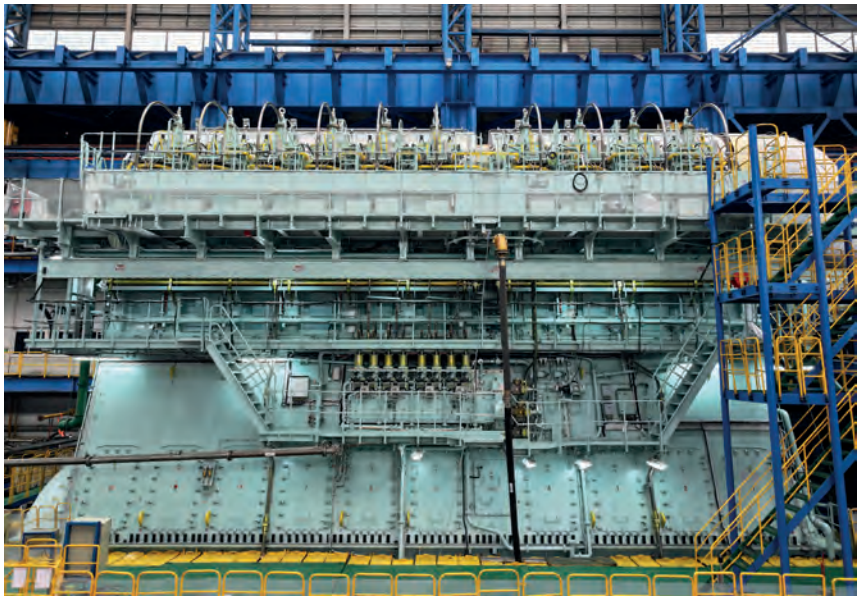
MAURIC's previous forays into wind-assisted propulsion include the 136m x 24.2m, sail-powered ro-ro cargo vessel *Neoliner Origin*, which was launched by RMK Marine's shipbuilding facility in Turkey earlier this year, and which made its first transatlantic voyage in October. Built by Chantiers de l'Atlantique, *Neoliner Origin* has incorporated two semi-rigid SolidSail rigs in an effort to reduce its fossil fuel consumption by more than 80% compared to a same-sized, conventional ship operating at 15knots (see *The Naval Architect* May 2025).

As a non-commercial use of WAPS, however, should the forthcoming patrol boat realise its predicted efficiencies without compromising on performance, it could inspire similar retrofits across Europe's patrol fleets, potentially cutting operational costs by thousands of Euros annually per vessel. ■

The PAMNG concept is for a 53.7m-long boat powered by a diesel-electric hybrid system and a Wisamo wingsail

RUNNING ON ETHANOL

Building on earlier experience with methanol dual-fuel engines, Swiss company WinGD sees a promising future for the latest addition to its marine engine portfolio, writes **Clive Woodbridge**



The new ethanol engine builds on WinGD's experience with methanol engines, with the first of the new X-DF-M platform being introduced earlier this year

Following an extensive research programme, Swiss marine power company WinGD is set to launch its first ethanol-fuelled two-stroke marine engine next year, with deliveries for newbuild and retrofit applications starting in 2027. The new engine will be adapted from the company's X-DF-M methanol-fuelled engine and will feature a modified control system and fuel injector nozzle arrangement to account for the higher energy density of ethanol and the consequently lower fuel volumes required.

Ethanol can be produced renewably from biomass and is prevalent at a competitive prices in some national markets, driving growing interest in this alternative fuel.

Sebastien Hensel, VP, R&D, says: "At WinGD our work on ethanol engines builds on more than a decade of research and development on alcohol fuels, of which ethanol was the first. From those explorations we developed a deep understanding of the combustion characteristics, thermal efficiency and emissions profile of alcohol fuels. This knowledge directly informed the X-DF-M methanol design launched earlier this year and now our new ethanol capability."

Crucial experience

Ethanol has a lower heating value than methanol, and WinGD has refined the injection system, control parameters and nozzle design to deliver the correct fuel volumes and maintain full power output. Hensel adds: "We also enhanced combustion and emissions control as ethanol's flame temperature and air-fuel ratio can influence NOx formation, which we manage through an advanced injection atomiser and updated control logic to ensure compliance with IMO regulation."

The updates to the injection atomiser and nozzle geometry are intended to ensure precise fuel delivery and stable combustion, while refinements to the engine control system maintain efficiency and emissions compliance. These developments represent an evolution of WinGD's existing dual-fuel technology, rather than a complete redesign, the company points out.

WinGD has been studying ethanol fuel, which has a similar combustion and emissions profile to methanol, since 2014, beginning with a project financed by the Swiss Federal Office of Energy. WinGD later led work to develop a flexible injector for alcohol fuels as part of the EU-funded HERCULES 2 project starting in 2016.

The earlier methanol engine experience is described as being "crucial" in this development. Hensel explains: "It gave us deep expertise in combustion control, injection technology and fuel management systems that directly support ethanol development. Since both fuels share similar combustion behaviour and operate under the same IMO safety framework, we were able to adapt our methanol platform with only a few manageable technical adjustments."

The main differences lie in ethanol's slightly lower heating value and its specific combustion profile. Hensel observes: "To address this we fine-tuned the fuel injection system and control parameters to maintain optimal efficiency and performance."

Ethanol adopters

WinGD believes that ethanol will be particularly well suited for those ships operating on routes to countries where it is already being produced and is readily available, such as Brazil, the US, Canada

Sebastien Hensel, WinGD: "We developed a deep understanding of the combustion characteristics, thermal efficiency and emissions profile of alcohol fuels"

and India. These countries have mature ethanol industries, established infrastructure and competitive pricing – in some cases, even lower than diesel – which makes ethanol particularly attractive amongst biofuels.

The company expects that the early adopters of ethanol dual-fuel engines are likely to be operators of bulk carriers and tankers trading in these regions. Container vessel operators already using methanol may also be wiling to explore ethanol as the engine can be optimised for either fuel with minimal adaptation.

WinGD reports that it is in discussions with several shipowners, ethanol fuel suppliers and class societies about the first commercial applications of its ethanol engine, and whether the engine will be optimised for ethanol or for methanol with secondary ethanol capability. Hensel says: "In principle, our engine concepts can run on both fuels and we are discussing which configurations will best meet the specific requirements of the first applications and will confirm those details closer to delivery."

The company expects the first ethanol-fuelled two-stroke engine to be introduced in 2026 with deliveries beginning the year after. Hensel observes: "Interest from shipowners has grown rapidly this year, particularly in regions where ethanol is abundant. Ethanol's main advantages include its cost competitiveness, scalability and use of existing infrastructure. The key challenge for the wider maritime supply chain will be expanding bunkering and logistics networks to support global availability as demand grows."

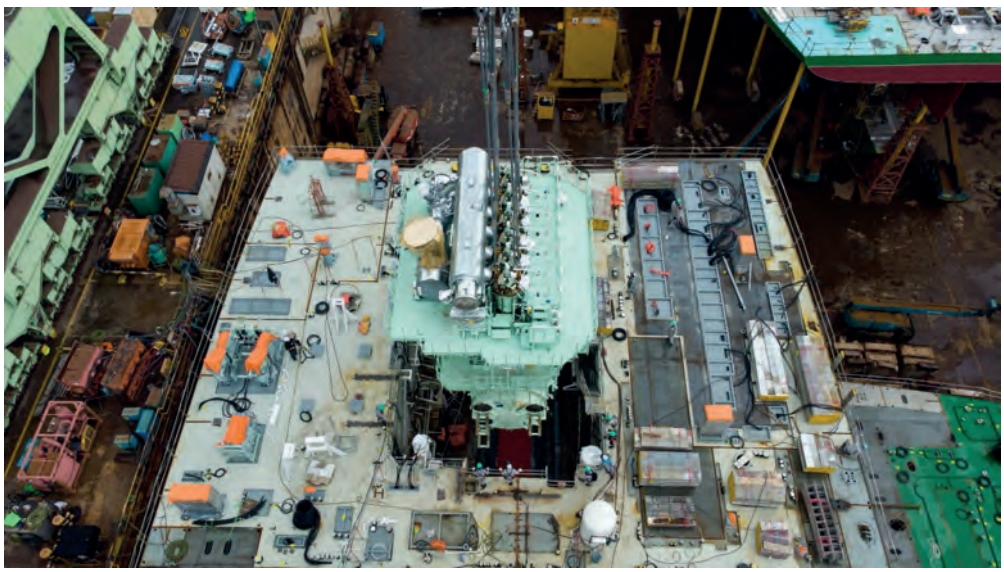
First applications

The first applications of the new ethanol engine type are expected to be for newbuildings. However, WinGD is developing a retrofit option based on its experience in converting diesel engines for methanol operations. "The shared IMO safety framework for alcohol fuels simplifies both newbuild and retrofit pathways, giving shipowners the flexibility to adopt ethanol efficiently as part of their broader decarbonisation strategies," Hensel points out.

WinGD continues to develop other new dual-fuel technologies and earlier this year introduced an ammonia-fuelled two-stroke marine engine following the delivery and installation of its X52DF-A engine on a 46,000m^3 LPG/ammonia carrier being built for Exmar. The 52-bore engine was built by HD Hyundai Heavy Industries' Engine & Machinery Business Unit (HHI-EMD) and installed on the first of four sister vessels to be built at HD Hyundai Mipo shipyard in South Korea.

The X-DF-A engine features high-pressure ammonia injection supplemented by a low, targeted pilot fuel dose of around 5% at full load. The engine is claimed to deliver load handling, dynamic response and fuel efficiency on a par with WinGD's equivalent diesel-fuelled XeEngines in both ammonia and diesel operating modes. Further optimisation will continue for the second engine in the 52-bore series, which will be delivered shortly.

WinGD reports an orderbook of around 30 X-DF-A engines to date. These will be installed on a wide range of vessels including gas carriers, bulk carriers and container ships. ■



WinGD's dual-fuel engine programme reached a milestone with the installation of the first X-DF-A ammonia-fuelled engine on an LPG/ ammonia carrier being built for Exmar

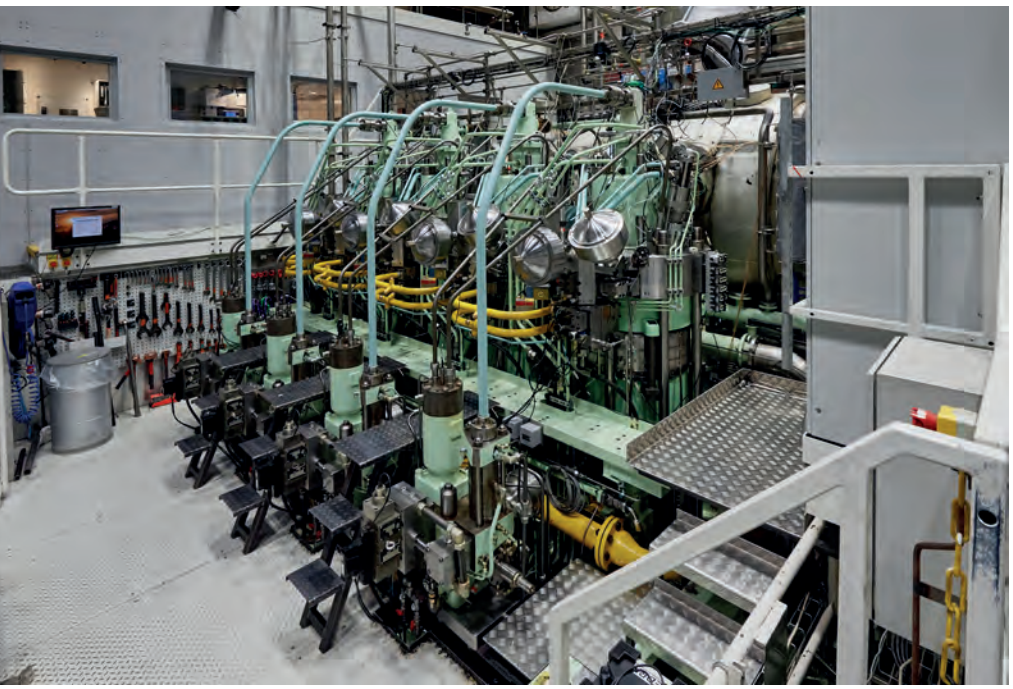
NEW AMMONIA ENGINE FROM EVERLLENCE

The marine engine manufacturer believes the introduction of its new ME-LGIA engine marks the beginning of an important new chapter in the industry's green transition, writes **Clive Woodbridge**

The adoption of ammonia as a marine fuel is expected to play a pivotal role in the shipping industry's response to regulatory pressures aimed at achieving net zero by 2050. As a step on this journey, Copenhagen-based engine manufacturer and designer Everllence has recently unveiled its new ammonia dual-fuel ME-LGIA engine to industry stakeholders.

Everllence (formerly MAN) started a research programme to develop a new two-stroke ammonia dual-fuel engine type in 2019. This led to the start of full-scale engine tests, running all cylinders on ammonia, at its Research Centre Copenhagen (RCC) in 2024. This R&D testing was finalised earlier this year, along with the completion of commercial design work for the S60 and G60 versions of the new engine type, paving the way for the first vessel deliveries with the new ammonia dual-fuel engines in 2026. Hrishikesh Chatterjee, senior promotion manager, newbuildings, says: "Ammonia needs respect as a fuel because of certain characteristics regarding its toxicity and combustibility. Our research programme has proceeded cautiously and steadily to give all parties confidence in this technology. The results of the testing have been positive and suggest that ammonia will be an excellent marine fuel."

The ammonia research engine under test at the Research Centre Copenhagen facility



To date, three separate newbuilding projects have been confirmed. A 7S60ME-C10.5-LGIA engine has been operating on ammonia at the Mitsui E&S facility in Japan. This engine is destined for a bulk carrier building at Imabari Shipyard, with delivery tentatively scheduled for Q1 2026. In addition, an order has been received for a pair of 93,000m^3 ammonia carriers being built at Hyundai Heavy Industries' Ulsan shipyard for Eastern Pacific Shipping. The 6G60MEE-C10.5 LGIA engines for these vessels are expected to be delivered in Q1 2026 as well. The third project is for four 7S60ME-LGIA type engines for Hoegh Autoliners' new Aurora-class pure car/truck carriers (PCTCs). HD Hyundai Heavy Industries will build the engines in South Korea with delivery anticipated in 2027.

Areas of focus

Chatterjee says: "We have engaged in a small number of pilot projects to safeguard the introduction of ammonia as a marine fuel. A full sales release of G50, S60, G60, G70 and G80 type ME-LGIA engines will be undertaken as soon as the first vessels have demonstrated positive seagoing experience operating on ammonia." Now, the 'best guess' for this general sales release is the end of 2026, with containerships, large bulk carriers and PCTCs amongst the initial target markets, although Everllence stresses that the technology is well suited to a wide range of vessel types.

Everllence highlights four key areas of focus during the research process for unlocking the potential of ammonia as a marine fuel – flame speed, auto ignition temperature, combustion slip and N2O emissions. The design philosophy adopted was that, in ammonia mode, only a small pilot flame should be needed, with a target of 5% specific pilot oil consumption at 100% load, and the same heat rate as in fuel oil mode. When

the engine is operating in fuel oil mode the aim was to achieve an identical performance to a conventionally fuelled engine. Safety has also been a high priority, and the new engine type features double-walled inlet and outlet piping.

Everllence expects a fast uptake for ammonia dual-fuel engines, and predicts that by 2050 around 35% of all newbuilding two-stroke engine orders will be for ammonia dual-fuel. Containerships are likely be the main early adopters of this technology, the company expects.

Growing demand

Recent years have seen growing demand for Everllence B&W dual-fuel engine types. Its order book in 2025 over the first three quarters of the year was around 40% dual-fuel and 60% single-fuel, which compares with a ratio of roughly 50:50 over the past few years. The slight apparent shift to single fuel is accounted for by market uncertainty with regards new regulations. This is expected to be a short-term trend and the company believes that a significant increase in dual-fuel orders will take place as global regulatory conditions are confirmed and more viable alternative fuels emerge on the market.

Most dual-fuel orders received by Everllence to date in 2025 have been for methane (LNG)-powered engines, around 85% of orders. Methanol dual-fuel engines have accounted for 7% of orders, followed by propane at 6% and ethane and ammonia for 1% each. Containerships have accounted for the majority of dual-fuel engine orders in 2025, the company reports.

As of the end of September this year, some 850 methane-fuelled ME-GI type engines were on order or in service. Earlier this year, the company introduced ME-GI on its new 10.7 two-stroke engine platform, with resulting upgrades including increased gas operating pressure, at 380bar, which has improved fuel efficiency. More than 50 engine orders have been achieved already for the fuel oil and methanol 10.7 engine variants. Refinements within the 10.7 platform compared with earlier generations include a simplified piping system, with both gas supply and purge pipes replaced with only one bi-directional pipe, resulting in: lower installation costs; the lowering of pilot oil consumption to 1.5% for some engines; and a gas cylinder cut-out enabling one cylinder to run on fuel oil while the remaining cylinders continuously operate on gas. ■

PASSING THE TEST

Rolls-Royce Power Systems' single-fuel methanol engine could be an attractive option for ferry, yacht or supply vessel operators who want to reduce their carbon footprint, writes **Clive Woodbridge**

Rolls-Royce Power Systems has successfully tested what it claims is the world's first high-speed marine engine powered exclusively by methanol, at a specially redesigned test bench in Friedrichshafen, Germany. This project was undertaken through the meOHmare research initiative, funded by the German Federal Ministry for Economic Affairs and Energy, which combines the expertise of Rolls-Royce, injection system specialist Woodward L'Orange and the WTZ Roßlau technology and research centre.

Using methanol requires significant changes to engine design, including modifications to the combustion process involving the fuel system, the charging and engine control systems, as well as all engine subsystems that come into contact with the fuel. The entire fuel system is made of stainless steel to prevent corrosion as a result.

The first test hours are said to have shown that the engine is running well, with only fine tuning now required. "The engine behaviour differs significantly from that of a diesel engine...we are currently improving the settings so that the engine runs smoothly and accelerates cleanly under load," says Dr. Johannes Kech, head of methanol engine development.

Biggest challenges

By the end of 2025, all components of the engine will have been extensively tested and further developed, and discussions are underway with partners and funding agencies to bring the technology into practical application.

In developing the methanol-only engine, Rolls-Royce has had to overcome challenges – particularly since, unlike diesel, liquid alcohol does not ignite spontaneously and requires a completely new injection technology. According to Steffen Theiß, development engineer and project lead, MeOHmare, at Rolls-Royce Power Systems: "The biggest challenges in designing the methanol engine are injection, mixture formation, the ignition system and the safety concept for liquid low-flashpoint fuels."

As there are no off-the-shelf methanol injectors available for this performance class, Rolls-Royce engineers are developing hardware that is consistently precise in its metering and is also highly durable.

Another major challenge is to achieve a homogeneous fuel-air mixture in the combustion chamber that can burn cleanly.

The first high-speed pure methanol engine has recently been tested on Rolls-Royce Power Systems' test bench in Friedrichshafen, Germany

Theiß explains: "Due to methanol's lower lubricity, the fuel cannot be injected into the combustion chamber at pressures of 2,000bar and above, as is the case with diesel. However, the lower the pressure, the more difficult it is to create a homogeneous mixture in the combustion chamber.

"Put simply, the finest possible methanol droplets must be present throughout the combustion chamber so that they evaporate quickly, ensuring a homogeneous and ignitable mixture at the spark plug."

Combustion and thereby flame propagation are highly dependent on the mixture distribution and the charge movement in the combustion chamber. Theiß says: "The challenge with ignition is to ensure that, at the thermodynamically optimal ignition point, the mixture composition and the degree of turbulence of the flow directly at the spark plug enable ignition. Compared to a diesel engine, the charge movement in the combustion chamber must be adjusted much more precisely."

New safety concept

Another aspect of the engine design is the ignition phase itself. "Since the ignition behaviour, mixture distribution and charge movement vary slightly from one combustion cycle to the next, there are also significant fluctuations in combustion and consequently in the pressure build-up in the cylinder and the power output," says Theiß. "In comparison, diesel engine injection and combustion are much more reproducible, so that the combustion cycles differ only slightly from one another."

Rolls-Royce has developed the safety concept of the new engine type in accordance with the requirements of classification society DNV.

Theiß says: "Unlike diesel engines, ensuring the necessary safety levels requires a double wall with ventilation. We paid particular attention to having a compact installation space and in addition we have integrated systems for detecting methanol."

In order to comply with Rolls-Royce's own safety standards, the team developed a new safety concept specifically for the test bench. This included special flame detectors, methanol detectors, ventilation systems and a flushing concept for all lines.

The combustion process for the methanol engine has been tailored to work with a specially designed turbocharging system, to ensure clean combustion, rapid boost pressure build-up and high efficiency across the entire operating range. The result, Rolls-Royce says, is that the engine combines the dynamic response of high-speed diesel engines with a fuel that advances the maritime energy transition. "For operators, this means familiar performance and a better carbon footprint," concludes Theiß.

While Rolls-Royce's methanol engine concept is generally suitable for all marine applications for which it offers propulsion systems, the company is initially focusing on workboats, such as tugs, ferries, offshore support vessels and yachts. The next stage will be to identify a pilot ship to test the new engine under operational conditions at sea.

In a parallel project, Rolls-Royce is also testing dual-fuel technology for methanol marine engines. Until green methanol is widely available, dual-fuel engines could serve as a bridging technology, the company believes. ■

REMEMBERING SS *EDMUND FITZGERALD*

Bruno Cianci reflects on the 1975 sinking in Canadian waters, the theories surrounding the accident and the safety legacy that it left

Fifty years have passed since the most infamous maritime disaster in the history of the Great Lakes – yet, the accident that saw the American-flagged SS *Edmund Fitzgerald* sink into the depths of Lake Superior, in Canadian waters, on the evening of 10 November 1975, continues to arouse considerable interest.

The reasons are manyfold. The first lies in the size of the ship in question, which, at the time of the launch in 1958, was the largest of all those operating in the Great Lakes region, a distinction she would hold until 1971. A second, more important reason concerns the aura of mystery that still surrounds the circumstances of the dramatic sinking.

Despite locating and inspecting the wreck's remains at a depth of 160m, it has proven impossible to reconstruct in detail the ultimate causes of an accident that cost the lives of the entire crew: a master, three licensed deck officers, a chief engineer, four licensed engineering officers and 20 unlicensed personnel – a total of 29 men whose bodies were never recovered.

The vessel

Built as hull no.301 by Great Lakes Engineering Works of River Rouge, Michigan, SS *Edmund Fitzgerald* was a 'straight-decker' ore carrier, a common configuration on the Great Lakes, featuring a pilothouse at the far bow, an aft deckhouse with engine room at the far stern and a continuous cargo hold in between. Access to forward and aft deckhouses could be accomplished topside or through specular tunnels located port and starboard, immediately below deck.

The 'Fitz', as the ship was nicknamed, had a 24,380m^3 cargo hold divided by two non-watertight transverse screen bulkheads. Outboard and below the cargo hold were eight ballast tanks, divided at the centreline into port and starboard tanks. The cargo holds featured 21 openings, each measuring 3.4m longitudinally and 14.6m transversely.

Operated by the Columbia Transportation Division of the Oglebay Norton Company, and owned by Northwestern Mutual Life Insurance Company (after whose chairman and president of the board the ship was named), SS *Edmund Fitzgerald*'s gross registered tonnage was 13,632. Her welded steel hull measured 222m in length, 22.86m in breadth and 11.89m in depth, an overall size that fell within the parameters of the maximum length allowed for passage through the Saint Lawrence Seaway.

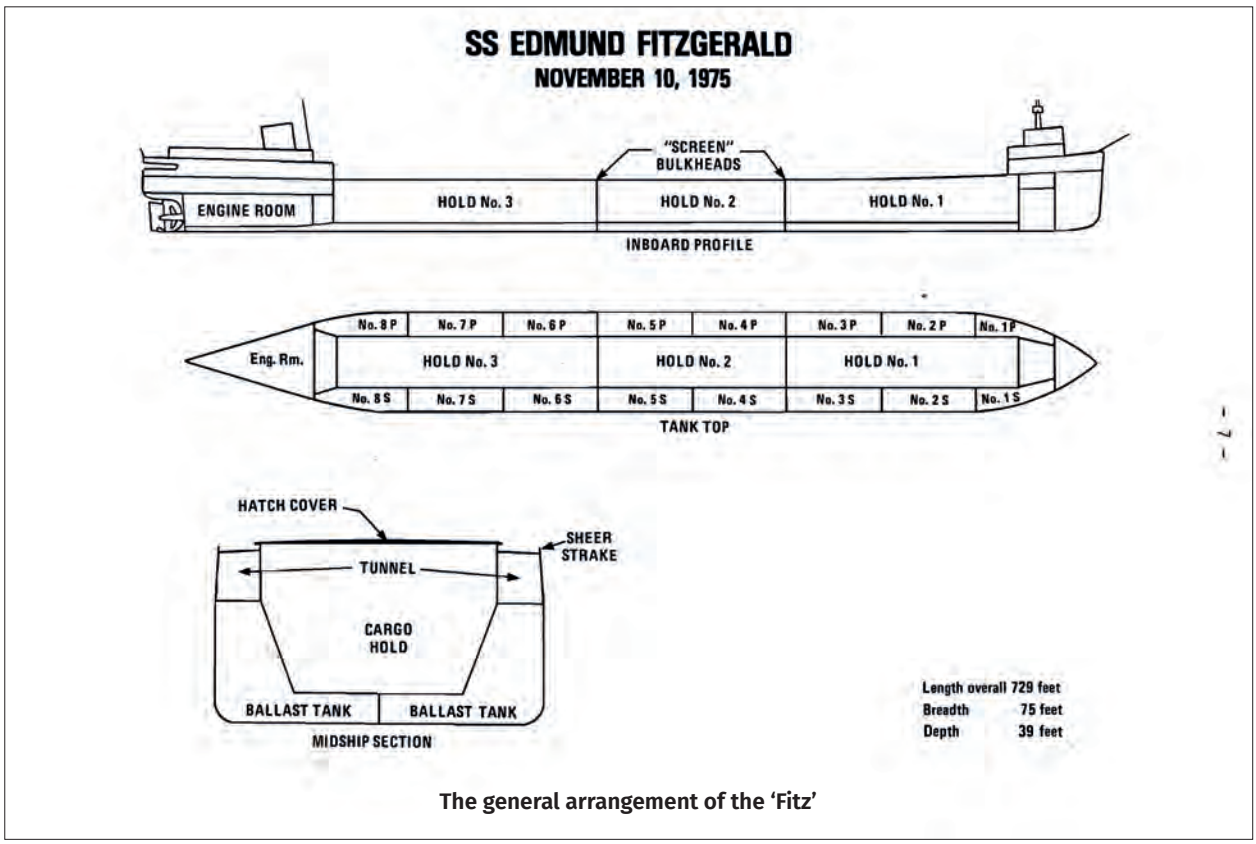
She was propelled by a steam turbine generating some 7,500hp (5,593kW). At the time of her launch, the latter was coal-fired, but during the works that took place over winter 1971-72 the power source was converted to oil, and the ship transformed to carry up to 272,255litres of fuel where the coal bunkers had once been.

Launched in 1958, SS *Edmund Fitzgerald* sank in the Great Lakes 50 years ago

Although a bulk carrier, SS *Edmund Fitzgerald* featured amenities that few other ships of the Great Lakes could provide, including passenger accommodations and a galley. That said, appearances should not deceive: life on board was very hard and the crew often did not see their families for long periods. Besides, navigation could bring about unimaginable dangers.

The tragedy unfolds

On the morning of 9 November 1975, SS *Edmund Fitzgerald* began loading taconite pellets at Burlington Northern Railroad Dock No.1 in Superior, Wisconsin. Loading was completed in the early afternoon and draughts were taken after receiving fuel. After this customary operation,



The general arrangement of the 'Fitz'

the 'Fitz' put to sea, bound for Sault Ste. Marie, Michigan, under the command of Ernest M. McSorley (1912-75), a highly experienced captain.

Because of predicted deteriorating weather, the receipt of storm warnings at 2am on 10 November and discussions via radiotelephone, the 'Fitz' and SS *Arthur M. Anderson* (a similar freighter en route to Gary, Indiana) departed the recommended shipping lane along the southern shore of Lake Superior, and instead proceeded northeastward to take advantage of the lee theoretically provided by the Canadian coastline.

Storms are far from uncommon on the Great Lakes, but the one about to unleash was anything but ordinary: it was the combination of at least two low-pressure systems – one known as the Alberta Clipper, and the other known as the Panhandle Hook – destined to collide right on Lake Superior: the proverbial 'perfect storm'.

About 3:30pm, while steaming northeast of Caribou Island, a crewman of the 'Fitz' called the *Anderson* – which was steaming 16 miles behind – and delivered the message: "I have a fence rail down, have lost a couple of vents, and have a list". How this damage had occurred is still unknown, and open to speculation. When asked specifically whether the bilge pumps were running, a reply was sent from SS *Edmund Fitzgerald*: "Yes, both of them". At 4:10pm, the 'Fitz' advised the *Anderson* that both her radars were inoperative and asked for navigational assistance.

The next few hours, with the lake waters swept by near-hurricane-force winds, snow and 15m waves, saw SS *Edmund Fitzgerald* experience the final moments of her glorious career. The last message from the ship was received at 7:10pm, when McSorley in person was heard saying: "We are holding our own". Within minutes – and just 15nm from the destination, and safety – the 'Fitz' disappeared from the *Anderson*'s radar.

The aftermath

While it took just a few days to determine the ship's exact position, the first underwater exploration had to wait until late May 1976, when the US Navy sent an unmanned submersible (a CURV-III) which found SS *Edmund Fitzgerald* in two large pieces: an 84m-long bow upright section and a 77m capsized stern section. In between the two severed parts – which were 52m apart, positioned at an angle of 50° from one another – lay a large mass of taconite pellets and the scattered wreckage of the 61m midship section.

Despite the official reports and survey, the ultimate cause of the sinking still remains unknown. A comprehensive report dated 4 May 1978, issued by the US National Transportation Safety Board (NTSB-MAR-78-3), concluded that "the most probable cause of the sinking...was the loss of buoyancy and stability which resulted from massive flooding of the cargo hold. The flooding...took place through ineffective hatch closures as boarding seas rolled along the spar deck".

According to the same report, an analysis of the contributing factors behind the loss offered the following conclusions and considerations, among others. The winter load line assigned to SS *Edmund*

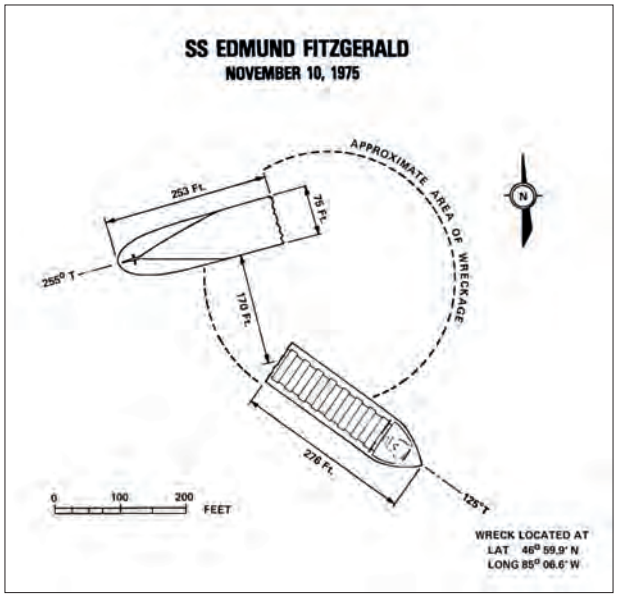
Many causes of the SS *Edmund Fitzgerald* disaster have been suggested, including the vessel striking an object

Fitzgerald under the changes to the Load Line Regulations in force "allowed 3ft, 3-1/4 inches [about 99.6cm] less minimum freeboard than had been allowed when the vessel was built in 1958"; the system of cargo hatch coamings, gaskets, covers and clamps and the manner in which this system was maintained "did not provide an effective means of preventing the penetration of water"; the cargo hold was not fitted with a system of sounding tubes or other devices to detect the presence of flooding water; "the cargo hold was not fitted with transverse watertight bulkheads" and "as a result, the flooding water...could migrate throughout the hold, extending the effect of the flooding and aggravating any trim which existed"; the topside damage the crew mentioned via radiotelephone, or even an "undetected damage opening the hull plating", could have been caused by the vessel striking a floating object; even though the Marine Board was unable to reconstruct the exact course of the 'Fitz', the topside damage and list could have been caused by "a light grounding or near grounding on the shoals north of Caribou Island"; and, alternatively, the list could have been caused by a localised hull structure failure, resulting in the flooding of one or more ballast tanks.

The Board concluded that "the exact cause of the damage reported cannot be determined", but that "the most likely cause was the striking of a floating object". This could have occurred in the forward part of the vessel, resulting in pitching down and diving into a massive wave, with the vessel unable to recover. With no witnesses nor survivors, and because of the complexity of the wreckage, the actual final sequence of events and sinking cannot be determined: however, it is evident that the end was so rapid that there was no time to attempt not only the launching of lifeboats or life rafts, but even to make a distress call.

Among the other possible causes, according to the same report, the 'Fitz' potentially sank because of a structural failure on the surface. However, this is considered "less likely because such a failure would have severed the vessel into two sections on the surface, and one or the other, if not both sections, would have floated for a short while". Given the 50knot winds and the state of the sea at the time of the accident, if either or both of the pieces had floated for some time, significant drifting would have occurred. Survey on the wreckage, though, showed that drifting had been limited.

A sketch of the relative positions of the stricken vessel's bow and stern sections after the incident



The legacy

In the 48 years since the report was compiled, nothing substantially new has emerged, and so the circumstances of the sinking remain a matter of speculation. SS *Edmund Fitzgerald* may have been swamped, suffered a major structural failure or topside damage, grounded on shoals or been the victim of a combination of all the above.

What is certain is that the sinking of the 'Fitz' and the sacrifice of her crew saved many lives on the Great Lakes. The living memory of the accident, awareness at large, stricter regulations, weather forecasting advances and common sense have all played their part. In fact, it is striking to note that since that fateful 10 November 1975, no significant sinking has occurred in the Great Lakes region. Yet – as John U. Bacon (author of *The Gales of November: The Untold Story of the Edmund Fitzgerald*, 2025) points out – in the hundred years preceding the disaster, some 6,000 ships had sunk in the region in question: on average, more than one per week for the duration of a century. ■

SMATECH CONFERENCE

The 7th International Conference on Smart & Green Technology for Shipping and Offshore Industries, hosted by MA Marine Consultants, will be held between 23-24 April at London Croydon Aerodrome Hotel. The event aims to offer delegates an unparalleled opportunity to network with researchers, technology developers, industrial players and supply chain partners involved in green ship designs and systems, including both seagoing and inland vessels.

Items on the agenda will include offshore renewable energy, efforts to decarbonise the shipping and offshore industries, wave and tidal energy resources and securing investments from government and the private sector. This year, for the first time, SMATECH will team up with the annual Conference on Renewable Energy (CORE) as delegates.

The 10 keynote speakers will include: Dr. Yao Zhang, assistant professor in marine/maritime digitalisation and automation at University College London (UCL); Tsoulakos Nikolaos, innovation & technology manager, Laskaridis Shipping; Professor Nigel Barltrop, emeritus professor at the University of Strathclyde and director of Barltrop Engineering; and Professor Tahsin Tezdogan, professor of marine hydrodynamics at the University of Southampton.

"One of the aims of this conference is to create a framework for knowledge sharing and to develop a roadmap for research activities in the context of smart and green technologies that are a relatively new and challenging field of interest," says MA Marine Consultants. "In particular, the conference will enable research activities leading towards innovative, cost efficient and environmentally benign offshore renewable energy conversion platforms for wind and wave energy resources." ■

For more information on the event, contact: info@mam.engineer

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