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Winter is coming

As the sun begins to set on 2024, it is time to look back at the state of key conflicts, how they have developed over the past year, and where things appear to be headed.

For the most part, Ukraine has continued to steadily lose ground to Russia along the key frontlines, and while it made some gains with the Kursk incursion, a large percentage of this captured land has since been recaptured by Russia. As of mid-October 2024, Ukraine has lost a large chunk of Toretsk, while Selydove appears to be in the process of being surrounded, as are Hirnyk, Kurakhivka, and Zoriane. Further South, Russian forces are gradually pushing northward, having captured Kostiantynivka and Vuhledar. Elsewhere, Pokrovsk appears to be relatively secure for the time being, but this state is not expected to last more than a couple of months, with the town already having been largely evacuated by late September 2024. A similar story seems the case for Kupiansk, with Kharkiv Regional Governor Oleh Syniehubov, ordering the town's evacuation on 15 October, following Russian advances to within less than 2 km of the Oskil River section near Kruhlyakivka. Despite Ukrainian attacks on several key Russian munitions depots in mid-September 2024, the overall pace of Russian advances does not appear to have slowed.

Against this background, on 16 October 2024, Ukrainian President Volodymyr Zelenskyy presented a 'Victory Plan' to Ukrainian Parliament, claiming "we may manage to end the war no later than next year". The plan includes various measures, such as Ukraine being invited to join NATO, deployment of an unspecified non-nuclear strategic deterrent, setting up a joint military-industrial complex with the West, and a lifting of restrictions regarding NATO weapon use against targets within Russia. On the latter point – while widely reported to be a problem of permission, this is not the case – many of these long-range weapons would in practice require NATO countries becoming more directly involved, by providing support in the form of targeting information, as well as planning and intelligence analysis. This is a step many have refused to take.

Among some analysts, the political reading of Zelenskyy's Victory Plan has been fairly cynical – not least because the plan almost entirely relies on actions by Ukraine's allies. Some have even gone as far as to say it is a diplomatic means of laying the groundwork for attribution of blame on insufficient support from the West in the case of Ukraine's defeat. Overall, the prospects of victory for Ukraine seem to be receding into the distance, while the looming prospect of a Trump presidency darkens Ukraine's horizon further.

In the Middle East, things only seem to have escalated since 2023, with Israel expanding its strikes beyond Gaza, and setting its sights against Hezbollah in Lebanon, following the latter's sporadic strikes on northern Israel. This started with a series of attacks starting on 18 September 2024, initially using compromised pagers, and on subsequent days followed by walkie-talkies, and various other electronic devices, all of which had been intercepted by Israel and high explosive materials implanted within by the Israeli secret services, allowing remote detonation. This was soon followed by a massed air strike campaign against numerous targets in Lebanon on 23 September 2024, continuing in the subsequent week, and aimed at wiping out Hezbollah's leadership. This saw success, with various key leadership figures confirmed to have died, most notably Hezbollah's leader Hassan Nasrallah on 27 September. Following Nasrallah's death, Naim Qassem has assumed leadership of the armed group. Bombings on Lebanon have continued, as Hezbollah has continued to prosecute a campaign of rocket and drone attacks on Israel.

Shortly after Nasrallah's death, Iran launching a major retaliatory strike against Israel on 1 October, using around 180-200 munitions, most of which were understood to have comprised various Iranian-built medium-range ballistic missiles (MRBMs), but also reported to have included one-way attack (OWA) drones. While some Israeli outlets claimed a high percentage of threat munitions were intercepted, this did not appear to be borne out by available photo and video evidence, which showed a large number of missiles leaking through Israel's defences, along with detonations and craters from missile impacts. Despite many successful impacts, the accuracy of the missiles seemed to have been relatively low, with many appearing to have struck nearby their presumed targets. The attack appears to have been aimed primarily at many Israeli intelligence and military facilities, including Mossad's HQ in northern Tel Aviv, Nevatim airbase (home to Israel-s F-35I Adir fighter aircraft) in southern Israel, and Tel Nof airbase (reported to house at least some of Israel's air-launched nuclear arsenal) in central Israel. The end result appears to have been variable damage to buildings and infrastructure, but minimal human casualties.

Given the lack of follow-up, Iran's 1 October strike should probably be read politically as a very strong shot across the bows, and a demonstration that it has the capability to break through Israel's defences. While a typically severe Israeli response is expected, such a course would be expected to trigger further retaliatory attacks, with many possible actors equipped to do so; including Iran itself, Hezbollah in Lebanon, Kata'ib Hezbollah in Iraq, and Ansar Allah in Yemen.

It will likely be challenging for Israel to expand its strike campaign significantly beyond current limits without significant US materiel support, and here again, much rests on the outcome of the US Presidential election. Given what is at stake for both Ukraine and the Middle East, this may well prove a 5th of November that will never be forgot.

Mark Cazalet

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Office Address:
Mittler Report Verlag GmbH
Beethovenallee 21, 53173 Bonn, Germany
Phone.: +49 228 35 00 870, Fax: +49 228 35 00 871
info@mittler-report.de, www.mittler-report.de

Managing Director: Peter Tamm

Editorial Team

Publisher and Editor-at-Large: Stephen Barnard (sb)

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Layout:
AnKo MedienDesign GmbH, Germany

Production:
Lehmann Offsetdruck und Verlag GmbH, 22848 Norderstedt, Germany

Advertising, Marketing and Business Development
Achim Abele
Phone: +49 228 25900 347
a.abele@mittler-report.de

Stephen Barnard
Phone: +49 228 35 00 886, Mobile: +44 7984 033154
s.barnard@mittler-report.de

Stephen Elliott
Phone: +49 228 35 00 872, Mobile: +49 1590 173 0346
s.elliott@mittler-report.de

Exhibition Management and Advertising Administration:
Renate Herrmanns

Advertising Accounting: Markus Wenzel

Subscription/Reader Service:
Mittler Report Verlag GmbH
Beethovenallee 21, 53173 Bonn, Germany
Phone: +49 0228 3500888
Email: abo@mittler-report.de

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Credit: GA-ASI

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Israel's enemies reap the whirlwind on first anniversary of Hamas terrorist attack

(pf) In the days preceding the one-year anniversary marking the 7 October 2023 Hamas terrorist attack on Israel, the country's prime minister, Benjamin Netanyahu, conceded that the country is now in conflict on multiple fronts and closer than ever to a direct confrontation with arch nemesis Iran.

Credit: IDF

"Today, Israel is defending itself on seven fronts against the enemies of civilization," Netanyahu said in a video statement on 5 October. He said those enemies include Iran-backed Hezbollah in Lebanon, Hamas in Gaza, the Houthis in Yemen, "terrorists" in the West Bank and Shiite militias in Iraq and Syria.

"And we are fighting against Iran, which last week fired over 200 ballistic missiles directly at Israel and which stands behind this seven-front war against Israel," Netanyahu added.

The Iranian ballistic missile barrage came in response to the Israel Defense Forces (IDF) proceeding on 1 October 2024 with what was described as a "limited ground operation" into Lebanon to target Hezbollah.

The incursions, which are the IDF's first since the 34-day war with Hezbollah in 2006, were reported as being limited in scope, focusing on two dozen or so villages in southern Lebanon from which the IDF told local residents to evacuate. From these areas the IDF intends to dismantle Hezbollah infrastructure such as tunnels and the ability to launch rockets into northern Israel.

Rear Admiral Daniel Hagari, the IDF's chief spokesman, said on 1 October that the ground raids "will target Hezbollah strongholds that threaten Israeli towns, kibbutzim and communities along our border".

Adm Hagari said that Israel would not allow an attack similar to the one by Hamas on 7 October 2023, launched from the Gaza Strip, to occur on its northern border.

"Hezbollah turned Lebanese villages next to Israeli villages into military bases ready for an attack on Israel," he said.

In a briefing released by the IDF in X/Twitter, Adm Hagari presented evidence that Hezbollah was planning an operation involving thousands of fighters that would have mirrored the October 2023 Hamas terror attack on Israel, including descriptions of preparatory tunnel complexes and maps detailing Israeli settlements and IDF positions.

In its 7 October 2023 attack on Israel Hamas killed around 1,200 people and took another 251 hostage, of whom 117 had been released or rescued as of 28 August 2024.

Adm Hagari said the IDF operations in Lebanon would be "limited geographically", adding, "We are not going to Beirut or the cities in southern Lebanon. We are focusing in the area of those villages, the area next to our border. We will do in this area what is necessary to dismantle and demolish Hezbollah's infrastructure."

Asked how long the IDF operation in southern Lebanon would last, Adm Hagari replied, "We are doing it as short as we can, days, weeks."

In addition to those ground raids, however, the Israeli Air Force has also pounded Lebanon from the air since mid-September, including the capital, Beirut. Already by 4 October the airstrikes had killed more than 1,400 people, injured nearly 7,500 others and displaced more than a million people from their homes, according to the Lebanese Health Ministry.

The 1 October Iranian ballistic missile attack on Israel was said by the Islamic Revolution Guard Corps (IRGC) to involve "dozens" of missiles, while the IDF put that number at around 180 missiles fired before Natanyahu revised the figure to "over 200".

Many of these deemed to be targeting populated areas were intercepted by the IDF's multi-layered air defence network, while US sources told the CBS news network that US forces in the region also intercepted some of the Iranian missiles.

In a press briefing on 1 October Major General Patrick Ryder, the US Department of Defense's press secretary, said two US Navy destroyers in the region were used to fire interceptors at the Iranian missiles.

The IRGC described the missile strike as retaliation for the assassinations of the Hamas leader Ismail Haniyeh in July and Hezbollah leader Hassan Nasrallah on 27 September, as well as the killing of Lebanese and Palestinian people.

Iran previously launched a direct attack Israel with ballistic and cruise missiles and bomb-laden unmanned aerial vehicles on the night of 13 April 2024; that was mounted in response to an Israeli air strike on the Iranian Consulate in Damascus on 1 April 2024 that killed Brigadier General Mohammad Reza Zahedi, commander of the IRGC's Quds Force.

Gen Ryder said the Iranian missile attack on 1 October was about "twice the scope" of Iran's April attack in terms of the ballistic missiles used, while Israeli Prime Minister Benjamin Netanyahu said at the opening of a cabinet meeting on 1 October that Iran "made a big mistake tonight, and will pay for it" and that Iran "does not understand" Israel's "determination to retaliate" against its enemies.

"They will understand," said Netanyahu. "We will stand by the rule we established: whoever attacks us - we will attack."

With its multi-front campaign Israel appears to have called Iran's bluff. While Iran's leaders had claimed to be presiding over an influential regional power, only the two missiles barrages against Israel, on 13 April and 1 October this year, have seen Iran confront Israel directly rather than behind the actions of its regional proxies.

Now, however, the commander of the IRGC's Quds Force is dead following the air raid Damascus on 1 April 2024, Hamas political leader Ismail Haniyeh is dead, having been assassinated – in Tehran – in the early hours of 31 July 2024, Hezbollah leader and key Iran ally Hassan Nasrallah is dead, having been killed by an Israeli airstrike on his underground bunker in Beirut on 27 September, and all the while the IDF are continuing to ruthlessly target Hamas, Hezbollah and all of their other regional foes.

It thus appears that, while Hamas may have sown the wind on 7 October 2023, all of Israel's enemies are now reaping the whirlwind.

ESA's first planetary defence mission launched from Cape Canaveral

(pf) The European Space Agency's (ESA's) first planetary defence spacecraft, Hera, was launched on a SpaceX Falcon 9 rocket from Cape Canaveral Space Force Station in Florida on 7 October 2024 at 10:52 local time.

The automobile-sized Hera will carry out the first detailed survey of a 'binary' – or double-body – asteroid, 65803 Didymos, which is orbited by a smaller body, Dimorphos. Hera's main focus will be on the smaller of the two, whose orbit around the larger asteroid was changed by NASA's Double Asteroid Redirection Test (DART) mission in 2022, which demonstrated asteroid deflection by kinetic impact.

Credit: ESA

The Hera mission is to sharpen scientific understanding of the 'kinetic impact' technique of asteroid deflection, thus making Earth safer by turning terrestrial asteroid impacts into a fully avoidable class of natural disaster.

The 7 October launch put Hera on a direct departure trajectory away from Earth, beginning its two-year cruise phase. A scheduled manoeuvre next month will be followed by a swing-by of Mars in March 2025, which will give the spacecraft added velocity for its eventual rendezvous with Didymos. During the Mars gravity assist, Hera will perform a survey of Martian moon Deimos, deploying its instruments for scientific use for the first time. Hera's arrival at Didymos is expected in the autumn of 2026.

"Planetary defence is an inherently international endeavour, and I am really happy to see ESA's Hera spacecraft at the forefront of Europe's efforts to help protect Earth," ESA Director General Josef Aschbacher was quoted as saying in an ESA press release. "Hera is a bold step in scaling up ESA's engagement in planetary defence," he added.

Hera will also perform challenging deep-space technology experiments, including the deployment of twin shoebox-sized CubeSats, called Juventus and Milani, to fly closer to the target asteroid, manoeuvring in ultra-low gravity to acquire additional scientific data before eventually landing. The main spacecraft will also attempt 'self-driving' navigation around the asteroids based on visual tracking.

The mission's launch and journey into deep space is being overseen from ESA's European Space Operations Centre in Darmstadt, Germany.

ESA, together with NASA and other partner agencies, maintains a watch on the sky to identify and track dangerous asteroids that could threaten Earth. On 26 September 2022 NASA's DART spacecraft performed humankind's first asteroid deflection by intentionally crashing into Dimorphos, the Great-Pyramid-sized moonlet of the larger, mountain-sized asteroid Didymos, shifting its orbit.

Based on observations from Earth, DART succeeded in shrinking the orbit period of Dimorphos around Didymos by 33 minutes, nearly 5% of its original value, while also casting a plume of debris thousands of kilometres in space.

However, many unknowns remain about the event, which scientists need to resolve in order to help turn this 'kinetic impact' method of asteroid deflection into a well understood and reliably repeatable planetary defence technique. Questions that need answering include 'How big was the crater left by DART's impact, or did the entire asteroid undergo reshaping?' and 'What is the mineralogy, structure and precise mass of Dimorphos?'

An essential component of the Hera mission is the Inter-Satellite Link (ISL) technology supplied by European advanced

Marketing Report: EVPÚ Defence

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EVPU Defence's TI cameras are used globally in both stationary and mobile solutions. National border guard services in the Czech Republic, Latvia, and other European countries are equipped with surveillance and monitoring vehicles from the Czech producer, while

Credit: EVPÚ Defence

the company's other solutions are deployed on patrol boats in the Mediterranean, surveillance towers in the Middle East, and armoured vehicles in Central Europe, to name just a few. As threats to critical infrastructure and strategic locations continue to evolve, EVPU Defence is committed to ensuring that their thermal imagers remain a pivotal component in safeguarding important areas worldwide.

unmanned aerial technology provider Tekever. The ISL capability deploys a unique communications and relative positioning infrastructure, enabling Hera and the two CubeSats to communicate among themselves and make precise position determinations.

China Coast Guard vessels enter Arctic Ocean for the first time

(pf) China Coast Guard (CCG) vessels have entered the Arctic Ocean for the first time while conducting a joint exercise with the Russian Border Guard.

In a 2 October 2024 post on its Weixin social media account the CCG stated, "A few days ago, a fleet of Chinese and Russian coast guard ships arrived in the Arctic Ocean. This is the first time that Chinese coast guard ships have entered the Arctic Ocean, which effectively expanded the scope of the coast guard's ocean-going navigation, comprehensively tested the coast guard ships' ability to carry out missions in unfamiliar waters, and provided strong support for active participation in international and regional ocean governance."

Credit: USCG

The previous day the US Coast Guard (USCG) issued a press release stating that it had located four vessels from the Russian Border Guard and Chinese Coast Guard conducting a joint patrol in the Bering Sea on 28 September.

While patrolling the maritime boundary between the United States and Russia on routine patrol in the Bering Sea, a USCG HC-130J Super Hercules aircraft flying out of Coast Guard Air Station Kodiak observed two Russian Border Guard ships and two Chinese Coast Guard ships approximately 440 miles southwest of St Lawrence Island. The vessels were transiting in formation in a northeast direction, remaining approximately five miles inside Russia's Exclusive Economic Zone. This marked the northernmost location where CCG vessels have been observed by the USCG.

"This recent activity demonstrates the increased interest in the Arctic by our strategic competitors," Rear Admiral Megan Dean, commander of the 17th Coast Guard District, was quoted as saying. "The demand for Coast Guard services across the region continues to grow, requiring continuous investment in our capabilities to meet our strategic competitors' presence and fulfill our statutory missions across an expanding operational area."

The HC-130J aircrew were operating under Operation 'Frontier Sentinel': an mission designed to meet presence with presence when strategic competitors operate in and around US waters. The USCG's presence is intended to strengthen the international rules-based order and promote the conduct of operations in a manner that follows international law and norms.

China frequently uses the CCG as an alternative instrument of power projection to the People's Liberation Army Navy, especially to assert China's claims in disputed waters in the South China Sea, for example.

France's first defence and intervention frigate begins sea trials

(pf) The first of the French Navy's future defence and intervention frigates (FDIs), *Amiral Ronarc'h*, began its sea trials out of Lorient in Brittany on 7 October 2024, French shipbuilder Naval Group has announced.

Launched at the end of 2022, *Amiral Ronarc'h* is the first of five FDI frigates being built by Naval Group for the French Navy under a contract awarded in 2017. The ship's sea trials will enable its crew to get to grips with their future ship and to test all the systems and equipment in real-life situations. As the *Amiral Ronarc'h* is the first unit in the FDI programme, the feedback from its trials will benefit the other ships ordered by the French Navy, as well as three similar but more heavily armed vessels being built for the Hellenic Navy. The first two Greek frigates, HS Kimon and HS Nearchos, were launched in October 2023 and September 2024 respectively.

Credit: Naval Group

Unlike initial tests usually carried out on frigates, the tests on *Amiral Ronarc'h* will go beyond the simple parameters of navigation and propulsion, with tests also being carried out on the ship's combat systems in real conditions at sea.

The 4,500-tonne FDIs, according to Naval Group, are multipurpose, resilient high-sea vessels capable of operating alone or as part of a naval force in all areas of combat: anti-ship, anti-air, anti-submarine, against asymmetric threats and for special forces projection. They are 122 m long, have a beam of 18 m, will capable of speeds of 27 kts (50 km/h) and will have an endurance at sea of 45 days. The ships will accommodate a crew of 125 and can carry 28 additional personnel.

"Bringing together the best of French naval technologies on a compact platform, the FDI is a powerful and innovative frigate, designed to cope with constantly evolving threats," Naval Group stated.

Designed and produced using latest-generation digital tools, the FDI frigates are also the first such vessels to benefit onboard from a digital architecture that will enable them to adapt continuously to technological and operational developments. "As a result, the FDIs will be able to deal with current and future high-spectrum threats, with 360° coverage in all frequency bands, and process an ever-increasing amount of data," according to Naval Group.

The FDIs will be armed with Exocet MM40 anti-ship missiles, ASTER surface-to-air missiles (SAMs), MU90 anti-submarine torpedoes and guns of various calibres. The ships built for the French Navy will be able to accommodate a 10-tonne-class helicopter, such as the Caïman Marine or future Guépard Marine, an unmanned aerial system and two commando boats to deploy special forces. The frigates are equipped with the new-generation Sea Fire radar with four fixed panels, developed by Thales, which, combined with their missile systems, gives them extended area defence capabilities.

The FDIs will also be the first French frigates to be natively protected against cyber threats, with a redundant IT architecture based around two data centres that host, in a virtualised manner, a large proportion of the ship's IT applications.

"In terms of operational innovation, the FDI is inaugurating the concept of a gateway dedicated to combating asymmetric threats. This system will make it possible to co-ordinate and lead the fight against small, close air and surface threats, in particular booby-trapped craft," Naval Group stated.

ECRS Mk2 radar takes to the skies on RAF Typhoon test aircraft

(pf) The prototype of the Royal Air Force's (RAF's) future European Common Radar System Mark 2 (ECRS Mk2) radar took to

the skies for the first time on 27 September 2024 on a UK Typhoon test and evaluation aircraft flying out of BAE Systems' flight test facility in Warton, Lancashire, BAE and the radar's developer, Leonardo UK, announced the same day.

The flight was the latest step in the ongoing development programme for the RAF's fleet of Typhoon fighters. The active electronically scanned-array (AESA) ECRS Mk2, otherwise known as 'Radar 2', can perform traditional radar functions such as search and targeting as well as providing advanced electronic warfare capabilities, making it an even more potent capability for the RAF's frontline fighter fleet. Typhoons equipped

Credit: BAE Systems

with the radar will be able to locate and deny use of an adversary's radar with a powerful electronic jamming attack while staying beyond the reach of threats.

The first flight of a prototype ECRS Mk2 follows a programme of integration through ground-based testing delivered by a successful collaboration between the UK Ministry of Defence (MoD), its Defence Equipment and Support (DE&S) organisation, the RAF and industry. BAE Systems and Leonardo first announced they had installed the first ECRS Mk2 on a Typhoon test aircraft in January 2024. The companies then announced in July 2024 that ground-based testing of the radar had been completed.

BAE Systems announced it had received an GBP 870 M (EUR 1.02 billion) contract from the UK MoD to continue development and integration work on the ECRS Mk2 for installation on the Typhoon in July 2023.

"Evolution of Typhoon's air combat capability is paramount to ensure it continues to deter potential aggressors, defend our nation and defeat our adversaries wherever we need to fly and fight, whether for the UK or in our staunch support to the NATO alliance," Air Commodore Nick Lowe, the RAF's head of capability delivery for combat air and Typhoon Senior Responsible Officer, was quoted as saying in a joint BAE Systems/Leonardo press release. "This first flight of this ECRS Mk2 prototype new radar in the test aircraft is a positive step towards ensuring this."

Nick Moore, Typhoon deputy head of capability acquisition for DE&S, stated, "This is another landmark moment in this strategically important programme, which will provide the RAF with battle-winning technology that gives them the edge to protect the nation. The ECRS Mk2 radar will further transform Typhoon's control of the air and provide exceptional capability our adversaries will struggle to match."

Tim Bungey, chief engineer for ECRS Mk2 at Leonardo UK, stated: "In parallel with the trials, the radar's production design has also been progressing apace. The development of the ECRS Mk2 is fully using the UK's world-class radar design skills. Over the past few months, its processor, receiver and antenna power supply and control units have all been re-engineered from the prototype design to further enhance the capacity, capability and performance of the Mk2 system in alignment with the new antenna and electronic warfare capability."

BAE Systems and Leonardo bill the ECRS Mk2 as potentially the world's most advanced AESA radar. While Kuwaiti and Qatari Typhoons are flying with ECRS Mk 0 AESA radars and German and Spanish Typhoons are being equipped with ECRS Mk 1 AESA radars, both of those radars are essentially narrow-band arrays. This means that, although they have many of the design advantages of a high-speed electronically scanned antenna, they are still designed primarily detect other airborne targets. The ECRS Mk 2, on the other hand, is a wide-band array that will not only detect its own emissions and find other targets in that way, but will also passively detect emissions through a far broader range of the frequency spectrum.

First guided firing of Sea Venom missile made from Royal Navy Wildcat

(pf) A Sea Venom medium-range anti-ship missile has successfully completed the weapon's first guided live firing from a Royal Navy Leonardo Wildcat helicopter at the UK Ministry of Defence (MoD) Aberporth range in Wales, the MoD's Defence Equipment & Support (DE&S) organisation reported on 9 October 2024.

The guided firing marks a significant milestone in the integration of Sea Venom onto the Wildcat helicopter to provide it with an offensive capability against targets up to corvette size, supporting the Royal Navy's Carrier Strike Group deployment in 2025 and beyond. A collaborative effort by MoD and industry teams, the live-fire trial consisted of a single firing against a single target.

Developed by MBDA for both the Royal Navy and the French Navy under the Future Anti Surface Guided Weapon - Heavy)/Anti Navire Léger (FASGW(H)/ANL) programme, the Sea Venom missile has been designed for use in demanding maritime operations under complex rules of engagement where it might need to target hostile threats among non-combatants in congested littoral environments. According to MBDA, it features state-of-the-art uncooled imaging infra-red seeker technology with advanced algorithms to accurately select the correct target in dense shipping scenarios and a robust two-way datalink to allow 'man-above-the-loop' supervision of the engagement from the cockpit.

The Sea Venom, which has a high subsonic speed and a range in excess of 20 km, offers a variety of different flight profiles – including sea skimming – and is armed with a 30 kg class warhead. The missile is able to select a very precise aimpoint to provide the operator with a full range of non-lethal as well as lethal options, such as disabling main armaments, sensors or propulsion and steering equipment.

Credit: DE&S

Pete Fawcett, the Senior Responsible Owner for the Sea Venom programme, was quoted as saying by DE&S, "This first guided firing is a significant step forward for the integration of Sea Venom onto the Royal Navy's Wildcat helicopters. The success of the trial was the result of an outstanding team effort across Leonardo Helicopters, MBDA, QinetiQ and the Ministry of Defence."

Commodore Naval Aviation Stuart Finn, the head of the Fleet Air Arm, added, "This successful firing demonstrates the continued development of the Fleet Air Arm's and Royal Navy's world-class warfighting capabilities and asserts the Wildcat as the world's leading maritime strike helicopter, capable of intercepting enemy ships at a time and place of the UK's choosing. This

capability further increases the already-potent warfighting effect delivered by the UK's Carrier Strike Group. This is another successful collaboration between MoD and industrial partners."
The Royal Navy introduced Wildcat helicopters into service in 2015. Along with the Martlet/Lightweight Multirole Missile (LMM) developed under the FASGW – Light programme, the Sea Venom missile ensures the Wildcat helicopter can provide a formidable capability against a range of targets at sea and in the littoral environment.

Naval Group signs contract to deliver Dutch navy's future submarine fleet

(pf) The Delivery Agreement for the Replacement Netherlands Submarine Capability (RNSC) programme has been signed, France's Naval Group announced on 30 September 2024.
The agreement was signed by Dutch Defence Minister Gijs Tuinman and Naval Group CEO Pierre Eric Pommellet at a ceremony held on 30 September at the Directie Materiële Instandhouding (DMI) in Den Helder, the Netherlands. It follows the signature of an industrial co-operation agreement between Naval Group and the Dutch Ministry of Economic Affairs.


Credit: Naval Group

The signing of the Delivery Agreement, however, effectively marks the official launching of the Orka-class programme, which will replace the Walrus-class diesel-electric submarines currently operated by the Royal Netherlands Navy.
Tuinman stated at the event, "With the signature of the delivery agreement, we officially confirm that the road to new submarines runs through France and the Netherlands. Through Naval Group, which has extensive experience in building submarines, but also through the Dutch maritime manufacturing industry, which has unique and specialised knowledge."
Pommellet added, "I am extremely pleased to be here today to sign this contract for the delivery of four expeditionary submarines to be operated by the Royal Netherlands Navy. Naval Group is honoured to have been selected by one of NATO's most advanced submarine fleet operators, meeting demanding operational and technical requirements. This co-operation reflects the trust that the Netherlands Ministry of Defence places in our common expertise and our commitment to deliver on its requirements."
Naval Group's selection by the Dutch Ministry of Defence for the RNSC project was announced on 15 March 2024, based on the group bidding a conventional diesel-electric-powered variant of its Barracuda-class nuclear-powered attack submarine design. The French design was selected ahead of bids from a Damen and Saab teaming, offering a derivative of Saab's A26 design, and ThyssenKrupp Marine Systems, which was offering its Type 212 design.

Lithuania orders more air defence systems from Kongsberg and Saab

(pf) The Lithuanian Ministry of National Defence (MND) has ordered more National Advanced Surface-to-Air Missile Systems (NASAMS) from Kongsberg Defence & Aerospace and more Mobile Short-Range Air Defence (MSHORAD) systems from Saab, the two companies announced on 4 October 2024.
As part of the EUR 193 million contract to Kongsberg, Lithuania will also upgrade parts of the NASAMS equipment the country acquired in 2017. The acquisition follows an order placed in December 2023 to increase the number of Lithuanian NASAMS fire units.
Previously, the Lithuanian MND has also purchased NASAMS missile launchers for donation to Ukraine, where the system has contributed to the protection of people and critical infrastructure.


Credit: Saab

The order for Saab, meanwhile, is valued at SEK 1.2 billion (EUR 0.11 billion), with deliveries scheduled for the period 2026-2029. The order includes mobile firing units, mobile radar units and a command-and-control system. Saab will integrate MSHORAD into Joint Light Tactical Vehicles (JLTVs)manufactured by US company Oshkosh before delivery to the customer.
Saab announced an initial MSHORAD order from Lithuania in July 2024. With this latest order, a second battery within the Lithuanian armed forces will be provided with Saab's mobile air defence capability.
NASAMS employs the AIM-120 Advanced Medium Range Air-to-Air Missile in a surface-to-air mode, although the latest-generation NASAMS can also ground-launch shorter-range AIM-9X Sidewinder air-to-air missiles.
Saab's MSHORAD system consists of a mobile radar unit based on the Giraffe 1X radar, a mobile firing unit based on the RBS 70 NG surface-to-air missile system, all connected with GBAD C2, which is Saab's command-and control-system for ground-based air defence.

Sixth Royal Navy Astute-class SSN enters the water

(pf) *Agamemnon*, the latest Royal Navy Astute-class nuclear-powered attack submarine (SSN), has entered the water at BAE Systems' shipyard in Barrow-in-Furness, Cumbria, for the first time. The boat was rolled out of its construction hall on 2 October 2024, put onto its ship-lift overnight and entered the water on the morning of 3 October.
Named after the ancient Greek king, *Agamemnon* is the sixth of seven Astute-class SSNs, all of which have been designed and built at Barrow. The SSN, which displaces 7,400 tonnes dived and is 97 m long, will now begin the next phase of its test and commissioning programme before leaving Barrow for sea trials with the Royal Navy.
Steve Timms, managing director of BAE Systems Submarines, was quoted in a company press release as saying, "This is a hugely significant milestone for everyone at BAE Systems, the Defence Nuclear Enterprise and the Royal Navy.
"The design and build of a nuclear-powered submarine is incredibly complex and a truly national endeavour and I pay tribute to the thousands of highly skilled people who have helped get *Agamemnon* to this stage," he said. "Submarines

Credit: BAE Systems

are a vital component of the UK's defence capabilities and we must now work collectively to ensure *Agamemnon* is ready to join her sister submarines in service with the Royal Navy."

The boat's commanding officer, Commander David 'Bing' Crosby, added, "There is still plenty to do until we get to exit *Agamemnon* from Barrow, but the entire workforce should be full of pride for what they have achieved with this build so far. I am looking forward to working with our friends at BAE Systems, the Submarine Delivery Agency and the wider Defence Nuclear Enterprise to get *Agamemnon* through these final tests and ready for her exit from Barrow."

The *Astute*-class boats are the largest and most advanced attack submarines ever built for the Royal Navy. Their state-of-the-art nuclear technology means they never need to be refuelled and, as they manufacture their own oxygen and drinking water for their 98 crew members, they are able to circumnavigate the globe without surfacing. They have a maximum speed of 30 knots (56 km/h) dived.

Astute-class SSNs would typically be armed with a mix of Spearfish heavyweight torpedoes and Tomahawk Block IV submarine-launched cruise missiles and can carry a combined total of 38 of these weapons.

The first five submarines in the class, HMS *Astute*, HMS *Ambush*, HMS *Artful*, HMS *Audacious* and HMS *Anson*, are now in service with the Royal Navy, with construction work well underway on the final *Astute* boat, *Agincourt*. However, construction of the *Astute* class has taken longer than expected; while the first in class, *Astute*, was commissioned within 116 months of being laid down, boats 3 to 6 have all taken at least 130 months according to analysis by the website navylookout.com, although *Agincourt* might finally buck this trend.

Northrop Grumman to produce first-of-its-kind Glide Phase Interceptor

(pf) The US Missile Defense Agency (MDA) is to proceed with Northrop Grumman in working on a Glide Phase Interceptor (GPI) programme, the company announced on 25 September 2024. The programme's aim is to develop a first-of-its-kind defensive countermeasure against hypersonic missile threats.

Working in close partnership with the MDA, Northrop Grumman will initiate a three-year developmental effort to produce a purpose-built, innovative design capable of defeating existing and emerging hypersonic threats.

During this next phase of development, Northrop Grumman will:

- continue to refine the preliminary design of the GPI, which will be fired from the US Navy's Aegis ballistic missile defence (BMD) destroyers and Aegis Ashore BMD installations using the standard Vertical Launch System;
- demonstrate system performance in hypersonic environments prior to conducting its Preliminary Design Review;

- complete flight experiments ahead of schedule, leveraging the company's own flight-proven systems;
- and use digital engineering practices to connect the entire GPI programme to accelerate design processes and develop interceptor capabilities faster and more efficiently.

Credit: Northrop Grumman

Northrop Grumman's design includes advanced technologies, such as a seeker for threat tracking and hit-to-kill accuracy, a re-ignitable upper-stage engine used for threat containment and a dual-engagement mode to engage threats across a wide range of altitudes.

Northrop Grumman will work closely with the US Department of Defense in support of its role under the GPI Cooperative Development programme with the Japanese Ministry of Defense to deliver interceptors to the MDA.

Wendy Williams, Northrop Grumman's vice president and general manager for launch and missile defence systems, was quoted by the company as saying, "GPI adds mission-critical stand-off to warfighters in scenarios where distance creates an advantage. Tailorable to a multitude of mission requirements, Northrop Grumman's revolutionary solution is designed to perform in the evolving threat landscape."

Rheinmetall completes development of latest-generation 120 mm KE ammunition

(pf) Rheinmetall has successfully completed development of the latest generation of its enhanced armour-piercing 120 mm kinetic energy (KE) ammunition to counter state-of-the-art protection technologies, the company announced on 8 October 2024.

The qualification readiness of the KE-2020Neo or eKE (enhanced Kinetic Energy) ammunition has also been proven and, as a result, Rheinmetall has been commissioned by the Bundeswehr and the British Army to manufacture qualification samples of the new ammunition. A corresponding official qualification contract was signed in September 2020 by the Federal Office for the Equipment, Information Technology and In-Service Support of the Bundeswehr (BAAINBw) and the management of Rheinmetall Waffe Munition.

The new 120 mm × 570 KE2020Neo kinetic energy ammunition continues the successful series of KE rounds from Rheinmetall. Thanks to the use of new technologies, the ammunition's high-strength tungsten penetrator will be able to penetrate the latest protection technologies, according to Rheinmetall.

The company's current KE projectiles also use a high-strength tungsten penetrator to offer superior performance against modern armour. The first generation to come into use was the DM13, which was followed by the more powerful DM23 in the mid-1980s and then the DM33. Rheinmetall developed two types of performance-enhanced KE ammunition when the Leopard 2 main battle tank (MBT) was upgraded to the A6 version. These were the forerunners of the DM53 and DM63 rounds currently used by the Bundeswehr. The DM63 is now available in a REACh-compliant A1 version. The enhanced DM73, meanwhile, is currently the most advanced iteration, which has been introduced in the Bundeswehr for use with the L55A1 high-pressure gun.

Rheinmetall's 120 mm Rh120 guns, along with their associated ammunition, are the de facto standard armament for MBTs in NATO and the Western hemisphere. The Rh120 gun, the L55A1, was introduced into service in 2019 on the Leopard 2A7V/2A7+ and will also arm the British Army's future fleet of Challenger 3 MBTs and the Swedish Army's Strv 123A MBTs.

Credit: Rheinmetall

Finnish Defence Forces take up remaining Patria 6×6 purchase option under CAVS

(pf) The Finnish Defence Forces (FDF) are exercising an additional purchase option to buy more Patria 6×6 armoured personnel carriers (APCs), the company announced on 23 September 2024.

In the summer of 2023 Patria and the FDF Logistics Command signed an agreement for 91 Patria 6×6 APCs with equipment. The procurement agreement included an additional purchase option for 70 vehicles, of which the FDF previously redeemed 41 at the turn of 2023–2024 and are now buying an additional 29 vehicles. The ordered vehicles will be delivered by the end of 2025.

The Patria 6×6 APC is the subject of the international Common Armoured Vehicle System (CAVS) programme, which was established by Finland, Estonia and Latvia in 2020 and joined by Sweden in 2022 and Germany in 2023.

"Redemption of the entire domestic additional purchase option is remarkable for Patria and the whole international CAVS joint programme," Jussi Järvinen, head of Patria's operations in Finland, was quoted as saying in a company press release. "The programme has progressed rapidly thanks to excellent co-operation between Patria and the participating countries. The joint programme between nations enables cost-effective vehicle development and lifecycle support, quick procurements and equipment compatibility, strengthening defence co-operation in Europe."

The research and development agreement for the CAVS programme was signed at the end of 2020, with deliveries to three countries starting within three years.

Credit: Patria

Mark Rutte becomes NATO secretary general, succeeding Jens Stoltenberg

(pf) Former Dutch Prime Minister Mark Rutte took office as the new NATO secretary general on 1 October 2024, succeeding outgoing secretary general Jens Stoltenberg, whose term has ended after 10 years.

Stoltenberg formally handed over to Secretary General Rutte at a special session of the North Atlantic Council at the NATO Headquarters in Brussels.

"It is a great honour to be here and to take up the position of NATO secretary general," Rutte said at the event before thanking the NATO allies for entrusting him with the responsibility of guiding the organisation in the coming years.

Credit: NATO

Secretary General Rutte outlined three key priorities for his tenure at the head of the Alliance. "The first is to keep NATO strong and ensure our defences remain effective and credible, against all threats," he said. "My second priority is to step up our support for Ukraine and bring it ever closer to NATO, because there can be no lasting security in Europe without a strong, independent Ukraine," he added, before noting that his third priority "is to strengthen our partnerships" in a more interconnected world.

Rutte also paid tribute to his predecessor, describing his tenure as "exemplary" and telling Stoltenberg, "Today, NATO is bigger, NATO is stronger and is more united than ever; that is in large part because of your leadership."

In his farewell remarks Stoltenberg commended Rutte's pragmatism and consensus-building skills while noting that "you don't compromise on our values and principles". He also praised his successor's "personal commitment to our transatlantic bond" and his "unwavering support for Ukraine".

Rheinmetall and Honeywell sign MoU on strategic co-operation

(pf) Germany's Rheinmetall and the US company Honeywell have signed a memorandum of understanding (MoU) to establish strategic co-operation in various fields of technology, including on new visual systems and auxiliary power units for vehicles, among other things, Rheinmetall announced on 30 September 2024.

Together, the companies intend to develop new visual systems that leverage the existing capabilities of the Honeywell 360 Display: a driver vision system that includes a variety of thermal imaging and daylight cameras distributed around the vehicle. With the system, a pair of glasses mounted on a driver's helmet uses augmented- and mixed-reality technologies to deliver advanced levels of situational awareness and provide a 360-degree view – even without direct vision through windows or periscopes. The Honeywell 360 Display would provide a significant capability boost for existing fleets of tactical vehicles as well as newly developed platforms.

Honeywell and Rheinmetall also intend to collaborate on auxiliary power units that are used in tactical wheeled and tracked vehicles when they are not moving under their own power. With auxiliary power units, the operating time and operational readiness of a turret system can be significantly increased while still maintaining a low thermal and acoustic signature. Auxiliary power units are a supplement to battery storage and can also be of great interest for stationary tasks, including in the protection of critical infrastructure or properties.

The planned strategic co-operation also aims to explore other areas of collaboration between the two companies, including localised maintenance and support for other Honeywell products installed on strategic platforms used by the Bundeswehr.

By leveraging their collective resources, Rheinmetall and Honeywell intend to pursue joint approaches in the field of industrial high-energy applications, specifically in building automation (such as air conditioning and ventilation, lighting and access control) and overarching thermal management. The companies will explore how a compact solution consisting of a high-performance battery coupled with an auxiliary power unit and a cooling system could supply the necessary electrical primary energy, including the dissipation of heat, for future weapon systems.

Rheinmetall and Honeywell are also in talks about closer co-operation with regard to capabilities in the areas of counter-unmanned aerial vehicle (C-UAV) systems and electronic warfare. As the co-operation progresses, the implementation of the individual measures will be specified in the coming weeks and months.

Credit: Rheinmetall

"From auxiliary power units and visual devices to building automation, the list of potential areas of co-operation for our two companies is long," Rheinmetall CEO Armin Papperger was quoted as saying in a company press release. "We are grateful to have gained Honeywell as a strategic partner, given their long history of innovation and broad technological portfolio."

Matt Milas, president of Honeywell Aerospace's Defense and Space business, added, "We are excited to collaborate with Rheinmetall AG to bring our cutting-edge technology to support the missions of our allies across the world. New and existing programmes will benefit from our joint development, production and sustainment efforts across an extensive list of global defence platforms."

Austria's fighter dilemma

Georg Mader

On 29 September 2024, Austria held national elections. The challenge for the new government will be to start and set aside billions of dollars to replace the mixture of fifteen early T1-B2R-B5 Eurofighter Typhoon single-seaters flown by the Luftstreitkräfte. Their primary goal, which has been internally blocked for the last year, is to acquire 12 to 15 Leonardo M346FA advanced jet trainer/light combat aircraft to replace the outdated SAAB-105OE, which was phased out in 2020 after 50 years.

After the contract for 18 (later reduced to 15) Tranche-2 Typhoon aircraft signed with (then) EADS in 2003, Austria's fleet of 15 single-seat aircraft are SRP 4.3-standard and have so far fulfilled a peacetime air-policing role without losses or serious incidents. However, the Austrians have initially accepted the general type-certificate papers – valid for 25 years – calculated from production in 2003, not from entry into service in July 2007. Eurofighter officials have admitted to the author, that this should have been projected instead based on flying-hours and not years, since this limit would have been reached much later and not in 2028.

Credit: Georg Mader

Two Austrian Luftstreitkräfte Eurofighter Typhoon fighter aircraft in flight.

Pending issues

As the German Luftwaffe is also aiming to extend the service life of Tranche-1 aircraft, as the upgrade for T2 and T3 would take several months for each aircraft – the Austrian MoD is in lengthy discussions with Airbus and Luftwaffe to extend this paperwork limit in accordance with the original 30 year-contract. While Vienna, because of the latter, expects this to be achieved by Airbus, the manufacturer is seeking to go with the government-to-government (G2G) option on this, via the Luftwaffe and the Eurofighter system support centre at Manching. This still seems to be waiting for a breakthrough. Given the changed security climate, the Austrian MoD now wants to re-install what once was removed from Austria's order, such as electronic countermeasures (ECM) and beyond visual range (BVR) capability with AMRAAM. Infra-red search and track (IRST) was also removed, however, in order to provide some night-identification capability, a few LITENING-V pods were acquired from Rafael. All these changes have to be weighed against the declining remaining lifespan of the airframes – Austria plans to bid farewell to the final Eurofighter no later than 2037.

This all means that a successor for Eurofighter has to touch down at Zeltweg Airbase around 2033 and then fairly quickly reach initial operational capability (IOC) and then full operational capability (FOC). This timetable requires that the purchase contract is signed by 2029 – which would be in the next scheduled election year.

As such, the new governing coalition partners will need to address the issue of what each of them genuinely want for the ensuing decades – a minimalist air force suited only for air policing, or a more robust force that can sustain air superiority in a potentially hostile environment, serve as a data hub for ground forces, and even strike supply lines of advancing enemy forces behind the front. Selecting the latter option would also lead to further fundamental decisions: For instance, will Austria then also decide to better protect its future fighter on the ground through hardened shelters at Zeltweg AB or other airports? Are alternative auxiliary runways or operating sites on motorways being considered, as Sweden or Finland have practiced for decades, well before their entry into NATO? Shouldn't Austria's (currently only 16) fighter pilots also train more often and thus fly more hours than they do currently?

F-35 against Gripen-E? Or the latest Eurofighter?

The decision appears to be made for one of them, even if the solution to this problem is still too far off. Within the US State Partnership Program (SPP), the state of Vermont chose Austria. The Vermont Air National Guard's (ANG's) 158th Fighter Wing (known as the 'Green Mountain Boys'), located at Burlington since 2019, was the first ANG unit to receive the F-35A 5th-generation fighter. The 158th Fighter Wing already visited and carried out joint flying on two occasions at Zeltweg, providing insights to Air Chief' Brigadier Promberger and the pilots and also leadership of the Austrian 'Überwachungsgeschwader' (Surveillance Wing). Lockheed Martin Vice President for Strategic Campaigns General (ret.) Jeff 'Cobra' Harrigian told ESD that by the time the Austrians would

Author

Georg Mader is a defence correspondent and freelance aerospace journalist based in Vienna, Austria, and a regular contributor to ESD.

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nothing comes close

Credit: Georg Mader

F-35A of the 158th Fighter Wing of the Vermont ANG.

be ready for type selection, there would be 500+ F-35s in Europe, including in the Czech Republic, Germany, Italy, Poland, Switzerland, and Romania. Furthermore, this community would undoubtedly be able to assist with any problems arising in that new "interoperable universe". Here, Harrigian pointed to the neighbouring Swiss alongside him at the AIRPOWER24 air show, Swiss AF Air Chief Peter 'Pablo' Merz nodded, when asked if neutral Austria would need a "dedicated striker to kick-in the door on the first day of war". 'Pablo' further explained that the Swiss would also rather not do that, but have selected the F-35A to exploit the aircraft's superior sensor technology to reconnoitre any opponent and distribute situation awareness to all forces.

For decades, Sweden's Saab were the key supplier of Austrian military jets – with Vienna their biggest export customer with the J-29 Tunnan, Saab 105OE and finally the J-35 Draken. Turning down the Gripen C/D in 2002 in favour of the later stripped-down Eurofighter configuration is forgiven, as the Saab Aeronautics Austria Managing Director Per Alriksson confirmed. Naturally, the proposed Gripen-E/F would be far less expensive than F-35; it is billed as a 'giant smartphone' with all new capabilities that are easy to 'upload', much like apps. Of course, for a neutral nation such as Austria, a further benefit is that Gripen E/F is International Traffic in Arms Regulations (ITAR)-free with nothing controlled from over the pond. However, this latter argument might also have been valid for Switzerland – but they have nonetheless chosen to join the global F-35 user club. Thus far, Gripen E has been selected by Sweden, Brazil, and most recently, Thailand.

Eurofighter meanwhile remains another possibility. The aircraft is now being produced in the Tranche 4 (T4) configuration with the CAPTOR-E AESA radar, for the German Lufwaffe (38 aircraft under the 'Quadriga' contract) and Spanish Air Force (20 aircraft under the 'Halcon' contract). However, it remains to be seen whether or not the proposed Long-Term Evolution (LTE) mid-life upgrade and possible Tranche 5 (T5) will be realised.

Credit: Georg Mader

M346FA, along with weapon and targeting pod loadout options on display at the Farnborough International Airshow 2024.

'Master' drags on endlessly

Following the February 2022 Russian invasion of Ukraine, Austria secured a cross-party agreement for an additional EUR 18 Billion in funding for the military until 2032. Thanks to this, another fixed-wing project for the Austrian Air Force is the re-initiated replacement of the Saab-105OEs that had been phased out in 2020. Although the initial goal of the programme was to reclaim jet pilot training from Italy, requirements significantly strengthened after Russia's 2022 invasion, and the Austrian Air Force is now essentially searching for a multi-role light combat aircraft (LCA). The air materiel department looked into the upcoming Boeing-Saab T-7A 'Red Hawk', the Czech AERO L-39NG and the Leonardo M346FA.

In 2023, the department suggested a single-type adjusted acquisition for 12 to 15 twin-engined M346FA in a G2G joint procurement process with Italy, in the same way as the ongoing Italy-Austria 36 AW169B/MA helicopter contract, or the contract for four Embraer C-390M transport aircraft signed jointly together with five for the Dutch RNLAF at Farnborough Air Show in July 2024. The department concluded that the L-39NG would not be able to fulfil some of its more demanding requirements (climb-rate, weapon stations, inflight refuelling, among others), while any weaponised version of T-7A looks to be delayed for two years and appeared too distant a prospect.

Yet the final confirmation of M346 acquisition has repeatedly postponed due to the various concerns and queries, including why the Turkish TAI 'Hürjet' was not looked into in the RFI, or the Korean KAI T-50. However, when the selected aircraft fulfils the requirements, the procurement officials are asked to buy European. The G2G-model is once more being questioned. Why? According to an unnamed acquisition official trying to explain the indecision, it appears that "high-level obstructors" would like to sabotage the acquisition project altogether for the time being, working with "other interests" who might see a strong LCA as upsetting or interfering with a decision to replace the Eurofighter later on.

Whether or not there will be continuity within Vienna's Ministry of Defence remains unclear while Austria waits for the next administration to be formed. The current Minister of Defence, Klaudia Tanner, replied to the author's question on whether she would continue: "Well, that's the plan." ■

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The many ways to skin a CA(s)T

Trevor Nash

Over the years, a number of different approaches to train commanders and their staffs have emerged. So-called Command and Staff Training (CAST) exercises featuring maps, counters and dice have been supplemented with computer-aided exercises (CAX), while more recently, games-based solutions are being offered. The challenge facing the military today is what solution, or solutions, should they adopt?

To say that the pace of military change is on an exponential path would be a vast understatement. Most modern military academics and writers presage their work with caveats such as 'the increasing complexity of the operational environment' but this only partially reveals the challenges facing today's military forces. In the West for example, military forces have moved on from a focus on high-intensity, manoeuvre warfare that featured heavy armour and highly centralised command and control (C2) prevalent 40 years ago during the Cold War to a counter-insurgency (COIN)-based model typified by operations in Iraq and Afghanistan. Weapons, and how they are used, have also changed.

Watching Ukraine from a distance, the world's military forces are now having to assimilate some painful realities of modern warfare. Innovation, decentralisation, complexity and adaption are generating a re-think of the centralised C2 model and axiomatically, how the military trains is commanders and staff to manage C2. Training to enable successful C2 of deployed troops is not new and has its roots in the Prussian *Kriegsspiel* – or wargame – that became popular in the 19th century. *Kriegsspiel* was used to train commanders and staff officers in how to conduct battles and in some cases, campaigns. Using maps, counters and dice, these wargames were often supplemented by riding over the real terrain to see the effects of cover, 'going' – the ease of moving over particular surfaces – and the impact of geographic features such as rivers. Known by the Prussians as Stabs-Reise, these 'staff rides' are still widely used today, normally at company level and higher.

In essence then, today's military has different options for teaching commanders and their staff at the tactical, operational/theatre and strategic levels. As well as staff rides, Tactical Exercises Without Troops (TEWTs) are used at the platoon and company level to teach tactical deployments.

Credit: Rolands & Associates

2024 saw NATO supervise a foundation course to introduce member countries to the Joint Theater Level Simulation – Global Operations system. JTLS began development in 1983 as a project funded by the US Readiness Command, the US Army Concepts Analysis Agency and the US Army War College.

Author

Following a career in the British Army specialising in air defence, **Trevor Nash** PhD spent four years in the T&S industry before becoming defence journalist concentrating on training, simulation technology and air power studies.

Credit: Raytheon UK

The UK's Exercise CERBERUS took place in 2022 and combined constructive and live training. The former was provided by Raytheon UK's ABACUS CAST system.

As with staff rides, TEWTs are overseen by a senior officer with staff rides often featuring input from an academic authority. CAST is also provided in the constructive domain using computers that replicate such elements as friendly forces, logistics, OPFOR, obstacles such as minefields, air assets and communications. Such systems are typified by the US Army's Joint Theater Level Simulation – Global Operation (JTLS-GO). According to system designers, Rolands & Associates, JTLS-GO "is an interactive, web-enabled, joint and coalition wargaming system [that] represents civil-military decision-making environments from a globally integrated operational-level perspective…"

As well as the US, the NATO Modelling & Simulation Centre of Excellence (COE) ran a JTLS-GO Foundation Course in Rome in June 2024. The plan is to expand the use of JTLS within NATO both as a "powerful simulation tool" but also as "a strategic asset, which enables us to model complex scenarios and analyse the effects of different courses of action," explained Col Francesco Pacillo, NATO M&S COE Director.

In the UK, its CAST is largely provided by Raytheon UK using its Advanced Battlespace Computer Simulation System (ABACUS), a solution also in service in Canada. In the case of the British Army, ABACUS is deployed at Warminster (UK) and also at Sennelager in Germany with a small detachment in Catterick (UK). According to Raytheon UK, the role of ABACUS is to "train and validate combat readiness of the UK's Warfighting Division Brigade Headquarters." In effect though, ABACUS can be used from Battle Group to Corps levels.

Although training and simulation systems have been historically stovepiped within the live, virtual and constructive domains, CAST constructive systems have frequently been used as the engine to drive integrated domain exercises. In the case of ABACUS, this was exemplified in Exercises CERBERUS and ULU WARRIOR. The former exercise featured 3,500 troops and 800 vehicles and was managed from the ABACUS site in Sennelager. Exercise ULU WARRIOR meanwhile was much smaller in scope, designed to 'train and validate' the 1 Battalion Royal Gurkha Rifles in Brunei.

Despite its clear capabilities, the British Army has been looking for an ABACUS replacement for a number of years with the Future Joint CAST (FJCAST) requirement being the latest to emerge. With a Prior Information Notice (PIN) issued in May 2024 for this GBP 50–70 million requirement, it now only needs to clear the hurdle of convincing the UK's new government and its strategic defence review.

Other options

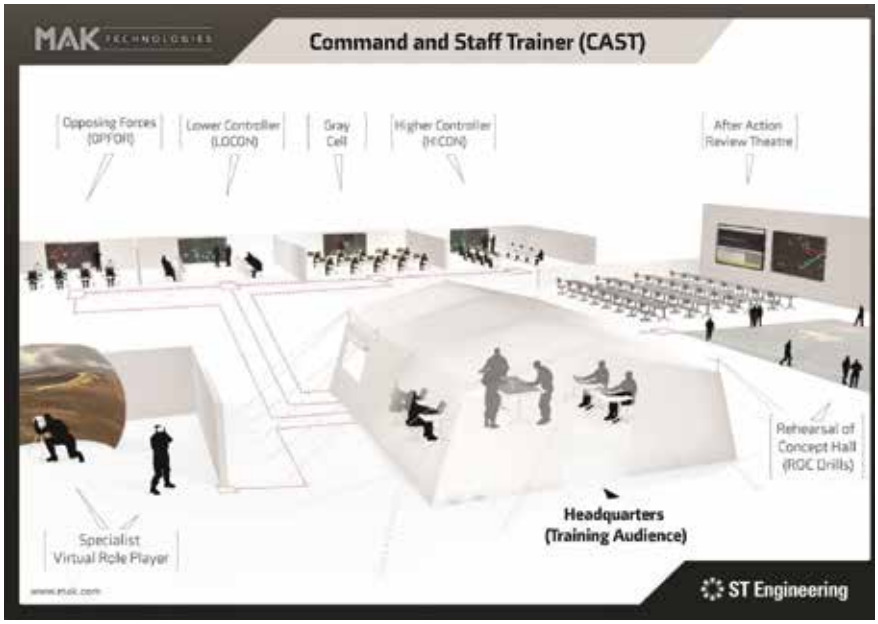
Systems such as JTLS-GO and ABACUS are aimed at providing the CAST solution for higher formation training and are typified by requiring significant engineering support. Companies such as CAE, MASA and MAK Technologies have all entered the CAST market to address the challenge of C2 training from a lower-cost perspective. CAE's offering is its GESI constructive training system that was launched more than 25 years ago. The system is used for computer-assisted exercises (CAX) and instructor-delivered classroom education. An example of the latter can be seen at the German Army's officer training school in Dresden where it is known as SIRA.

n France, MASA Group's SWORD provides CAST for battalion to divisional size staffs. In service with some 27 users worldwide, it continues to generate considerable interest. In many ways, SWORD epitomises some of the changes that are occurring in the world of CAST. Historically, the prime contractor would provide the complete technological infrastructure

Credit: Trevor Nash

The CAE GESI system can be used for conventional CAST or for teaching tactics. These officer cadets are using the system at the German Army Officer Academy in Dresden.

Credit: MAK



A typical CAST environment showing the major constituent parts. This example uses MAK ONE components from MAK Technologies.

for the product but MASA has recently worked with 4C Strategies and Hadean to use the latter's Exonaut exercise management and assessment software to provide a more 'user friendly' experience. The company also provides integration with BISim's VBS4 visualisation software thereby leveraging other sources of expertise where required.

In a modified form, SWORD is also used for civil defence, emergency service planning and crisis management. This version, known as SYNERGY, is used in France at Le Havre; it is also used by the NATO Crisis Management and Disaster Response School of Excellence in Bulgaria, as well as by the governments of Brazil and Bangladesh for flood response exercises.

The result of companies such as CAE and MASA providing lower cost CAST solutions and technological enhancements being available through the likes of 4C Strategies, VBS and Hadean with its Exonaut scenario generation solution has opened the door to the increased interest in CAST systems. Peter Swan, Director of International Business at MAK told ESD that CAST "is certainly a hot topic at the moment with adopters highlighting the need to aggregate forces [typically] from the brigade level down".

The aggregation of forces describes the ability to define the size and complexity of a given asset. In the case of an infantry company for example, this could see replication levels vary from a company-size entity, through platoons, sections (squads) to individual riflemen. Depending on who is being trained dictates the level of aggregation.

Historically, MAK has either built its own CAST solutions based on its VR-Forces – part of its MAK ONE simulation toolbox – or provided VR-Forces to other companies to develop their own offerings. "One of the advantages of MAK ONE in general and VR-Forces in particular is its scalability," explained Swan. MAK's CAST customers are numerous and include the US DoD, Slovenia, the Royal Netherlands Army [with Elbit as the prime contractor], India and Rafael.

Return to *Kriegsspiel*?

One of the main themes at IT2EC 2024 held in London was war gaming. A number of speakers pointed out the challenges involved in assembling the correct staff and command personnel to conduct an exercise using constructive CAST systems while others challenged the true capabilities of these higher-end constructive systems.

"CAST has no value for training," explained Maj Tom Mouat, Head of the UK's Defence Modelling & Simulation School at the Defence Academy in Shrivenham. "Conventional CAST systems are good for assessment and validation but for practise they have no value."

Another perspective was provided by Maj Theo Bossom from the British Army's Land Warfare Centre in Warminster. "Time to train is being squeezed and we need to replace opportunities that were previously provided by BATUS [British Army Training Unit Suffield – the British Army's live training facility in Canada]. The result is that we are looking to expand war gaming for joint and land applications." Maj Bossom's comments about lack of time to train are echoed in the recent UK National Audit Office (NAO) report on the time and resources being expended by the UK MoD to train Ukrainian forces to the detriment of domestic training.

With the publication of the NATO Wargaming Handbook in 2023, it is clear that the subject is being taken seriously at the very highest levels. In his foreword, VAdm Guy Robinson, Chief of Staff at HQ SACT said, "Wargaming is a powerful tool for generating insights into complex issues and problems. Whether the insights are from player decisions made in analytic wargames or insights for players participating in learning wargames, wargaming is a tested and effective method for organisations to generate greater understanding across the military and political spectrum at all echelons."

HQ SACT has now created an Experimentation and Wargaming Branch that is "supported by wargaming professionals across NATO" to monitor emerging technologies and methods and to develop best practice.

In many ways, NATO is playing catch-up as despite the rise in the use of constructive CAST systems, wargaming has never really gone out of fashion. The British Army's Wargaming Handbook, published in 2017 states that historically "…the UK military was accomplished at wargaming but this culture has largely been lost." The British Army is now going through a process of "reinvigoration" that is seeing the wider adoption of wargaming at all levels.

One of the significant challenges facing NATO and committed adopters such as the US and UK is how they present war gaming and describe its application so as to inform others of its potential benefits. There is also the challenge of defining the wargame and positioning it alongside conventional constructive CAST systems. According to Stavroula Oustoglou, a NATO Defence Analyst and Innovation Officer, "…it is high time that we had this debate."

We then come to the question of wargame credibility and perception. After all, how can the roll of a dice be considered to match the carefully constructed, high-fidelity software that drives a constructive CAST simulator? Such simulators use a Monte Carlo simulation method that include elements of uncertainty and randomness. In fact this approach simulates the roll of a dice and both replicate the friction and uncertainty of war. To muddy the waters still further, another medium to provide CAST has emerged through the professional gaming sector.

Matrix Pro Sims – through Slitherine Software UK Ltd, Slitherine Corporation (USA), and Matrix Games LLC – is focusing on strategy videogames and wargames to military forces. Through its offices in the

Credit: USMC

US Marine Corps officers conduct a war game at the US Marine Corps War College in Quantico, Virginia. Such systems have the benefit of being low-cost and take little effort to organise, therefore providing opportunities for frequent use.

US, UK, Poland and Italy, Matrix Pro Sims is pushing a number of different wargame products such as Command Modern Operations, Combat Mission and Flashpoint Campaigns to military users throughout the world. With 150 clients in 23 countries, customers include the US Army, Air Force and Marine Corps, the UK's Dstl, Taiwan and Australia.

"These wargames bring new capabilities to the military training, education and analysis sectors, becoming benchmarks that are leading a rapidly expanding and disruptive business unit," the company stated.

Iain McNeil, CEO of Slitherine Ltd and Matrix Games Ltd explained that "our databases are easy to build and include such things as geography, weapon systems and airfields that together, provide a monolithic battlespace that you can plug-in entities as required."

The company's next step is to integrate an analysis tool, McNeil added, "We're talking to some providers to address this at the moment and it is certainly something that is of interest to us."

Flashpoint Campaigns has been developed by On Target Simulations (OTS) and is published by Matrix and Slitherine. OTS says that "Flashpoint Campaigns are games of modern grand tactical combat, with players in charge of formulating and managing the battle plan for their forces. Players issue orders during their specific orders phase and then the game resolves all actions until a new orders phase occurs."

There is no doubt that this games-based approach is gaining traction, especially when one considers the UK Fight Club that was formed in early 2020. UKFC provides an opportunity for all ranks to experience or expand their gaming capabilities through weekly gaming competitions. This approach has become extremely popular and has been taken-up by a number of other countries.

On balance

Like most things in the world of military procurement, selecting the right tools for the job come down to understanding what the job is, what the tools are and how those tools fit in to the wider scheme – the context. Iain McNeil is very forthright on these issues: "The main issue is that the military needs to understand what a wargame is," he told delegates during a panel discussion at this year's IT2EC in London.

The other issue is that "defence understands that they are not an informed customer. In the UK for example, there is no simulation career path, unlike the US." This, argues McNeil, makes it difficult for the customer to understand what they are being offered and to evaluate that offering against competitor solutions.

As to the future of CAST, there is still room for improvement. Matrix's McNeil suggests better integration of cyber, UAV and EW models. From MASA's perspective, technical support manager Zubair Hossain added that, "as well as EW and cyber, I would like to see improvements to crowd behaviour to enhance urban operations training".

All three types of solution are viable and present valid methods to teach, what the UK MoD Wargaming Handbook describes as to "gain and sustain an intellectual overmatch" and "enhancing the cognitive capacities of joint warfighters". The real question is should the "Wild West" of CAST teach current doctrine and tactics, techniques and procedures (TTP) or develop new ones? If it is the latter, who has oversight? ■

Credit: On Target Simulations

There is an increasing trend towards using commercial gaming engines to provide professional military training. This example is Flashpoint Campaigns, developed by On Target Simulations and published by Slitherine Software.

The future of stand-off weaponry, a tale of three approaches

Sam Cranny-Evans

From Russian missile barrages in Ukraine, to Houthi drones and US programmes the author explores how stand-off weapons are changing modern warfare, and the shape of things to come.

A carefully planned and successfully delivered strike with stand-off weapons can change the trajectory of a war. For example, the pressure on Ukraine to withstand Russia's invasion changed dramatically on the 22 March 2024 when Russia launched 151 missiles and drones in a significant mass strike targeting Ukraine's energy infrastructure. Many Ukrainians awoke to find that they had no water, no power, and no heating. The 22 March strike was the start of a concerted campaign and by June, the country had lost almost 50% of its energy production capacity, according to Ukraine's President Volodymyr Zelensky. The Russians have continued to employ their stand-off weapons in this way, leading to further strikes against hydroelectric plants and substations. Those strikes are interspersed with others against Ukraine's defence industry, training sites and troop concentrations. The prospect of scheduled blackouts into the winter and insufficient power to meet the needs of Ukraine's citizens will increase the pressure on the populace and reduce its willingness to continue the war, it also pressures Ukraine to move air defences away from the frontline and into Ukraine's urban centres to protect the latter. Already, 44% of surveyed Ukrainians thought it was time to negotiate, and 32% felt it was time to cancel Zelensky's 2022 decree that prohibited negotiations with Putin.

This is not the only example of stand-off weapons shaping a war's trajectory, the two conflicts fought against Iraq, or the 2018 use of cruise missiles to reinforce Western red lines in Syria come to mind as other examples. As a category of weapons, stand-off systems have rapidly evolved in the past decade and will evolve again in the next. This article will explore three technology approaches that help understand the current and future trajectory of stand-off weapons, which are defined here as a guided missile or drone with a range exceeding 150 km. The first approach can be considered as a blend of conventional cruise and ballistic missiles launched from all domains and is represented here by Russia's arsenal of stand-off weapons employed against Ukraine. The second consists of one-way attack (OWA) drones and a collection of artisanal missiles that can be combined into large strikes to threaten actors in new and inventive ways. This approach is represented here by the Houthis and to a lesser extent by their state sponsors, Iran. The third approach involves the development of new technologies that stretch the limits of what is physically possible in a bid to counter air defence networks and cover long distances at speed to limit an opponent's time to respond. This approach is represented by the US and its various hypersonic glide vehicle (HGV), and hypersonic cruise missile (HCM) programmes.

So, what enables stand-off weapons to contribute to a conflict in this way? This ultimately depends on the relative fragility of the target nation. The March 2024 attacks are not the first on Ukraine's energy infrastructure – over 50% of its energy generation capacity was damaged in 2022, but the impact has been mitigated by the country's determination to continue and external support. Secondly, an opponent must have infrastructure worth striking with stand-off weaponry, this can also vary from critical national infrastructure (CNI), to the facilities used to build or upgrade rockets or missiles in Lebanon, or command and control (C2) centres.

Credit: State Emergency Service of Ukraine

A Ukrainian firefighter works to control a fire caused by a Russian strike on the Trypilska Thermal Power Plant in April 2024.

Author

Sam Cranny-Evans is a research analyst focusing on Russia, China, and C4ISR at the Royal United Services Institute (RUSI) in London. He joined RUSI in 2021 after five years at Jane's as editor and author of the Armoured Fighting Vehicles Yearbook.

Typically, the risk posed by the target, or the potential military benefits from striking it, must justify the cost of a stand-off weapon. A Block V Tomahawk costs the US around USD 2 million and hardened targets or large physical infrastructure will require much more than a single missile to achieve effect. From this it follows that the stand-off weapon user must be able to secure sufficient intelligence on the targets in question to hit them, which often requires good satellite imaging capabilities for some missile designs, and effective access to a global navigation satellite system (GNSS) in almost all cases, as well as granular data. For example, Russia's strikes against Ukraine's energy infrastructure tend to be advanced in what they target, with the potential effects magnified by striking substations or specific buildings within a power plant. In sum, if an opponent has targets worth striking that are critical to the functioning of its society, and the attacker can secure targeting data of sufficient granularity, there is the opportunity to inflict conflict-altering damage upon an opponent using stand-off weapons, although the confounding factor of resolve and resilience has to be accounted for somehow, and will likely extend a stand-off strike campaign rather than shorten it.

Mass, precision, and speed

Mass, precision, and speed are the three words that characterise Russia's approach to the use of stand-off weapons in Ukraine. It has deployed tiered capabilities that are represented by the 9M723 Iskander-M quasi-ballistic missile at the shorter-range end of Russia's conventional stand-off toolkit, with a range of 500 km, and the 2,500 km range Kh-101 in the upper range limits. Russia has increased its missile production and stockpiles since the war began, and has coupled its missile capabilities with production and procurement of the Shahed-131 and Shahed-136 OWA drones (respectively known as Geran-1 and Geran-2 in Russian service), which are typically added in waves to Russian missile strikes. Conventional cruise capabilities that are essentially represented by missiles such as the air-launched Kh-101 and air/sea-launched 3M-14 Kalibr family are paired with short-range ballistic missile launches from Iskander. Additionally, this mix is increasingly supplemented by Kh-47M2 Kinzhal aeroballistic missiles.

Russia has also started employing the 3M-22 Zircon HCM, with the Kyiv Scientific Research Institute of Forensic Expertise stating such a missile was used in an attack on Kyiv which took place on 7 February 2024, based on evidence from gathered

Credit: RecoMonkey

An Iskander-M 9P78-1 TEL showing two 9M723 short-range ballistic missiles raised to the launch position. Production of missiles has increased significantly in Russia, allowing continued strikes against strategic and tactical targets.

missile debris. Russian President Vladimir Putin later affirmed Russia's use of the missile in his state of the nation address on 29 February 2024. This adds a further and potentially significant new threat into Russia's existing mix.

Many of Russia's missile strikes have proven to be very accurate, which indicates that Russia is not only able to access granular intelligence for its strikes in Ukraine, but that the underlying guidance technology is suitable for long-range strikes against infrastructure. The mix of missiles varies, but Table 1 provides an indication from the 22nd March and 26th August strikes. At least 40% of the strikes consisted of Shaheds, and the interception rate of conventional cruise missiles such as the Kh-101 and 3M-14 is relatively high - 83% and 86% for the March and August strikes respectively. However, Iskander and Kinzhal prove difficult to intercept when combined with other missiles, as does the Kh-22, an anti-ship missile which flies at around 4,000 km/h, and typically climbs to very high altitudes before diving onto its target.

The missiles themselves – with the possible exception of Zircon – represent a mix of conventional long-range strike capabilities that are on a par with most large militaries in the world.

The 9M723 Iskander quasi-ballistic missile is 7.3 m long, using solid propellant and capable of carrying a 480 kg to 700 kg warhead that can be high explosive, cluster, or nuclear. Russian sources indicate that it

Table 1:
Breakdown of Russian missiles used on 22 March and 26 August 2024.

Missile	22nd March	Intercepted	26th August	Intercepted
9M723	12	0	6*	1
Kh-47M2	7	0	3	1
Kh-101/Kh-555	40	35	77	99***
Kh-59	2	2	10**	–
Kh-22	5	0	3	1
3M-14/3M-54	0	N/A	28	–
'S-300'****	22	0	0	N/A
Shahed/Geran	63	55	109	99
Total	151	92	236	99

*May have included KN-23.
**Included Kh-69s.
***99 cruise missiles were intercepted, no distinction was provided between Kh-101, Kh-59, and 3M-14. 115 missiles were fired between these three types in total.
****Exact missile models were not specified, but presumably comprised 5V55R and/or 48N6 series missiles.

Source: Ukrainian Air Force Command (22 March 2024 and 26 August 2024)

Credit: Air Force Command of the Ukrainian Armed Forces, via Wikimedia Commons (CC-BY-4.0)

This image shows a Kh-101 that was shot down in the Vinnytsia Oblast in January 2023. The missiles are rarely successful in breaching Ukraine's air defences despite being used in large quantities.

can be fitted with a seeker including optical and synthetic aperture radar to provide precise targeting of vehicles and command posts, video footage from Ukraine seems to confirm this. The missile includes a datalink that is used to upload coordinates from the 9P78-1 transporter erector launcher (TEL) prior to launch, and is understood to have an additional satellite datalink in the base of the missile that allows for further course adjustments in flight. It is also fitted with radio frequency countermeasures that are designed to confuse and complicate target tracking and engagement. Iskander missiles are ground-launched and equip the Missile Brigades of the Russian ground forces, they are typically paired with reconnaissance assets such as long-range drones as well as human intelligence. Their use in strikes on Ukraine's critical infrastructure declined as Russian units were pushed away from Kyiv, however, they are frequently employed against battlefield targets, and may have been responsible for the 3 September 2024 attack against a building used for training Ukrainian communications specialists, which killed more than 50 and wounded at least 200 more.

The Kh-101 is an air-launched low-observable cruise missile with a range between 2,500 and 2,800 km. It is 7.45 m long and carries a 450 kg conventional warhead. It can fly for up to 10 hours and travel as low as 30 m from the ground with a cruising altitude of 6,000 m. The missile navigates using a combination of GLONASS – Russia's satellite navigation constellation – and inertial navigation. Inertial navigation works by measuring changes to the missile's acceleration and orientation in space over time to understand the missile's position and velocity. As it derives its data from the sensors on board the missile – using instruments such as gyroscopes and accelerometers – inertial navigation provides a reliable form of navigation in the event that satellite navigation is denied or degraded. When the two are combined with the Kh-101's optoelectronic mid-course terrain matching navigation system, its terrain following radar, and its infrared/TV seeker for guidance in the terminal phase, the missile can reliably strike within 10 m of a given target. It can be launched in salvos from the Tu-160, Tu-95MS16, and Tu-22 strategic bomber aircraft used by the Russian aerospace forces.

The 3M-14/3M-54 Kalibr is a family of sea-launched cruise missiles, with 3M-14 series being for land-attack, and the 3M-54 series for the anti-ship role. The Kalibr family has been the mainstay of Russia's naval modernisation, with almost every ship receiving a Kalibr launch capability during upgrade and modernisation processes. The missiles are vertically launched from the 3S14 launch complex and have an estimated range of 1,500–2,500 km. They have been launched from the Caspian Sea against targets in Syria, which indicates a range of around 1,500 km. Like the Kh-101 and Iskander, it carries a 450 kg high explosive warhead, although there is also understood to be a nuclear variant.

The Kalibr family is also joined by the 3M-22 Zircon HCM, which are designed to be sea-launched and employ a solid propellant booster and scramjet for the cruise phase. While little hard data is available, it likely cruises at speeds in excess of Mach 5 which would technically make it 500% faster than the Kh-101 for portions of its flight. The Kh-101 has a top speed of Mach 0.78 (833 km/h), whereas Mach 5 places a missile's speed at around 6,000 km/h for portions of the flight. This drastically limits the reaction time of an opponent, if a Kh-101 travelled at Mach 0.78 for the entire flight of a 1,500 km engagement, it would take 108 minutes to reach the target. The same distance would be covered in 15 minutes at Mach 5. Neither missile is likely capable of travelling at top speed for the entirety of a flight, however, this calculation serves to illustrate the difference that the speed of an HCM provides over conventionally-powered cruise missiles.

The Kh-47M2 Kinzhal aeroballistic missile is slightly different in that it is carried by a MiG-31K and their take-off seems to provide Ukraine with some warning that a Kinzhal strike is imminent. However, that warning is still brief, indeed, stay in Kyiv for long enough and it may become apparent that

Credit: Office of the President of the Russian Federation

The Kh-47M2 Kinzhal is an air-launched version of the 9M723. Its speed and approach make it very difficult to intercept.

the only air raid warnings that are taken seriously are those that involve Kinzhal. The 8 m missile also carries a 480 kg warhead and has a range of 1,500–2,000 km, essentially an air-launched variant of the 9M723 with a redesigned rear section. Once launched the missile accelerates to Mach 4, from the initial acceleration of the MiG-31K, which can reach Mach 2. The missile may reach Mach 10 for some portions of its flight, but this is difficult to confirm. In any case, if a MiG-31K took off from the Savasleyka airfield in Nizhny Novgorod and flew 300 km before launching a Kinzhal, the missile would take 7.5 minutes to travel the 600 km to Kyiv if it stayed at Mach 4. That time would be reduced considerably if it is indeed capable of reaching Mach 10. A MiG-31 has a cruising speed of 2,500 km/h, and could theoretically travel 300 km in around 7 minutes at that speed. This indicates that an overall engagement time with a Kinzhal launched from Russian airspace at a target in Kyiv – a distance of 960 km – could occur within 20 minutes of the aircraft being ready to take off.

The mass in Russian missile strikes is arrived at through a combination of the Shahed-136 OWA drones procured from Iran and manufactured domestically as the Geran 2. The delta-wing design has a two-blade propeller at the rear of the fuselage that provides a range of 2,000 km with a top speed of 185 km/h. The drone is launched from a catapult from one of three primary launch sites in Crimea, Rostov-on-Don and Belgorod. They typically fly circuitous routes into Ukraine rather than a straight line to their intended target, with some Gerans flying around 580 km from Yeysk Airport in Crimea to strike a target near Zaporizhzhia, a straight line distance of around 280 km. The warhead has a weight of 40–50 kg and may be high explosive or thermobaric in nature, at least one example has been found with a warhead using a fragmentation sleeve at either end, and multiple small explosively-formed penetrators (EFPs) comprising the middle section. Russia has launched upwards of 60 Shaheds or Gerans in a single strike, they are typically arranged in salvos and arrive on a target within a strike window along with the cruise and ballistic missiles. The primary tactic of Russia's strikes appears to be the combination of effects to complicate the air defence challenge for Ukraine, as well as wear those air defences down. A Geran is sufficiently accurate and effective that Ukraine must take action against it, potentially depleting its valuable air defence missile stocks yet further, although much of the task of tackling Gerans has been provided by mobile air defence teams with heavy machine guns.

Credit: FARS Media Corporation/Behrouz Ahmadi, via Wikimedia Commons (CC-BY-4.0)

This image shows a Shahed-136 on display at a 2023 exhibition celebrating the achievements of the IRGC's Aerospace Forces. The munition is large and launched from the catapult shown beneath it here.

Russia's conventional strikes reveal the limits of conventional stand-off strike capabilities. Even when large salvos of 100 plus missiles and drones have been launched in a short space of time, it is common for Ukraine to achieve a relatively high interception rate. Even during Russia's relatively successful 22nd March strike, Ukraine was still able to intercept 92 of the stand-off weapons launched against it, leaving 59 to reach their targets. HCMs such as Zircon and ballistic missiles such as 9M723 and Kinzhal have higher rates of success, which is indicative of the future of stand-off precision strike for conventional militaries.

Low complexity, high impact

Between the 19th October 2023 and 2nd September 2024, the Yemen Conflict Observatory has tracked 130 Houthi attacks in the Red Sea and Yemen, 120 of them against vessels trying to transit the Bab-el-Mandeb Strait between Yemen and Djibouti. Ansar Allah (Houthi) attacks employ a range of stand-off weapons that reflect the third approach that will shape the future of this class, and that is those weapons that are relatively low in complexity but potentially high in impact. For example, a remotely operated OWA boat is technically less complex than an air-launched cruise missile such as Kh-101, however, as Ukraine and the Houthis have shown, they can be remarkably effective against surface vessels. The Ukrainians have used sea drones and missile strikes to drive the Russian fleet out of the Black Sea and open a grain corridor. Ukraine is understood to have damaged or sunk at least 12 Russian ships using its sea drones, which have ranges up to 800 km and can carry up to 250 kg of explosives.

The Houthis have used similar technology to drive merchant shipping out of the Red Sea and around the African continent. Ansar Allah had attacked at least three ships with sea drones within a few weeks of first using them in July 2024, and they contributed to the sinking of the MV Tutor. These attacks have increased the cost of shipping and insurance, as well as the time taken for many journeys, and incurred financial costs on the US, UK, France, and others in intercepting their missiles. Whether their actions have hurt the Israeli economy is unclear, but it is clear that despite the relatively low complexity of the Houthi arsenal, they have had an impact on bulk shipping at a strategic level, and at a tactical level have succeeded in sinking ships despite vessels with sophisticated air defence systems operating in the area. The arsenal is best viewed through three categories; the anti-ship cruise missile (ASCM), the anti-ship ballistic missile (ASBM), and long-range drones – both air and sea-based. Moreover, while the focus for this section of the article is on the Houthi sea-denial campaign, it is important to note that many of these capabilities have also been employed in long-range strikes against Saudi Arabia and Israel.

The Houthis showcased an ASBM named Asif in 2022, closely resembling the Iranian Khalij Fars. The latter is an anti-ship version of the Iranian Fateh-110 ballistic missile, equipped with an optoelectronic infrared seeker for ship targeting. The Fateh-110 is a solid fuel missile with a 650 kg warhead

Credit: Fars Media Corporation, via Wikimedia Commons (CC-BY-4.0)

This 2012 image shows the Fateh-110 during launch from an Iranian TEL. A derivative of the Fateh-110 is believed to provide the Houthi ASBM capability.

and a top speed of 1,029 m/s in its terminal phase. It reportedly achieved a hit within 8 metres of a moving target in 2013. However, uncertainty remains about whether it possesses a manoeuvring re-entry vehicle, crucial for ASBM accuracy. The Houthis claim their Asif has a 400 km range and a 550 kg warhead. They have also displayed a missile called Falaq-1, similar to the Khalij Fars, offering a 200 km range with an optoelectronic seeker.

Optoelectronic seekers often have a narrower field of view than radar seekers, requiring more precise target cuing but they are typically less susceptible to decoys or jamming. The primary challenge in using an ASBM is accurate, real-time intelligence on the target's location because the missile seeker has a limited window to search for and acquire a target before engaging. If the ship moves between launch and engagement, the missile may not find its target. The difficulties of targeting with an ASBM are illustrated in Table 2, which shows the breakdown of missiles and drones launched between July and August and their success rate. Nevertheless, the missiles represented a significant challenge to US vessels in the area; the commander of the USS Carney reported that his crew had between 9 and 20 seconds to detect an ASBM launch and decide whether or not to engage.

The ASBM threat represents the most complex missile available to the Houthis, however, the way in which the missiles were employed often lacked complexity - with one or two missiles launched at a time in concert with a selection of drones. The US and industry reporting of Houthi attacks indicate that they tended to unfold in sequence, allowing each threat to be handled in turn rather than simultaneously, which would logically have been more challenging.

The Houthi attacks tend to involve small densities of missiles and drones compared with Russian strikes, which has enabled interceptions to be conducted effectively by western ships in the area with relative ease. They are notably more successful against individual ships that are outside of the protective zones of the air defence assets in the area. The ranges of Houthi strikes are also much reduced compared to those involved in Ukraine; a lot of cruise and ballistic missile strikes occur in the Gulf of Aden, which is between 220 km and 330 km across from the coast of Yemen to Somalia, the Red Sea is between 21 km and 300 km wide. The range of the Houthi missiles enable them to launch from Sanaa, which is believed to be their main missile base, as well as Dhamar. Some successful strikes with ASBMs indicate that the Houthis have a relatively capable targeting set up that enables them to identify and hit dynamic targets with ballistic missiles. However, the frequent misses indicate that this remains a challenging feat to achieve.

Ansar Allah have a range of ASCMs available to them, and have displayed many different types of missiles claiming to possess longer range or capabilities. However, one missile that they are understood to possess and use is the called Al-Mandeb 2, which is believed to have evolved from the Chinese C-802, an export variant of the YJ-82 ASCM developed by the China Electro-Mechanical Technology Academy and sold to Iran in the 1990s. The C-802 is powered by a solid fuel accelerator that detaches after launch, before a turbojet engine takes over, providing a range of 120 km. The missile has a semi-armour piercing high explosive (SAPHE) warhead weighing 165 kg. The missile can fly 20–30 m above sea level and descend to 5–7 m for the final approach. The top speed is around 300 m/s and it employs a radar seeker. It is not clear how closely the Al-Mandeb 2 is based on the C-802, however the Houthis are understood to have launched two missiles at the UAE's HSV-2 *Swift* logistics vessel in 2016, causing extensive damage. Missiles of both types appear to be the preferred method of attack for targets in the Gulf of Aden, although not exclusively.

In contrast, many of the attacks in the Bab-El-Mandeb Strait and Red Sea are conducted by aerial and sea drones. Houthi uncrewed surface vessels (USVs) – or weaponised USVs as they are sometimes known – come in a variety of forms and are believed to have been supplied as kits from Iran that were used to convert old Yemeni interceptor or fishing boats. They are often remotely piloted and even require a human to physically pilot them for a portion of their journey to a target, according to analysis from H.I. Sutton at Covert Shores. Converted boats may be fitted with mannequins to give them an innocuous

Table 2:
Reported breakdown of missiles and drones used by Houthis against commercial vessels in the Red Sea.

Weapon type	July 2024	Reported hits	August - September 2024	Reported hits
ASBM	1	0	10	3
'Anti-ship missiles'	9	2	6	0
Aerial drones	9	1	11	1
Sea drones	19	3	6	1

Note: Reporting on Houthi missile attacks lacks detail. Events are frequently reported as "an explosion near the ship" without indicating the cause. This data reflects those reports with sufficiently clear indications of the weapon type to track.

Source: Yemen Conflict Observatory

Credit: Earth Science and Remote Sensing Unit, NASA Johnson Space Center

This image taken during Expedition 62 of the International Space Station (ISS) shows the Bab-el-Mandeb strait between the Red Sea and the Gulf of Aden. The point is very narrow and provides a channelling function for Houthi missile operators. However, the sea lane is congested and may present targeting challenges as they seek to avoid Chinese- and Russian-flagged vessels.

look and armed with the warheads from Soviet anti-ship missiles or packed with high explosives. The Houthis also have a series of purpose-built USVs with warhead weights between 150 kg and 500 kg, all are powered by outboard motors and appear to require a human pilot for a portion of their approach to target. The range of the Houthi USVs is unclear, however they do appear to have been relatively effective so far with around 16% of the identified attacks having resulted in a hit against the target vessel.

Aerial drones have formed a significant component of the Houthi strike patterns, constituting around 40% of the total events in the Red Sea, according to data collected by the Armed Conflict Location & Event Data team. The group also states that 75% of drone attacks were intercepted, which is in line with the data provided above. The group's drones provide it with the greatest range, the Samad-2 and Samad-3 are typical of the types used by the Houthis, and these carry explosive payloads up to 18 kg. The latter has a range of 1,500 km, which is greater than the Samad-2, and they are believed to have a top speed of 250 km/h. Long-range drones such as the Samad family have been used in strikes on Saudi Arabia and Israel and often combined with ballistic missile strikes. Between 2015 and 2021, the Houthis are understood to have launched 430 ballistic missiles and 851 armed drones at targets in Saudi Arabia, leading to damage on critical national infrastructure and oil production facilities.

Overall, the Houthi arsenal of missiles and uncrewed attack vehicles in multiple domains are indicative of a possible future in the sphere of stand-off weapons. With the exception of ASCMs and ASBMs, which are most likely the result of Iranian technology or expertise, much of Ansar Allah's stand-off weapons are produced using commercially-available components and expertise. It indicates that non-state actors are now capable of developing their own stand-off weapon capabilities and that this technology could proliferate to other actors that are suitably motivated. It suggests that long-range precision strikes are no longer the preserve of advanced Western militaries and can be expected as a tool of terrorism and state-on-state combat alike.

Speed and reach

The US armed forces' ambitious efforts represent the leading edge of stand-off precision strike. This approach is best represented by the Multi-Domain Task Force (MDTF) concept, which are new units being developed by the US Army to employ multi-domain effects including cyber and electronic warfare, as well as kinetic long-range effects that are designed to degrade an opponent's air defence assets and critical infrastructure.

The US Air Force and US Navy also have their own air-launched HCM programmes in development, respectively known as Hypersonic Attack Cruise Missile (HACM) and Offensive Anti-Surface Warfare (OASuW) Increment 2, while the US Marine Corps (USMC) has obtained a ground-launched configuration of the Naval Strike Missile (NSM) subsonic ASCM for use in the Indo-Pacific. One of the driving factors for the US development is the increase in opposing air defence assets and stand-off weapons. The aforementioned Russian weapons provide an example of the ability of an opponent to hold US assets at risk from stand-off distances. For the US, it is necessary to provide air defence against these threats as well as their own long-range capabilities that can hit an opponent's strike assets before they can hit their US equivalents. This prioritises the speed and range of the missile.

Credit: US Navy

The USS Carney engages a Houthi missile in the Red Sea in October 2023. The Carney engaged Houthi missiles 51 times over an eight month deployment to the Red Sea that started in October 2023.

Credit: US Army

This image shows the LRHW deployed to Exercise Resolute Hunter in 2024. It is assigned to Bravo Battery, 5th Battalion, 3rd Field Artillery (Long Range Fires Battalion), 1st Multi-Domain Task Force. Although the ground equipment is already employed for training, the missile is still awaiting fielding.

Credit: US Army

The MRC leverages existing technology such as the Mk 41 VLS to provide a rapidly developed land-based capability that can launch Tomahawk Land Attack Missiles and SM-6. The shared supply chains with the US Navy further reduce any programmatic risk.

Table 3:
Missile complement of an MDTF

Missile	Number of launchers	Number of missiles ready to fire
LRHW	4	8
Tomahawk	4*	16
LRHW	4*	16
PrSM	6	12 PrSM; 36 GMLRS

*The MRC can carry four missiles and is designed to launch both the SM-6 and Tomahawk. It is possible therefore that an MDTF could have 16 ready to fire missiles of either type.

Source: Congressional Research Service (CRS).

The MDTFs are due to be equipped with the Long-Range Hypersonic Weapon (LRHW), which has been developed by Lockheed Martin to be fired from a trailer carrying two missiles. The weapon consists of a two-stage rocket booster armed with the Common Hypersonic Glide Body (C-HGB), which provides a range of at least 3,200 km and a speed of at least Mach 5 (1,715 m/s), and probably higher. The C-HGB is propelled out of the atmosphere and released from the booster stages before returning back to the atmosphere and transitioning into a glide trajectory. Once within the Earth's atmosphere, the glide body generates lift, enabling the HGV to manoeuvre, and glides to its target at hypersonic speeds. The US Army hopes to field its first operational LRHW missiles in 2025.

LRHW is complemented by the Mid-Range Capability (MRC), also known as Typhon, which employs a Mark 41 Vertical Launch Cell from the *Arleigh Burke* class ships that has been repurposed by Lockheed Martin into a ground-based launch system to launch the Tomahawk Block IV cruise missile with a range of 1,600 km, and the SM-6, with an estimated range from 240 km to 460 km.

The MDTF will also be able to employ the Precision Strike Missile (PrSM) with a range of 499 km, which is designed to be launched from the M142 HIMARS. The US will eventually wrap a number of air defence and targeting networks around these capabilities that enable many different sensors to be connected to provide targeting outputs at strategic depths. The total missile complement of an MDTF is indicated in Table 3. It indicates that the bulk of the strike capability is provided by the Tomahawk in terms of ready-to-launch missiles. However, the survivability of Tomahawks against a layered and prepared air defence network could be relatively low and force greater reliance upon the LRHW for initial operations against an opponent's air defences.

The US Air Force is developing the HACM HCM in partnership with Raytheon and Northrop Grumman. Flight tests are expected between 2025 and 2027 before a production decision is made. The design is expected to employ a rocket booster with a scramjet, and to be launched from tactical aircraft such as the F-15 and F/A-18. It is complemented by the Navy's OASuW Increment 2, also known as the Hypersonic Air-Launched OASuW (HALO) under development for the US Navy for use from F/A-18s to provide near-hypersonic strike capabilities against an adversary's vessels. Both

Credit: USMC/Cpl Earik Barton

USMC Lance Cpl Cade Heller, an artillery cannoneer with Fox Battery, 2nd Battalion, 11th Marine Regiment, 1st Marine Division, prepares a Navy/Marine Expeditionary Ship Interdiction System (NMESIS) to be launched at Naval Air Station Point Mugu, California, on 27 June 2023.

designs are in a relatively early phase of development, although they are expected to be rapidly prototyped and brought into service. It is understood that the adversary around which these weapons are built is China, and that they are expected to address the very significant distances involved in a conflict in the Indo-Pacific as well as fill gaps in the existing US long-range strike arsenal.

The final stand-off weapon of note is the USMC's Navy/Marine Corps Expeditionary Ship Interdiction System, or NMESIS, which pairs the Naval Strike Missile (NSM) with the Oshkosh Remotely Operated Ground Unit for Expeditionary Fires (ROGUE-Fires), a remotely operated JLTV 4×4 fires platform. NSM is being produced for the USMC and US Navy by Raytheon, which has partnered with Kongsberg to offer the Norwegian missile in the US. It provides a range in excess of 185 km and contributes to the US Navy's concept of distributed lethality, which is designed to make its surface vessels more lethal and enable them to perform as hunter-killer surface action groups that can disperse over a wide area, thereby complicating an opponent's own targeting process, as well as seizing maritime areas for force projection.

NSM is designed to strike ships as well as land targets, and is fitted with an automatic target recognition system for engaging ships as well as a high resolution imaging infrared (IIR) seeker that enables the missile to select a hit point on a target. It is described as being high subsonic in speed with the ability to manoeuvre to evade air defences. The warhead weighs 226 kg in the naval version and is programmable. The USMC has also adopted the principle of distributed lethality in its Force Design 2030, as it reconfigures its forces to create multiple dilemmas for an opponent and bring more lethality to bear at stand-off ranges.

Looking ahead

The approaches explored here provide an indication of the future of stand-off weapons and long-range strikes. Most countries will have to fall within one of these brackets in terms of the weapons that they choose to employ. However, it is apparent that there is a general trend towards faster missiles, and that ballistic designs can be more difficult to intercept. This may drive future design decisions as many countries debate how best to counter the increasingly capable air defences that have proliferated as hypersonics are a costly and far from proven technology, that may not offer a marked improvement in performance over existing ballistic missile designs. It is also clear that many of these weapons either already are, or will have to be procured in large quantities as a prepared opponent can enjoy significant success against certain missile and drone types. Finally, stand-off weapons will continue to form an important element of arsenals, however, it is clear that achieving war altering effects with them – even when used in their thousands as Russia has – is not straightforward. It may be that hypersonic missiles shift the balance away from the air defender, but it will remain essential to identify the nodes that are truly critical and strike them decisively while exploiting the effects they provide with other forces. ■

Special mission aircraft for covert insertion

Sidney E. Dean

Special Operations Forces (SOF) worldwide can choose from a wide array of aircraft for covert insertion, exfiltration and resupply, with new technologies being integrated into current and developmental platforms to enhance performance and survivability.

SOF transport aircraft fall into various categories based on type, range, size and performance parameters. The vast majority are specially modified and equipped variants of general air-transport aircraft families.

Large fixed-wing aircraft

Large fixed-wing aircraft make up a significant portion of SOF transport fleets. Their advantages include very long range, high passenger or payload capacity, the ability to operate at both high and low surface ceiling, and sufficient space to integrate advanced avionics and other specialised mission systems, including optional armaments.

MC-130J

The C-130 Hercules has been used for special operations insertion for decades. The current variant operated by the US Air Force Special Operations Command (AFSOC) is the MC-130J Commando II, which entered AFSOC service in 2012; the last of the 57 ordered units will be delivered in 2025.

The MC-130J Commando II is based on the newest Hercules variant, the C-130J 'Super Hercules'. Compared to the previous MC-130H variant, the MC-130J has a 15% greater airspeed, 21% greater cruising altitude, and 25% longer range, as well as a faster climb rate, thanks in part to more efficient Rolls Royce AE 2100D3 turboprop engines with six-blade composite rotors. It is capable of landing on a 975 m dirt strip while carrying a 19,000 kg load; with a reduced payload the plane can also operate from shorter 615 m dirt strips in high mountain ranges. Onboard systems include an advanced two-pilot flight station with fully integrated digital avionics, colour multifunctional liquid crystal displays (LCDs) and head-up displays (HUDs), modern navigation systems including a dual inertial navigation system and GPS, AN/APN-241 Low Power Color Radar (LPCR), digital moving map display, Combat Systems Operator and auxiliary flight deck stations, and integrated defensive systems including the Large Aircraft Infrared Countermeasures (LAIRCM) missile detection and countermeasures system. The cockpit systems enable nighttime all-weather flight operations under blackout conditions at altitudes as low as 80 m to evade detection over hostile or non-permissive territory. The MC-130J is also equipped with the Universal Air Refueling Receptacle Slipway Installation (UARRSI) which significantly extends the aircraft's basic 4,828 km (2,607 NM) operating range.

In addition to infiltration/exfiltration and resupply of SOF, the MC-130J also escorts SOF helicopters for long-range missions. For these Helicopter Air-to-Air Refuelling (HAAR) operations, the Hercules is equipped with underwing fuel pods. In September 2024, two MC-130J crews received awards for 'exceptional service during a high-stakes contingency operation' involving a ten-hour nonstop flight-to-target by multiple helicopters, setting an endurance record for helicopter missions.

The MC-130J is currently being upgraded with new communications, navigation and sensors. The Block 8.X software upgrade improves satellite communications (SATCOM) security including the anti-jam NATO-interoperable SATURN UHF system. In addition, Silent Knight Terrain-Following/Terrain Avoidance (TF/TA) radar mounted in a second radome beneath the cockpit, Radio Frequency Countermeasure (RFCM), and Airborne Mission Networking (AbMN) are all part of the planned Capability Release 2, which will enhance the aircraft's ability to operate in high-end-threat environments. This upgraded aircraft will be redesignated 'Combat Talon III' to reflect the significance of its new capabilities.

Credit: USAF/Senior Airman James Bell

A 522nd Special Operations Squadron MC-130J Commando II aircraft flies over New Mexico on 4 January 2012.

A400M

The Airbus A400M Atlas turboprop is operated by seven nations, with France, Germany and the UK operating the largest fleets, making it the second most popular medium-lift aircraft worldwide after the C-130. The Atlas' maximum speed of 741 km/h (400 kn), unrefuelled range of 6,390 km (3,450 NM) with a 20-tonne payload, and a 8,700 km (4,698 NM) ferry range, service ceiling of 12,300 m and maximum payload capacity of 37 tonnes all exceed those of the C-130J/MC-130J.

The multi-mission airframe is well-suited for SOF insertion missions, evacuation operations, and other tasks requiring covert access to contested regions. As a large airframe, the A400M can deploy SOF personnel together with a wide range of vehicles and ancillary equipment including UAVs, or a single H145M helicopter (suitable for SOF missions); alternatively, the plane's

Credit: Bundeswehr/Jane Schmidt

A Bundeswehr A400M takes off from Gao International Airport in Mali.

transport bay can be configured for SOF-assisted casualty/medical evacuation (CASEVAC/MEDEVAC). Two underwing fuel pods to support long-range missions of other aircraft are available. Certification for refuelling helicopters in flight, at airspeeds as low as 194 km/h (105 kn), was approved in 2021.

The aircraft can operate from austere landing fields under total blackout conditions and have been used extensively for SOF deployments and evacuation missions in Afghanistan, the Middle East and Africa, as well as during SOF exercises in the Arctic. The aircraft is capable of very rapid descent to reduce exposure to hostile sensors or weapons. Low-level flight can conducted as far down as 90 m off the ground at airspeeds of 556 km/h (300 kn), while avoiding obstacles. Over water, the aircraft can descend to 50 m above the surface for SOF boat drop missions. Alternatively, it can deploy commandos for high-altitude (HALO/HAHO) parachute drops. French and German SOF, in particular, make extensive use of their nations' A400Ms, and also deploy the aircraft in support of Allied special operators.

Small fixed-wing aircraft

Smaller aircraft can be preferable for missions requiring a lower profile or involving a small number of personnel, as is often the case with SOF missions. A case in point is the C-146A Wolfhound operated by AFSOC, which entered service in 2011. Measuring approximately 21.3 m in fuselage length and 21 m in wingspan, the Wolfhound is inconspicuous. Moreover, it bears no military designators or colour scheme, but a neutral blue and white which blends in with small commercial operators at major or minor airfields in any region.

The short take-off and landing (STOL) capable aircraft can conduct covert delivery of personnel and cargo, support and liaison for regional partners, and casualty evacuation missions at prepared and semi-prepared airfields. It achieves airspeeds of 500 km/h (270 kn), with an operating range of approximately 2,778 km (1,500 NM) with a payload of 907 kg (2,000 lb). The aircraft requires a three-person crew (two pilots and a loadmaster) and accommodates 27 passengers, four litter patients or 2,700 kg of cargo. The service's 20 aircraft support overseas intra-theatre contingency operations across four geographic combatant commands. In 2023, a Wolfhound participated in Exercise Arctic Edge in northern Alaska, demonstrating it capability to operate in austere and extreme cold weather conditions.

The C-146A is based on the Dornier 328 regional airliner and modified for the military by Sierra Nevada Corporation (SNC). Modifications include: a night vision compatible cockpit; navigational aids to support operations in GPS-degraded environments; military communications systems including the ARC-231, PRC-117, and Iridium communications suite; changes to the passenger cabin to better accommodate military missions including CASEVAC; and fuselage enhancements to support STOL and austere facility operations. On 2 September 2024, Dornier and SNC celebrated 200,000 flight hours of the C-146A.

Tiltrotor aircraft

Tiltrotor aircraft combine advantages of fixed wing aircraft – such as higher airspeed, longer range and greater fuel efficiency – with the flexibility of helicopters. This makes them especially attractive to SOF.

The best known SOF-dedicated tiltrotor is the CV-22B Osprey operated by Air Force Special Operations Command (AFSOC). Primary missions include SOF long-range infiltration, exfiltration and resupply. According to the USAF, this enables the CV-22 to perform missions that normally would require both fixed-wing and rotary-wing aircraft. Initial operating capability (IOC) of the CV-22B was declared in 2009. Performance parameters include a maximum airspeed of 519 km/h (280 kn), a service ceiling of 7,600 m, and a combat radius of 926 km (500 NM) with one internal auxiliary fuel tank. In addition to the four-person crew (pilot, co-pilot and two flight engineers), the Osprey accommodates up to 24 personnel seated, 32 personnel floor-loaded or 4,500 kg of cargo. A GAU-21 12.7 mm heavy machine gun is mounted on the rear ramp.

The aircraft is equipped with a digital cockpit management system, digital map system, integrated threat countermeasures, Silent Knight TF/TA radar navigation (currently being introduced), gimballed infrared (IR) sight (typically slaved to the flight path vector), secure jam-resistant com-

Credit: USAF/Senior Airman Cory D. Payne

US SOF personnel prepare to load medical equipment onto a C-146A Wolfhound during an exercise at Camp Rudder, Florida, on 23 April 2015.

Credit: USAF;Tech Sgt Westin Warburton

A CV-22B recovers SOF personnel via hoist.

munications and other avionics optimised for the penetration mission. The planned Airborne Mission Networking (AbMN) upgrade, which is also being applied to the MC-130J, will provide the crew with a common air/ground picture and help to manage complex workloads. Other ongoing and planned upgrades include an infrared searchlight, lightweight ballistic armour, electronic warfare upgrades, and improved situational awareness tools. The engine nacelles are being modified to reduce their infrared signature and dust ingestion, and to remediate mechanical issues with the proprotor gearbox which have been identified as the cause of a deadly CV-22B accident in 2023.

To finance the ongoing upgrade programme, the USAF has placed 15 of the 51 operational CV-22B aircraft in 'flyable storage' status until at least 2026. Current plans do not call for net retirement of aircraft before 2029. "With respect to the CV-22 at large, it is answering a long-held requirement and that no other capability can answer in the special operations community as we go forward," said AFSOC Commander Lt. Gen. Tony Bauernfeind in February 2024.

Helicopters

For short-to-medium range SOF insertion, helicopters remain the aircraft of choice for most nations. Their primary benefit is the flexibility to deliver and retrieve operators to and from very small landing zones in urban as well as natural terrains, including through fast-rope insertion and winch recovery.

Heavy Lift

The US Army Special Operations Command's MH-47G Chinook is the SOF-dedicated variant of Boeing's multi-mission heavy-lift CH-47F helicopter. Currently the largest operational SOF helicopter, the Chinook has the capacity for 33 combat-equipped soldiers (or a smaller number of personnel with tactical vehicles), plus the three-person crew. Personnel can egress and embark quickly via the stern ramp or via the Fast Rope Insertion Extraction System (FRIES). The MH-47 is armed with M134 7.62 mm gatling and M240 7.62 mm machine guns to provide suppressive fire. The AN/AAQ-24 LAIRCM countermeasure system provides defence against heat-seeking missiles.

The upgraded Block II variant of the MH-47G is currently in production, with first deliveries to the Army in 2020. The new variant has a lighter but more rigid airframe, an upgraded drive system and the Advanced Chinook Rotor Blade, which together improve lift performance and efficiency, especially at high altitude and hot conditions. New, unsegmented fuel tanks increase capacity, improving range over previous iterations. The helicopter has an unrefuelled operational range of 630 km (340 NM) and an extendable refuelling probe to enable longer-range insertions. Maximum airspeed is 315 km/h (170 kn), with a cruise speed of 222 km/h (120 kn).

The Block II's Common Avionics Architecture System (CAAS) integrates upgraded software and hardware components, including active matrix LCDs and newer processors. FLIR and a multi-mode/terrain following radar system enable pilots to navigate through narrow canyons and gaps, flying with as little as 200 m error space on either flank while using terrain to mask their approach. The 6,100 m service ceiling makes the helicopter suited for mountain operations, with two extendable fuel dump pipes mounted at the rear of the fuselage permitting rapid weight reduction if additional lift is needed in the thin air of high altitudes.

Medium lift

Worldwide, numerous medium-lift multi-mission helicopters have been adapted for SOF operations. These include the Airbus H225M Caracal, which the manufacturer describes as the most advanced member of its Super Puma/Cougar military helicopter family. While the Caracal (previously marketed as the EC725) is used by the armed forces of 11 nations for a variety of missions, including troop transport and CASEVAC, it has been specifically selected for SOF aviation units by France and The Netherlands. This all-weather capable aircraft can operate from both land or ships, offering maximum mission flexibility. The twin Makila 2A1 turboshaft engines and five-blade main rotor pro-

Credit: US Army/Sgt Christopher Plows

Army MH-47G helicopters are used to transport US Navy special boat team watercraft and personnel to and from lakes when overland transport is not practical.

Credit: Airbus

French SOF conduct H225M Caracal operations from land and from warships.

vide an exceptionally low vibration level for precision flight, reduced noise level and enhanced comfort. The H225M can be refuelled in flight, extending the 1,259 km (680 NM) range by up to ten hours of flight time, enabling non-stop long-range deployment when no permissive ground refuelling options are available. Top speed rating is 324 km/h (175 kn), with a recommended cruise speed of 259 km/h (140 kn). The aircraft carries 28 combat-equipped commandos, plus the three-person crew for assault missions and insertion. Modular armour and a variety of weapons packages can be applied on a mission-by-mission basis.

Airbus is developing a dedicated special operations variant of another proven medium lift helicopter – the NH90 – under an agreement signed in 2020 with the NATO Helicopter Management Agency. The new NH90 Standard 2 will be based on the NH90 Tactical Troop Helicopter variant, but will have numerous upgraded features developed specifically for special forces. These include a Euroflir 410 gimballed optronic sight from Safran, with displays and controls for the pilots, commandos, gunners, and loadmasters. Planned future upgrades will include the Thales TopOwl helmet featuring an integrated HUD, providing tactical information and sensor data, augmented reality and tactical 3D symbols directly to the flight crew. Future integration of the wide field of view version of Safran's Eurofl'Eye optronic pilot aid is also planned, which will enhance the pilot's capability to fly in reduced-visibility conditions such as sand, snow or fog. The passenger cabin will receive additional ceiling-mounted anchor points for quicker fast-rope exfiltration. The helicopter provides crashworthy seating for 20 passengers, plus the three-person crew. Maximum range is 907 km (490 NM) with a fast cruise speed of 296 km/h (160 kn). The new aircraft are destined for the French Army's SOF, with deliveries scheduled to begin in 2025.

Light helicopters

Light utility helicopters (LUH), with their reduced visual and acoustic footprint, can be the best option for insertion of small commando or reconnaissance teams. The Airbus H145M LUH SOF was chosen in 2013 by the German special operations command. The agile aircraft has proven itself on global missions including in high (up to 6,000 m) and hot operating zones. The helicopter has a length of 13.64 m, with a maximum speed of 268 km/h (145 kn), a fast cruise speed of 241 km/h (130 kn) and a maximum range of 663 km (358 NM) with standard fuel tanks.

The H145M LUH SOF features two fast-rope beams, a high-performance camera system for reconnaissance, an electronic warfare (EW) system, and weapon mounts for fire support. The helicopter can be flown by one or two pilots, with seating for up to ten passengers (nine in the Bundeswehr LUH SOF configuration) and a sling capacity of 1,600 kg. Cabin doors can be removed before take-off to facilitate fast egress upon arrival at the target; this will not impede flight performance. The 11 m rotor diameter facilitates hover and landing in urban areas, and the fenestron minimises acoustic signature, again delaying detection while approaching the target.

Future options

Research on new or improved SOF transport options is ongoing. US SOCOM would like to see high- speed VTOL aircraft that combine the flexibility of rotary aircraft with airspeeds approaching those of jet aircraft. The Defense Advanced Research Projects Agency (DARPA) is conducting the Speed and Runway INdependent Technologies (SPRINT) on behalf of and in partnership with SOCOM. Contractors have been soliciting industry to submit proposals for a proof-of-concept technology demonstrator designed for speeds of 741–833 km/h (400–450 kn) and a range of at least 315 km (170 NM). According to DARPA, two performers – Aurora Flight Sciences and Bell Textron, Inc. – have so far been awarded contracts for Phase 1B. If previous DARPA deadlines are retained, the preliminary design work for these aircraft is to be presented by spring of 2025. If the technology proves viable, it could eventually prove to be the proverbial 'game changer' for SOF insertion. Experience would indicate, however, that developing and validating the technology will take considerable time. ■

Credit: Bundeswehr/Jana Neumann

A H145 LUH SOF helicopters insert German commandos during an urban exercise.

Bolstering the Ukrainian Air Force: the case for Gripen

Peter Felstead

While current plans a focused on providing the Ukrainian Air Force with F-16s, the Swedish government has started to put money behind the potential supply of Gripens to Kyiv.

When Ukraine's West European allies set about bolstering the Ukrainian Air Force (Povitryani syly Zbroynykh syl Ukrayiny; PS ZSU), to develop the air threat to Russian forces and deny Russia air superiority over the Ukrainian battlefront, the Lockheed Martin F-16 Fighting Falcon was an obvious place to start.

This was because five European F-16 fighter operators – Belgium, Denmark, Greece, the Netherlands and Norway – had either converted over to the Lockheed Martin F-35 Joint Strike Fighter or are in the process of doing so, leaving older-model F-16s available for donation to Ukraine in sizeable numbers.

Beyond these plans, however, a number of sources – most expectedly within Saab – also touted Saab's JAS 39 Gripen C/D as an ideal candidate fighter for the Ukrainians. This idea remained a theoretical possibly while plans proceeded to transfer F-16s to Ukraine and to train Ukrainian aircrew and maintainers on the Falcon, but in September 2024 the Swedish government started to get serious about the prospect of providing Gripen C/Ds to Ukraine.

Presenting its 17th military support package for Ukraine on 9 September 2024, the Swedish government stated in a press release, "At the moment, transferring [the] JAS 39 Gripen to Ukraine is not a viable option, as it would interfere with the prioritised introduction of F-16 fighters. However, in parallel the Swedish government is continuing its efforts to establish conditions for a possible future support of JAS 39 Gripen fighters to Ukraine. Support package 17 does so by acquiring materiel parts for the JAS 39 Gripen worth approximately SEK 2.3 billion (EUR 0.2 billion)."

The press release further noted that "Materiel parts are JAS 39C/D parts that are being reused in the construction of new JAS 39E aircraft. By acquiring new materiel parts, a number of JAS 39C/D will be saved from being dismantled and can – if the Swedish government decides so – be considered for a possible future donation to Ukraine."

Credit: Saab

A Saab Gripen C in flight. The Swedish government has started to commit funding to the potential supply of Gripens to Ukraine.

While the Swedish government press release clearly opens a path to the potential future supply of JAS 39C/D fighters to Ukraine as the Swedish Air Force (SwAF) transitions to the more modern JAS 39E, the statement was somewhat confusing given how SwAF plans for its Gripen fleet have changed in recent years.

When, in February 2013, the Swedish government decided that the SwAF would acquire 60 Gripen Es, this was originally to be through upgrading Gripen C/Ds. However, it was subsequently decided that at least some of the SwAF's Gripen C/D fleet would be retained to preserve the combat mass of the SwAF, with a number of Gripen Es being produced as new-build aircraft. Deliveries of the first serial-production Gripen Es began in November 2021, while the SwAF is currently believed to be operating 71 single-seat Gripen Cs and 23 two-seat Gripen Ds of 75 and 25 of these types respectively delivered from 2004.

In December 2021 the Swedish defence procurement agency (FMV) announced that 40 Gripen Es would be fully new-build aircraft, meaning that a similar number of Gripen C/Ds could be retained rather than cannibalised.

Asked to clarify the situation, a spokesperson for the Swedish Ministry of Defence (MoD) told ESD on 7 October 2024, "The original plan was to take some specific parts out of JAS 39C/Ds and to reuse them when building new JAS 39Es. Back in 2013 the decision on Gripen E required 60 Gripen C/Ds to be dismantled to build 60 Gripen Es. No decision has been taken yet on the remaining 40 Gripen C/Ds. However, since the security situation in Europe has been deteriorating, decisions have been taken to manufacture those specific parts, instead of dismantling a number of JAS 39C/Ds for parts to be reused in JAS 39Es. Now, in Package 17, an additional number of specific parts will be manufactured, saving an additional number of JAS 39C/Ds from being dismantled and instead possibly making them available for donation to Ukraine."

Credit: Saab

Two Gripen Es in flight. The SwaF plans to acquire 60 such aircraft.

Meanwhile, a Saab source told ESD on 3 October 2024, "The Gripen E is a totally new design and all Gripen Es are newly produced aircraft. Since continuous development and low life-cycle cost is in Saab's DNA, Gripen E has been designed to allow some systems to be re-used between the aircraft models per the customers' choosing, or you can opt to go to brand new solutions. This is typically only done for systems not vital to the important feature set provided by the new aircraft.

"Sweden had previously planned to use this possibility for a small portion of systems in some aircraft," the source added, "but per their communication now opted to go forward with the new system approach."

Beyond the Gripen C/Ds in SwAF service, Saab is also understood to be holding between 18 and 22 'white tail' Gripen C/Ds that were ultimately never sold to a customer, although it remains unknown how many of these have powerplants and could thus be offered to Ukraine.

Asked how many Gripen C/Ds could in theory be transferred to Ukraine, the Swedish MoD spokesman replied, "No decision has been made regarding the donation of JAS 39s. If it becomes relevant, factors such personnel, training conditions, associated equipment will have to be considered. We will not comment on specific numbers of possible JAS 39 donations."

A capable platform

A single-engined fighter like the F-16, the Gripen C is a lighter aircraft with slightly lower performance overall but can still attain a maximum speed of Mach 2.0 (2,100 km/h) at 15,240 m and features a combat range of 800 km and a maximum payload of 5,300 kg. The Gripen C/D has eight hardpoints for weapons, while single-seat C models also have a 27 mm Mauser cannon. Missiles in the Gripen C/D inventory include the Meteor and AIM-120B AMRAAM beyond-visual-range air-to-air missiles (BVRAAMs), IRIS-T and AIM-9L Sidewinder dogfighting missiles, the Taurus KEPD-350 air-launched cruise missile, the AGM-65 Maverick air-to-ground missile and the RBS-15 anti-ship missile, while precision-guided bombs such as the GBU-12 Paveway II and GBU-39 Small Diameter Bomb can also be carried.

All of the above weapons, with the exception of the Taurus KEPD-350, are currently in the SwAF inventory and could presumably be supplied alongside any donated Gripens. Ukrainian employment of the ramjet-powered Meteor BVRAAM in particular, which travels at speeds above Mach 4 and has a range in excess of 200 km, could make a significant difference in air-to-air engagements over eastern Ukraine.

The Gripen C/D's primary sensor is the PS-05/A pulse-Doppler radar, while the aircraft also features an IR-OTIS infra-red search and tracking sensor, Saab's Countermeasures Dispenser System for self -protection and also an aerial refuelling probe for long-range operations.

Among those who have touted the Gripen as an ideal solution for the Ukrainians, a key aspect has been the ease with which a pilot can learn to fly the aircraft. The SwAF, after all, has opted not to procure two-seat Gripen F conversion trainers as the Brazilian Air Force has done. Instead, SwAF pilots, who will have already had experience of flying Gripen C/Ds, will simply put in the required number of hours on a Gripen E flight simulator before taking to the skies in the real thing.

One source familiar with both Gripen C/Ds and older-model F-16s cited multiple reasons to ESD as to why a Gripen C/D would be easier to train on and operate in combat.

"Early versions of the F-16 – in fact, the majority of variants prior to Block 70 – do not incorporate autothrottle or the means to set and maintain a constant airspeed without pilot monitoring," the source explained. They noted, *"Gripen, just as other fourth- and fifth-generation fighters, incorporates both autothrottle and specific excess power (SEP) indications, which significantly reduce the workload of the pilot by providing automatic control of airspeed or a computer-assisted indication of the desired throttle setting to maintain. This is particularly useful when conducting operations such as close air support (CAS) and battlefield air interdiction, which frequently require the pilot to look into the cockpit at the electro-optical targeting system display or other sensors to locate, track and target accordingly."*

"Similarly," the source added, *"the Gripen auto-pilot system reduces workload by allowing the pilot to select attitude hold (maintaining the aircraft at the desired level and angle of bank/heading) and then being able to increase or decrease angle of bank (and therefore turn rate) via inputs to the rudder pedals. In doing so the pilot can fly a very effective CAS 'wheel' around a target with only the use of his feet (and without fear of loss of control or stalling), freeing up their hands to programme weapon data or take notes from airborne or ground controllers."*

Thirdly, the source noted that the Gripen *"features a full 'care-free' flight control system (FCS) that limits pilot control inputs to maximise turn and roll performance with-*

Credit: MBDA

Having a platform able to launch the MBDA Meteor missile could make a significant difference to Ukraine's air-to-air capability.

Credit: Peter Felstead

A Gripen C landing on a Swedish highway near Såtenäs Air Base during a SwAF ACE exercise on 17 May 2024. Gripens need just 700 m of road to land and take off during ACE operations: a capability that could prove very valuable to the Ukrainian Air Force.

out exceeding the structural limits of the aircraft. The more basic F-16 FCS modes require manual pilot monitoring of aircraft limits across the flight envelope (particularly when carrying external stores and weapons). The F-16, unlike the Gripen, can be departed from controlled flight – particularly when engaging in SAM [surface-to-air missile] defence manoeuvres or aerial combat (dogfighting). The requirement to observe aircraft limits places a huge additional workload on the pilots."

Beyond these issues, the Gripen's ability to conduct dispersed operations – what NATO terms Agile Combat Employment (ACE) – could prove very valuable to a Ukrainian Air Force whose assets are being hunted by the Russians. Gripens need just 700 m of road to land and take off during ACE operations. Conversely, the source noted to ESD that the US Air Force works on a minimum runway length of 2,438 m (8,000 ft) for routine operations.

"The requirement for such runway lengths decreases flexibility (availability of runways in Europe)," the source explained. *"The absence of reinforced front gear and undercarriage, combined with no integrated high-lift devices, poor handling qualities on approach, angle-of-attack limitations on approach (due to the risk of tail-strike) and poor braking capability on landing further limit the short field capability of the F-16 (all variants)."*

Ukraine's F-16s

For all of that, however, for the Ukrainians the F-16 is the only viable current option and they are clearly very pleased to have them, with the first F-16s to be donated to Ukraine since the Russian invasion entering the Ukrainian Air Force inventory in early August 2024. In a video posted on the X/Twitter account of Ukrainian President Volodymyr Zelenskyy on 4 August 2024, Zelenskyy could be seen addressing a ceremony for Ukrainian Air Force pilots and maintainers at an unknown location with two F-16s behind him sporting Ukrainian insignia. The video footage also showed two additional F-16s conducting a flypast of the ceremony.

"We are now in a new phase of development for the air force of the armed forces of Ukraine," said Zelenskyy in his address. *"We have done a lot to transition the Ukrainian Air Force to a new aviation standard: Western combat aviation. … We have held hundreds of meetings and negotiations to strengthen the capabilities of our aviation, air defence, and defence forces. We often heard the word 'impossible' in response, but we made possible what was our ambition, our defence need, and now it is a reality in our sky: F-16s in Ukraine. We ensured this."*

The first batch of six F-16s are understood to have arrived in Ukraine in late July 2024 from Denmark, with one lost in action around 28 August, according to a statement from the Ukrainian Armed Forces, while the first Dutch-donated aircraft had followed by early October. Denmark and the Netherlands had both committed to donating F-16s to Ukraine on 20 August 2023. Denmark said it would provide 19 aircraft, while Zelenskyy claimed the Netherlands had committed to providing 42.

Belgium, meanwhile, signed a security agreement with Kyiv on 28 May 2024 that confirmed it would transfer 30 F-16s to Ukraine. Norway, which decided in 2023 to donate a number of F-16s to Ukraine under the framework of the Air Force Capability Coalition (AFCC) for Ukraine led by Denmark, the Netherlands and the United States, stated on 10 July 2024 that it would donate six aircraft, with deliveries to start in 2024. The Royal Norwegian Air Force phased out its F-16s in 2021 following its adoption of the F-35 Lightning II, but sold 32 F-16s to Romania.

The F-16s that Ukraine is receiving are F-16AM/BM variants: single-seat F-16As and twin-seat F-16Bs that have undergone a mid-life upgrade that, among other features, introduced an improved radar – the APG-66(V)2A – that offers the ability to track and engage more targets simultaneously and at greater ranges.

Credit: Volodymyr Zelenskyy X account

An F-16 sporting Ukrainian insignia takes off from an unknown location on 4 August 2024, when Ukrainian President Volodymyr Zelenskyy officially announced that F-16s had entered the Ukrainian Air Force inventory.

Could France beat Sweden to it?

Even if the Swedish government were to fully sanction the donation of Gripen C/Ds to Ukraine, their arrival would certainly be at least a year away. Asked by ESD if there were any moves in process to train Ukrainian aircrew and maintainers on the Gripen C/D should a Gripen donation proceed, the Swedish MoD spokesperson replied, "Planning regarding training and education of Ukrainian pilots and personnel are taking place within the Air Force Capability Coalition."

"Co-ordination with AFCC is crucial for determining when the introduction of an additional combat aircraft system could take place," the spokesperson added. They noted, "Sweden remains in close contact with the coalition, also in regard to the training of Ukrainian pilots on the ASC 890 [the Saab 340-based airborne early warning and control aircraft, of which Sweden has pledged two to Ukraine]. If necessary, training of Ukrainian personnel will be prioritised within the Swedish Air Force if a donation becomes relevant."

Meanwhile, on 8 October 2024 French Armed Forces Minister Sébastien Lecornu posted on X/Twitter that the Dassault Mirage 2000 fighter is "bound for Ukraine", with deliveries scheduled for the first quarter of 2025. "In Cazaux, in Gironde, they will be equipped with new equipment: [for] air-ground combat and anti-electronic warfare defence," he stated, adding, "The training of Ukrainian pilots and mechanics continues."

This confirmed a statement made by French President on 6 June 2024 that Mirage 2000-5s, which are being replaced in the French Air Force by Dassault Rafales, would be sent to Ukraine. The quantity of Mirage 2000s to be sent was not mentioned by either Lecornu or Macron. ■

Credit: USAF/Tech Sgt Joseph McKee

A KC-130J, assigned to the Marine Aerial Refueler Transport Squadron 352, refuels a Dassault Mirage 2000-5 assigned to French forces as part of a refuelling training mission on 22 November 2012.

Joined-up thinking

Thomas Withington

Warfighting in a saturated radio spectrum places a premium on command and control, and spectrum management. The US Joint Electromagnetic Battle Management system should help both.

War may be raging in Ukraine but, for the most part, cell phone coverage is available. Broadcasters near the front transmit their footage and reports across satellite links. SpaceX's Starlink satellite constellation provides military and civilian users alike with broadband internet coverage. Ukraine's heavily tasked emergency services use their radios to communicate. Meanwhile, Russian and Ukrainian troops use their transceivers to share voice and data traffic. Much of this civilian and military communication takes place in very/ultra high frequency (V/UHF: 30 MHz to 3 GHz) wavebands in the radio segment of the electromagnetic spectrum.

Credit: Signals Analysis Training_(USMC;Staff Sgt Samuel Ruiz)

A US Marine conducts signals analysis during a training event at Marine Corps Base Hawaii on 3 April 2024.

The COMINT battle

Communications Intelligence (COMINT) operatives in both the Russian and Ukrainian military must search and locate their Signals of Interest (SOI) in this morass of electromagnetic noise. The collection of COMINT at the tactical and operational levels has two key roles: Firstly, COMINT operatives are trying to locate and identify hostile radio emissions. If you are a Russian communications intelligence operative, finding the location of Ukrainian military radios in a specific locale is a key part of the land battle. It is a truism of electronic warfare (EW) that if you find an enemy radio, you usually find the enemy. Soldiers, platforms, weapons, sensors and bases, henceforth known as assets, all depend on radio communications. These signals carry command and control (C2) and situational awareness (SA) traffic. By plotting where hostile radio signals are discovered, COMINT experts can plot the locations of hostile units.

Simply observing these signals can reveal much about the prevailing tactical and operational situations. If radio transmissions suddenly cease on the other side of the frontline, does this mean that an enemy attack is imminent? Are troops observing radio silence to this end? Similarly, if hostile traffic begins to increase, does this mean units are sharing plans in preparation for manoeuvre? If the observed radio signals are moving, is manoeuvre occurring? It may be possible for COMINT operatives to break into encrypted communications. Unsurprisingly, militaries prefer to keep their communications discreet. Significant work goes into making signals as difficult as possible to detect. Radio transmissions are often extremely discreet, being as 'quiet' as possible. The intention is to ensure these signals largely disappear into the prevailing electromagnetic noise discussed above.

If radio traffic is discovered, encryption will hopefully add an additional layer of protection. COMINT cadres will have to break through this encryption in order to exploit the information carried in the traffic. This may be easier said than done. The sophistication of the encryption may mean it is not possible to do this in real time. Nonetheless, once codes are cracked, traffic may give up its secrets, revealing important intelligence which can be exploited. Communications intelligence experts will then be able to see the C2 and situational awareness information zipping between enemy units. This COMINT can be exploited for the edification of one's own side. Alternatively, once the hostile radio networks have been hacked, false or misleading radio traffic can be implanted to hamper command and control, and SA.

As seen in Ukraine in the past, breaking into a hostile radio network may enable the insertion of malicious code. Military assets all depend on digital systems to some extent. Computerised battle management systems aid command and control. Digital fire control systems aid artillery. Troops rely on zeros and ones transmitted across radio networks for maps and reconnaissance pictures and inserting malicious code via a radio transmission into these networks can wreak havoc in these systems. Alongside cyber effects, COMINT efforts which identify hostile

Author

Thomas Withington is an independent electronic warfare, radar and military communications specialist based in France.

radios and their accompanying networks indicate jamming targets. These radios and networks can be targeted by hostile jamming waveforms which will do their best to get the former off the air.

Managing the spectrum

The sheer saturation of radio communications in military and civilian life makes the efficient management of the COMINT mission vital. According to statista.com, a data analysis and business intelligence platform, as of 2022, over 88% of the world's population had access to cellular coverage. Impoverished countries including Afghanistan and Iraq, where US-led coalitions waged operations in the recent past, have featured ubiquitous cell phone connectivity. The reality is that tomorrow's wars will be fought in environments were thousands, if not millions, of signals will inhabit the ether. This may even be the case across comparatively small areas. COMINT cadres have several tasks: Firstly, SOIs must be found in the cacophony of noise. These SOIs must be located and identified. Once this process is complete, decisions must be made on how these signals of interest will be engaged. Will the signals be jammed? Will they be exploited for intelligence? Will identified radios, and their networks, be used as conduits for cyberattacks? Will the signals, radios and their networks simply be left alone instead perhaps for exploitation at another date, or simply to silently watch to learn about the enemy's situation and intentions at that moment?

Credit: Alexey M., via Wikimedia Commons CC-BY-SA-4.0

The television tower in the southern Ukrainian coastal city of Kherson seen here in happier times. The ongoing war in Ukraine has highlighted the extent to which militaries must share their use of the radio spectrum with the civilian world.

Credit: DISA

The Defence Information Systems Agency (DISA) announced in December 2023 that the first iteration of the Joint Electromagnetic Battle Management system had been released. Development of the EMBM-J is continuing.

Automating this process as much as possible makes sense. Even if operations are being performed over a comparatively small area, this area may be deluged with radio signals, particularly if it is an urban environment. At the operational level, jointness will be essential. It may be an army's electronic warfare units that are tasked with jamming a hostile radio network, but; it could also be a naval unmanned aerial vehicle (UAV) operating over land that discovers the network in the first place. This information needs to be taken from the UAV, analysed and then shared with the army EW unit. Navies, armies, air and space forces, and cyber forces, often maintain their own tactical and operational level signals intelligence (SIGINT) C2 systems. These C2 systems will handle COMINT and electronic intelligence (ELINT). ELINT is a catch-all term for any radio signals not associated with communications. Such signals can include radar transmissions or position, navigation and timing signals from global navigation satellite system constellations.

To ensure the smooth flow of operationally and tactically relevant SIGINT between deployed forces, it is necessary to break down the stovepipes which may exist between service signals intelligence C2 capabilities. The US Department of Defense (DOD) is embracing this approach via the Joint Electromagnetic Battle Management (EMBM-J) system. As its name suggests, the EMBM-J is an operational-level SIGINT software-based command and control system for use by the joint force. The EMBM-J will act as a clearing house for SIGINT with ELINT and COMINT received from across the joint force analysed by the EMBM-J and then shared with whichever part of the joint force needs this.

US government documents provide useful insight into the EMBM-J's architecture and mission. The US Defense Information Systems Agency (DISA), which is responsible for the system, was contacted during the preparation of this article for comment, but declined to participate. Palantir Systems, a key EMBM-J contractor, also left several emails asking for more information on their involvement with EMBM-J unanswered. Available US DOD documents state that key EMBM-J capabilities include the following: to extract and analyse information from multiple sources across security levels; to enable situational understanding of the electromagnetic operating environment

(EMOE); to create and display the EMOE browser-based desktop environment and identify impacts of electromagnetic interference; to enable a suite of tools that provide SA, C2, decision-support and training, and provide the near real-time integration and display of foundational data and processed electromagnetic spectrum feeds. These feeds are essentially the streams of incoming SIGINT that the EMBM-J will process.

As the documents make clear, the EMBM-J has clear operational and strategic roles to play. In the first instance, the system supports the US DOD's prevailing Joint Electromagnetic Spectrum Operations (JEMSO) doctrine. Published in May 2020, the JEMSO doctrine stipulates how US forces will manoeuvre in the electromagnetic spectrum to achieve positions of electromagnetic supremacy and superiority (E2S). Echoing airpower doctrine, electromagnetic superiority is the condition in which the red force is only capable of isolated and sporadic challenges to blue force's ownership of the spectrum across a specific locale. Electromagnetic supremacy is the condition where the red force cannot meaningfully contest blue force spectrum ownership; While electromagnetic manoeuvre is intended to win and sustain E2S at the expense of one's adversary, the ultimate goal is to deprive the latter of the ability to exploit the spectrum to support their warfighting.

Credit: US DoD

The realisation of the EMBM-J plays close adherence to the aims and goals of both US JEMSO doctrine and the DOD's Electromagnetic Spectrum Superiority Strategy.

The strategic role of the EMBM-J is to support the wider DOD's Electromagnetic Spectrum Superiority Strategy. The strategy was published a few months after the JEMSO doctrine in October 2020 and in its own words: "(The strategy) seeks to align EMS (Electromagnetic Spectrum) resources, capabilities, and activities across the DOD to support our core national security objectives while remaining mindful of the importance of US economic prosperity." The strategy takes a whole-of-government approach. The approach covers the DOD's use and exploitation of the spectrum. The protection of domestic spectrum use within the United States is also a key aim of the strategy. Civilian reliance on the radio segment of the electromagnetic spectrum means that access to it must be safeguarded. In addition, "(the strategy) addresses how (the) DOD will develop superior EMS capabilities; evolve to an agile, fully integrated EMS infrastructure; pursue total force EMS readiness; secure enduring partnerships for EMS advantage; and establish effective EMS governance to support strategic and operational objectives."

Credit: US Army

The US Army's EWPMT was to have originally formed the basis of the EMBM-J's decision-support tool, although the DISA is now looking for a new prototype software development to fulfil this requirement.

Implementation

According to the US government documents, over USD 43 million may have been spent by the DOD on EMBM-J over 2023 and 2024. Work on the initiative appears to have started in 2017. A further USD 19 million is expected to be spent on the EMBM-J in 2025. During 2024, DISA will continue to develop the EMBM-J's mission capabilities in support of the overall Electromagnetic Spectrum Superiority Strategy. This overarching task includes situational awareness software releases. The releases build towards what is termed the Minimum Viable Capability Release (MCVR). Progressively more data and functionality will be loaded into the EMBM-J architecture via the SA releases to achieve an MCVR status which can be made available to the user community.

Alongside the SA software releases to support the move towards MCVR, work on the EMBM-J will include the development of a decision-support tool as part of the systems' architecture. The tool is intended to support joint electromagnetic spectrum planning processes and

is a key element of the EMBM-J. The decision-support tool is needed so that the software can assist tasks such as operational spectrum deconfliction. Broadly speaking, spectrum deconfliction is the process of managing the radio spectrum to avoid events such as electromagnetic blue-on-blue. For example, in EW there is the attendant risk that some jamming degrades friendly electromagnetically-dependent systems, including radars or radios. This is a particular concern when blue forces use similar frequencies to those employed by red forces. Likewise, it may be vital to ensure that joint spectrum operations do not adversely affect civilian spectrum use. Excessively impeding the latter for military ends could be counter-productive from a 'hearts and minds' perspective. Blocking out cell phone coverage through excessive jamming could, in some cases, alienate the very populations that US forces are deployed to protect.

Raytheon's Electronic Warfare Planning and Management Tool (EWPMT) equipping the US Army as an operational/tactical level EW C2 system was chosen as the basis for the EMBM-J's decision-support tool. However, the government documents noted that the EWPMT "does not fully satisfy requirements". Instead, a prototype decision-support tool will be developed. Other tasks performed in 2024 include planning for the integration of the decision-support tool and SA software updates into the EMBM-J architecture. Work is ongoing to integrate the situational awareness capabilities of the EMBM-J into the US DOD's Joint Worldwide Intelligence Communications System (JWICS). The JWICS is a classified intranet housing top secret information. Planning is also afoot to realise an EMBM-J training capability alongside developing the system's command and control functions.

The US government documents continue that work in 2025 will focus on the development of the EMBM-J's mission capabilities while bringing the SA software releases to a conclusion. Next year, DISA will deliver the decision support tool prototype and begin developing the EMS joint planning process functionality. Work will continue integrating the SA and decision-support tools into the wider EMBM-J architecture. This work is expected to conclude in 2026. Over the longer term, efforts to develop and implement the EMBM-J will continue until at least 2029.

The US armed forces will receive progressively more EMBM-J functionality as the software is developed and rolled out. It is interesting that the documents mention the EWPMT which is one of several US tactical and operational EW command and control systems with similar capabilities in the navy, air force, marine corps and space force.

The US DOD's articulation of both its JEMSO doctrine and Electromagnetic Spectrum Superiority Strategy provide useful guides and aspirations around which the EMBM-J can be fashioned. The system's design underscores the fact that electronic warfare, particularly the electronic attack element of the EW triumvirate, alongside electronic protection and electronic support, cannot be separated from spectrum management. Wars are fought within civilisations and E2S must be won and sustained while those civilisations use the spectrum. The advent of the EMBM-J will help to manage this delicate reality. ■

F-35: "The system as a whole is a cultural change!"

One of the Vice Presidents at Lockheed Martin is Jeff 'Cobra' Harrigian, Commander of the US Air Force in Europe (USAFE) until 2022, with 4,100 hours on F-22, F-15C and A/OA-37. Now he is responsible for 'Strategic Campaigns' at the world's largest defence contractor. On the sidelines of AIRPOWER-24, ESD spoke to him about the F-35 fighter jet, its European distribution and the approaching Austrian Eurofighter succession. The interview was conducted by Georg Mader.

Mader: According to the internationally visible timelines, our next government will not avoid preparing and making decisions about what should come after the 15 early Eurofighters. So RFI from around 2027, then RFP etc., contract 2028 or 2029, to delivery in 2033 and then IOC. And if you ask around in the air force – right up to the top – you can already see some 'glowing' eyes here and there when it comes to the F-35. So what do LM think of the current production rates and delivery times for the F-35? Our Czech neighbours in Fairford said they signed up for 2023 and won't get the first ones at home until 2031.
Harrigian: Well, we know all this of course. Our production has stabilised at 156 F-35s per year. And the Czechs will receive their jets prior, but at Ebbing AFB because Luke AFB is already overcrowded with various customers. But delivery in 2031 was their choice, a customer request.

Mader: 156 per year – and the projected number for the USAF alone is still 1,763 units, isn't it?
Harrigian: Yes, that is still the planned number, which has been in place for several years. But ultimately it will be the US Air Force that decides whether this number will be maintained, based on the global situation, technical progress and budgets. For us, the key to all of this will be to work closely with the nations and to understand the requirements of the nations and the wishes of the customers in terms of schedules – as in the case of Austria. Because, as you have emphasised, there is a special preparation process everywhere to work out its individual and unique characteristics. And that is always a challenge everywhere. The countries have to plan this – and our job is to be a strategic partner for it.

Mader: Have you been approached here yet, with some indications of when something should happen?

Credit: Georg Mader

F-35A with chute deployed at Evenes Air Station in Norway.

Harrigian: The discussions here with the AF Commander were primarily related to his or your relationship with the Vermont Air National Guard present here in Zeltweg, with their F-35s. And that's a great relationship. That's not a given. I don't know if you know my background, but in my previous job I was commander of the US Air Force for Europe. And there the Air Force of our National Guard (ANG) plays a major role in providing very flexible support for some of our requirements across the theatre. And I think the relationship with the 'Green Mountain Boys' of the Vermont ANG is very instructive for the entire Austrian Air Force in terms of understanding the F-35. Not only from an operational point of view, but also from a maintenance and repair point of view. And what it takes to do that with F-35. A good thing.

Mader: There are people here – and it was the same in Switzerland – who are media representatives, bloggers and enthusiasts and who think that the F-35 has a rather expensive footprint, including life cycle costs and the ALIS logistics program, or ODIN then.

Harrigian: So I think the important part here – and you know this better than anyone – is the context. It may seem expensive – in comparison to what? You have to understand the life cycle costs and how they are distributed over many years, or how they will play out in the long term, again but in comparison to what? In terms of against operational or mission value? We are very relaxed about that.

Mader: There is a lot to do at the technical level here over the next few years anyway. Last year, a 'final' support contract was signed for the current [Eurofighter] Tranche 1 for the next seven years, including for the engines, etc. Some upgrades are still planned, but otherwise no operator wants to invest in T1 anymore. And if – in theory – an F-35 in particular were to be selected, when would you start with the infrastructure? And then, until the war in Ukraine, we had a rather 'underdeveloped' electronic warfare capability with a lot of theory only – but the F-35 is largely EW! Especially for this solution, we would have to start training for it now! Couldn't the 'comrades' from Vermont help with that initially?

Harrigian: Of course, you have to prepare for such a succession early on, including in terms of personnel. And as for a possible F-35, there are already a number of nations across Europe that could help now. If you look at the number of these aircraft that will be in Europe during that period, it's 600 to 700. You could look north, for example, to Germany, which has been known for years to be very knowledgeable in the field of EW. Of course, it is important to learn about utilising EW and to study the mindset and operations of the 5th generation in even greater depth. And the U.S. Air Force – including the 'Vermont Boys' – would also provide support, for example in training. But as I said, there is already a great deal of expertise in Europe that is available.

Mader: And then by then, our neighbours the Czechs, the Swiss or the Italians will already be 'in the middle' of the F-35. We have been working very closely with Italy in particular recently.
Harrigian: Exactly. That's why I think that participating in this broad program, especially among Europe, would really offer significant advantages.

Mader: And you think that this 'networking' could possibly help to reduce the financial footprint?
Harrigian: At the end of the day, it's going to be a government-by-government decision and they have to work through how it's all going to play out in their organisation. I would just suggest that when you look at it strategically across Europe, you don't just look at the important interoperability from an operational perspective. The system as a whole is a cultural change. And there are nations that have already initiated or implemented it.

Mader: I think this change should be driven by relatively young people or people who are attracted by the new technology. For larger NATO countries, this may not be such a big deal, but for us, in terms of personnel, it's a bit like 'space exploration'.
Harrigian: That may well be, but in this respect, every user is part of a huge and growing community.

Mader: A brief word about the – reported – costs. One hears that when the Swiss carried out their assessment, the bill of 36 aircraft over a lifespan of 20 years resulted in a platform that was two billion cheaper than the other contenders. Did that include everything?
Harrigian: The Swiss included airframes, life cycle costs, infrastructure and training in this their calculation.

Mader: One argument or 'accusation' that you often come across, is that the Americans 'dictate' that you have to demolish everything at the location, build protective structures and erect a high-tech perimeter, etc. Your VP Randy Howard said to me in Dubai, that if you have such an important resource – and it's also a coalition one – you want to protect it.
Harrigian: Randy Howard retired, by the way, last month. But he's absolutely right about that. And again, a lot of countries have been through this process already and could be very helpful in coming up with a plan based on the lessons learned on all the aspects you mentioned, from the infrastructure area you mentioned, to training and all those things. Several countries that are partners and allies of the Austrians certainly have a wealth of experience in this area.

Mader: Do you actually need a complete mission simulator or just a few cockpit computer workstations? Or could you share a simulator with other users or neighbours?
Harrigian: Of course, that will be their decision. But I think these discussions also need to be held because, as you point out, the maturity of simulation technology is constantly changing, every two years. So is the miniaturisation or the software and the possibilities of what is possible. There are certainly opportunities for discussion, which options can be used? Perhaps the overall scope will be smaller. This would always be negotiated in the G2G regime, government to government, or with the F-35 Joint Program Office (JPO) to ensure that the customer's requirements are met, who can ultimately make the decision.

Mader: Regarding the aircraft itself. The big topic at the moment, and for the near future, is the software standard 'Technology Refresh 3' (TR-3), as a prerequisite for Block 4, right? It is now coming in a kind of initial configuration, after a number of aircraft had to be produced 'on stockpiles' because no acceptances were possible. Is that right, or what is the status?
Harrigian: TR-3 has been communicated to all nations. There is a combat-training-capable release in those aircraft that are currently being delivered, both from the production line and from those that were held back until we reached TR-3. This release will be continuously improved throughout this year, so the plan from the beginning of 2025 is to provide the fully operational TR-3 version from then on. And as that continues to advance, the JPO is working specifically on Block 4. And I would describe it best, as being refined in the future, that the goal was to complete the infrastructure for it from Block 3. So that you can then further expand this infrastructure with TR-3 and with Block 4 functions. We expect continual software updates related to TR-3 insertions and Block 4 capabilities, with major milestone software drops along the way, to ensure we are always providing our customers with the most advanced technology.

Mader: And the new capabilities of that Block 4 will be more in the direction of armament or sensors? Or, to put it another way, what new features and capabilities will Block 4 aircraft have, that previous blocks have not?
Harrigian: A mixture of both, I would say. The JPO is currently working on this and will announce over the next few months – as far as possible – what the exact configuration will look like in the future. In any case, the Block 4 upgrades will represent the most significant development to date in the F-35's capabilities, with likely increased missile numbers, additional advanced non-kinetic EW-capabilities and improved target detection. They will ensure air superiority for us and our allies and partners and increase deterrence against so-called 'near-peer threats' for decades to come. But we can't go into more detail at this point.

Credit: Georg Mader

USAF F-35A deploying landing gear as it comes in to land at Andravida Air Force Base in Greece.

Credit: Georg Mader

USAF F-35A landing at Andravida Air Force Base in Greece.

Mader: Some people here think that the short-take vertical landing version, the F-35B, has a certain charm: it could operate from anywhere in our topography, logistics provided, etc. But it has no cannon, smaller bays, and is well a third more expensive, etc. What do you think of that?
Harrigian: As you know, this version provides options to the nations, whether it be launching from aircraft carriers or austere locations. Nations ultimately make the decision on which model they prefer based on their operational requirements. For Austria, as long as they haven't reached the point of officially announcing that they are even considering procuring F-35s, it is not appropriate to say anything about a preferred version or similar customer-specific details.

Mader: Ok. Another claim or question that one also hears here – for example from political defence speakers etc. – is that the F-35 is a stealth attack aircraft that 'smashes' the door to a heavily defended hostile airspace on the first day of a conflict. Do we need that? Would we ever use it? One of our former 'Air Chiefs' said to me just the other day, that we wouldn't need a bomber to bomb Moscow!
Harrigian: [shaking his head] It is primarily about air defence, isn't it? Can I give you my perspective on this?

Mader: Yes, please.
Harrigian: So, first of all, I go back to the time when the Russians invaded Ukraine in 2022 and I – then Commander of the US Air Force in Europe – went to my Defense Secretary and said, "I need F-35s." Why did I want F-35s? First, to deter Putin, to make sure he understood that we would be able to protect the eastern flank.

Mader: And this intention was, because they respect this particular aircraft?
Harrigian: Exactly, yes. Because of the capabilities that the F-35 system brings. The second aspect was that it enabled the other friendly and allied actors, whose fourth-generation aircraft – and even some third-generation aircraft – then had a better situational awareness. In other words, the information that the F-35 collected could be shared with everyone. Because I wanted to make sure that we were making smart decisions. Our mission was to defend NATO's eastern flank, while being prepared for anything that should follow… clearly we did not want a war, but we had to be prepared.

Mader: So F-35 as a multiplier...
Harrigian: It clearly is…There are various options for sharing information. All these mechanisms are in place. But the point is that the F-35 was able to make everyone perform better. When we were sitting on the eastern flank, our first task was to make sure that Putin was aware that we had F-35s in the airspace. Our second task was to keep everyone informed of the situation. And my final point was that if we put young men and women in harm's way, we have to equip them with the best possible resources and aircraft available.

Mader: Yes, you never know what will happen in five or seven years. It's the same argument as in Switzerland, where they also said that it was an 'offensive' or 'aggressive' fighter aircraft, not just for airspace surveillance.
Harrigian: Of course, the F-35 can do that but also can execute offensive operations – if that is the mission. If that is the mission, we must be prepared to deter and also penetrate the considerable threat of Russian forces. The aircraft for this is the F-35, because they are survivable. Thanks to the weapons and sensors that I know, it can achieve the specific goals for which they were developed.

Mader: Nevertheless, air-to-air will be our top priority here, at least for the foreseeable future. The question is how robust this concept should be in the near future. Will it remain the practice of active air surveillance as it is now – or should it become what our generals always now tell everyone? Real defence mode? No air policing, but true air defence. For me however, that also means hardened aircraft shelters, alternate runways, robust logistics. So a much broader approach – not just the aircraft.
Harrigian: I agree, the concept of agile combat operations, to which you are referring I believe, however applies to the whole of Europe today. However, I think that one or the other aspect is important here, especially in view of the requirement of joint forces to not only interact with others in the air, but also to recognise the information we see in the air and to share or distribute it. Be it other enemy fighter jets – which at that time do not yet know about me – or incoming cruise missiles, or a new ground-based anti-aircraft radar, etc. So also in concert with the air defence of the land forces, so that you have a multi-layered defence capability for the nation, given its size. And there are countries all over Europe that are working on exactly this problem. And they recognise that F-35 is the decisive factor that will help them all.

Mader: Thank you for your time here at Zeltweg.
Harrigian: Thanks for your interest in the F-35. ■

Credit: Georg Mader

USAF F-35A landing at Andravida Air Force Base in Greece.

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Pakistan's road to defence-industrial self-reliance

David Saw

Pakistan's journey to defence-industrial self-reliance has been marked by geopolitical challenges and shifting alliances. This article traces the evolution of Pakistan's indigenous defence industry, highlighting key milestones along its journey from reliance on foreign arms to developing indigenous nuclear and conventional weapon systems.

Upon independence in August 1947, Pakistan faced a significant problem as it attempted to build a sustainable defence structure. True, it had ground, air and naval forces that were well equipped with modern weapons, which had emerged from the partition of the pre-independence military of British India. Unfortunately, although colonial India did have a defence industry and a credible maintenance, repair and overall (MRO) structure, these assets were now not in post-partition Pakistan.

Clearly this was an unacceptable situation for Pakistan, and this resulted in the decision to start a programme to establish a national defence industrial base. Pakistan worked with the Royal Ordnance Factories (ROF) in Britain to establish the first factories of what would become Pakistan Ordnance Factories (POF) at Wah Cantonment. Production of 7.7 × 56 mmR small arms ammunition and then Lee Enfield No.4 Mk1 rifle manufacture commenced in 1952. Later, once Lee Enfield production had ceased at ROF Fazakerley in Britain, all the tooling was transferred to the POF, thereby allowing No.4 Mk2 production to commence in 1957.

Over the course of the 1950s, Pakistan began to draw closer to the US and this saw them join both the Southeast Asia Treaty Organization (SEATO) and the Central Treaty Organization (CENTO). Pakistan also signed up for a Mutual Defence Assistance Agreement with the US in May 1954, which resulted in a substantial amount of military aid being delivered to Pakistan. This aid was absolutely transformative for the Pakistani military throughout the 1950s; the Pakistan Army received 345 M47 tanks, 150 M24 and 50 M41 light tanks, along with 105 mm, 155 mm and 203 mm tube artillery, while the Pakistan Air Force (PAF) received 120 F-86 Sabre fighters and 26 B-57B bombers.

Credit: Pakdef.info, via Wikimedia Commons (Public Domain)

The Pakistan Air Force (PAF) B-57B bombers of the 31 Wing, which received its aircraft in 1957.

The defence relationship with the US was seen as giving Pakistan an effective deterrent against its much larger neighbour, India. US deliveries continued into the early 1960s with the Pakistan Army receiving 200 M48 tanks and 109 M113 APCs and more artillery. Following the 1965 Indo-Pakistani War, US military assistance was halted and an embargo on military support was imposed. This was seen as a betrayal by Pakistan and would lead to new defence supply relationships elsewhere and a new emphasis on developing the national defence industrial base.

From the beginning, the primary strategic threat to Pakistan was India; meanwhile China was having its own strategic issues with India, as evidenced by the 1962 Sino-Indian border war. A strong Pakistan was therefore in China's interest, while Pakistan was at the same time relieved to have a reliable supplier of defence equipment. China provided 200 Type 59 tanks in 1965 – all of which were delivered by 1966. Pakistan also placed an order for 550 Type 59 tanks in 1965, which were delivered between 1967 and 1970; a significant quantity of artillery was also supplied.

The Soviet Union also supplied Pakistan with equipment, but the defence relationship never solidified; instead, Moscow would become India's primary arms supplier. The end result was that China would become a crucial partner in terms of defence equipment supply to Pakistan, a position it holds still to this day. In the context of the Pakistani defence industry, this influx of Chinese and Soviet equipment operated in tandem with US/NATO pattern equipment, created a situation in which Pakistan had to have the ability to, at a minimum, produce ammunition and basic consumables domestically. The POF had started off producing British small arms calibre munition, and would go on to produce standard NATO calibres in parallel with standard Soviet/Chinese calibres. Today, the POF's product range covers the majority of NATO and Soviet artillery calibres and the full spectrum of other munitions.

As can be imagined, trying to operate a military force equipped with a highly diverse selection of equipment with limited interoperability is a challenge. The problem for Pakistan was that it was unable to turn to a reliable single supplier or grouping of suppliers to meet its equipment needs. In

1966, Pakistan turned to France to acquire three *Daphne* class submarines (delivered in 1970) 24 Dassault Mirage IIIEP aircraft ordered in 1967 (delivered in 1969), 30 Mirage 5PA fighter-bombers ordered in 1970 (delivered in 1971/72), followed by ten more Mirage III aircraft in 1975 (delivered in 1977), and finally 32 additional Mirage 5PA aircraft in 1970 (delivered in 1980/83), further complicating interoperability.

Building a deterrent

In the wake of the 1971 Indo-Pakistan War and the loss of what was then East Pakistan (today Bangladesh), the Pakistani leadership found themselves in an incredibly difficult geo-strategic situation. To survive this new reality, Pakistan would need to have an effective deterrent, made even more pressing when India detonated a nuclear device at Pokhran on 18 May 1971, with New Delhi describing this as a "peaceful nuclear explosion". At that point, it became clear to Pakistan that they would have to develop their own nuclear weapons capability and Pakistan subsequently achieved this aim, but at the cost of suffering extended embargoes by many of its defence equipment suppliers.

Concern over Pakistani nuclear efforts led the US to halt military assistance in 1990. An immediate consequence was that 11 F-16A/B Block 15 OCU aircraft that were to be supplied to the PAF under the Peace Gate III programme were embargoed. The follow-on Peace Gate IV programme for 60 F-16A/B aircraft for the PAF was also embargoed, with the 17 already built aircraft put into storage and the remaining 43 aircraft under production subject to a 'stop work' order.

The fact that the PAF would not receive these 71 F-16A/Bs represented a major blow. The solution was a major upgrade programme for existing PAF aircraft. Established in the 1970s, the Pakistan Aeronautical Complex (PAC) located near Kamra was first designed as an MRO facility for Chinese F-6 aircraft. The next step was the opening of the Mirage Rebuild Factory (MRF); this provided life extension and MRO services for the PAF Mirage III/Mirage 5 fleet. In 1990, Pakistan was able to acquire 50 ex-Royal Australian Air Force (RAAF) Mirage III aircraft from Australia, and went on to acquire second-hand Mirage III/Mirage 5 aircraft from Spain, Lebanon and eventually France throughout the 1990s.

With the F-16s embargoed, Pakistan decided to embark on an extensive upgrade programme for the Mirage fleet – known as Retrofit of Strike Element (ROSE). In the ROSE I programme, the PAC upgraded more than

Credit: Pakistan Air Force

The Pakistan Air Force (PAF) has acquired a substantial Mirage III and Mirage 5 fleet over the years. To support this fleet, the Pakistan Aeronautical Complex (PAC) built the Mirage Rebuild Facility; later this provided the basis to conduct the Retrofit of Strike Element (ROSE) upgrade programme which further enhanced PAF capabilities.

30 Mirage III and 30 Mirage 5 aircraft; the follow-on ROSE II and ROSE III programmes would cover some 50 aircraft that were subsequently acquired from France. Pakistan would continue to acquire second-hand Mirage III/Mirage 5 aircraft and spares wherever it could, to provide long-term sustainment for the fleet. MRO experience gained with the F-6 and the Mirage fleet, as well as the ROSE upgrade, provided the basis for the PAC to embark on the co-development and production, with Chinese assistance, of the JF-17 Thunder combat aircraft which is being acquired in large numbers by the PAF and being offered for export.

Prior to that, Pakistan had acquired the right to the Swedish MFI-15 basic trainer which was produced in Pakistan as the Mushshak; the PAC further then developed it into the Super Mushshak configuration. Initially the Mushshak was acquired to meet Pakistani requirements, but subsequently the Super Mushshak managed to achieve export sales, with customers including Azerbaijan, Iran, Iraq, Nigeria, Oman, Qatar, Saudi Arabia, Syria and Türkiye. Of course, export sales for the JF-17 are a much more challenging task, yet sales have already been agreed with Azerbaijan, Myanmar and Nigeria. In addition, a potential order from

Credit: Pakistan Air Force

The JF-17 was co-developed by China and Pakistan and is produced by the Pakistan Aeronautical Complex (PAC) at Kamra. Built to meet a Pakistan Air Force (PAF) requirement for an F-7 and Mirage replacement, the PAF has over 180 JF-17 aircraft in service or on order, with Block 1 and 2 aircraft due to be upgraded to the latest Block 3 standard.

Iraq has generated much speculation. Into the future, beyond the JF-17, the idea is that Pakistan will be able to design, develop and manufacture a totally indigenous advanced combat aircraft.

Missiles

Returning to the subject of the nuclear programme, the first weapon would be a free fall nuclear bomb, which would be carried by PAF F-16 and Mirage aircraft. However, Pakistan would have to acquire other delivery systems, such as missiles; these would provide a strategic deterrent as well as the option of an extended range conventional strike capability. The Pakistan Army had embarked on the development of a tactical ballistic missile (TBM), the Hatf, with a conventional warhead and range of 70 km. Progress was slow and the impetus to develop a functioning missile grew exponentially, especially after India test launched its Prithvi TBM in February 1988, with its 150 km range. Eventually though, Pakistan did achieve its deterrent objectives. Proof that Pakistan had a nuclear deterrent came in May 1998, when Pakistan conducted six nuclear tests in response to five Indian nuclear tests earlier that month.

The National Engineering & Science Commission (NESCOM), established as the overall authority for major national defence programmes in 2000, has overseen the development of an extensive family of missiles from TBMs, to short-range (SRBM) and medium-range (MRBM) systems, including an MIRV capability. The development of the Babur cruise missile family for the Pakistan Army and Pakistan Navy (PN) followed, and these are available with either nuclear or conventional warheads. The initial ground-launched Babur-1 was followed by the Babur-1A with a 450 km range and the Babur-1B with a 900 km range, both of which were tested in 2021. Alongside these, there is also the Babur-2 variant with a reported 750 km range, and the Babur-3 submarine-launched variant, successfully tested in 2017 and 2018, with a reported 450 km range, and which can be equipped with a nuclear warhead. An anti-ship cruise missile (ASCM) variant equipped with a conventional warhead, known as Harbah, has also been developed for the PN.

NESCOM has also developed the Ra'ad air-launched cruise missile (ALCM) with a 350 km range for the PAF, which can be fitted with either a conventional or nuclear warhead. The later Ra'ad 2 variant has a 600 km range, and both missiles can be used from PAF JF-17 or Mirage aircraft. Other NESCOM origin air weapons include the H-2 guided glide bomb with a 60 km range, and H-4 guided glide bomb with a range of 120 km, along with Hafr anti-runway bombs. NESCOM also manufactures UAVs.

Another Pakistani state-owned entity active in the missile, rocket and air weapons area is Global Industrial Defence Solutions (GIDS). They have developed the Taimur air-launched cruise missile, with a 290 km range, and produce the Takbir range extension kit (REK) for conventional gravity bombs, which converts them to GPS-guided glide bombs. The company also produces the Anza man-portable air defence system (MANPADS) family derived from the Chinese QW-2 design, and the Baktar Shikan anti-tank guided missile (ATGM) derived from the Chinese HJ-8 design. More recently GIDS introduced the Fatah I (140 km range) and Fatah II (400 km range) Guided Multiple Launch Rocket Systems (GMLRS). The company also produces UAVs.

One significant programme being developed at GIDS is the Faaz missile system. Allegedly based on the Chinese SD-10 (PL-12) radar-guided medium-range air-to-air missile (MRAAM), the Faaz will be available in several variants: the Faaz-RF (with an active radar seeker) and Faaz-IIR (with an imaging infrared seeker) for air-to-air applications, both with a range of over 100 km, and the Faaz-SL for surface-launched applications, with a maximum range of 20-25 km and maximum altitude of 6-8 km. GIDS also offers the newer Faaz-2 air-to-air missile, which according to the company will have a range of 180 km range and will be offered with RF and IIR guidance. Also under development at GIDS is the LOMADS air defence system, which is described as a "fully autonomous self-propelled truck mounted system". The range is between 7 and 100 km, altitude coverage is 30 m to 20 km, with the system capable of engaging 12 targets simultaneously.

Credit: Skybolt101, via Wikimedia Commons (CC-BY-SA-3.0)

A transporter erector launcher (TEL) armed with four Babur surface-launched cruise missiles, displayed at the IDEAS 2008 exhibition.

Naval sector

In the naval sector in Pakistan the key strategic asset in both naval and commercial shipbuilding is the Karachi Shipyard & Engineering Works (KSEW). Pakistan's objective has been to improve the capabilities of KSEW by adding technology transfer and local production requirements to naval programmes.

Credit: ISPR Pakistan

PNS Babur (F280) was the lead unit of a class of four 'Pakistan MILGEM' corvettes for the Pakistan Navy, with two being built at the Istanbul yard in Türkiye and two at the Karachi Shipyard & Engineering Works (KSEW) in Pakistan.

For example, in the early 1990s, the PN contracted for three *Khalid* class (Agosta-90B) submarines from DCNS (now Naval Group) in France. The first unit was built in France, the second was assembled at KSEW and the third built entirely at KSEW. In 2011, KSEW was responsible for the retrofit that added an air-independent propulsion (AIP) capability to all three boats.

The PN decided to acquire a new diesel-electric attack submarine (SSK) class in 2015, with eight *Hangor* class, the S26 export derivative of the Type 039B design. With four units being built in China and four at KSEW, the keel was laid for the first KSEW unit in December 2022 and for the second unit in February 2024. Other programmes with China have included the *Zulfiquar* class frigate (Chinese designation F-22P), with three units built at Hudong-Zhonghua in China, with unit number four, PNS Aslat, being built at KSEW and commissioned in 2013.

The naval relationship between Pakistan and Türkiye is an important development for both the PN and KSEW. One aspect of this was the 17,000-tonne displacement fleet replenishment tanker PNS *Moawin*, commissioned in 2018. The tanker was built at KSEW to a design from STK in Türkiye. More recently, the PN decided to acquire four MILGEM corvettes from Türkiye, classified as the Babur class by the PN; the first two units were built in Turkey, with the second two, PNS *Badr* (launched May 2022) and PNS *Tariq* (launched August 2023) built at KSEW.

The most ambitious future naval programme between Türkiye and Pakistan is the *Jinnah* class frigate. The frigate will be jointly designed by ASFAT in Türkiye, who were responsible for the MILGEM corvettes, and a PN design team. In total, the PN intends to acquire six of these multipurpose frigates and all will be built at KSEW.

Armour

Heavy Industries Taxila (HIT) is an important capability in the land systems sector of the Pakistani defence industry. In the 1990s, HIT licence produced the Chinese Type 85 tank. The next step was to produce a more advanced tank more suited to Pakistan Army needs, with the Chinese Type 90-II (VT-1A export designation) tank chosen as the basis for the Pakistani tank produced at HIT as the Al Khalid, which was followed into production by the improved Al Khalid variant. Mention should also be made of the Al Zarrar tank programme, a comprehensive upgrade programme for the Type 59 tank, with more than 500 tanks upgraded.

In March 2024, HIT unveiled the first new Haider main battle tank for the Pakistan Army, based on the Chinese VT-4 export design, modified for Pakistani requirements and produced at HIT. Reportedly the Pakistan Army could acquire as many as 679 Haider tanks to replace legacy vehicles. Some years ago, Pakistan produced a number of M113 vehicles from US-supplied kits; after further supplies from the US were embargoed, they began building their own M113 version, the Talha APC. Other variants have been developed on the basis of the Talha, including the Sakb command vehicle variant, the Maaz anti-tank variant (armed with a single Baktar-Shikan ATGM launcher), and the Mouz air defence variant (armed with a single RBS 70 missile launcher). HIT also developed a stretched subfamily with six roadwheels instead of five; versions include the Saad APC, the Al Qaswa logistic vehicle and the Al Hadeed armoured recovery vehicle (ARV). HIT has also conducted rebuild programmes on Pakistani M113 and M109 vehicles, and they also have a gun barrel manufacturing capability from 105 mm to 203 mm, including 125 mm smoothbore barrels.

Credit: ISPR Pakistan

The first Haider tank for the Pakistan Army made its debut in March 2024. Produced at Heavy Industries Taxila (HIT) in Pakistan, it is based on the Chinese VT-4 design. Reportedly, the Pakistan Army could acquire up to 679 vehicles to replace early generation systems based on the Type-59 tank.

Hitting the big reset button

Dr Lee Willett

The Russo-Ukraine war has underlined that the threshold for potential nuclear weapons use still remains where it has always been – to deter threats to the survival of the state

There is one simple reason why there has been no further use of nuclear weapons in warfare since August 1945. The destructive power unleashed by the dropping of the only two nuclear weapons exploded in anger wrought an extent of devastation that was almost incomprehensible. Since then, a number of countries have developed a nuclear weapons capability: moreover, the destructive power of many of these weapons is of many orders of magnitude larger than those detonated in 1945; in addition, these weapons now exist in their thousands.

It is almost inconceivable that further use would occur without the realisation that such use would bring – or at the very least, would risk – unimaginable destruction on a global scale.

'Little Boy', the atomic bomb that was dropped on Hiroshima from the US Air Force B-29 bomber 'Enola Gay' on 6 August 1945 and exploded 579 m (1,900 ft) above the Japanese city at 08:15, carried an explosive power of roughly 13 kT – equivalent to 13,000 tonnes of TNT. 'Fat Man', the weapon that was dropped three days later on Nagasaki, carried an explosive power of roughly 21 kT – equivalent to 21,000 tonnes of TNT.

A US Navy (USN) Ohio class nuclear-powered ballistic missile submarine (SSBN) is fitted with 24 missile tubes that can carry the Trident II/D-5 submarine-launched ballistic missile (SLBM). The 14 Ohio boats carry different nuclear weapons options, designed to provide the US with flexibility in its deterrent capability. They can carry the W76-2 lower-yield warhead, designed to deter the use of tactical nuclear weapons: this warhead has a reported explosive power of 5-7 kT, so equivalent to roughly 5-7,000 tonnes of TNT explosive power. However, the primary armaments onboard the USN's SSBNs are the W76 and W88 warheads. According to *Janes Weapons: Strategic*, the respective yields of these two individual warheads are 100 kT and 475 kT each: so, the equivalent explosive power of 100,000 tonnes and 475,000 tonnes of TNT. The two warheads are delivered via multiple independently targeted vehicles (MIRVs), with up to eight warheads fitted per missile.

Russia is reported to be completing development of its new RS-28 Sarmat 'heavy' intercontinental ballistic missile (ICBM). While Sarmat's warhead yield and other performance characteristics are unknown, the 2024 *Bulletin of the Atomic Scientists* Russian nuclear weapons report pointed to sources indicating that a Sarmat ICBM could carry up to 14 warheads. Incidentally, the most recent Sarmat flight test in late September 2024 ended in a catastrophic failure, with the missile judged to have exploded inside its silo, according to imagery analysis of the Plesetsk Cosmodrome launch site post-incident, published by the International Institute for Strategic Studies' (IISS') Missile Dialogue Initiative.

Russia's own in-service SLBM is the RSM-56 Bulava, which is currently deployed onboard seven Project 955/955A *Dolgorukiy* (Borei) SSBNs within a class that could number up to 14 boats in the longer term. According to *Janes Weapons: Strategic*, it is expected that each re-entry vehicle (RV) will carry a 100–150 kT nuclear warhead. That is an explosive power per warhead equivalent to 150,000 tonnes of TNT. Each boat has 16 missile tubes; *Janes Weapons: Strategic* has reported that each missile likely will carry four (or maybe more) MIRVed warheads.

Under the 2010 New START strategic arms control treaty, the United States and Russia (the agreement's two signatories) had been sharing data every six months on strategic weapons levels numbers relating to the terms of the deal. On 21 February 2023, nearly a year after the outbreak of the Russo-Ukraine War in February 2022, Russia suspended its participation in New START. Consequently, the latest available combined dataset released was in March 2022. According to information provided by the US State Department at that time, the reciprocal declared force levels as of 1 March 2022 were: for Russia, 526 operationally deployed strategic launchers, 1,474 deployed warheads, and 761 deployed or non-deployed ICBM, SLBM, and nuclear-capable heavy bombers; and for the United States, 686 strategic launchers, 1,515 deployed warheads, and 800 deployed or non-deployed ICBM, SLBM, and nuclear-capable heavy bombers.

Credit: US Navy

A test launch of the Trident II (D-5) missile, taking place at 18:45 on 12 June 1987, from Complex 46 on Cape Canaveral. The D5 is a three-stage, solid propellant, inertially guided fleet ballistic missile launched underwater from US Navy Ohio class, and Royal Navy Vanguard class submarines.

Author

Dr Lee Willett is an independent writer and analyst on naval, maritime, and wider defence and security matters. Previously, he was editor of Janes Navy International, senior research fellow in maritime studies at the Royal United Services Institute, London, and Leverhulme research fellow at the Centre for Security Studies, University of Hull.

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Major General
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Swedish Army

Credit: Russian MoD

Russia's new Sarmat ICBM, which is in development, is reported to be able to carry up to 14 warheads.

Despite the overall trend of US-Russian reductions in warhead numbers in recent decades, this is still a vast amount of nuclear firepower. Moreover, there are other nuclear players on the world stage. Given the current geostrategic context of conventional conflict in the Euro-Atlantic theatre between Russia and Ukraine, and persisting concerns regarding crisis and conflict risk in the Indo-Pacific between China and the United States, it is worth noting that China, France, and the UK are amongst these other nuclear players.

China has deployable ICBM and SLBM capabilities, and has an emerging strategic bomber fleet – so, like the United States and Russia, it operates all three legs of a nuclear triad. However, reflecting its focus on regional deterrence, a core emphasis of its nuclear posture is on medium- and intermediate-range systems like the hypersonic glide vehicle (HGV)-capable DF-17 medium-range ballistic missile. It is worth noting also that China's nuclear force levels are not currently constrained by any nuclear weapons accord.

France is upgrading both elements (air and sea) of its nuclear dyad. The UK maintains a single, SSBN-based leg, but deploys it in a continuous at-sea deterrent (CASD) operational posture based around one SSBN on patrol. In the 2015 Strategic Defence and Security Review (SDSR), the UK confirmed the single boat on patrol carries 40 warheads, deployed across up to eight operational missiles.

Strategic impact

Pictures taken in 1945 of US service personnel standing in the ruins of Hiroshima underlines just how little was known at the time about the full impact of even a single nuclear weapon detonation.

What the short, select discussion above of the current nuclear orders of battle (ORBATs) of five of the world's nine nuclear powers (India, North Korea, Pakistan, and most likely Israel being the other four) demonstrates is that, while much more is now known about nuclear strategy, nuclear posture, nuclear capabilities, and the potential effects of nuclear use, such increased knowledge is still unlikely to be able to comprehend the likely scale of devastation that would be wrought by even a short exchange of tactical and possibly strategic weapons – for example in central Europe, where such a risk was a dominant fear in the Cold War. With the Russo-Ukraine war, that fear has now returned.

In the 79 years following the attacks on Hiroshima and Nagasaki, there have been a small number of occasions where general fears about the risk of nuclear war appeared to come quite close to reality. In the 1962 Cuban missile crisis, the Soviet Union deployed but then subsequently removed ballistic missiles in an incident that balanced nuclear rhetoric in public with diplomacy in private. In the latter instance, a now-famous letter from Soviet premier Nikita Krushchev to US president John F Kennedy underlined the risk for both countries, and the wider world, if a solution could not be found, with the "terrible forces [the] countries dispose" risking "reciprocal extermination".

In the 1983 'Able Archer' incident, a NATO exercise designed to simulate events and processes that could be part of escalation to nuclear war concerned the watching Soviets that the United States might be using the drill as cover for an actual attack; the Soviet response was to put its own nuclear forces on alert, concerning the United States in return but also prompting realization of the urgent need to de-escalate the crisis.

These two events occurred at particularly tense times in the Cold War period. The third occasion when international concern about the risk of nuclear war has been highest is now, during the Russo-Ukraine war. While the Cuban missile crisis and 'Able Archer' incidents took place at 'hot' times in a Cold War, they still took place in times of peace. Russia and Ukraine are at war, in what is the first state-on-state conventional conflict in Europe since 1945. In invading Ukraine, Russia appears to be trying to take a step towards rebuilding a territorial barrier, buffer zone, or sphere of influence between itself and NATO. As a consequence of the Russian invasion, Ukraine is fighting for national survival, and is relying on significant political and military equipment support from NATO and its member states. NATO's support is what

Credit: US Air Force, via US National Archives

This picture of post-bombing Hiroshima in March 1946 speaks volumes regarding the level of devastation wrought by a single nuclear weapon, even one which is fairly low-yield by modern standards.

has prompted regular Russian mention of its options for using its nuclear capability, mentions designed to deter NATO from continuing with such support.

Nuclear rhetoric

In January 2022, the world's five major nuclear powers – China, France, Russia, the United Kingdom, and the United States – released a combined statement on preventing nuclear war and avoiding arms races. Collectively, the five countries said they "consider the avoidance of war between nuclear-weapon states and the reduction of strategic risks as our foremost responsibilities".

"We affirm that a nuclear war cannot be won and must never be fought. As nuclear use would have far-reaching consequences, we also affirm that nuclear weapons – for as long as they continue to exist – should serve defensive purposes, deter aggression, and prevent war," the statement continued.

Yet, from the very outset of the Russo-Ukraine war, the risk of nuclear confrontation between Russia and NATO countries has been a constant factor. The war has been punctuated with Russian nuclear rhetoric, with such rhetoric continuing to bookend events as they unfold. For example, as Russian forces began rolling into Ukraine on 24 February 2022, Russian president Vladimir Putin said "To anyone who would consider interfering from outside: if you do, you will face consequences greater than any you have faced in history. All the relevant decisions have been taken. I hope you hear me."

As the conflict has ebbed and flowed, fears of nuclear use and escalation risk have persisted. As reported by the BBC, the Director of the US Central Intelligence Agency (CIA), William Burns, pointed to particular moments of concern. Speaking alongside UK Secret Intelligence Service (SIS; also known as MI6) chief Sir Richard Moore at the FT Weekend Festival in London on 7 September 2024, after the two intelligence service leaders had published a joint article in the Financial Times, Burns said there was a moment in late 2022, when Russia was suffering battlefield setbacks, when there was a "genuine risk" of potential Russian use of tactical nuclear weapons on the battlefield in Ukraine. Underlining the enduring role of nuclear diplomacy, Burns said he passed messages to Russian officials warning of the consequences of nuclear use. The risk persists, however: "None of us should take lightly the risks of escalation," said Burns, adding that Russian nuclear sabre rattling is likely to continue.

Credit: Office of the President of the Russian Federation

Putin's 24 February 2022 speech included a veiled nuclear warning against intervention by external actors.

Credit: Russian MFA

Russian Foreign Minister Sergei Lavrov giving a statement to the UN on 28 September 2024.

The most recent rattle came in late September 2024. It occurred while Ukrainian president Volodymyr Zelenskyy was visiting Washington, DC, and amid ongoing discussion in the West about whether to allow Ukraine to use Western-supplied missiles for long-range conventional strikes into Russia. In comments reported in Western media, Putin followed up a meeting of Russia's security council by indicating that Russia may be considering adjustments to its nuclear doctrine. "It is proposed that aggression against Russia by any non-nuclear state, but with the participation or support of a nuclear state, be considered as their joint attack on the Russian Federation," said Putin. According to the reports, Putin said Russia would consider the possibility of nuclear use if it detected the start of a large-scale conventional strike that threatened the country's sovereignty.

Kremlin spokesperson Dmitry Peskov expanded on Putin's statement, the reports added. Briefing reporters, he said "It must be considered a specific signal – a signal that warns these countries of the consequences if they participate in an attack on our country by various means, not necessarily nuclear."

In a speech to the United Nations on 28 September 2024, Russian foreign minister Sergei Lavrov said (according to a BBC report) that Western powers were trying to use Ukraine as a means to defeat Russia strategically. "I'm not going to talk here about the senselessness and the danger of the very idea of trying to fight to victory with a nuclear power, which is what Russia is," Lavrov added.

As always with the language of nuclear deterrence, while clear words may be used, interpretations of their potential application and implication may be more ambiguous. Russian discussion of using a tactical nuclear weapon on the battlefield versus the option of using a nuclear weapon against a NATO state that has provided conventional missiles to Ukraine that have been fired against downtown Moscow may, according to deterrence theory, prompt different responses from the United States and NATO. In practice, however, they may not. As perhaps inherent in CIA chief Burns' comments regarding messaging to Moscow, United States signals to Russia may well be that nuclear use is nuclear use. Moreover, China and India – two of Russia's strategic allies – have both issued public statements warning against the use of nuclear weapons in the context of the Russo-Ukraine war.

Yet one area of concern is that Russia could detonate a single, small nuclear weapon somewhere that would not be a direct attack on a NATO member state and thus could be intended as not seeking to directly provoke the United States, while still being part of a demonstration to NATO and to Washington in particular. The use of a tactical nuclear weapon on the battlefield in Ukraine is one much-discussed option, here. There is another less-discussed option: the use of a nuclear weapon at sea.

In a BBC article published on 28 February 2022, just after war broke out, the BBC's Steve Rosenberg asked 'would Putin press the nuclear button'? In the piece, Rosenberg quoted Moscow-based defence analyst Dr Pavel Felgenhauer's discussion of the options Putin might have if progress in the war was difficult for Russia and if Western powers imposed, for example, significant economic and financial sanctions.

Credit: US Navy

The US Navy ballistic missile submarine USS Tennessee transits the Norwegian Sea on the surface in June 2024. The use of the sea has featured as a forum for communicating nuclear deterrence messages in the context of the Russo-Ukraine war.

"One option for him is to cut gas supplies to Europe, hoping that will make the Europeans climb down," Dr Felgenhauer was cited as saying. "Another option is to explode a nuclear weapon somewhere over the North Sea between Britain and Denmark and see what happens."

An implication of this point is that dropping a single nuclear weapon over the North Sea would effectively be a 'shot across the bows' of NATO, seeking to deter NATO from giving any further support to Ukraine.

Senior Russian figures have discussed another, similar option. In April 2023, following sanctions imposed by the UK on Russia, Dmitry Medvedev – deputy chair of Russia's security council, and a former president – wrote on Telegram that the UK could be "sent into the abyss of the sea by waves created by the latest Russian weapons system". Talking publicly about conducting a nuclear attack on a NATO member state that is a geostrategically isolated island could be part of Russian deterrent messaging to the United States and the rest of the alliance that Russia could consider a demonstration attack to dissuade NATO from continuing its support for Ukraine.

Such a demonstration attack would not necessarily need to involve a nuclear weapon, either. In recent years, and especially since 2022, media reports in the UK and Irish press have routinely discussed Russian operations at sea to survey critical undersea infrastructure (CUI) around the UK and Ireland. Using conventional forces to target CUI would be a means of isolating the UK and sending another strategic-level message to NATO and the United States.

The United States may also have used the sea to conduct – and communicate – demonstrations of nuclear capability and commitment, in the context of the Russo-Ukraine war and wider Euro-Atlantic insecurity. Usually, it is unheard of that an SSBN would sail visibly on the surface while out at sea (as opposed to being in or near its homebase); it would usually be even more unheard of that the USN would take and actually publish photos of it happening. Yet, occasionally in recent years, this is just what has happened. Most recently, on 23 June 2024, a picture was published on the US Navy's website of the Ohio class SSBN USS Tennessee transiting the Norwegian Sea on the surface. A few days previously, Putin had announced that Russia was considering changes to its nuclear doctrine following what Moscow perceived as NATO's own discussion of lowering the threshold for nuclear use.

It is worth noting that Tennessee was the first Ohio SSBN to be fitted with the W76-2 lower-yield warhead, with its first deployment with the capability understood to have commenced in late 2019 (according to Janes reports).

Strategic use

The discussion of options for using nuclear weapons must be set in the context of why – in other words, what is the perceived purpose of using nuclear weapons, for example at sea? In the context of the Russo-Ukraine war, any Russian use of nuclear weapons at this stage in the conflict would not be for warfighting output but for strategic deterrent effect, signalling to NATO to stay out of it.

Moreover, it can be argued that the Russo-Ukraine conflict and the escalation risk therein has re-baselined deterrence theory and practice to its original setting in the nuclear world. Conventional war in Europe appears to have reinforced the position that options

Credit: NATO

Oil and gas platforms are part of critical infrastructure in the North Sea. Targeting such infrastructure would be a non-kinetic, non-nuclear way for Russia to isolate NATO states.

A UK-led carrier strike group operates in the North Sea in November 2023. Any Russian demonstration use of a nuclear weapon over the North Sea may strike the numerous NATO ships that operate in the region.

for using nuclear weapons still sit solely at the strategic level, relating to the survival of the state. Despite the nuclear rhetoric and red lines in Russia's language since February 2022, Putin's latest statement underlines the clear link being drawn between options for nuclear use and perceived threats to the survivability of state sovereignty.

Certainly, a demonstration use needs to be clearly visible, and arguably attributable. However, even a demonstration use at sea would come with risk. For example, NATO naval ships are present widely across the North Sea region: this would raise the question of whether NATO might construe the destruction of NATO ships at sea to be a direct attack on those member states.

Yet the high stakes in the Russo-Ukraine war have only – so far – served to reinforce the risks of escalation in any prospective nuclear weapons use. Discussion of options for using 'tactical' weapons – whether on the battlefield in Ukraine, or over the North Sea – only seem to have underlined that the devastating effects that would be generated by *any* nuclear use, however small, would create not only an unprecedented level of unimaginable damage but would run the increased risk for the world of wider nuclear use, and the wider devastation that would accompany it. ■

Exhibition Dates 2025

Date	Event	Location
January		
14.-16.1.25	Navy SNA Symposium	Crystal City/USA
21.-22.1.25	20. NATO LCM Conference	Brussels/ Belgium
21.-23.01.25	IAV – International Armoured Vehicles	Farnborough/UK
21.-25.01.25	Shot Show	Las Vegas/USA
27 -28.01.25	DWT Perspektiven der Verteidigungswirtschaft	Bonn/GY
27.-28.01.25	Maritime Reconnaissance and Surveillance Technology	London/UK
28.-29.01.25	Mobile Deployable Communications	London/UK
29.-30.01.25	SecD-Day Conference & Exhibition	Helsinki/Finland
February		
03.-05.02.25	Sicherheit & Verteidigung	Berlin/GY
05.-06.02.25	Cyber Security & Cloud Expo	London/UK
10.-12.02.25	DGI 2025 - Defence Geospatial Intelligence Conference	London/ UK
11.-13.02.25	Navy Tech	Helsinki/ Finland
12-13.02.25	SITM – Intern. Mountain Troops Summit	Grenoble/ France
14. -16.02.25	Münchener Sicherheitskonferenz	München/GY
17. -21.02.25	IDEX/ NAVDEX	Abu Dhabi
18.-20.02.25	Xponential Europe	Düsseldorf/GY
24.-26.02.25	EnforceTac	Nürnberg/GY
25. -27.02.25	International Military Helicopter	London/UK
26.-27.02.25	Additive Manufacturing for Defense, Aerospace & Space	Bristol/UK
27.02.-02.03.25	IWA Outdoor Classics	Nürnberg/GY
March		
tbd	ASD Alliance	Paris/France
tbd	Joint Military Training & Simulation Conference	UK
tbd	Future Indirect Fires Conference	UK
10.-12.03.25	Future Soldier Technology	London/UK
12.-13.03.25	LOG.NET	Koblenz/GY
19.-20.03.25	Farnborough Intern. Space Show	Farnborough/UK
25.-26.03.25	DWT Unbemannte Systeme X	Bonn/GY
25.-27.03.25	Combat Engineer Combat Logistics	Warsaw/Poland
25.-27.03.25	IT2EC	Oslo/Norway
25.-27.03.25	UDT- Undersea Defence Technology	Oslo/Noway
26.-27.03.25	Homeland Security Expo 2025	Stockholm/Sweden
26-27.03.25	DPRTE 2025	Farnborough/UK
25.-27.03.25	Military Flight Training	London/UK
25. - 30.03.25	Avalon Airshow – Australian Intern. Airshow	Melbourne/Australia
31.03.-02.04.25	Military Robotics & Autonomous Systems	London/ UK
April		
01.-03.04.25	SOFINS – Special Operations Forces Innovation Network Seminar	Gironde/France
01.-04.04.25	LAAD Defence & Security	Rio de Janeiro/Brasilia
01.-03.04.25	Counter UAS Technology Europe	London/UK
02.-03.04.25	GPEC digital	Leipzig/GY
06.-09.04.25	Sea Air Space 2025	National Harbor, Maryland/USA
tbd	DWT – Im Dialog mit Militärattaches	Berlin/GY
08.-09.04.25	3rd European Military Additive Manufacturing Symposium	Bonn/GY
08.-10.04.25	ASDA	Zagreb/Croatia
10.-13.04.25	SITDEF	Lima/Peru
08.-10.04.25	The Security Event	Birmingham/UK
16.-17.04.25	Air Defence Summit	Berlin/ GY
20.-24.04.25	IQDEX	Bagdad/Irak
23.-24.04.25	Future Armoured Vehicles Situational Awareness	London/UK
28.-30.04.25	Military Space Situational Awareness	London/UK
tbd	KADEX	Astana/Kasachstan
May		
05.-09.05.25	SOF Week	Tampa/USA
05.-06.05.25	DWT Celler Trialog	Celle/GY
06.-08.05.25	IMDEX Asia 2025	Singapore
06.-08.05.25	DEFEA – Defence Exhibition Athens	Athens/Greece
06.-08.05.25	AOC Europe	Rome/Italy

Exhibition Dates 2025

Date	Event	Location
07.-08.05.25	Ground Based Air Defence Summit	Berlin/ GY
12.-14.05.25	FEINDEF	Madrid/ Spain
13.-15.05.25	Aerospace & Defense Meeting Central Europe	Rzeszow/ Poland
19.-20.05.25	Future Armoured Vehices CEE	Prague/ Czech R.
19.-22.05.25	Xponential 2025	Houston,TX/ USA
20 -25.05.25	Combined Naval Event	Farnborough/ UK
20.-22.05.25	NCT Europe 2025	Shrivenham/ UK
20.-25.05.25	LIMA – Langkawi Intern. Maritime & Aerospace Exhibition	Langkawi/ Malaysia
21.-22.05.25	Helicopter Technology CEE	Prague/ Czech R.
21.-23.05.25	DSEI Japan	Tokyo/ Japan
27.-28.05.25	AFCEA Fachausstellung	Bonn/ GY
28.-30.05.25	IDET – Intern. Defence & Security Technologies Fair	Brno/ Czech R.
28.-30.05.25	Land ISR & C2 Battle Management Summit	London/ UK
28.-31.05.25	MADEX Korea	Busan/ Southkorea
tbd	Shield Africa	Abidjan/ Cote d'Ivoire
June		
10.-12.06.25	Future Soldier Technology USA	Arlington/USA
16.-22.06.25	Intern. Paris Air Show	Paris/ France
July		
01.-03.07.25	Dismounted Close Combat	Shrivenham/ UK
22.-27.07.25	IDEF – Intern. Defence Industry Fair	Istanbul/ Turkey
August		
06.- 08.08.25	SMDC Space & Missile Symposium	Huntsville/ USA
tbd	DALO Industry Days	Denmark
September		
02.-03.09.25	BWI Industry Days	Berlin/ GY
02.-05.09.25	MSPO	Kielce/ Poland
03.-05.09.25	RÜ.NET	Koblenz/GY
tbd	Partner Belgrade	Belgrade /Serbia
tbd	Unmanned Systems Defense	Washington DC/USA
09.-10.09.25	DWT Forum Bundeswehrlogistik	Erfurt/ GY
09.-12.09.25	DSEI London	London/ UK
18.-20.09.25	TADTE - TAIPEI Aerospace & Defense Technology Exhibition	Taipeh/Taiwan
22.-24.09.25	27. DWT Marineworkshop	Linstow/GY
24.-25.09.25	Countering Explosive Threat & demining	London/ UK
24.-25.09.25	Uncrewed Systems/Helitech	London/ UK
25.-27.09.25	SOBRA	Gorna Radonja/ Slovenia
25.-27.09.25	AD2S	Bordeaux/ France
29.-30.09.25	Dismounted Soldier	London/ UK
29.-30.09.25	Future Mortar Systems	London/ UK
29.09.-02.10.25	Sea Future	La Spezia/ Italy
30.09.-02.10.25	CBRNe Protection Symposium & Exhibition	Malmö/Sweden
tbd	BIDEC – Bahrain Intern. Defence Exh. & Conf.	Manama/ Bahrain
October		
07.-09.10.25	it-sa	Nürnberg/ GY
tbd	GSOF Europe	Thessaloniki/ Greece
07.-09.10.25	Balt Military Expo	Danzig/ Poland
09.10.25	DWT Cyber Defence Conference	Bonn/ GY
13.-15.10.25	AUSA	Washington/ USA
16.-17.10.25	Airborne ISR	London/ UK
20.-22.10.25	Expodefensa	Bogota/ Columbia
29.10.-02.11.25	Seoul ADEX	Seoul/ S.Korea
November		
04.-06.11.2025	Indo Pacific	Sydney/ Australia
10.-13.11.25	Defense & Security	Muong Thong Thani/ Thailand
17.-21.11.25	Dubai Airshow	Dubai
18.-21.11.25	Milipol Paris	Paris/ France
25.-26.11.2025	Air Force Tech Summit	Berlin/ GY
December		
01.-05.12.25	I/ITSEC	Orlando/USA
01.-04. 12.25	EDEX	Cairo/ Egypt
09.-12.12.25	Cyber Defence Conference	Bonn/GY
15.-17.12.25	GDA – Gulf Defense & Aerospace	Kuwait

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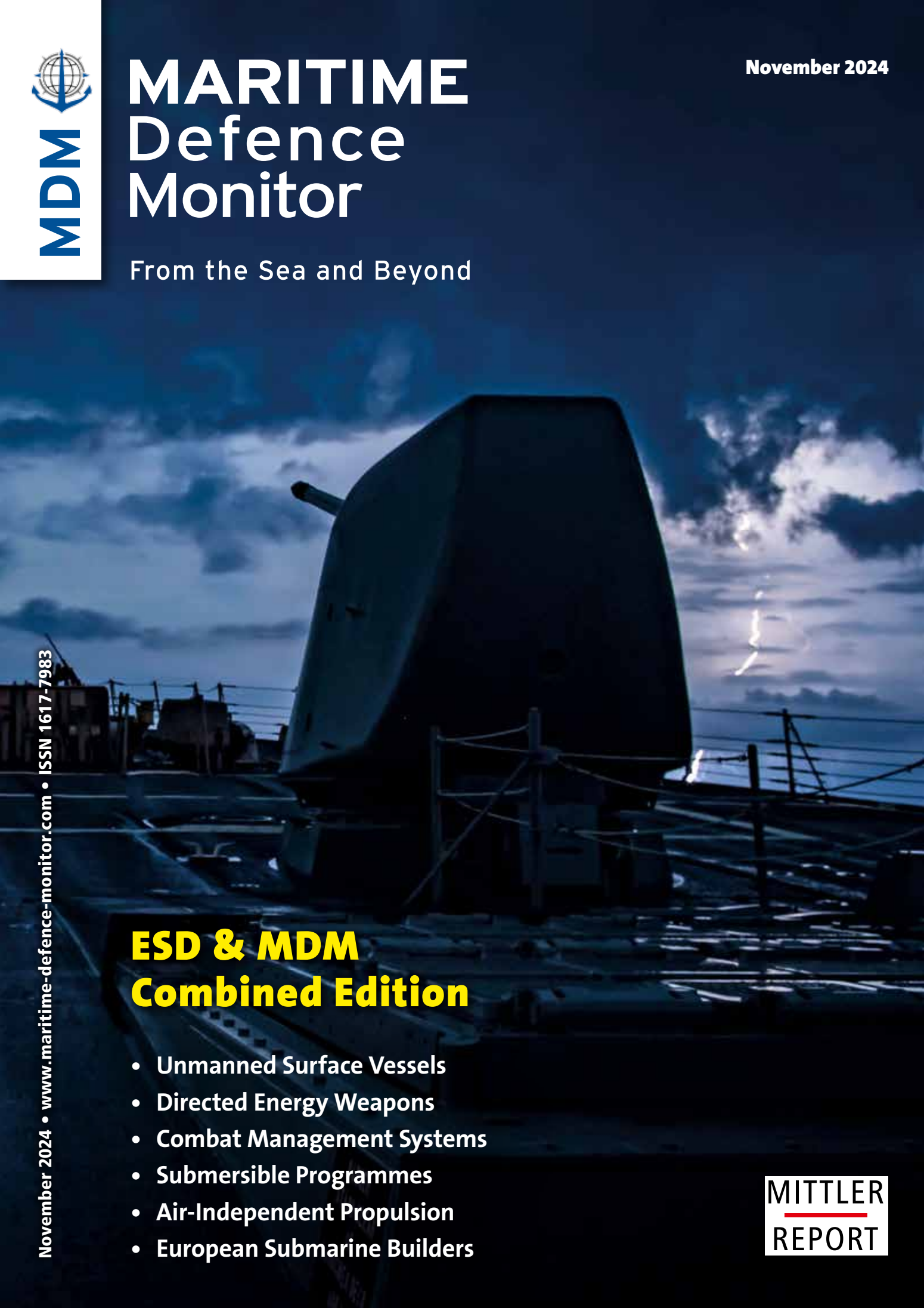
MDM

MARITIME Defence Monitor

From the Sea and Beyond

November 2024



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FUTURE ON BOARD

Photo: author

Emerging Naval Technology for Emerging Naval Threats

This edition of *Maritime Defence Monitor (MDM)* has been published to coincide with the EURONAVAL 2024 world naval defence exhibition in Paris. The latest iteration of EURONAVAL takes place against the backdrop of a fast-changing and increasingly threatening international environment. With the Covid-19 pandemic now seemingly firmly in the rear view mirror, the world's attention has turned to events in the geopolitical domain. Certainly, a lot has been happening on the global stage since the pandemic first started to wreak its havoc at the start of 2020. Amongst these events, Russia's 2022 invasion of Ukraine, the Hamas atrocities against Israel in 2023, and the subsequent expansion of the latter conflict across the Middle East all have significant consequences for both naval operations and industry.

The Russo-Ukraine war is, perhaps, most noteworthy for being the conflict in which drone warfare has come of age. Most attention has inevitably been drawn to the influence of unmanned and autonomous vehicles of various types and sizes on the dominant, land-based aspects of the war. However, the conflict has also been notable for the extent to which these vehicles have been used to shape the naval aspects of the conflict. The success of uncrewed surface vessels such as Ukraine's 'Magura V5' sea drone to sink and damage a number of Russian warships has been one, very visible sign of this influence. However, the significant impact of drones' ISR capabilities to support Ukraine's effective asymmetric anti-access/area denial (A2/AD) campaign against Russia's Black Sea Fleet should also not be overlooked.

The Russo-Ukraine war has certainly also served to highlight the difficulties of sustaining naval operations in littoral waters against a well-equipped opponent. This has, to a lesser extent, also been evidenced in the Houthi rebel campaign against vessels transiting the Red Sea. Here, the defensive measures taken by the various nations that have dispatched warships to the region in defence of trade have proved largely successful. Nevertheless, these forces have been stretched thinly over a wide area whilst countering relatively sophisticated attacks that have included ballistic and cruise missiles, as well as numerous drones. On occasions, weapons and control systems have not worked quite as intended. More significantly, the limitations in using a finite supply of expensive missiles to destroy a plentiful supply of attritable drones have been clearly demonstrated.

The deterioration in the global security situation means that more money is available to address these issues than during the previous, financially constrained, post-Cold War-era. Articles in this edition of *MDM* point to the significant expansion in surface warship and submarine construction that is already evident across the European continent as navies scramble to regain capacity. One of our particular objectives has been to introduce the wide range of new technology – ranging from counter UAV technologies through to combat management system developments – that will equip and supplement the capabilities of these various vessels, so as to combat some of the emerging threats just discussed. More information on much of this equipment will be readily available in the various exhibitor booths spread across EURONAVAL 2024's halls.

MDM's editorial team hope that you, the reader, will find this edition informative as we all seek to navigate changing seas.

Yours Aye

Conrad

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Masthead

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Editors-in-Chief: Capt. (ret) Hans Uwe Mergener (hum), Conrad Waters (cw)

Publisher: Peter Tamm (pt)

Regional Correspondents
France: David Saw
NATO: Joris Verbeurgt
Nordic-Scandic: J. Bo Leimand
USA: Sidney Dean

Layout:
AnKo MedienDesign GmbH, Meckenheim, Germany

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Lehmann Offsetdruck und Verlag GmbH, Norderstedt, Germany

Office Address:
Mittler Report Verlag GmbH
Beethovenallee 21, 53173 Bonn, Germany
Phone.: +49 228 35 00 870, Fax: +49 228 35 00 871
info@mittler-report.de, www.mittler-report.de

Managing Director: Peter Tamm

Advertising, Marketing and Business Development
Achim Abele
Phone: +49 228 25900 347
a.abele@mittler-report.de

Stephen Barnard
Phone: +49 228 35 00 886, Mobile: +44 7984 033154
s.barnard@mittler-report.de

Stephen Elliott
Phone: +49 228 35 00 872, Mobile: +49 1590 173 0346
s.elliott@mittler-report.de

Exhibition Management and Advertising Administration: Renate Herrmanns
Advertising Accounting: Markus Wenzel

Cover Photo: The *Arleigh Burke* class guided-missile destroyer USS Carney (DDG 64) transits the Black Sea, on 22 August 2018.
Credit: US Navy/Petty Officer 1st Class Ryan U. Kledzik

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EUROPE

UNITED KINGDOM: NEW ROYAL NAVY F-35B SQUADRON DEBUTS AT SEA

At the start of October 2024, the British Royal Navy announced that F-35B Lightning II strike fighters from 809 Naval Air Squadron (NAS) had joined the *Queen Elizabeth* class aircraft carrier HMS *Prince of Wales* in the North Sea for a month of training. 809 NAS had previously been stood up at the British F-35B operating base at Royal Air Force (RAF) Marham in December 2023, a few months later than first anticipated. The squadron's embarkation represented the first time in well over a decade that a Royal Navy fast jet squadron had operated from the deck of a British aircraft carrier; the last occasion being when the Harrier-equipped 800 NAS departed the former HMS *Ark Royal* in November 2010 prior to both the squadron's and the ship's retirement.

The United Kingdom now has two operational squadrons of F-35B strike fighters to embark aboard its Queen Elizabeth class aircraft carriers.

809 NAS is currently one of only two frontline British F-35B squadrons, the other being RAF 617 Squadron, 'The Dambusters'. There is also an operational conversion (training) unit (RAF 207 Squadron) and a test and evaluation formation (RAF 17 Squadron). Like the previous Harrier squadrons, the British Lightning II strike fighter force is jointly operated by Royal Air Force and Royal Navy Fleet Air Arm personnel on a roughly 50/50 basis. Given this background, 809 NAS' 'badging' with a Royal Navy identity is largely symbolic. Consequently, the Royal Naval Air Squadron's return to sea is more significant as another milestone towards the reconstruction of a national British carrier-based strike force, for which full operational capability is expected to be declared before the end of 2025.

MDM Editorial Commentary: The United Kingdom's efforts to re-establish a credible carrier strike capability continue to make progress in spite of finite financial resources and the inevitable challenges involved in resurrecting a capacity that was 'gapped' more than ten years ago. The ability to deploy two operational squadrons is a significant and positive development, arguably reducing some of the reliance that has previously been placed on the United States to support the resuscitation of British aircraft carrier operations. Notably, the 2021 global CSG-21 carrier strike group deployment headed by HMS *Queen Elizabeth* relied on embarkation of the US Marine Corps' Marine Fighter Attack Squadron 211 (VMFA-211) to boost 617 Squadron's limited numbers. The training now being carried out by 809 NAS is part of preparations for the next global British carrier strike group deployment, which is anticipated to be carried out over eight months during 2025.

The end of 2025 is expected to see the United Kingdom take delivery of the last of the 48 F-35Bs currently contracted, one of which was lost to an accident during CSG-21. Orders for a further tranche of 27 aircraft (including one to replace the lost jet) were planned by the country's previous Conservative government but it is not clear whether or not this plan will proceed given the backdrop of a new defence review by the incoming Labour administration. The decisions taken in this review will therefore likely be critical to the future development of Royal Navy carrier aviation given that the current limited number of F-35Bs also has to be divided between land and sea based missions in line with the joint operating concept.

GREECE: HELLENIC NAVY'S SECOND FDI TYPE FRIGATE LAUNCHED BY NAVAL GROUP

The launching ceremony for HS *Nearchos*, the second FDI ('frégate de défense et d'Intervention') type frigate being built by Naval Group for Greece's Hellenic Navy took place on 19 September 2024 in the presence of Nikolaos Dendias, the Hellenic Republic's Minister of National Defence and other dignitaries. The formal ceremony occurred after the new vessel had been floated out from the ship hall at Naval Group's shipyard in Lorient during the previous day.

HS *Nearchos* entered the waters of Lorient's Scorff River less than a year after the launch of HS *Kimon*, the first Greek ship of the class. This lead vessel is cur-

Credit: Naval Group

HS Nearchos, the second Hellenic Navy FDI frigate was launched in September 2024, less than a year after her sister HS Kimon, pictured here.

rently undergoing harbour trials whilst *Nearchos* will now progress to final outfitting. This will include installation of its Panoramic Sensors and Intelligence Module (PSIM) mast, which is too tall to be fitted in Naval Group's Lorient ship hall. A third Greek ship, *Formion*, completed its hull assembly phase in August 2024, whilst it looks likely that an option for a fourth vessel will be exercised soon. Current plans call for the three Greek frigates under firm order to be delivered during 2025 and 2026. This is an aggressive timescale and the structure of the programme has already been altered to achieve delivery of the Greek ships earlier than all except the first of the five FDIs being built for France. Nevertheless, construction at Lorient continues to gain momentum with *Amiral Ronarc'h*, the lead French ship, commencing sea trials on Monday 7 October 2024.

ITALY: FINCANTIERI STARTS WORK ON LEAD PPX TYPE OFFSHORE PATROL VESSEL

A steel cutting ceremony for the first of four next-generation offshore patrol vessels on firm contract with the Fincantieri-Leonardo Orizzonte Sistemi Navali (OSN) joint venture for the Italian Navy was held at the Riva Trigoso shipyard near Genoa on 24 September 2024. The event followed the signature of an agreement to acquire three of the vessels in July 2023 under a framework that included options for an additional three units. One of these options was subsequently exercised in August 2024. Fincantieri stated at the time of the first steel cutting that the total value of the first four vessels is around EUR 1.2 billion, including associated logistical support.

Displacing around 2,400 tonnes and having a length of about 95 m, the new offshore patrol vessel design is based on the FCX-20 variant of Fincantieri's 'FCX' family of patrol vessels and corvettes. The Italian ships will have a main armament of a 76 mm gun and helicopter facilities in line with their primary constabulary role. However, the design is capable of being

Credit: Fincantieri

Fincantieri started work on the first of four firm orders for next-generation offshore patrol vessels for the Italian Navy on 24 September.

outfitted with a greater level of combat capability. The vessels also benefit from innovations found in other recent Italian warships, including the innovative 'naval cockpit' introduced in the *Paolo Thaon di Revel* class.

The next generation offshore patrol vessel project forms just one element of the planned renewal of the Italian Navy's constabulary forces. Italy also continues to coordinate the European Patrol Corvette (EPC) programme, which should give rise to a somewhat 'higher end' capability around the end of the current decade. Meanwhile, work continues on the even more sophisticated *Paolo Thaon di Revel* class multi-role patrol vessels, which are essentially frigates in all but name.

THE NETHERLANDS: SUBMARINE CONTRACT SIGNED

On 30 September 2024, Dutch State Secretary for Defence Gijs Tuinman and Naval Group CEO Pierre Eric Pommellet signed the delivery agreement for the Replacement Netherlands Submarine Capability (RNSC) programme at a ceremony in Den Helder. The agreement followed the announcement made by previous Dutch defence minister, Christophe van der Maat, in March this year that Naval Group's diesel-electric 'Blacksword' variant of its 'Barracuda' family had been provisionally selected to meet the requirement for four submarines to replace the existing *Walrus* class boats. The new submarines are to be known as the *Orka* class.

Credit: Conrad Waters

Naval Group has concluded contract negotiations to supply four new Orka class submarines to the Netherlands, finally paving the way for the replacement of the elderly Walrus class. HNLMS Walrus, pictured here, has already been retired as part of plans to provide sufficient spares to keep two boats in service until the new submarines arrive.

The conclusion of the delivery agreement after a protracted procurement process will undoubtedly come as a relief to the Royal Netherlands Navy, which is already starting to withdraw some of its existing submarines so as to support the remainder in service. According to information released when Naval Group's provisional selection was announced, deliveries of the new boats should commence within 10 years of contract signature.

The project's framework includes an industrial cooperation agreement signed on 10 September 2024 that commits Naval Group to cooperate with numerous key Dutch companies and knowledge institutes over a period of 20 years in the supply of key systems and components. In addition to supporting the Netherlands' industrial base, the intention is also to ensure that the Dutch Ministry of Defence maintains national autonomy to operate, maintain and modernise the *Orka* class submarines throughout their entire lives.

THE AMERICAS

UNITED STATES: LITTORAL COMBAT SHIP PRODUCTION DRAWS TOWARDS AN END

A number of announcements relating to US Navy Littoral Combat Ship construction made over recent months have heralded the imminent completion of one of the most controversial American naval procurement programmes of recent times. Once seen as central to US Navy modernisation, Littoral Combat Ship orders have been split between *Freedom* (LCS-1) mono-hull and *Independence* (LCS-2) catamaran variants produced respectively by Fincantieri Marinette Marine (under contract to Lockheed Martin) and Austal USA. Increasing doubts over the survivability, lethality and modular nature of the Littoral Combat Ship concept have seen, initially, the truncation of the original production programme and, subsequently, retirement of earlier members of both classes before the final ships have entered service.

Credit: US Navy

The delivery of USS Nantucket (LCS-27) to the US Navy on 29 July 2024 was closely followed by that of USS Beloit (LCS-29) on 30 September.

Out of the two variants, production of the *Independence* class has progressed more smoothly. A total of 19 of the ships have been ordered for US Navy service, with the 18th vessel – USS *Kingsville* (LCS-36) – being commissioned in Corpus Christi, Texas on 24 August 2024. The same month saw Austal USA issue a release confirming the technical launch of *Pierre* (LCS-38) from its shipyard in Mobile, Alabama; an event which the US Navy's official Naval Vessels Register confirmed as taking place on the preceding 30 May. The ship will be delivered during 2025, bringing Austal USA's construction of the type to a close.

Production of the 16 *Freedom* class Littoral Combat Ships has been somewhat more protracted, partly reflecting labour and skills shortages. However, Marinette Marine has hit two major programme milestones in recent months, with the delivery of USS *Nantucket* (LCS-27) on 29 July 2024 being closely followed by that of USS *Beloit* (LCS-29) on 30 September. This leaves the shipyard with only *Cleveland* (LCS-31) to complete before its work on the type also ends. However, Marinette Marine is also responsible for constructing four Multi-Mission Surface Combatant iterations of the *Freedom* type for the Royal Saudi Navy following Saudi Arabia's decision to acquire the type in 2017 and on which assembly continues.

MDM Editorial Commentary: The many twists and turns of LCS procurement have seen the type's reputation shift from being the 'poster child' of the post-Cold War US Navy's reconfiguration towards littoral operations towards something more akin to a 'white elephant' in search of a role. Whilst expectations for the type's modular concept – based on a lean-manned 'sea frame' being readily adapted to perform a range of missions through rapid embarkation/disembarkation of specialised equipment and associated crew – probably underestimated the training and support challenges this involved, it is arguable that this dramatic shift in perspective has been overdone. Instead, it is possible to contend that the US Navy never gave the LCS concept a fair trial against a backdrop of re-emerging 'great power' tensions and an associated change in operational priorities.

After much vacillation, it now seems that the US Navy intend to dedicate 15 *Independence* class vessels to mine countermeasures (MCM) operations. Here their suitability for receiving modular mission packages makes them well-suited for the emerging MCM 'mothership' role. Meanwhile, 10 *Freedom* class variants will be focused on lower intensity anti-surface warfare, potentially undertaking a valuable 'presence' role.

BRAZIL: CHRISTENING CEREMONY FOR FIRST MEKO TYPE FRIGATE

The Brazilian Navy marked an important step forward in realising its plans for the renewal of its surface fleet with the holding of a formal naming ceremony for the lead *Tamandaré* class frigate at the thyssenkrupp Estaleiro Brasil Sul shipyard in Itajaí, Santa Catarina on 9 August 2024. The importance of the event was highlighted by the attendance of Brazilian President Luiz Inácio Lula da Silva at the head of some 550 invited guests. The new frigate was later transferred to a floating dock prior to her technical launch and transfer to the yard's fitting out quay on 17 August. She is expected to be commissioned in 2026; a challenging deadline given Brazil's lack of recent experience in completing a major surface warship.

The first of four frigates ordered from the Águas Azuis consortium of thyssenkrupp Marine Systems (tkMS), Embraer Defense & Security and Atech in March 2020, Tamandaré has been widely described as a MEKO A-100BR. However, she is somewhat larger than tkMS' portfolio of standard A-100 corvette/light frigate

Credit: Brazilian Navy

The lead Brazilian Tamandaré class frigate pictured in the course of being floated out on 17 August 2024 after her naming ceremony the previous week.

designs, with a reported length of 107 metres and displacement of 3,500 tonnes falling between these ships and the company's larger A-200 series. The class will replace former British-designed frigates of the Type 22 and *Niterói* classes – some of which have already been retired – once they enter service.

COLOMBIA: CONTRACT NEGOTIATIONS CONCLUDED WITH DAMEN FOR NEW SIGMA TYPE FRIGATE

Colombia is another South American country advancing the upgrade of its flotilla of surface combatants. In August 2024, it was announced that contractual negotiations between state-owned shipyard COTCEMAR and Damen for technical support and components relating to the local construction of a SIGMA 10514 type frigate had been successfully concluded. The agreement followed the earlier selection of the Damen design in September 2022 to meet a requirement for what may ultimately be as many as five PES 'strategic surface platforms' under the framework of the country's broader Naval Development Plan 2042.

Whilst the current contract appears to be for just a single ship, it nevertheless overturns local speculation that implementation of the programme might be delayed or even renegotiated against a backdrop of reports suggesting the cost of the initial unit has increased due to inflation and equipment selection choices. The decision to proceed may reflect the recognition that Damen is well placed to support delivery of the project by a yard that has no previous experience of frigate construction given its success in similar situations in both Mexico and Indonesia.

Credit: Damen

Damen has been contracted to support Colombia's COTECMAR in the construction of a Sigma 10514 type frigate.

ASIA-PACIFIC

SINGAPORE: TYPE 218 SUBMARINES COMMISSIONED

The Republic of Singapore Navy's acquisition of a quartet of German-built tkMS Type 218SG submarines saw tangible progress on 24 September 2024 when Singapore's Prime Minister and Minister for Finance Lawrence Wong officiated over a commissioning ceremony for the first pair of boats at Changi Naval Base. In a statement issued to publicise the event, the Singapore Ministry of Defence noted that the two submarines – RSS *Invincible* and RSS *Impeccable* – are now fully operational. *Impeccable* had previously arrived in Singapore by heavy-lift transport ship in July 2023. She was followed by the lead vessel *Invincible* – believed to have remained in German waters for a longer period to facilitate crew training – earlier in September 2024.

Credit: tkMS

Inimitable, the final member of the Type 218SG Invincible class submarines is pictured at Kiel prior to launch.

Two pairs of Type 218SG submarines were ordered under separate contracts with tkMS in 2013 and 2017. Completion of the second pair – *Illustrious and Inimitable* – is also well advanced, with a formal naming ceremony for the latter being held at tkMS Kiel in April 2024. At that time, tkMS reported that this final boat would be handed over in 2025 following extensive testing. However, the Singapore Ministry of Defence press statement accompanying the initial pair's commissioning suggests that the two later submarines may remain in Germany for some considerable time yet, stating only that they were expected to return to Singapore "by 2028".

MDM Editorial Commentary: The *Invincible* class are Singapore's first purpose-built submarines, with the country's underwater flotilla previously relying on second-hand Swedish boats. Only limited information has been released on the Type 218SG, which has been widely reported to be based on the air independent propulsion-equipped Type 214 'export' design but also to incorporate features from the German Navy's Type 212A. tkMS claims that the submarines are the largest built by the company to date. Official statements indicate that they have a length of approximately 70 m, a submerged displacement of 2,200 tonnes, an underwater speed in excess of 15 knots and an armament of eight torpedo tubes but this data may be subject to a degree of disinformation. Singapore states that the class is specifically designed for operations in Singapore's shallow and busy tropical waters, although their overall size suggests that they may well be intended for long-range deployment.

Delivery of the Type 218SG programme has been far more protracted than originally anticipated. Part of the explanation for this has been laid at the door of the disruption caused by the Covid-19 pandemic but other factors may also have been in play. In any event, the entry into service of these sophisticated boats gives Singapore an arguably unmatched underwater capability within Southeast Asia, where submarines are becoming an increasingly popular asset.

MALAYSIA & NEW ZEALAND: NAVAL VESSELS LOST

The inevitable dangers of operating warships at sea have been demonstrated by the recent loss of two warships in separate incidents in the Asia-Pacific region.

The first loss occurred close to the Singapore Strait on 25 August 2024 when the Royal Malaysian Navy's *Handalan* (Spica-M) class fast attack craft KD *Pendekar* began to take in water in her engine room and subsequently sank as a result of uncontrolled flooding. It is suspected that the ship had been in collision with an underwater object but the ship's considerable age – she was delivered in 1979 – has inevitably attracted some attention given the slow progress being achieved with the country's naval modernisation. Fortunately, all 39 of Pendekar's crew were safely evacuated before the vessel went down.

Subsequently, on 6 October 2024, the Royal New Zealand Navy's (RNZN's) multi-role offshore support vessel HMNZS *Manawanui* – completed in 2003 as the civilian survey ship MV *Edda Fonn* and commissioned into New Zealand service in 2019 – sank off the coast of Samoa after losing power and running aground on a reef the previous day. Again, all 75 crew members and other personnel aboard at the time were safely evacuated before the ship capsized. One unfortunate result of her sinking was subsequent unsubstantiated and misogynistic abuse directed at the ship's (female) commanding officer. The incident – the first loss of a RNZN warship since the Second World War – is another unfortunate blow to a navy that is already suffering a crewing crisis that has resulted in a number of vessels being laid up in reserve.

INDIAN OCEAN

NEW VESSELS FOR INDIA AND PAKISTAN

Regional rivals India and Pakistan have both recently seen significant progress with projects that will bolster their respective naval forces.

In August 2024, the Indian Navy's lead Project 17A *Nilgiri* class frigate commenced sea trials from Mumbai-based Mazagon Dock Shipbuilders Limited (MDL). She is the first of seven new vessels ordered by the Indian government under contracts awarded in February 2015 as a follow-on class from the three units of the previous Project 17 *Shivalik* design. Four of the frigates are being built by MDL and three by Garden Reach Shipbuilders & Engineers (GRSE) in Kolkata. Displacing a little under 7,000 tonnes in full load condition, the vessels represent a significant technological advance over their predecessors, including further progress towards a truly stealthy design. They also incorporate the Israeli EL/M-2248 MF-STAR multifunction radar and Barak 8 surface-to-air missiles found aboard the larger Project 15A and 15B *Kolkata*/*Visakhapatnam* class destroyers, as well as the new aircraft carrier INS *Vikrant*. As the lead vessel of the Project 17A type, *Nilgiri* is likely to undergo an extensive series of first-of-class trials before entering Indian Navy service, likely in the course of 2025.

Meanwhile, the Pakistan Navy held an induction ceremony attended by President Asif Ali Zardari at Karachi in early September 2024 to welcome the corvette PNS *Babur* and offshore patrol vessel PNS *Hunain* into fleet service. The corvette is the first of four enlarged 'Ada' type vessels ordered from Turkey in 2018 under a contract that will see two of the quartet delivered by Karachi Shipbuilding & Engineering Works (KSEW). She had previously been commissioned in Turkey in September 2023, arriving in Karachi in June 2024. PNS *Hunain* is the lead vessel of a pair of Damen OPV 2600 type patrol ships that were ordered to supplement two smaller *Yarmook* class vessels of the Damen OPV 1900 type that were delivered in 2020. All these patrol ships have been constructed by Damen's shipyard at Galati in Romania, with *Hunain's* official commissioning taking place at the port of Constanta in that country in July 2024.

MDM Editorial Commentary: The pending induction of the Project 17A frigates into Indian Navy service will represent a marked enhancement in that country's naval capacity, providing a new class of technologically advanced warships that will integrate well with the capabilities of the similarly-configured Project 15A/B series of destroyers and INS *Vikrant*. From an industrial perspective, it is worth noting that the class has previously been reported as the first Indian-built warship design to benefit from modular (block) construction techniques, thereby offering the potential for an improvement in Indian shipyards' previously lacklustre production schedules. Whilst the *Nilgiri* class still appear to be subject to considerable delays compared with initial expectations, it seems that the lead ship will be delivered around seven years after first being laid down; a material improvement over the nearly 9 years it took to complete the first Project 17 *Shivalik* class ship.

The Pakistan Navy's recent arrivals do not represent the same level of capability seen in India's Project 17A class. The new ships do, however, provide welcome reinforcement to the fleet's surface flotilla and enhance the anti-access/area denial (A2/AD) capacity that will primarily rest with the navy's future Chinese-built submarines. Delivery of PNS *Babur*, is, however, noteworthy in reflecting the arrival of Turkey's shipbuilding sector and the success that has been achieved in leveraging the investment made into the 'Milgem' national ship project. In addition to Pakistan, variants of the 'Ada' class developed under Milgem have also been built for Ukraine, whilst Malaysia has also ordered a variant of the type for the second tranche of its Littoral Mission Ship (LMS) programme.

PNS Babur, pictured here arriving at Karachi in June 2024, is the first of four new Pakistan Navy corvettes based on the Turkish 'Ada' design.

Credit: Pakistan Navy

Kit and CONOPS:

REPMUS demonstrates new ways and means for using USVs

Dr Lee Willett

Uncrewed surface vessel (USV) operations amongst NATO members are undergoing something of a sea change, due in large part to lessons learned from the maritime components of the ongoing Russo–Ukraine war. At the recent Portuguese Navy-led, NATO co-hosted 'REPMUS 2024' (Robotic Experimentation and Prototyping with Maritime Unmanned Systems) exercise held at Troia, southern Portugal, Allied navies and their supporting naval industrial base tested USV platforms in new concepts of operation (CONOPS) designed to harness and enhance what is an evolving contribution of maritime uncrewed systems (MUS) as a whole to NATO capabilities and operations.

NATO navies have introduced MUS capabilities into operations initially for two broad purposes: intelligence, surveillance, and reconnaissance (ISR) tasks; and mine counter-measures (MCM) activities. The primary aim of so doing was to exploit the absence of personnel onboard to conduct what are termed the '3-D' missions ('dull', 'dirty', and 'dangerous'), with the uncrewed system able to step into harm's way in order to conduct, for example, anti-submarine warfare (ASW) sensing or mine identification and destruction. In these contexts, keeping the operator out of harm's way was key. USVs were often seen as the platform that would be positioned up-threat, and would then deploy uncrewed underwater vehicles (UUVs) to tackle the ASW or MCM problem.

As Western navies have become more knowledgeable of and more comfortable with what MUS technology could offer and how it could be exploited, inevitably their ways and means for using USVs, for example, have begun to evolve.

However, the realities of high-end conventional combat in the ongoing Russo–

Author

Dr Lee Willett is an independent writer and analyst on naval, maritime, and wider defence and security matters. Previously, he was editor of *Janes Navy International*, senior research fellow in maritime studies at the Royal United Services Institute, London, and Leverhulme research fellow at the Centre for Security Studies, University of Hull in the UK.

Credit: Peter Felstead

The Ukrainian Navy's very effective operational use of USVs in the Black Sea has shown others, including NATO, how USVs can add effect in high-end naval operations. Here a mock-up pictured at Eurosatory 2024.

Ukraine war appear to have accelerated this thought process, perhaps prompting more of a revolution in thinking about how to use MUS capability – even if evolutionary development may have drawn the same conclusions in due course.

The Russo–Ukraine conflict has demonstrated not only key capabilities but key lessons for Western navies in thinking about MUS use.

First, while these navies certainly see MUS as providing mass at sea to generate non-kinetic outputs – like sensing presence, in particular – combat in Ukraine has shown that systems both old and new will be fired in considerable numbers in contemporary conventional conflict, for both defensive and offensive purposes.

Second, for USVs in particular, the Ukrainian Navy has been able to use this relatively new capability – remotely operated through a 'first person view' (FPV) concept of employment (CONEMP) – and other stand-off systems including cruise missiles in offensive operations across the Black Sea to drive Russia's Black Sea Fleet back to its own coastline. The ability to strike a ship at sea or a submarine in port with a missile, or to literally drive a USV straight into a ship at sea or in port, has enabled the Ukrainian Navy to establish an operational-level anti-access/area denial (A2/AD) 'bubble' – and thus achieve a significant degree of sea denial – effectively without having at sea a traditional naval force structure, command-and-control (C2) capability, or even people.

Credit: Dr Lee Willett

Around 20 USVs were present at REPMUS 2024. NATO used exercise serials to test and demonstrate emerging alliance concepts of operations for USV use.

While some have argued that Ukraine's experience in the Black Sea, including with its use of USVs, has demonstrated that traditional, large-scale naval force structures may no longer be needed, others have argued that Ukraine has demonstrated the use of a new kind of naval force structure.

Ukraine's offensive operations conducted in the Black Sea have also underlined the importance of mass even with new capabilities including USVs, with the vessels designed to be expendable against targets and facing the risk of being attritable by Russian defences. While Western naval budgets may be beginning to grow over the longer term, they may not yet be growing fast enough or far enough to build the mass the navies may need in the shorter term; thus, USVs offer the chance to build mass and, as demonstrated in Ukraine, the opportunity to develop new and highly effective force-multiplying tactics.

Today, too, the wider availability of technology acts as another force multiplier when harnessed to new platforms such as USVs – for example, using FPV technology to turn the vessels into uncrewed kamikaze assets.

Credit: BBC

Two Swedish Piraya USVs are pictured ashore at the REPMUS exercise base in Troia, Portugal. The Saab Kockums' USVs were employed in complex serials, where defensive and offensive multi-domain operations were demonstrated.

Lessons learned

The exercise serials constructed and conducted at 'REPMUS 2024' seemed to reflect a shift in operational emphasis amongst NATO navies, with greater focus on using USVs for kinetic purposes, including in integrated, multi-domain operations (MDOs). This indicated that NATO has learned some significant lessons from observing how Ukraine's use of affordable but capable USVs can fundamentally shape and impact naval operations.

At the REPMUS exercise, which took place in September, around 20 USVs from different countries and different companies participated; a collection of surface ships were also present.

USVs were used in defensive operations, for example in harbour protection serials and to secure critical undersea infrastructure (CUI). They were also used to conduct offensive operations, including being integrated with other MUS like unmanned aerial vehicles (UAVs) to generate MDO-based outputs.

At the Royal United Service's Institute's annual C4ISTAR conference, held in London on 3 October 2024, participants discussed how MDO-based operations were conceived in large part to offset A2/AD 'bubbles'. Clearly here, USVs and UAVs working together can add different layers to the MDO capability, and thus to its efforts to lance such 'bubbles'.

An operational experimentation exercise like REPMUS evolves and builds across its timeline to conclude with a tactical phase, where 'free play' is used to test

capabilities and tactics with greater operational realism. For REPMUS 24, the tactical phase was designed to help further improve understanding of using USVs in live operations in both defensive and offensive modes.

"For the first time, we will play a LIVEX where we inject incidents but give freedom of manoeuvre to the 'blue forces' and 'red forces', with Exercise Control (EXCON) assuring safety," Captain António Mourinha, a Portuguese Navy officer and chief of staff for the exercise, alongside his posting as Director of the Navy's Centre for Naval Operational Experimentation (CEOM), told *European Security & Defence*, in an interview at CEOM's base in Troia, during the exercise. The tactical phase focused on surface exercises (SURFEXs) for surface ships and USVs, but also included anti-air warfare serials. "Under this construct, we are testing defence against both USVs and UAVs," said Capt Mourinha.

This SURFEX was designed to achieve two aims, Capt Mourinha continued: first, to defend 'blue forces' against USV and UAV threats; and second, to evolve 'red force' tactics to use USVs in attack missions. "So, in a single exercise, we double the results because we test USVs in attacking ships and we test the defences the ships can have against USVs," Capt Mourinha explained.

"One of the focus areas for REPMUS this year is counter-UxVs, in all domains," Capt Mourinha added. "We are trying to protect the [CEOM] site from all types of drones, with many 'red forces' and many surveillance capabilities. We are also using uncrewed systems against uncrewed systems."

The Ukrainian Navy was expected to participate in the SURFEX serials, including by supporting the 'red force' team. Ukraine's USV presence would have enabled NATO navies to draw on Ukraine's real-world operational experience of using such capabilities in the Black Sea, enhancing the realism in training benefit.

The serials enabled the assembled navies to work through methodologies, including C2, for conducting both offensive and defensive operations using USVs. The numbers of USVs present at the exercise also enabled a degree of mass to be implemented in the serials, with USVs on the 'red force' (for example) able to use different axes of attack to confuse 'blue force' defences. In addition, larger and smaller USVs were mixed together in the serials, to provide respectively both overt and covert lines of attack, with such attacks often conducted in a co-ordinated manner to further confuse defences.

Credit: Portuguese Navy

The presence of different sizes and types of USV at REPMUS 2024 enabled the operators to test USV mixes, with larger and smaller craft taking on overt and covert roles, respectively.

In defensive contexts, REPMUS also tested the use of USVs in defending high-value assets (HVAs). Protecting HVAs like carrier strike groups (CSGs) or amphibious ready groups (ARGs) is a core operational priority for NATO navies. The US Navy has already talked about the future role large USVs could play in operating within such task groups, positioned out forward to conduct surveillance sweeps or to attack targets posing an anti-ship missile threat to the groups.

For both offensive and defensive operations, the relatively congested waters in the REPMUS exercise area – with, for example, different types and sizes of commercial vessels widely present – created the opportunity to test USV C2 and tactics in a cluttered environment, including for mission planning and collision avoidance.

USV capability

Amongst the 20 or so USVs present were four Piraya (Piranha) vessels from Swedish company Saab Kockums comprising two 4-m and two 1.5-m craft.

Underlining the focus on MDO, for some serials the Piraya USVs worked in partnership with UMS Skeldar V-200 UAVs. Participating in REPMUS for the first time, the Skeldar UAVs were fitted with a WESCAM MX night/day electro-optical/infra-red (EO/IR) camera payload. Experiments were conducted with this capability package to relay video data from the UAV, via its RadioNOR antenna system, to the Pirayas, so the USVs could see and use live video footage, Michel Egerborn, UMS Skeldar's Demonstrations Manager, told *ESD/MDM* during an interview at REPMUS: this C2 capability was used to support ISR operations, augment the USV's overall battlespace picture, and help identify potentially hostile targets.

Egerborn pointed to benefits offered by the combined capability. First, he said, at an operational level, "It's an addition to have a common picture and to take decisions based on data." Second, he added, at a tactical level "Skeldar can lead the USV to a target in a silent way."

The presence of Swedish and Ukrainian USVs at REPMUS will have helped those two navies practice tactics, techniques, and procedures (TTPs) in a NATO context. In turn for NATO, the Swedish and Ukrainian participation will have provided NATO navies with the opportunity to draw on their operational experience in the Baltic and Black Seas, respectively – two key areas of strategic interest for the Alliance.

One USV capability revealed for the first time at the exercise – a system that demonstrates the enduring NATO focus on surveillance requirements, but also the evolving capacity to tackle other tasks – was the Portuguese Navy's new Trator do Mar (or Sea Tractor) USV.

For a primary sensor, this USV is fitted with a towed array sonar system, and its basic CONOP is to conduct grid search patterns (like a tractor ploughing a field). However, it can also carry other capabilities, Commander Marco Guimarães, director of CEOV (Célula de Experimentação Operacional de Veículos Não Tripulados; the Navy's MUS technology innovation and development cell) told *ESD/MDM* at REPMUS.

"This is a low-profile, discreet USV that was designed, built, and tested by the Portuguese Navy .... It is our design, our drawings, our specifications, and built by ourselves in our shops," said Cdr Guimarães.

Powered by a hybrid propulsion system, the stealthy USV has long endurance – able to stay at sea for more than 30 days – and a long-range communications suite.

As regards its mission capabilities, Cdr Guimarães said "It's a new USV with a mission that is multi-purpose. We plan to fit a towed-array sonar, to screen and to protect CUI." The keel is fitted with nine attachment points, to which various different sensors can be fitted. "We can use all the sensors that are used by our hydrographic institute .... These sensors support scientific research and military operations," Cdr Guimarães added.

The USV can be operated autonomously or remotely. At REPMUS it was run remotely, to enable the navy to connect and test more sensors with it.

With adaptable spaces onboard, the USV can be reconfigured to meet mission requirements, and thus can be equipped to contribute to operations in all domains. On operations, Cdr Guimarães explained, a single USV can be deployed or more than one can be sent together.

The USV was present at REPMUS to conduct testing of the vessel, its systems, its capabilities (including the sonar and communications suites), and its interoperability, as a final part of the process for demonstrating its readiness for operations. The exercise trials process for the USV included "Just tuning and small tests .... We are running checks: ticks in the boxes; this is done; this is done; this is done", said Cdr Guimarães.

The USV tested at REPMUS was the first in an initial batch of four vessels: the others are in build. The navy is proceeding with the programme, Cdr Guimarães confirmed.

Credit: NATO

USVs are pictured integrating with crewed naval platforms, during the REPMUS exercise in 2022.

"We are ready," Cdr Guimarães added. "This is just one piece of the puzzle."

A core part of the CONOPS for the USV is to be able to deploy it on board the navy's planned new ship, dedicated to MUS operations. Named Dom João Segundo, this new ship is known in the Portuguese Navy as the 'drone carrier'.

"The USV was built in order to be one of the pieces that will embark on the 'drone carrier'," said Cdr Guimarães. "This will be an organic USV for that ship." With all cranes and lift systems on board intended to be able to launch and recover the USV, it can be deployed over the side or over the stern.

"We also can use the USVs in our coastal patrol vessels," Cdr Guimarães added.

In terms of the CONOPS for the 'drone carrier', "The platform is threat agnostic, but you choose the effectors you want onboard," Admiral Henrique Gouveia e Melo, Portugal's Chief of Navy, told *ESD/MDM*. "What's the threat? It's an aerial threat? OK, we can move to that ship a big air wing with a lot of UAVs, and will be effective combating the threat in that environment. What is the threat? It's surface. OK, we will move a lot of USVs and the ship will be surface warfare-capable. Or the threat is multi-scenario: we will deploy UAVs, USVs, UUVs."

"That platform gives us the flexibility and the agility to adapt to threats into the future. That's our vision," Adm Melo added.

To deliver integrated capability, the 'drone carrier' also will deliver interoperability. This process was tested too at REPMUS. A core part of the exercise in its 2023 and 2024 iterations has been the establishment of several shore-based 'virtual ships' to represent and operate – in simulated terms – sea-based commander task units (CTUs).

The CTUs – of which there were four naval operational nodes at the exercise, CTUs Lisbon, London, Madrid, and Washington – provide C2 nodes through which exercise serials are conducted. They also provide a construct around which OPEX takes place – including how to integrate MUS into operations with both crewed and uncrewed assets.

Cdr Guimarães commanded CTU Lisbon during REPMUS. "From the CTU Lisbon side, one of our goals was experimenting with co-ordination, because we are building the 'drone carrier'. For us, CTU Lisbon is that ship," he explained. "We are experimenting now with how we can integrate uncrewed systems onboard that ship and how can we play with those assets in that ship."

In this context, at REPMUS the navy experimented with building MUS interconnectivity; the capacity to operate MUS deployed from the same ship simultaneously in the air, surface, and sub-surface environments; and industry integration within the development of this approach. Testing MUS connectivity through CTU Lisbon at 'REPMUS' in order to develop integration capacity for MUS systems and the 'drone carrier' helps the navy understand which systems can be deployed from the carrier, as well as which systems may also be suitable for the coastal patrol vessels.

The Portuguese Navy is also working with other navies on USV concepts and programmes that could be developed together to provide interchangeable capabilities for each other's ships.

"Until now, we were working on the pieces of a puzzle: now, we are putting the puzzle together," concluded Cdr Guimarães.

Smarter weapons: torpedo enhancements improve effectiveness

Tim Fish

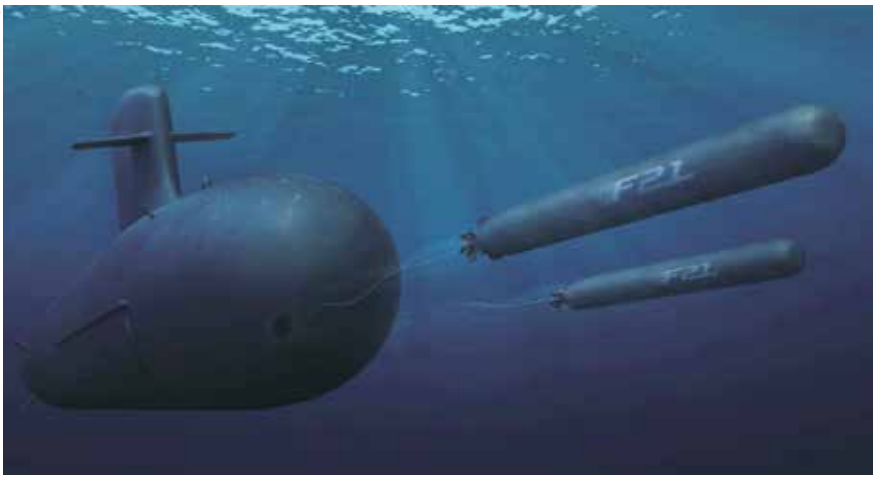
Torpedoes are an essential part of the naval weapons inventory, providing an underwater attack capability that can be launched by submarines, ships and maritime helicopters. Emerging trends indicate that naval operations are increasingly being conducted closer to the shore, where there are environmental considerations that present a challenge in the underwater domain. This article analyses some of the latest developments in torpedo capability.

General trends

The focus of development during the Cold War era was for torpedo designs to be optimised for destroying submarines and warships in the deep blue waters of the Atlantic Ocean, where NATO naval forces were operating to protect against Soviet submarine threats to allied sea lines of communications. Variants of the torpedoes that were produced in this era are still in use by navies worldwide. Accordingly, the challenge is to ensure that the latest torpedoes – both new and upgraded – are capable of operating in and are optimised for 'green water' conditions in the littoral environment.

There are two main categories of torpedo: heavyweight and lightweight. Heavyweight torpedoes are large weapons that carry a significant payload in terms of a warhead, sensors, fuel and propulsion machinery to achieve longer underwater attack ranges. The size of heavyweight torpedoes – usually about 533 mm (21 in) diameter and weighing in excess of a tonne – means they can only be launched from platforms such as submarines and major surface combatants. Meanwhile lightweight torpedoes are smaller – at about 324 mm in diameter – and are more readily carried by aircraft such as maritime patrol aircraft or maritime helicopters, as well as smaller surface craft. Although lightweight torpedoes have a shorter underwater range they can be deployed on aircraft conducting long-range patrols and rapidly launched against submarine targets that are detected far from the coastline or their host platform.

Credit: Naval Group



Safety has been an important aspect of development work on France's F21 torpedo. This focus includes the design of its seawater battery, which requires a water intake to be primed; the design of the IM warhead and slapper firing technology; and its software and cybersecurity features.

Torpedo development has, arguably, not been a priority in recent decades. However, in order to meet the developing operational profile referenced above, torpedoes must be able to function in littoral zones. Here, there are higher levels of acoustic reverberation, sound propagation is much worse, and there are increased noise levels due to higher volumes of maritime traffic. This means there will be more incidents of false targets being generated and better opportunities for submarines to hide among the clutter. Furthermore torpedo countermeasures are getting smarter.

A spokesperson from France's Naval Group told *ESD*: "The maritime environment is changing, with an increase in economic activities (maritime traffic, underwater infrastructures such as platforms or offshore wind farms, underwater work), a shift in tensions towards coastal areas and an increase in the quantity and quality of underwater detection resources. This makes underwater warfare increasingly complex, and to maintain a tactical advantage over the adversary, heavyweight torpedoes must be capable of engaging further than the adversary while knowing how to manage this increase in complexity."

In response, renewed attention is being given to torpedo modernisation and new technologies are being employed to enhance capabilities. These include:

Author

Tim Fish is a freelance defence journalist with 20 years of experience in writing for and editing a variety of naval and military publications.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- The use of new sensors, such as active and passive homing systems, along with updated software and more processing power to increase the chance of detecting targets.
- Increased autonomy to allow a fire-and-forget capability at longer ranges.
- The replacement of copper wire with fibre-optic cable to improve data transfer, increase the torpedo's monitoring capability, and enhance the ability to update the weapon post-launch via a submarine's combat system.
- The provision of greater resistance to anti-torpedo countermeasures to increase the chances of hitting the target.

Beyond these improvements to guidance and control, upgraded propulsion components are being fitted and new fuels are also becoming available that are cheaper and safer to use. Other changes are intended to ensure compliance with NATO STANAG 4439 regulations – the NATO policy covering the introduction and assessment of insensitive munitions (IMs) – and to reduce the through-life cost of maintaining torpedo fleets.

F21 heavyweight torpedo

In France, Naval Group has developed the F21 heavyweight torpedo for the French Navy. It is replacing the older F17 Mod 2 heavyweight torpedo in the existing *Le Triomphant* class ballistic missile submarines and *Rubis* class nuclear-powered attack submarines. It also equips the new *Suffren* class nuclear-powered attack submarines that are now entering service and, in due course, will be used by the third generation (SNLE 3G) strategic boats. Just under 100 units have been ordered from Naval Group for the French Navy.

The F21 was developed under the 'Artémis' programme. This commenced in 2008 under the direction of the French DGA procurement authority. The F21 represents a substantial technological leap in development from the earlier F17 Mod 2 weapons, utilising a modern, digital design. Some 6 m long, the F21 weighs 1.5 tonnes and has a top speed of at least 50 knots. It has a range in excess of 50 km and can operate in shallow waters less than 10 m deep as well as in the open ocean at depths of more than 500 m. Whilst the older F17 was powered by a silver oxide-zinc battery, which gave a range of just 20 km and a maximum speed of about 40 knots, the F21 has a silver oxide-aluminium seawater battery – developed by Saft – to achieve a higher level of performance. According to a Naval Group spokesperson: "The F21 is, in fact, the first torpedo designed indigenously for long-range engagement (in excess of 20 nautical miles). The weapon's endurance makes it possible to carry out longer and more complex missions than in the past,"

Specific enhancements for littoral operations include the addition of an improved hydrophone sonar array, as well as enhanced software and signal processing. The ability to collect large amounts of acoustic data and process it is essential for littoral operations due to the higher levels of noise and reverberations found in these areas. A highly sensitive multi-beam sonar array receiver that employs new waveforms will be able to locate and identify targets that are close together and differentiate between enemy targets, neutral shipping and clutter.

Thales has developed the acoustic head for the F21 in partnership with Naval Group, while Atlas Elektronik developed the power and propulsion system. The F21 also includes enhanced processing that allows basic decisions to be taken by the torpedo. This leaves the operator to focus on more important high-end tasks with an improved man-machine interface to ensure the right information is delivered at the right time to aid decision-making. "The performance of its sonar coupled with its intelligence gives it the ability to establish a true tactical situation. This tactical picture is also enhanced by information from the submarine's sensors, thanks to advanced integration with the combat system and the high data exchange rate offered by fibre optics," the Naval Group spokesperson explained.

Using fibre-optic technology is an important enhancement compared to the copper wires that were previously used to connect torpedoes to the submarine. Fibre-optic wires offer a higher data transfer rate so that the operator can receive information from the torpedo's sensors and control the weapon to manage complex scenarios. If the fibre-optic cable ends the torpedo moves into automated guidance mode. Often the operator will select the automated mode for the final attack onto a target.

Credit: Leonardo

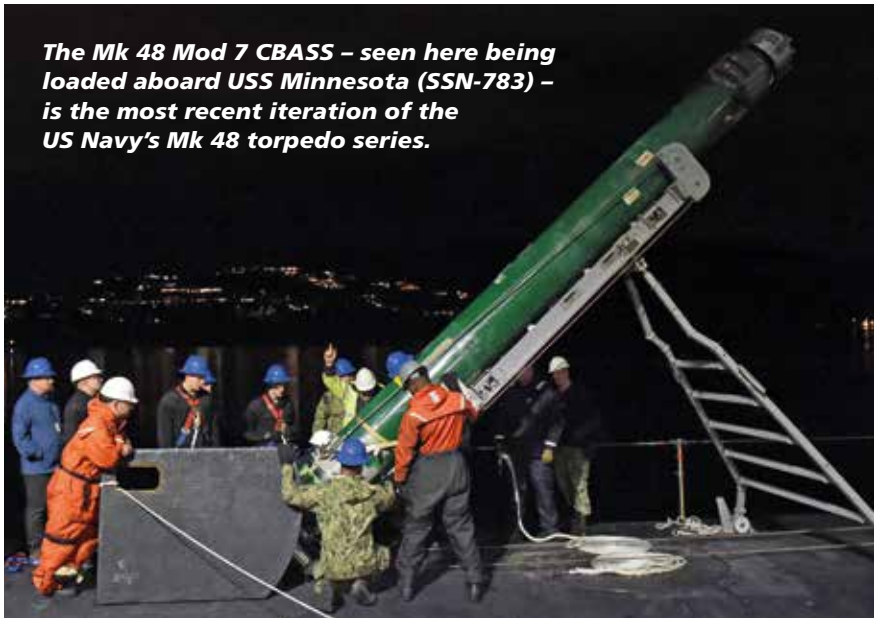
The Italian Navy's Black Shark Advanced (BSA) torpedo is an evolution of the export-focused WASS Black Shark torpedo, pictured here.

According to Naval Group, by the end of 2023 more than 100 sea trials of the F21 had been completed, including development and qualification trials performed by the French and Brazilian navies. "The torpedo has undergone full weapon qualification, following a strict process that includes land and sea trials," the Naval Group spokesperson said. "Qualification was granted in 2019, which also corresponds to the delivery of the first batch [of torpedoes] to the French Navy. The F21 is now qualified and integrated on all the French Navy's platforms (*Rubis* class, 'Barracuda' [*Suffren*] class and *Le Triomphant* class), as well as on the Brazilian 'Scorpène' class patrol submarines." Naval Group has assisted the local construction of four 'Scorpène' type *Riachuelo* class diesel-electric submarines for the Brazilian Navy. The F21 is also being offered to India, whose *Kalvari* class patrol submarines are also a variant of the 'Scorpène' design.

Black Shark Advanced and DM2A4 heavyweight torpedoes

Another new heavyweight torpedo is the Black Shark Advanced (BSA). This torpedo was developed by Leonardo's former Whitehead Alenia Sistemi Subacquei (WASS) subsidiary; subsequently restructured as the group's Underwater Armaments Systems (UAS) business unit prior to its sale to Fincantieri in May 2024. The company was awarded development contracts for the weapon in 2011 under Italy's 'Nuovo Siluro Pesante' (NSP) programme to replace the Italian Navy's ageing A184 Mod 3 torpedo. BSA has been widely described as an evolution of the export-focused WASS Black Shark torpedo – itself derived from the A184 – that incorporates further technological advantages.

BSA includes an IM warhead, fibre-optic wire guidance and silver oxide-aluminium battery technology. It is equipped with



The Mk 48 Mod 7 CBASS – seen here being loaded aboard USS Minnesota (SSN-783) – is the most recent iteration of the US Navy's Mk 48 torpedo series.

Credit: US Navy

an ASTRA (Advanced Sonar Transmitting and Receiving Architecture) acoustic head that provides up-to-date active and passive sensing capability. Test launches of BSA commenced in 2014 and the weapon has been ordered for Italian Type 212A Batch 2 and Type 212NFS submarines. Open source data suggests the torpedo has a similar speed and range to the F21.

The success of the original Black Shark torpedo in the international torpedo market is arguably second only to the SeaHake Mod 4; the export version of the German Navy's DM2A4. This was developed by Atlas Elektronik and entered service in 2004. The standard version of the SeaHake Mod 4 weighs around 1.5 tonnes and is 6.2 metres long but a modular silver oxide-zinc battery concept that permits varying operating characteristics means that these details vary depending on configuration. Key design elements include the use of fibre-optic cables and the incorporation of a conformal array sonar and advanced processing characteristics. Several hundred DM2A4/SeaHake Mod 4 torpedoes have been delivered to at least 10 navies.

Emerging heavyweight torpedoes

Elsewhere in Europe, Turkey's Roketsan has commenced deliveries of a new heavyweight torpedo known as AKYA following the achievement of initial operational capability in December 2023. The electrically-powered AKYA had a reported range of over 50 km and a top speed of more than 45 knots and incorporates an active/passive sonar head with an acoustic countermeasures capability and wake homing. It can utilise fibre-optic and autonomous homing. It will equip the Turkish Navy's existing Type 209 submarines, as well as the new Type 214 'Reis' class submarines that are starting to enter service.

Further afield, South Korean company LIG Nex1 has developed the new Tiger Shark heavyweight torpedo for use by the Republic of Korea Navy's patrol submarines, replacing existing weapons that include LIG Nex1's previous White Shark. Full operational capability was achieved in 2022 following completion of test trials earlier that year. Weighing around 1.7 tonnes, the Tiger Shark has similar performance characteristics to European heavyweight torpedoes; around double those of its predecessor. It can reportedly operate in depths as shallow as 2 m and as much as 600 m. Guidance is by fibre-optic cable and its active and passive sensors allow for a wake homing capability.

Older torpedoes upgraded

In addition to new and evolved torpedo designs, a number of existing weapons are being updated. Notably, the US Navy is continuing to upgrade its Mk 48 heavyweight torpedo, the initial iteration of which was first fielded in 1972. The latest model is the Mk 48 Mod 7 CBASS (Common Broadband Advanced Sonar System), which was developed in partnership with Australia. It achieved initial operational capability in 2006; an event which was followed by a fleet-wide roll-out of the update under a contract awarded to Lockheed Martin in 2011.

The Mk 48 Mod 7 CBASS torpedo has a weight of 1.7 tonnes and a length of 5.8 metres. In contrast to its battery-powered comparators in Europe and elsewhere, it is powered by an Otto-fuelled Swash-plate engine that gives a performance considerably over its official speed of 28 knots and range of 8 km. The CBASS upgrade included hardware and software processing upgrades intended to improve the effectiveness of the torpedo's target acquisition and attack capability against emerging threats. However, the Mod 7 keeps its copper wire guidance, therefore not benefiting from the advances provided through using fibre-optic cables.

Problems with the Mk48 torpedo were discussed in the 2023 annual report published by the US Navy's Director, Operational Test and Evaluation in February 2024, which stated that reliability levels have degraded below navy-defined requirements. Ongoing software updates – known as Advanced Processor Builds (APBs) – are being progressively provided to existing torpedoes. The latest is APB 5+, which is focussed on improving the interface between the torpedo and the submarine's combat management system. A further upgrade has been implemented to enhance torpedo capabilities in shallow water. APB 6 is in development and will focus on target detection and is set for delivery in US FY 2026. APB 6 will also support an upgraded sonar array that will be part of a future Mk 48 Mod 8 torpedo variant that will be delivered from FY 2028.

In the United Kingdom, BAE Systems is upgrading the British Royal Navy's gas-turbine powered Spearfish Mod 0 heavyweight torpedo to a new Mod 1 version. Under a contract awarded in 2014, BAE is enhancing the torpedo's software to improve threat and target modelling and increase lethality by analysing the underwater environment, assessing target strength and detecting and avoiding countermeasures. The Mod 1 upgrade will incorporate fibre-optic cables to increase bandwidth for data transfer and improve signal processing to identify targets in clutter. Deliveries are due to be completed by the end of 2024. Initial operating capability was declared in 2021, with first-of-class firings on existing submarine classes completed following sea acceptance testing aboard a *Vanguard* class strategic submarine during 2024.

Meanwhile Swedish defence company Saab is upgrading the Royal Swedish Navy's Torpedo 62 heavyweight torpedo under a SEK 485 million contract awarded in July 2020. The Swedish FMV procurement authority wants the Torpedo 62's life to be extended into the 2040s for use on the new *Blekinge* class (A26) patrol submarines. However, at the time of writing, Saab was not able to comment on the progress of the upgrade work.

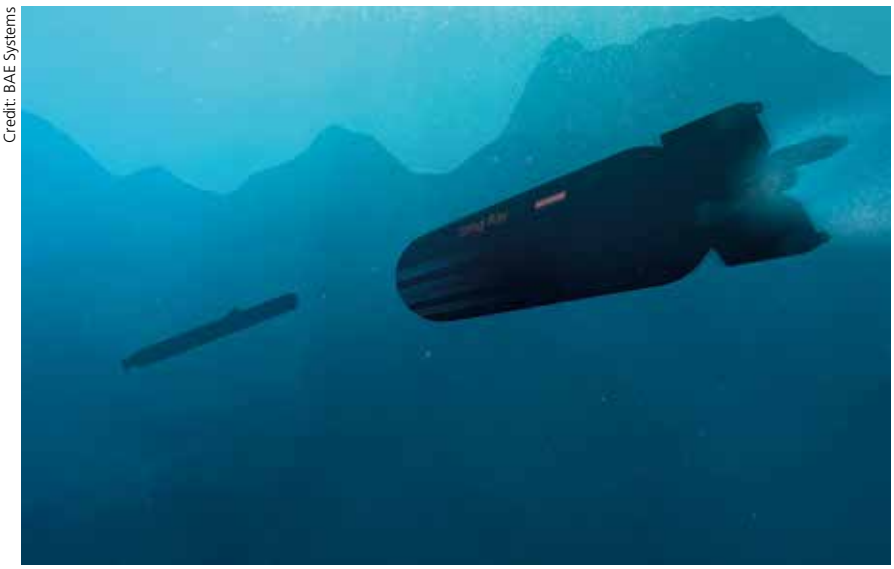
Credit: Saab

Deliveries of Torpedo 47 – also known as the Saab Lightweight Torpedo (SLWT) in export markets – to the Swedish Navy commenced in 2022.

Credit: US Navy

The US Navy's Mk 54 lightweight torpedo was first developed in the early 2000s but has subsequently been subject to ongoing improvement.

Credit: BAE Systems



A Sting Ray Mod 2 iteration of the Royal Navy's lightweight torpedo is currently under development.

SLWT enters the market

Turning to lightweight torpedoes, one of the most recently developed products is the Saab Lightweight Torpedo (SLWT), known in Swedish Navy service as the Torpedo 47. Saab was contracted to develop the weapon by the Swedish FMV procurement organisation in 2016 under its New Lightweight Torpedo (NLT) programme. According to Niclas Kolmodin, head of Saab's Underwater Systems business unit, the main design driver for the Torpedo 47 was for a torpedo that was suited to the waters of the Swedish archipelago and Baltic Sea "where the depths are relatively shallow with complex underwater topography and variable salinity making it challenging in terms of hydroacoustics when searching for a submarine." He added that submarines remain the "primary threat" in this domain and that Saab wanted to produce a new torpedo with improvements over the previous Torpedo 45. These include the capability to function in any complex coastal or shallow sea areas and be adaptable enough for deployment from a wide range of naval platforms from fast surface vessels through to helicopters and submarines.

The 3 m long Torpedo 47 is has a larger 400 mm diameter than the standard 324 mm that is common in NATO navies. Increasing speed was not a priority because it is difficult to find targets in a cluttered littoral when moving at more than 30 knots. Accordingly, the focus was on achieving additional time in the water – up to an hour – to conduct a submarine hunt. This is considerably longer than the endurance of most existing lightweight torpedoes.

Torpedo 47 is equipped with a digital passive/active homing system optimised for shallow and brackish waters, where less sophisticated systems would be blind. It has a bi-directional wire (galvanic or fibre optic) communication link for control and monitoring from the launch platform to maximise its overall effectiveness in targeting and pursuing an enemy submarine. Power comes from a lithium-based battery and an electronically controlled brushless DC motor in combination with a pump-jet used for propulsion. This can increase or decrease the speed depending on the duration needed in the water. "These propulsion aspects combined means it can travel through the water silently, making it much harder to detect and thereby delay any attempt to counter it," Kolmodin said, "If launched from a submarine, it is designed to swim out from the torpedo tube thereby removing the launch signature that comes with other torpedo designs and adds to its very quiet method of operation."

Deliveries of Torpedo 47 to the Royal Swedish Navy, where it will be used aboard both patrol submarines and corvettes, commenced in 2022. Finland is also acquiring the weapon, with acceptance firings from its *Hamina* class fast attack craft being undertaken in October 2023.

Lightweight torpedo modernisation

As is the case for heavyweight torpedoes, a number of lightweight weapons are currently subject to upgrades. For example, LIG Nex1 is undertaking research and development work on an improved version of the K745 Blue Shark lightweight torpedo under a contract from South Korea's DAPA procurement organisation that was awarded in November 2021. This work will include improving the torpedo's capability to detect and hit submarines, extending its range, and enhancing its ability to avoid anti-torpedo countermeasures. Completion of development work is scheduled for 2029 and should be followed by production orders to replace the existing variant, which has been in service with the Republic of Korea Navy since around 2005.

The US Navy's Mk 54 Mod 0 lightweight torpedo was developed in the early 2000s to replace and update older weapons. The Mk 54 has been subject to incremental hardware and software 'block' updates, whilst a Mk 54 Mod 1 variant – that includes the addition of upgraded sonar hardware, processing power and software – achieved initial operational capability in 2023. The Mod 1 uses APB 5 software from the Mk 48 heavyweight torpedo which was delivered in December 2021. Further improvements with APB 6 software are expected to begin testing in FY 2026. The will reduce operator workload and allow salvo firing, as well as providing better terminal phase homing.

A new Mk 54 Mod 2 Advanced Lightweight Torpedo (ALWT) is also under development that includes a stored chemical energy propulsion system (SCEPS), guidance and control system upgrades, and a new warhead. It will use APB 6 as baseline for its software. In water testing is due to start in FY2 025 with an initial operational capability expected during FY 2028.

In the United Kingdom, the Royal Navy has recently embarked on a mid-life upgrade of its Sting Ray Mod 1 lightweight torpedo, itself a development of the 1980s-era Sting Ray Mod 0. In September 2024, BAE Systems announced it had been contracted to design and develop the Sting Ray torpedo upgrade over a four-year assessment phase, which will include the construction of prototypes and in-water trials of what will become Sting Ray Mod 2. The intention is to extend the life of the weapon, ensure it can meet emerging threats, and reduce through-life sustainment costs.

Conclusion

The efforts being undertaken to build new heavyweight and lightweight torpedoes and the funding provided to enhance existing inventories of older torpedoes is indicative of the importance of anti-submarine operations to many navies. With more submarines now entering service across the globe and new technologies and designs allowing them to be quieter and stealthier, there is a need to modernise torpedo capabilities to confront them.

Penetrating the underwater domain is difficult. Unlike the surface and air domains – which are becoming more transparent due to the proliferation of uncrewed systems, sensors and data transfer capabilities – the underwater environment remains opaque and disconnected. The new torpedo capabilities that are now being delivered will go some way to help navies detect and counter submarines. However, much will depend on whether these systems and technologies can perform as anticipated in difficult environments.

High speed naval assets

Sidney E. Dean

A number of high-speed naval vessels currently in service are capable of speeds between 40 and 70 knots, significantly outpacing most surface combatants. Some high-speed vessels are specialised on performing particular mission profiles, while others are multi-mission craft. One characteristic that they all share is their relatively small size, with even the largest units being classified only as corvettes. A comparatively recent phenomenon has been the autonomous or semi-autonomous unmanned speed boats which are increasingly being deployed for armed reconnaissance or assault missions. This article examines a selection of in-service and proposed vessels of various categories.

Assault craft

SAAB CB90: One of the best known high-speed vessels is the Saab CB90 fast assault craft. More than 250 units are operated by the Swedish Navy and seven other nations worldwide. Ukraine's Holovne Upravlinnia Rozvidky (HUR, Directorate of Military Intelligence) became the newest operator in 2024, deploying the boats for reconnaissance and surveillance missions.

The current production variant is designated the CB90 NG ('next generation') or, in the Swedish Navy, the Docksta CB90 HSM. The first of 18 ordered units was delivered to the Swedish Navy in October 2019, where they are expected to serve beyond 2040. The CB90 NG is equipped with a new driveline and engine placement, optimising the boat's centre of gravity for increased stability and quieter operation. It also features new waterjets that contribute to its higher efficiency and speed. Saab cites a top speed of over 40 knots at maximum load, leading some observers to postulate a speed of around 45 knots with a lighter load. The combination of low silhouette, high speed and agility optimise the CB90 for covert approach. For assault or insertion missions the boat can drive up onto unprepared beaches or extend a ramp onto rocky coastlines to land or retrieve up to 18 fully equipped soldiers.

Weapon options to date include up to three large calibre machine guns and one Mk 19 grenade launcher, as well as naval mines and depth charges. The CB90 NG can also accommodate smaller missile systems including the Hellfire. The Swedish Navy also plans to add mortars, air-defence missiles and guns, and a new anti-ship missile (ASM) to be designated RBS 18 to the boat's modular arsenal.

Credit: Saab

The Swedish Navy's new Docksta CB90 HSM variant of the longstanding CB90 assault craft design.

'Jehu' class: The Finnish Navy acquired the first of 12 U-700 'Jehu' class assault craft in June 2015. The 20 metre long, 32 tonne boats are based on Marine Alutech's M18 Armoured Modular Craft (AMC). They serve as assault transports or combat support vessels, perform casualty evacuation missions, and conduct littoral surveillance patrols. The U-700 can transport 24 combat equipped soldiers in addition to its crew. Two 900 hp Scania DI 16 007 Diesel engines and two Rolls-Royce (now Kongsberg) 40A3 water jets, combined with a 1.1 metre draught, make the boats highly manoeuvrable in shallow coastal or archipelagic waters, and provide the boats with a sprint capability in

Credit: Finnish Navy

Finnish marines disembark from a 'Jehu' class assault craft.

excess of 40 knots. A stabilised 'Trackfire' remote weapon station (RWS) has equipment options that include 12.7 mm or 7.62 mm machine guns and a 40 mm automatic grenade launcher. It is augmented by hard points for two additional 12.7 mm weapons. The aluminium hull and composite superstructure offer ballistic protection, as well as resistance to chemical, biological, radiological and nuclear (CBRN) threats.
In 2022 Lithuania announced its intent to purchase two 'Jehu' class units for surveillance and security missions in the Curonian Lagoon. Deliveries are expected in 2025.

Coastal/littoral patrol and defence

***Skjold* class:** The Royal Norwegian Navy's 47.5 metre, 274 tonne Skjold class coastal defence corvette displays a strong combination of speed and firepower. Its cruising speed of 40 knots exceeds the maximum speed of most warships, while a 60 knot sprint speed facilitates interception of hostile or suspect vessels. Its arsenal includes a 76 mm Oto Super Rapid deck gun and eight Kongsberg Naval Strike Missiles (NSMs). The latter have a range in excess of 100 NM and are carried internally to preserve stealth. Man-portable Mistral air defence missiles and 12.7 mm machine guns provide additional defensive capabilities.
Developed in the 1990s by Umoe Mandal and entering operational service from 2010, the six active units are currently undergoing a service-life extension programme (SLEP) focussed on installation of new sensors and combat systems. Umoe Mandal and Kongsberg are collaborating on the SLEP under contracts awarded in 2022. Sensor upgrades include introduction of the Scanter 6000 radars with an all-weather capability >to track small targets. According to Kongsberg, the combat system upgrades consist primarily of a new combat management system based on that installed in the *Fridtjof Nansen* class frigates, as well as improved tactical data link capabilities.

K5 Kraken: The K5 Kraken gunship – which is currently being developed by UK-based Kraken Technology Group – is also intended to combine speed and combat power, albeit in a much smaller footprint than the corvette-sized *Skjolds*. According to Kraken, the K5 has been designed from the keel up as a fully integrated weapons platform for littoral environments, utilising input from former British and US Special Operations personnel. Its powertrain will consist of twin inboard Diesel engines with surface drives, enabling a fully-laden top speed of 65 knots. Alternatively, a cruising speed of 50 knots will permit a 400 NM operating range that can be further increased through extended-range fuel tanks. The 15 metre boat will also be heavily armed for its size. Its proposed arsenal includes two 7.62 mm mini-guns, a roof-mounted Seahawk compact weapon station with a 30 mm automatic cannon, four Thales Lightweight Multi-role Missiles, four aft-launched Leonardo Black Scorpion mini-torpedoes, and tube-launched UAVs/loitering missiles. An interchangeable aft deck will be able to accommodate various payloads up to 1,500 kg that could include unmanned surface or underwater vehicles.
The K5's mission spectrum includes strike missions against coastal or offshore targets, interdiction and engagement of surface vessels, and defence of offshore and coastal infrastructure or harbours. The gunships will also be able to be carried and launched at sea by large surface vessels equipped with a stern ramp or dock. This permits the K5 to provide force security for surface ships and expeditionary task groups in littoral waters and chokepoints; intercepting fast attack craft, manned or unmanned boat swarms, subsurface and aerial threats. The K5 will have a four-person crew and be able to operate independently or as part of a swarm.

Credit: Kraken Technology Group

A concept image of the Kraken K5 gunship.

Credit: Royal Norwegian Navy

KMN Storm, a Royal Norwegian Navy Skjold class corvette, practices coastal defence with British Wildcat helicopters in April 2024 during the course of Exercise Tamber Shield.

Special Operations vessels

The US Navy's Special Operations forces currently operate several fast boat types. These include the Combatant Craft Assault (CC-A), Combatant Craft Medium (CC-M), and Combatant Craft Heavy (CC-H). Whilst many aspects of these streamlined vessels remain classified, the military and the builders have released some important details. Their size and performance parameters vary but all three types are optimised for high-speeds, manoeuvrability, and suitability for both open water and shallow water operations. They conduct a variety of missions including covert transport and support of Special Operations personnel; reconnaissance, surveillance and intelligence missions; counter-terrorism; fire support; and armed interdiction. They are suitable for medium-to-high threat environments. All can operate from ships with a well-deck, while the CC-A can also be airdropped into an operating zone via a C-17 transport aircraft.

Combatant Craft Assault: The smallest of these vessels, the 12.5 metre mono-hull CC-A, achieved full operating capability in 2017 with a full complement of 32 units. The boats continue to be built by United States Marine, Inc. (USMI) under a 2020 contract to replace older units with upgraded versions. Sensors include a mast-mounted surface search radar and a Combatant Craft Forward Looking Infrared II (CCFLIR II) system incorporating infrared, day and low light video cameras as well as a laser range finder and pointer. It carries a crew of four plus eight operators. Civilian sources dealing with Special Operations widely report that the CC-A has a top speed around 52 knots. While that speed has not been confirmed officially, the CC-A exhibits many design similarities with the 13 metre High Speed Interceptor Craft (HSIC) that is also produced by USMI. The HSIC is powered by twin Cummins QSC 8.3 marine diesel engines with outdrives and is credited with a top speed of over 55 knots by its builder. It incorporates a deep-vee mono-hull that is constructed from high-tech composites and provides and offers shock mitigating seating for its 12 occupants.

Credit: US Navy

A Combatant Craft Assault exercises in Alaskan waters during Operation Polar Dagger 2023.

Combatant Craft Medium: The 18.5 metre CC-M was designed and constructed by Oregon-based Vigor Industrial LLC. US Special Operations Command (SOCOM) operates a total of 31 of the craft. The boat can accommodate 19 operators plus its four person crew. A CCFLIR II is mounted atop the cabin. The rear deck is sized to accommodate a Combat Rubber Raiding Craft (CRRC) whilst installation of a universal launch and recovery system for future payloads is planned. Two medium or heavy machine guns can be mounted at the aft corners of the deck. SOCOM has confirmed plans to add precision strike loitering munitions. An eight round pop-up launcher, which appears to retract flush into the deck when not in use, is currently being evaluated on one operational CC-M. According to US Navy Commander Marty Burns, surface systems program manager at SOCOM, testing should conclude by early Fiscal Year 2025 and will be followed by a decision regarding installation across the CC-M fleet. The CC-Ms are equipped with two MTU 8V2000 M94, 1,250 hp engines. Vigor confirms a top speed of 52 knots and a cruise speed of 40 knots, with an operating range of 600 NM.

Credit: US Navy

A Combatant Craft Medium pictured off Guam in 2021.

Combatant Craft Heavy: The 25 metre CC-H is also known as the SEALION (SEAL Insertion, Observation and Neutralization). The low-profile, spearhead-shaped boats are the stealthiest members of the combatant craft family; they are capable of semi-submersion to avoid detection during surveillance missions. In addition, their sensors and weapons are retractable to minimise the radar signature. The first three CC-Hs were designed and built by Vigor; two of these were originally built as demonstrators but subsequently accepted as operational craft in 2014. The third unit, which entered service in 2021, was the first purpose built operational craft. The US Navy contracted a fourth vessel from Fincantieri in April 2024 and there is an option for a fifth unit that SOCOM seems determined to exercise. The Pentagon's FY 2025 budget request cites a 40 knot speed and a 400 NM range, as well as a capacity for 12 passengers and a seven person crew. Non-official sources frequently cite higher sprint speeds and range. While these cannot be verified, it would be logical to assume that the US military is publicly downplaying capabilities to mislead adversaries.

High speed naval transports

Expeditionary Fast Transport: Catamaran hulls are particularly suited for high speed transport vessels such as the *Spearhead* class (T-EPF-1) Expeditionary Fast Transport units built by Austal USA for the US Navy. According to Austal, the 103 metre long vessels can achieve 43 knots speed without a payload, or 40 knots fully loaded. They have a 1,200 NM range at a 35 knot cruising speed.

The class's fifteenth unit, USNS *Point Loma* (EPF-15) was christened in August 2024. This vessel is the second unit being built to the EPF Flight II configuration, which is equipped with enhanced medical facilities that include primary surgery, an intensive care unit, ward beds, and limited diagnostic facilities. The catamaran's inherent stability permits surgery to be conducted while underway.

The 13 Flight I EPF vessels (originally designated as the Joint High Speed Transport) are configured for rapid delivery of personnel, supplies or vehicles. Airline style seating for 312 troops and berthing for 104 troops is provided (in addition to accommodation for the 41 person crew). Additionally the mission deck provides more than 1,800 m² space for palettes, ISO containers or vehicles up to the size

Credit: Vigor

A Special Operations Combatant Craft Heavy.

Credit: US Navy

The Expeditionary Fast Transport USNS Burlington (T-EPF-10) pictured pier-side in Honduras during a deployment as part of Operation Continuing Promise 2024.

of main battle tanks. Complete company-level units can be quickly relocated together with their equipment in one sortie, and debark combat ready. Alternately the mission deck can be used as a mission support platform for mine countermeasures, unmanned systems operations, or special operations forces.

Ghostworks M90: At a smaller scale, the developmental, 28 metre long Ghostworks M90 offers similar versatility. Developed by the relatively new (2022) Michigan-based Ghostworks Marine, the design incorporates a so-called 'M-Hull' configuration to provide enhanced stability at all sea states. Depending on configuration, the vessel will be able to achieve 50 to 55 knot speeds, with a 700 to 900 NM range carrying payloads of up to 35 tonnes. In addition to acting as a fast transport, the M90 will also be able to function as a mothership/support ship. A multi-purpose reconfigurable launch bay can accommodate 11 metre RHIBS, as well as small uncrewed systems. A basic three to five person crew can be augmented by up to 15 mission specialists, with three-day endurance at sea.

The unmanned future

MARTAC Devil Ray T38: In recent years, high speed unmanned surface vessels (USVs) have been subjected to ongoing tests of their suitability as surveillance and reconnaissance assets. Moreover, attention is now turning to the utility of armed patrol and interceptor USVs. Among the highest performers is the 11 metre long MARTAC Devil Ray T38. The USV is developed by Maritime Tactical Systems of Florida, which cites a burst speed capability ranging between 70 and 100 knots dependent on powertrain option and payload. The craft's fastest documented run took place in July 2021, when the T38 transited the Florida Straits from Palm Beach to the Bahamas in only 53 minutes. The average cruise speed was clocked at 61 knots, with a fast segment recorded at 71.5 knots. The round trip transit was conducted under full autonomy, with an average tracking accuracy of +/- 1.3 degrees and a steady state cross track error of +/-3 m, all the while avoiding shipping traffic.
The Devil Ray's payload capacity of 1,800 kg provides for a variety of sensor and weapon options. Operational scenarios include unarmed or armed surveillance and reconnaissance, electronic warfare and signals intelligence, interdiction of hostile or suspect vessels, and armed force protection missions for coastal, offshore, or floating assets. For the latter scenario, the T38 can be carried aboard larger ships and deployed via well deck or winch to escort ships through chokepoints or littoral waters. The armed T38 can operate singly or in swarms, autonomously or under remote control, to intercept fast attack craft and boat swarms well in advance of the protected ship or asset.
The US Navy has included the T38 in its extensive testing of unmanned systems as part of Task Force 59 in the Central Command area of responsibility and, subsequently, in other regions. The Devil Ray can be equipped with the Kongsberg Protector RWS and armed with machine guns or grenade weapons. As part of the TF 59 evaluation, the T38 also demonstrated the capacity to deploy with an aft-mounted Lethal Miniature Aerial Missile System, firing Switchblade 300 loitering missiles. This was credited with destroying multiple surface targets during an October 2023 test in the Persian Gulf.

Magura V5 – and Beyond: High-speed USVs are also being developed to serve as a form of loitering munition in their own right. The Ukrainian company SpecialTechnoExport (STE) has developed the Magura (Maritime Autonomous Guard Unmanned Robotic Apparatus) V5 as a multi-mission USV that has become best known for its successful attack runs against Russian ships. The 5.5 metre long, highly manoeuvrable Magura operates in fully autonomous mode for many missions, following waypoints and avoiding obstacles by using advanced algorithms. With extended endurance capabilities, the V5 can remain on station for extended periods to await targets. On the other hand, the USV's 450 NM range permits dedicated attack runs against distant targets. In these scenarios, a human operator assumes control via satellite link for the final mission phase, using drone-mounted video systems to guide targeting. Mounted on jet skis, the USV achieves attack speeds of 42 knots. Operated by Ukraine's HUR, V5 drones – usually operating as swarms – have sunk at least five Russian warships with their 250 kg explosive payloads.
As secure wireless control technology and artificial intelligence progress, direct action offensive operations by USVs will become more commonplace. High speed, agile platforms will be the logical choice for such missions. The Ukraine War and Kiev's pioneering deployment of technology such as the Magura V5 can be seen as a pivotal point in this course of development. ■

Credit: US Navy

A MARTAC Devil Ray T38 escorts a Littoral Combat Ship during evaluation in the Middle East.

Mine countermeasures vessels

Sidney E. Dean

Several Western navies are modernising their mine countermeasures capabilities with new, specialised vessels.

Naval mine warfare remains a potent threat in the 21st century. The mine countermeasures (MCM) vessels of many nations are ageing and – in some cases – are in urgent need of replacement. The need to introduce new MCM vessels (MCMVs) is not, however, solely based on aging hulls. MCM concepts of operation are changing. The introduction of new unmanned and autonomous mine-hunting and mine-neutralising systems requires that future MCMVs need to be configured to store, operate and maintain these off-board systems, whether they are aerial, surface or underwater in nature. In some cases, fleets are also planning to use their MCMVs for secondary missions utilising the same capability set, such as the inspection and security of critical underwater infrastructure (CUI) including pipelines and communications cables. As recent examples demonstrate, modernising MCM capabilities requires careful planning in order to avoid setbacks caused by immature technology or exaggerated expectations. Various approaches to MCMV design are being taken.

Credit: US Navy

The Independence class littoral combat ship USS Savannah (LCS-28) sails in the Pacific Ocean during a mine countermeasures training exercise.

Credit: US Navy

An unmanned surface vehicle is craned aboard the Independence variant littoral combat ship USS Canberra (LCS-30), as a part of the first embarkation of the MCM mission package in April 2024.

United States: Littoral Combat Ship

The US Navy originally planned a modular approach to replacing the *Avenger* (MCM-1) class MCMVs that were introduced in the late 1980s. Both classes of the multi-mission Littoral Combat Ship (LCS) type were to alternate between MCM, anti-submarine warfare (ASW) and surface warfare by exchanging specialised mission modules depending on the task at hand. This approach was ultimately abandoned. Instead, 15 *Independence* (LCS-2) class LCS variants will now be permanently dedicated to the MCM mission. Their trimaran hull provides stability during stationary MCM operations whilst a 40 knot top speed and 4,300 NM range enhance responsiveness. A 57 mm deck gun and CIWS provide self-defence capability. Berthing is available for 35 MCM mission specialists. A 1,400 m² reconfigurable mission bay can accommodate mission systems including unmanned underwater vehicles (UUV), unmanned surface vessels (USV), modular sonar and sensor packages, as well as control consoles and maintenance equipment for the MCM components.

Following years of delayed development, the US Navy has assembled a functional expeditionary MCM Mission Package (MCM MP). This consists of various integrated sensors and mine neutralisation systems. These will be deployed by manned MH-60S helicopters and autonomous, 11 metre USVs to perform the full MCM spectrum of hunt, neutralise and sweep. In contrast to the wooden-hulled, fibreglass-coated *Avenger* class, which enters the minefield, the LCS will maintain a standoff range of at least 10 miles, deploying aircraft and unmanned systems with no risk to human operators or the vessel. Command and control of the individual MCM systems will be executed from the ship, with multiple systems able to be directed simultaneously. In this way the LCS acts as a 'mothership' for the deploy-

able minehunting and mine-neutralisation subsystems which form the actual MCM capability. "We don't want to put the man in the minefield, we want to put the sensor in the minefield," said Brig.Gen Marcus Annibale, director of expeditionary warfare and resource sponsor for mine warfare, in May 2024.

The MCM MP achieved initial operating capability (IOC) in May 2023. The first operational MCM MP embarked in USS *Canberra* (LCS-30) in April 2024. The crew is currently training to operate and maintain all components as part of their predeployment workup. Continuous forward deployments of MCM MP-equipped littoral combat ships to Bahrain and Japan are due to begin in 2025 and 2027, respectively.

Credit: Crown Copyright 2023

The United Kingdom's RFA Stirling Castle exercising with autonomous minehunting boats.

United Kingdom: RFA *Stirling Castle*

The United Kingdom's Mine Hunting Capability (MHC) programme aims to completely transition the MCM mission to unmanned systems by 2033. However, the autonomous boats, underwater vehicles and towed sensors executing the immediate MCM mission will still need a human-staffed mothership as a base of operation. Accordingly, the British Royal Navy is planning to acquire four of these vessels to replace its legacy MCMVs. In early 2023 the UK purchased a 97 metre long, 5,800 tonne offshore support vessel (OSV) as its first replacement platform. The ship, built in 2013 to strictly commercial standards, will be operated by the civilian-manned Royal Fleet Auxiliary (RFA) and has been renamed RFA *Stirling Castle*. It formally joined the fleet in April 2024.

This approach has two distinct advantages over developing and acquiring clean-sheet MCMVs. One is cost. The purchase of RFA *Stirling Castle* cost GBP 40 million; much lower than for a LCS or a dedicated MCMV. The other is speed of acquisition. The Royal Navy's new vessel was on the market for immediate acquisition, and took little more than a year to be declared mission ready; much less time than new design and construction.

However, having gained experience of evaluating and operating the RFA *Stirling Castle*, the RN's leadership is firmly advocating purpose built survivable but non-complex warships rather than commercial-design auxiliaries to fulfil the remainder of its MCMV requirement. Primary arguments in favour of a bespoke design include its higher survivability level and greater damage control capabilities; its organic military communication, command and control systems and sensors; and its more capable self-defence systems. Additional concerns centre on the expectation that the unmanned MCM systems currently under development will be larger, more sophisticated, and therefore more demanding than those currently in operation or in testing. RFA *Stirling Castle*'s 600 m² working deck is already considered too small for these future MCM systems. The ship's 10 tonne capacity crane– currently the ship's only launch and recovery system (LARS) – is another inadequacy given the expectation that future MCM operations will require the simultaneous launch of multiple off-board systems (including USVs that will likely be larger and heavier than those currently in service or testing).

As it stands today, the MHC program is divided into three phases, with the ongoing Block 1 centred on *Stirling Castle* and new autonomous minehunting USVs. Block 2 is to be incrementally delivered beginning in 2026. The RN hopes this will include three MCMV motherships designed and built to military standards. Block 3 will be initiated circa 2034, with requirements yet to be developed. The actual course of the MHC programme will inevitably depend on future funding. With other, high-profile acquisition programmes underway, the MCM mission could ultimately be relegated to a lower priority on the assumption that converted OSVs will suffice.

Belgium and the Netherlands: rMCM

The furthest advanced European MCM programme – titled rMCM – is delivering six replacement MCMVs (rMCM) to each of the Belgian and Royal Netherlands (RNLN) navies as successors to the aging 'Tripartite' class minehunters built under a previous collaborative project that also included France. The Belgian ships are designated the 'City' Class, while the RNLN units form the *Vlissingen* class. The acquisition contract was awarded in 2019 to Belgium Naval & Robotics, a consortium of Naval Group and ECA Group (now Exail). Naval Group's

Credit: Netherlands Ministry of Defence

A conceptual image of the operational Belgo-Dutch rMCM system.

responsibilities include ship design, system integration and testing, while Exail supplies the robotic systems which will operate from the vessels. Kership, a joint venture between Naval Group and Piriou, is the actual builder of the MCMVs as a subcontractor.

The 82 metre MCMVs displace 2,800 tonnes and can accommodate 63 people, including both the ship's crew and mission specialists. Their force protection capabilities include a 40 mm Bofors gun capable of engaging surface and airborne targets; cybersecurity has also been designed in from the beginning. The ships feature very low acoustic, electrical and magnetic signatures, and are built to withstand mine detonation. While this could permit their entering a minefield, the actual concept of operations calls for the vessels to function as motherships. As such, minehunting, neutralisation and sweeping will be conducted at standoff range by a suite of robotic systems including 12 metre, 18 tonne USVs, UUVs, remotely operated vehicles (ROVs) and a UMS Skeldar V200 UAV. LARS capabilities include a 15 tonne and a 3 tonne crane as well as two side gantries with floating docks for USVs and manned boats.

Keel-laying of the programme's first vessel – the Belgian Oostende – took place in November 2021, with launch in March 2023 preceding the commencement of builder's trials in July 2024. She was followed into the water by the Dutch first-in class – HMNLS *Vlissingen* – in October 2023. Commissioning of each partner navy's lead ship is planned for 2025, with subsequent units entering service yearly through to 2030.

In October 2022 France confirmed that it planned to base its new 'bâtiments de guerre des mines' (BGDM) on the rMCM mothership design. Since France plans to utilise a different family of robotic vehicles, some design adjustments will need to be made. Plans call for a total of six BGDMs to be in service by 2035.

Italy: New Generation Minehunter/Coastal (NGM/C)

The Italian Navy is pursuing a dual-capable vessel for MCM and coastal seabed surveillance/CUI protection. The contract for the first five NGM/C units was awarded in July 2024 to a partnership of Intermarine (which will design and build the vessel) and Leonardo (which will provide mission systems). The first vessel is expected to enter service in 2028. The contract includes an option for additional ships.

The 2024 contract award was preceded by a three year preliminary risk reduction study and project definition phase. According to the Italian Ministry of Defence, the New Generation Minehunters will feature highly integrated and automated mission systems, and represent one of the most technologically advanced MCM concepts in the world. The SADOC 4 multi-domain command and control system – including integrated management of unmanned vehicles – will be organic to the platform. Sensors will include advanced radar and electro-optical systems as well as broadband sonar with mine detection and classification capabilities. The shock resistant fibreglass hull will have a low magnetic and acoustic signature.

While the operating concept calls for off-board autonomous assets to act as force multipliers, the ships will be configured to operate inside the minefield. "Maritime unmanned systems will be the future, taking the man out of the minefield," said Rear Admiral Gianguido Manganaro, head of the Italian Navy's MCM forces command MARICODRAG, in June 2023. "However the Italian Navy believes we are still in a transition phase where the legacy capability cannot be completely abandoned and lost. [We are] looking to a concept of operations based on a very modern and flexible MCM platform able to safely approach a minefield and deploy unmanned system wherever and whenever is necessary". He added, 'In our job we do not know when we enter a minefield, therefore the new MCMV will have to feature the same shock resistance and underwater low signature of legacy MCMVs ...making a massive use on unmanned systems in a multi-domain environment."

The initial tranche of five vessels will be 63 metres long with a displacement of around 1,300 tonnes. The Italian Navy's current planning also calls for procuring larger, expeditionary MCMVs once the five coastal MCMVs are delivered. These vessels would be capable of extended long-range deployments in support of the blue-water fleet or allied operations. They would likely be larger, in the 80 metre range, to enhance endurance and to accommodate a greater number or variety of mission systems including autonomous systems, (and the associated larger, specialist crews). Specific timelines for the second tranche of the NGM family have not yet been published, although the overall requirement for both coastal and expeditionary MCMVs has been provisionally pegged at 12 units.

Other selected MCM modernisation initiatives

While some nations are putting their current MCMVs through upgrade or service-life extension programmes, a few others are also acquiring new vessels using various approaches.

Finland: In February 2022 the Finnish armed forces issued a tender for new MCMVs to replace the nation's 1970s-era 20 tonne *Kiiski* class minesweepers. The new MCMVs will feature crew accommodation but will also be configured for optional autonomous or remotely-controlled operation. They will be outfitted with new integrated systems capable of influence sweeping for acoustic, magnetic, and electric mines as well as legacy equipment (salvaged from retiring vessels) for mechanical sweeping of contact mines. Given the specific operating environment of Finland's coastal waterways, the requirement remains for small vessels of up to 24 metres in length. According to the Finnish Ministry of Defence, implementation of the acquisition has been postponed due to budgetary constraints. While the first round of negotiations with industry was originally planned for summer of 2022, procurement is now slated to continue in 2026 when a new call for tenders will include more detailed criteria.

Credit: Swedish Ministry of Defence

The Finnish Kataanpää class Minesweeper FNS Vahterpää exercising with the Swedish Navy.

The new MCMVs are expected to conduct lower-end MCM operations, leaving more complex operations to the 52 metre, 650 tonne *Kataanpää* class. Derived from the Italian Navy's Lerici class, they were delivered by Intermarine from 2012 to 2016 and are likely to serve into the 2040s. These larger vessels have hull-mounted sensors and deploy autonomous underwater vehicles and remotely operated vehicles, enabling them to operate from within and outside the mined zone. They are capable of operating in ice.

Poland: The Polish Navy is taking a traditional approach, expanding its MCM capabilities by acquiring three additional 'Kormoran II' class ships under a 2022 contract with Remontowa Shipbuilding. The navy already operates three ships of the class, which were commissioned between 2017 and 2023. The new vessels are to be delivered between 2026 and 2027.

The 58.5 metre, 830 tonne displacement 'Kormoran IIs' are Poland's most modern MCMVs. They feature non-magnetic steel hulls rather than fibreglass or composite hulls; this has the advantage of lower cost and greater resistance to fire. The hull and superstructure are designed to reduce radar signature as well. A bow thruster enhances manoeuvrability, enhancing safety when transiting mined waters. Self-defence capabilities include a 35 mm Oerlikon gun, Grom anti-aircraft missiles, and three machine gun mounts.

MCM operations are conducted via the state-of-the-art Ship Combat Tactical-Minehunter (SCOT-M) combat management system developed at the Maritime Technology Centre of the University of Szczecin. Mission systems include a hull-mounted SHL-101/TM sonar, as well as deployable Kongsberg Hugin 1000 AUVs, Teledyne Marine Gavia AUVs with side-scan sonar, and Kraken Robotics Katfish-180 Synthetic Aperture Sonar towfish. Mine destruction can be carried out by divers, or by deploying ROVs and self-propelled explosives. An on-board hyperbaric chamber is carried to support EOD divers.

Australia: Rather than pursue a clean-sheet, dedicated MCMV design or rely on a converted commercial platform, Australia had seemingly chosen a middle path. In 2021 the government announced that the new MCMVs to be procured under the SEA 1905 programme (Tranche 2) would be derived from the Royal Australian Navy's (RAN) new *Arafura* class offshore patrol vessels (OPV)s; the same derivative platform would also serve for hydrographic missions. The 80-metre, 1700 tonne OPV's 4,000 NM range would serve well in the expansive waters surrounding the nation. However, the truncation of the *Arafura* programme – already declared a 'project of concern' in October 2023 following serious delays – as a result of the country's 2024 Surface Fleet Review (SFR) and subsequent cancellation of SEA 1905 has left the future direction of travel unclear. The remaining *Arafura* class OPVs have, however, been left looking for a role as a result of the SFR and it is not inconceivable they could yet be adapted for MCM mothership duties in due course.

Credit: Australian Ministry of Defence

The lead Arafura class OPV at Osborne Naval Shipyard, South Australia. It is a matter of speculation as to whether the design will ever serve in the MCM mothership role.

Advantage unmanned

While some navies continue to plan for all scenarios by procuring MCMVs capable of entering the minefield, almost all services are placing the primary emphasis on remotely controlled or autonomous minehunting, neutralisation and sweeping systems. This has advantages beyond risk reduction to human operators. Unmanned boats can move more quickly, and a single mothership can deploy multiple boats or UUVs simultaneously, potentially clearing a minefield in less time. The modular character of the unmanned MCM systems permits their deployment from a variety of vessels or even from shore, permitting nations to adapt their MCM strategy to national requirements and budgets, or to temporarily operate from vessels of opportunity if no MCMV is available. Overall, dedicated MCMVs – with hull mounted sensors, optimised LARS, and organic command and control centres – remain the best choice as platforms for deploying these smaller MCM systems. Given current developments in artificial intelligence and the trend toward autonomous aerial, ground and sea systems, the question now becomes: when will the first optionally manned, full-sized mine-warfare mothership be developed? ■

Credit: Remontowa Shipbuilding

ORP Jaskółka, the fourth Kormoran II type MCM, was launched on 26 June 2024 at the Remontowa Shipyard in Gdansk.

Sustaining the fleet: current logistic support ship acquisitions

Conrad Waters

Having been largely neglected during the post-Cold War era, the procurement of logistic support ships has undergone a resurgence in recent years. The reasons for this market upsurge are many and varied, including the life-expiry of existing ships, the desirability of meeting enhanced environmental standards, and revised operational concepts that place greater demands on maritime logistic support. The vessels now in the course of construction and delivery are typically a generation-removed from those in existing support ship flotillas, often bringing significant technological evolution. This article reviews some of the main programmes currently underway.

United States

The United States is currently in the course of undertaking the world's largest logistic support ship acquisition programme. It has a requirement for 20 new fleet replenishment oilers, largely to replace the existing vessels of the ageing *Henry J. Kaiser* (T-AO-187) class. In contrast to many other fleets, the US Navy mostly operates distinct logistic support ship classes focused primarily on either liquid (fuel and potable water) or solid (food, ammunition and general stores) replenishment requirements, albeit with a capacity to provide a range of consumables of both types. This approach is likely driven by the heavy demands associated with supporting the navy's carrier strike groups.

The current oiler programme originated more than a decade ago as the Future Fleet Replenishment Ship (T-AO-X) project. After conclusion of design studies and a competitive procurement process, General Dynamics NASSCO was awarded a 'bulk buy' design and production contract for the first six ships of what became the *John Lewis* (T-AO-205) class in June 2016. This involved a firm contract for the lead vessel and options for the other five units, all of which have subsequently been exercised. A further three ships were ordered from the shipyard in 2022 and 2023. A further bulk buy announced in September 2024 encompasses an additional eight units, taking production to a total of 17 out of the 20 planned vessels if relevant congressional approvals are forthcoming. To date, the first three members of the class have been delivered.

Credit: General Dynamics NASSCO

The third John Lewis class fleet replenishment oiler, Earl Warren (T-AO-207), pictured during construction by General Dynamics NASSCO. The photo shows the twin skeg arrangement, with two shaft-lines and twin rudders, that is increasingly common in modern replenishment vessel design.

Displacing nearly 50,000 tonnes when fully loaded, the *John Lewis* class oilers are able to carry 162,000 barrels of fuel and 200 tonnes of potable water. There is additional capacity for dry and refrigerated stores. A total of five refuelling stations – three to port and two to starboard – are supplemented by a stern refuelling position, two stations for transferring solid cargo and two cargo handling cranes. Provision of a helicopter deck allows a vertical replenishment (VERTREP) capability. Most defensive capabilities are provided on a 'fitted for but not with' basis.

The *John Lewis* class was deliberately configured to reduce project risk by avoiding the specification of new technologies. Despite this, the ships reflect modern design practices that include the use of a double hull in line with environmental standards for commercial tankers. Their hull form also incorporates a twin skeg arrangement, with two shaft-lines and twin rudders assisting manoeuvrability and reliability during potentially hazardous replenishment operations. The main propulsion system utilises two 14.4 MW Fairbanks Morse MAN 12V

48/60 CR main diesels linked to the shafts by reduction gearing. A power take-off/power take-in (PTO/PTI) capability provides additional operating flexibility.

In common with many other US Navy projects, the oiler programme is proving expensive to implement. The lead ship cost USD 716 million when delivered in 2022; USD 76 million more than originally envisaged. The latest eight ship block buy has a reported cost of USD 6.75 billion (just over USD 840 million per unit). Moreover, the implications of the navy's Distributed Maritime Operations (DMO) concept are putting upward pressure on logistic support requirements. A new T-AOL 'Light Replenishment Oiler' is therefore now under development to provide a cheaper vessel to supplement the T-AO-205 design. It is hoped that the first of these will be authorised during FY2027 at a cost of around USD 450 million; more than three times the initial estimate. A programme encompassing 13 of these ships is currently envisaged.

Credit: Fincantieri

The Italian Navy's second Vulcano class logistic support ship ITS Atlante pictured ahead of her launch on 18 May 2024.

France & Italy

Turning to Europe, the continent's most significant logistic support ship programme involves the acquisition of four vessels each by France and Italy to a broadly common Italian Fincantieri design. Their construction has its origins in the order for the Italian Navy's logistic support ship ITS *Vulcano*; one of a number of vessels that were authorised as part of a programme of fleet renewal under the so-called 'Naval Law' of 2014. Commissioned in March 2021 after delays caused by an onboard fire and the subsequent Covid-19 pandemic, she is being followed by a second vessel – *Atlante* – ordered in December that year. The two additional units are still in the planning phase. The lead ship was integrated at Fincantieri's Muggiano shipyard near La Spezia from sections fabricated at nearby Riva Trigoso and at Castellammare di Stabia near Naples. However, the last-mentioned facility will take sole responsibility for the other Italian Navy ships. Together, the *Vulcano* class will replace three *Stromboli* and *Etna* class support vessels. The final cost of *Vulcano* was EUR 375 million, whilst the order for her sister Atlante was valued at EUR 410 million.

The selection of the *Vulcano* design to meet France's FLOTLOG requirement to replace its Durance class fleet replenishment oilers can be traced to Fincantieri's ultimately abortive plans to acquire the Chantiers de l'Atlantique shipyard at Saint-Nazaire, where the new vessels were to be assembled. The decision to adapt the Italian design to French requirements replaced previous proposals based on a Naval Group logistic support ship concept known as BRAVE. An order for four units that are officially designated 'bâtiments ravitailleurs de forces' (BRFs) was placed in January 2019 at a reported cost of EUR 1.7 billion. Although Naval Group's design was not selected for construction, they form part of the winning consortium with an important systems-integration role. Assembly of all four ships will take place at Chantiers de l'Atlantique from sections constructed at that yard and at Castellammare di Stabia. The lead ship, FS *Jacques Chevallier*, was officially delivered in July 2023 after an extensive series of trials. The second and third vessels are presently at various stages of construction.

In contrast to US Navy practice, the *Vulcano* class and their French derivatives are true multi-role logistic support ships with a relatively greater emphasis on carrying ammunition and other dry stores than the *John Lewis* class. There is also extensive provision for repair and maintenance activities, whilst a fully-equipped (NATO 'Role 2') hospital is incorporated in line with a post-Cold War 'dual use' ethos supporting humanitarian and crisis response activities. Displacing around 27,000 tonnes at full load, the Italian variants can reportedly carry around 14,500 m³ of liquids within their double hulls. This is supplemented by some 220 tonnes of ammunition, additional other solid stores, and eight ISO 20 containers. Two replenishment at sea (RAS) stations for liquid and solid stores are located to both port and starboard, with a stern refuelling station, two cranes and VERTREP providing additional replenishment options. A combined-diesel electric and diesel (CODLAD) propulsion system linked to twin shaft lines is more flexible than traditional all-diesel powered solutions. It provides high endurance whilst allowing a useful maximum speed of 20 knots.

The French *Jacques Chevallier* class vessels incorporate various differences from their Italian counterparts, perhaps most visibly evident in a revised bow form. Displacing some 31,000 tonnes, they are also broader than the Italian ships and have greater cargo carrying capacity. Another important difference is the specification of an all-electric propulsion system that uses GE Vernova-manufactured electric motors supplied by MAN diesel generators. In common with the Italian ships, the French vessels have better 'as fitted' defensive capabilities than their American counterparts, as well as a greater command and control capability. This reflects the greater likelihood of their operating outside of the protective umbrella of a carrier strike group, as well as the smaller number of large ships available to perform a command role.

United Kingdom

Having already modernised its force of fleet tankers with the British-designed but South Korean-built 'Tide' class, the United Kingdom is now embarking on the construction of three Fleet Solid Support (FSS) ships in an approach reflective of the US Navy's split of its combat logistics force between liquid and solid replenishment. The new vessels' primary role will be resupplying the British Royal Navy's *Queen Elizabeth* class aircraft carriers with ammunition and other general stores.

Credit: Team Resolute®

The future British Fleet Solid Support ships will be constructed by a Navantia-led consortium to a BMT Group design.

Following a protracted procurement process, a consortium (Team Resolute) led by Navantia was selected as preferred bidder for construction of the ships in late 2022. This was followed by a GBP 1.6 billion contract in January 2023. Assembly of the ships is to be carried out at the Harland & Wolff shipyard in Belfast from sections built in both Spain and the United Kingdom, with construction of the lead vessel expected to begin in 2025 for entry into service during the early 2030s. These plans may be impacted by the financial insolvency of the Harland & Wolff group parent company in September 2024.

Whilst construction is being overseen by Navantia, the actual FSS design has been produced by the British BMT Group, which was previously responsible for both the four 'Tide' class tankers and the single Norwegian logistic support ship, KNM *Maude*. The new solid support ships are reportedly derived from the 'Aegir'® design concept that inspired these earlier vessels, albeit with altered hull lines to reflect the different type of cargo carried. As such, they utilise the twin skeg design and combined diesel-electric propulsion system seen in these previous design iterations. Displacing nearly 40,000 tonnes, the as-yet-unnamed class will reportedly have over 7,000 m³ of stores capacity dispensed from three RAS positions.

Germany

The German Navy is also modernising its fleet replenishment capability, acquiring two Type 707 replenishment tankers to replace its elderly Type 704 *Rhön* class vessels. The new ships were contracted with Germany's NVL in July 2021 after receipt of parliamentary approval the previous month. Much of the actual construction effort is being focused on Meyer Werft's shipyards in Rostock and Papenburg. The keels of the two tankers were laid in Rostock in August 2023 and April 2024 respectively. The lead ship was subsequently floated out in June 2024 prior to an anticipated delivery in 2025. After some reduction in the programme's scope, estimated cost is nearly EUR 915 million. This figure has attracted some criticism.

Displacing some 20,000 tonnes, the Type 707 is a modern, double-hulled design with an emphasis on environmental compliance. In comparison with Germany's other large logistic support vessels – the Type 702 *Berlin* class combat support ships – the focus is on carrying a greater volume of liquid stores (almost 13,000 m³) at the expense of overall flexibility. Accordingly, provision for solid cargo largely restricted to 10 containerised positions and medical facilities are also more limited. Replenishment is carried out from three positions; one on each beam and one astern. Propulsion is by a single, diesel-powered shaft supplemented by a PTO/PTI arrangement.

The publication of the German Navy's 'Vision 2035+' fleet structure plan in March 2023 indicates a requirement for three replenishment tankers, suggesting that an order for an additional vessel will be placed in due course. The same document also outlines a requirement for a flotilla of six smaller support ships to replace the existing Type 404 *Elbe* class tenders. Whilst no details on specific characteristics have been released to date, NVL has publicised its NTV 130 concept as a possible design solution. Reportedly displacing around 14,000 tonnes, NTV 130 is heavily influenced by the current

Credit: Copyright NVL

NVL is lead contractor for two Type 707 replenishment tankers being built for the German Navy.

trend favouring modular, containerised equipment.

In the meantime, the Type 702 *Berlin* class design is also being used as the basis of Canada's construction of two *Protecteur* class joint support ships by Seaspan ULC in Vancouver. After considerable delays, the lead ship is expected to be launched before the end of 2024. Keel laying for her sister, HMCS *Preserver*, took place in October 2023.

Other selected acquisition programmes

Elsewhere in Europe, Damen is close to completing the new combat support ship HNLMS *Den Helder*, which was ordered from Damen in February 2020. In common with many other Royal Netherlands Navy vessels, much of its construction has been carried out at the company's Romanian yard in Galati. However, final systems' integration will be performed 'in country' at Vlissingen. Displacing around 22,500 tonnes, *Den Helder* can carry nearly 9,000 m³ of liquids, around 400 tonnes of solid stores and 20 containers. She is equipped with two main replenishment positions. Propulsion is by means of two GE Vernova electric motors supplied by four Wärtsilä diesel generators.

Turkey is also another major builder of logistic support ships, constructing vessels both for the Turkish Navy and export. Its most significant recent programme is for the fast combat support ship TCG *Derya*. She was built by the Sefine Shipyard and commissioned in January 2024. Displacing nearly 26,500 tonnes she is unusual in utilising twin GE LM2500 gas turbines as a primary form of propulsion, allowing her to achieve a relatively high maximum speed of 24 knots at the cost of restricted endurance. Some sources also credit her with auxiliary diesel-electric propulsion. Other characteristics are broadly similar to other contemporary logistic support ships. This included capacity for about 11,000 m³ of liquid stores and 48 containers. Replenishment is carried out from two main RAS stations on either beam.

The other major focal point of logistic support ship construction is Asia. South Korea's powerful shipbuilding sector has carried out a number of projects for the Republic of Korea Navy and for export, including the 'Tide' class and *Maude* referenced above. A particularly innovative project was the Royal New Zealand Navy's HMNZS *Aotearoa*, which was built by Hyundai Heavy Industries and commissioned in July 2020. Intended for regular deployment to the Southern Ocean and Antarctica, she incorporates a degree of ice-strengthening and 'winterisation', whilst utilising a wave-piercing, axe bow hull form for better seagoing performance.

Future years will bring new programmes, new builders and new designs into the mix. Notably Japan is beginning the renewal of its flotilla of replenishment ships, obtaining approval for a new 14,500 tonne (light displacement) logistic support ship in its recent, FY2024 budget. Another significant development took place in August 2023 with India's long-awaited order for five 45,000 tonne fleet support vessels from Hindustan Shipyard Ltd at a cost of INR 190 billion (USD 2.3 billion). The ships were to be built to a design provided by Turkey's TAIS but local reports suggest that the company was dropped from the deal for political reasons. It seems probable that other significant new programmes will be launched as developing navies realise the imperative of fielding effective logistical and replenishment support to advance their 'blue water' naval ambitions. From a technological standpoint, the ongoing trend towards modular solutions reflected in vessels such as NVL's NTV 130 will likely remain a key consideration. The need to sustain the growing number of autonomous naval vehicles will likely be another important future design influence. ■

Credit: Damen

An early computer-generated image of the new Dutch combat support ship Den Helder.

Credit: Royal New Zealand Navy

A view of HMNZS Aotearoa under construction at Hyundai Heavy Industries showing her innovative hull form.

Guiding light: lasers provide new direction for dealing with massed maritime threats

Dr Lee Willett

In the contemporary operating environment at sea, navies need more mass in conducting both defensive and offensive tasks. For Western navies, defeating threats to ships at sea across the spectrum of operations – from maritime security challenges such as small boats swarming around choke points, to high-end naval warfare threats like large-scale anti-ship attacks – requires significant weight of fire. Cost constraints and avoiding the need to 'crack a nut with a hammer' means navies are seeking more affordable ways to generate mass to meet mass. Non-kinetic options in particular laser-based directed energy weapons (LDEWs) are central to this thinking.

Whether in the Indo-Pacific or Euro-Atlantic theatres, the ongoing disputes indicate that Western armed forces will probably need to engage in large-scale combat in the near future. In the Euro-Atlantic theatre, fighting in the Russo-Ukraine war (with Moscow's full-scale invasion in February 2022) has demonstrated that high-end conventional warfare is blending new technologies such as uncrewed systems and hypersonic missiles with raw mass in weight of fire. As regards kinetic effect, several uses of uncrewed systems have illustrated the operational impact new technology is having. In the air, of note is the use of unmanned aerial vehicles (UAVs) – remotely operated by personnel using 'first-person view' (FPV) headset technology, to operate the vehicles – either to drop small explosive charges in an anti-personnel capacity, or to dive directly onto targets in a kamikaze manner. UAVs are also taking on other UAVs in air-to-air combat. In the maritime domain, Ukraine has deployed FPV-controlled unmanned surface vessels (USVs) to target Russian warships and support ships in port and at sea, sometimes manoeuvring several USVs together to confuse defences and defenders.

On the perimeter of the Indo-Pacific theatre, the Yemen-based Ansar Allah/Houthi rebels' anti-shipping campaign – since November 2023 targeting commercial and naval ships sailing in the Red Sea/Bab-al-Mandeb/Gulf of Aden corridor – has underscored the particular challenge for Western armed forces in finding affordable means to generate effect to counter massed in-bound threats. The Houthis have been launching relatively rudimentary (in technological terms) ballistic and cruise missiles, plus UAVs and USVs: occasionally, the air threat has been generated in such numbers that the US military has referred to the attacks as 'waves'. The difference between 'wave' and 'swarm' attacks is that swarm tactics require a degree of co-ordination, mandating command-and-control (C2) integration between platforms.

The DragonFire LDEW system is a technology option the UK is developing within a wider programme to generate more affordable firepower mass for deterring and defending against high-performance, low-cost air threats.

In response to the incoming Houthi attacks, the assembled Western naval forces – deployed to ensure that a globally significant waterway remains open to maritime trade – have fired various surface-to-air missiles (SAMs) in the local air-defence role. These have included Raytheon's Standard Missile (SM)-2 and SM-3 Block-2A, and MBDA's Aster 15, Sea Ceptor, and Sea Viper SAMs. Various onboard ship's guns have also been used.

As regards using SAMs to target a threat that can manifest itself *en masse*, although the SAM systems have shot down many incoming weapons, the Houthi missile and uncrewed system attacks do not present the highest of high-end air threats. Yet the fact that such straightforward systems can be mass produced and deployed en masse challenges Western armed forces in terms of the cost-benefit curve for defending against such threats with, for example, high-end SAMs.

In sum, are there more cost-effective options that Western navies need to develop to provide the capacity to counter such lower-end mass, leaving the higher-end SAMs for the higher-end fight?

Credit: Bundeswehr

Pictured: damage to a drone after several seconds of illumination by a high-energy laser.

Meeting the requirement

Alongside providing capacity to tackle a range of threats – including multiple, swarming uncrewed systems in the air and on the surface, plus ballistic and cruise missiles – new technologies such as laser-based weapons offer a new way to tackle such threats. What LDEW systems can offer here is the potential to generate mass effect, a sustainable capability and inventory (through being run on a ship's electrical power), precision and speed in engagement, simplified logistics including no weapons re-supply requirement, a more compact at-sea footprint, and reduced collateral damage risk (bringing no ammunition onboard). Moreover, as LDEWs can be fired providing the ship has power, the 'cost per engagement' ratio offered should be more favourable – and affordable – for navies, as the only thing expended is the energy to power the system.

This nascent technology must still overcome some technical challenges. These include: maintaining the laser in a set point on a moving target, including maintaining laser power through that point; power generation to build the speed to tackle faster-moving threats and reduce the 'burn time' required to disable the faster-moving target vehicle; enhancing a ship's cooling to maintain safety when generating higher levels of electrical power output; maturing the technology against continuously evolv-

Credit: US Navy

The USN AFSB platform USS Ponce is pictured alongside in Bahrain in 2015, with an LaWS system fitted. While deployed to the Gulf region, the ship hosted a three-year trial of the USN's emerging LDEW capability.

ing operational requirements; and wider airspace management issues including removing any risk to other air assets (military or commercial) moving line-of-sight beyond the target vehicle.

Despite these challenges, the game-changing capability LDEW systems are perceived to offer – particularly in generating cost-effective power and mass – mean that several navies are accelerating capability development programmes to enable near-term introduction of operational systems.

The US Navy (USN) has been leading the way on maritime LDEW developments, working on laser-based technology and testing operational capabilities for some time.

In 2013, the USN conducted a three-year trial of its emerging LDEW capability, the Laser Weapon System (LaWS), onboard the afloat forward staging base USS *Ponce* amphibious support ship while the vessel was deployed to the Middle East.

In May 2020 and December 2021, the Flight I LPD-17 *San Antonio* class landing platform dock amphibious transport vessel USS Portland was used as a test platform for demonstrations of the Solid State Laser – Technology Maturation Laser Weapons System Demonstrator (LWSD) Mk 2 Mod 0 system. In the first test, conducted in the Pacific Ocean, the system disabled a small UAV; in the second, conducted in the Gulf of Aden, it successfully engaged a static surface training target. In a US Fifth Fleet statement released for the second test, the LWSD system was referred to as "a next-generation follow-on to ... LaWS".

USS *Portland* began testing the system in 2018, having been selected by the Office of Naval Research (ONR). The testing programme was slated to conclude in fiscal year 2024, to be followed up with the publishing of an assessment report.

The USN has also developed a 60-plus kW-class high-energy laser with integrated optical-dazzler and surveillance (HELIOS) capability. This is the first tactical LDEW system set for integration onboard in-service USN ships and has been fitted already to the DDG 51 *Arleigh Burke* class Flight IIA guided-missile destroyer USS Preble.

The USN's at-sea laser capability development is being reflected in testing ashore. In February 2022, an ONR demonstration of what is referred to as a Layered Laser Defence (LLD) system – an all-electric, high-energy laser – was used to defeat in-flight a subsonic cruise missile representative target. A USN statement noted the LLD system included a high-resolution telescope, used for tracking and identifying inbound air threats and conducting post-targeting damage assessment. ONR held the test at the US Army's High Energy Laser Systems Test Facility at White Sands Missile Range, New Mexico.

"Innovative laser systems like the LLD have the potential to redefine the future of naval combat operations," said Rear Admiral Lorin Selby, the USN's Chief of Naval Research, in the statement. "They present transformational capabilities to the fleet, address diverse threats, and provide precision engagements with a deep magazine to complement existing defensive systems and enhance sustained lethality in high-intensity conflict."

"LLD is an example of what a very advanced laser system can do to defeat significant threats to naval forces," David Kiel – a retired USN officer posted as programme officer for ONR's Aviation, Force Projection, and Integrated Defense Department – added, in the statement.

Operational learning

Another navy developing DEW technologies and learning lessons from operational experience, particularly from Red Sea region deployments, is the UK Royal Navy (RN).

The UK Royal Navy Type 45 air-defence destroyer HMS Diamond (right) is pictured on deployment in the Red Sea, countering Houthi threats to shipping in the region. The UK's capability requirement for its current and future escort ships includes capacity to carry LDEW weapons.

Broadly, the UK Ministry of Defence (MoD) is taking forward a joint capability development programme, designed to develop DEW systems that can be deployed across the services. So far in 2024, two key milestones in this process have been reached.

In January, the MoD announced that – during a trial at its Hebrides testing range, off western Scotland – the UK's DragonFire LDEW capability development programme had achieved the country's first high-power laser firing against aerial targets. The tests demonstrated the ability to engage aerial targets at what the MoD referred to in a statement as "relevant ranges".

The RN and British Army are considering using the capability to meet future air-defence requirements.

In the statement, the MoD introduced DragonFire as a line-of-sight weapon that can engage with any visible target, offering greater accuracy over long ranges and reduced reliance on higher-cost ammunition. DragonFire is designed to deal with high-performance but low-cost threats.

The statement explained the core principles of some LDEW capability components. Such weapons can engage targets at the speed of light. They also use an intense beam of light to cut through the target, precipitating structural failure – or more significant impact, if the warhead is targeted.

"The precision required is equivalent to hitting a GBP 1 coin from a kilometre away," the statement said. "[LDEW] has the potential to be a long-term, low-cost alternative to certain tasks missiles currently carry out. The cost of operating the laser is typically less than GBP 10 per shot."

Shimon Fhima, the MoD's Director Strategic Programmes, said in the statement that the MoD would now accelerate programme development.

The DragonFire programme is led by the MoD's Defence Science and Technology Laboratory (Dstl), working with industry partners MBDA, QinetiQ, and Leonardo. Alongside having overall responsibility for the system, MBDA provides advanced C2, image processing capabilities, and effects management systems. QinetiQ provides the laser source: it has built a phase-combined fibre laser and associated phase control system, along with beam-combining technology to enhance power density; the laser has capacity to generate around 50 kW of power, but with scope to scale up firepower levels; the company also has developed precision laser source technology that can direct the laser output with extreme accuracy, achieving an enhanced power density on a target at range. Leonardo has developed the beam director, which brings together the laser source; integrated into a turret, the company's capability includes electro-optical target identification and tracking, with a focus on advanced targeting of incoming threats at various ranges in varied weather conditions over land and water.

Credit: Bundeswehr/BAAINBw

A containerized laser weapon system from Rheinmetall and MBDA was installed for testing on the German frigate Sachsen in 2022-23. The trials provided proof that dynamic targets can be successfully engaged under near-operational conditions.

It is the combined effect of the different concepts, components, and technologies that generate the game-changing outputs LDEW systems such as DragonFire can bring. "Working together, the technologies of the system [combine] to overcome an engineering challenge of delivering accuracy and stability, at long range, whilst maintaining [the laser beam] on a moving target, and whilst the laser system's host platform is moving," Richard Wray, UK Engineering Director at MBDA, told *European Security & Defence/Maritime Defence Monitor* on 30 August, in a written interview. There is also the challenge of addressing atmospheric interference between the platform and the target.

Wray pointed to a couple of LDEW capability components that could contribute to a game-changing output. "When we say defeat threats, we don't necessarily mean destroy. For example, you could use DragonFire to disable key parts of a threat like the sensors or propulsion, which might be a useful game-changing capability in operational terms for dealing with some scenarios," he explained. "The sophisticated sensor system that DragonFire requires to track and control the laser also provides the operator with an additional ISTAR asset when the laser is not in use."

Programmatics

The DragonFire trial was sponsored by the MoD's Defence Science and Technology (DST) and Strategic Programmes organisations. In 2017, the MoD's Chief Scientific Advisor's office had awarded the DragonFire consortium a GBP 30 million (EUR 36 million) research contract to demonstrate potential LDEW capabilities. This was an early step in the UK's wider programme to transition LDEW technology from the research environment to the operational environment. In 2019, the MoD established a three-year DEW concept phase programme to analyse and mature technologies, including both LDEW and Radio Frequency DEW (RFDEW) systems. A maritime LDEW system is a priority requirement within this programme, alongside a land-based LDEW system and a land-based RFDEW system (the latter intended to counter UAV threats).

The January trial combined elements tested previously. In earlier trials, the DragonFire consortium had demonstrated the technology's ability to track moving air and sea targets at distance with high degrees of accuracy.

Testing at the UK's Porton Down land-based test range in late 2022 focused on developing the laser itself and using several different targets at different ranges to develop the beam director's accuracy. "The ability to deliver high levels of laser power with sufficient accuracy are two of the major areas that need to be demonstrated in order to provide confidence in the performance and viability of LDEW systems," Dstl said, in a statement released alongside the testing.

In July 2024, again at Porton Down, Dstl trialled a separate LDEW system – a lightweight, portable, speed-of-light weapon, produced by Raytheon UK and developed again to tackle uncrewed system threats (especially aerial) – fitted to a British Army Wolfhound armoured vehicle. In a statement, Dstl said this was the first firing of an LDEW fitted to a land vehicle. "The advanced capability demonstrator will allow the MoD, along with the British Army, to understand the utility of LDEW systems against an evolving threat," Dstl's statement added.

For DragonFire, its capability and performance – as demonstrated in the trials to date – have contributed to the UK's decision to accelerate the maritime LDEW programme and bring forward the in-service date by five years to 2027. "The trials have seen us take a huge step forward in realising the potential opportunities offered by DragonFire, and the step-change it will provide in the ability to deal with high-performance and low-cost threats," said Wray.

Maritime implication

For the RN, the importance of non-kinetic, lower-cost systems like LDEWs is underlined by the fact that LDEW capabilities are being considered for some of the navy's core future platforms, including the Type 26 City class frigate and Type 83 destroyer. Eight Type 26s are to be delivered from 2028, and the first two vessels – future HM Ships Glasgow and Cardiff – are in the water. Type 83, which is due to begin entering service in the mid-2030s, is the platform around which the RN's future air-defence system (FADS) multi-domain dominance concept will be based, with the destroyer being the platform 'hub' to which a range of onboard and offboard sensors and effectors will be connected up. As the RN's First Sea Lord and Chief of Naval Staff Admiral Sir Ben Key told the Defence and Security Equipment International (DSEI) exhibition conference in London in September 2023, FADS is being designed to generate dominance in air defence and long-range precision targeting. Both Type 26 and Type 83 will be required to counter various air-defence and uncrewed system threats.

Initially, a third UK MoD LDEW development strand – a maritime-specific programme developed under what was called Project Tracey, with Thales leading a team including BAE Systems and Chess Dynamics – was underway. The MoD concluded the programme in December 2023, drawing design, engineering, integration, and other technology lessons into the UK's wider LDEW work.

While the UK's forthcoming Strategic Defence Review (SDR) – commissioned by the new Labour government, and set for publication in the first half of 2025 – will no doubt set out further details on the UK's DEW requirements, the most recent MoD Defence Command Paper – published under the previous government in July 2023 in tandem with the Integrated Review refresh, and detailing the capability programme that will deliver the defence operational outputs required to support the UK's strategic direction – stated that laser-based systems like DragonFire "will give the UK armed forces the capability to neutralise targets without the need for ammunition"; "DEW such as high-power lasers will form the basis of capabilities that deliver protection against new threats like drone swarms," it added.

Maritime integration

DragonFire's concept, capability requirements, and core roles demonstrate the UK's focus on integrating LDEW systems with other capabilities, both existing and emerging, to provide integrated effect against threats, again both existing and emerging.

As regards prospective integration into maritime operations, "DragonFire will provide an additional layer within integrated air and missile defence [IAMD] in both the maritime and land domains, able to tackle a range of modern threats," said Wray. "It will serve as a complementary effector to traditional defensive systems such as guns, Sea Viper, and Sea Ceptor."

As regards dealing with emerging threats – for example, mass attacks using ballistic or cruise missiles, UAVs, or USVs – DragonFire's role as an effector within such a networked IAMD construct would encompass providing close-in defence and short-range air defence against high-volume, low-cost asymmetric threats, said Wray. "As the technology matures, this capability will increase to intercept more stressing targets although, due to the limitations of being a line-of-sight system, it will not replace the need for traditional effectors," he continued.

Indeed, while the DragonFire capability brings unique advantages, integration with traditional effectors remains a central element of the system's concept, to maximise overall IAMD effect.

"DragonFire's advantage will be that it offers unlimited magazine depth, near instant in-to and out-of action times, and the potential to be a long-term, low-cost alternative to certain tasks conventional kinetic weapons currently carry out," Wray noted. "However, it is a line-of-site weapon, and certain weather conditions do not lend themselves to effective LDEW operation. Whilst we are progressively understanding and working to limit this aspect, it is why LDEWs are a complementary effector to traditional defensive systems like guns and missiles."

This integration with other systems is critical to how DragonFire can add mass in modern naval combat operations, Wray explained. "LDEWs provide an unlimited stockpile, increasing the overall quantity of effectors on board. While LDEW [capability] cannot deal with every threat, what it allows is traditional missiles to be used against the threats that are more stressing, increasing the overall effectiveness of the platform's air-defence capability," he said. "To improve this further, integrating LDEW effectors with the other air-defence capabilities on board into a single C2 [construct] will provide the opportunity to rapidly optimise the effect to the threat, further improving effectiveness."

There is another angle to the cross-programme integration element. Despite being based around non-traditional, groundbreaking technologies, DragonFire also draws on technologies being used in other, in-service systems. "The system uses algorithms that are an extension of MBDA's missile technologies, which are fundamental in being able to detect an aimpoint on a moving target – at range – and ensure that the high-energy optical beam is maintained upon this target aimpoint," Wray explained.

As regards DragonFire's physical integration into maritime platforms, "Significant redesign is not anticipated, and initially the system will have minimal integration to allow for rapid deployment, with the intent being for this to increase over time," Wray explained. For example, the design intent would be for the system to draw on the host platform's power and cooling rather than bringing a standalone supply. What would require careful assessment, he added, would be the optimum onboard location, which would also depend on the platform type.

DragonFire's design concept also reflects the long-standing Western military focus on building platform modularity through containerisation. For example, it has a modular system design based around using standard ISO shipping containers, enabling it to be moved between platforms and between domains, said Wray. Thus, he added, "[it provides] a capability that can be shared by services if needed". ■

Future integration

Combat management systems provide core naval capability for countering – and harnessing – emerging technologies. A Swedish Example.

Dr Lee Willett

A combat management system (CMS) is often referred to as a naval vessel's 'brain', linking the vessel's sensors – its 'eyes' and 'ears' – to its effectors – the 'limbs' that deliver the required kinetic and non-kinetic effects. Given the role of CMS in collecting data, processing this data into information, and distributing tasks and other commands, a CMS is perhaps more comparable to a human body's central nervous system – which consists of the brain and spinal cord, and which assesses information, takes decisions, and directs activities and movement. Just as the human body has evolved over time to respond to the demands of its environment, CMS capabilities must now evolve to respond to evolving operational needs. Moreover, with operational requirements in the naval environment now changing very rapidly, data collection and task direction capabilities within a CMS must enable navies to handle such change at pace.

Looking at the Euro-Atlantic theatre alone, across the full length and breadth of the theatre, navies are engaged in the full length and breadth of operational tasks. Conventional conflict ashore in Ukraine is having operational and strategic spill-over into the Black and Baltic Seas, and further afield. The current Middle East crisis is prompting greater Western naval presence in an Eastern Mediterranean region already busy due to NATO navies seeking to ensure access in the face of Russian efforts to use naval capabilities to help inflate anti-access/area denial (A2/AD) 'bubbles'. In the North and Baltic Sea region, NATO navies are tracking Chinese and Russian ships, in particular watching Russian naval and other vessels they suspect may be seeking to target critical underwater infrastructure. In the High North, nuclear-powered attack submarines (SSNs) joust for strategic position, while NATO navies continue to prepare (just as they are in the Baltic) for the need to reinforce NATO territory ashore from the sea.

Together, the Euro-Atlantic theatre presents a very complex geographical and operational environment, with this complexity enhanced by the emergence of maritime uncrewed systems (MUS) in all operational domains. While Western naval operators have been steadily easing

Credit: Saab, FMV

In an artist's rendering, ships from the Royal Swedish Navy's (RSwN's) current primary surface combatant class, the Visby class corvette (right), and the future Luleå class vessel are pictured together at sea. Increasingly complex naval operating environments underline the need for increasingly capable combat management systems (CMSs).

MUS into their operational inventories to conduct mine countermeasures (MCM) and intelligence, surveillance, and reconnaissance (ISR) tasks, Russia and Ukraine have been forced by the realities of warfare to introduce MUS across the full spectrum of military operations, from ISR to kinetic combat. Adding in command and control (C2) of MUS systems is another layer of complexity that the modern – and the future – CMS will have to handle.

One NATO navy dealing with increasingly complex operations in an increas-

Credit: Norwegian armed forces

The RSwN Visby class corvette HSwMS Karlstad and an unidentified NATO submarine are pictured during the Alliance's 'Trident Juncture' exercise off Norway in 2018. Saab's 9LV CMS, which is fitted to the Visby class vessels, is designed for surface ships and submarines alike.

ingly contested environment is the Royal Swedish Navy (RSwN), which is focused on the Baltic Sea and waters through the Kattegat/Skagerrak straits round to Sweden's west coast off Gothenburg. With Sweden a new NATO member, the RSwN may also wish to contribute more to NATO activities in the North and Norwegian Seas.

One key component of the RSwN's future force structure designed to provide the operational and capability flexibility to meet this combination of enduring and emerging tasks will be the *Luleå* class surface combatant. In 2022, the RSwN announced that it would develop a class of larger, more capable surface ships to provide enhanced capacity to support NATO standing naval force and integrated air/missile defence requirements. Four *Luleå* class ships are due to be built, with two scheduled for delivery before 2030, and two before 2034.

In May 2024, it was announced that Babcock will provide engineering support (including in structural design and auxiliary systems) for Saab's development of the *Luleå* class ships' basic design. Several core capabilities for the new vessels are likely to be drawn from the RSwN's in-service *Visby* class corvettes, with these capabilities being developed further through a mid-life upgrade (MLU) programme for the five *Visby* class vessels.

One such capability could be Saab's 9LV CMS, which is fitted to the *Visby* class.

According to Saab, 9LV is designed for all types of naval platforms, including submarines. The CMS supports multi-domain operations (MDO) and decision-making, collating, analysing, and distributing data in support of tasks across the operational spectrum, ranging from: environmental control, and search and rescue (SAR); to peace support, border control, counter-piracy and wider maritime patrol and response operations; up to force protection/escort and A2/AD taskings. The open architecture-based system is also designed for ease of upgrade, and ease of integration with navies' sensors and effectors: this in turn enables interoperability between allies and partners for coalition operations.

The 9LV CMS is deployed with navies operating across the Euro-Atlantic and Indo-Pacific theatres.

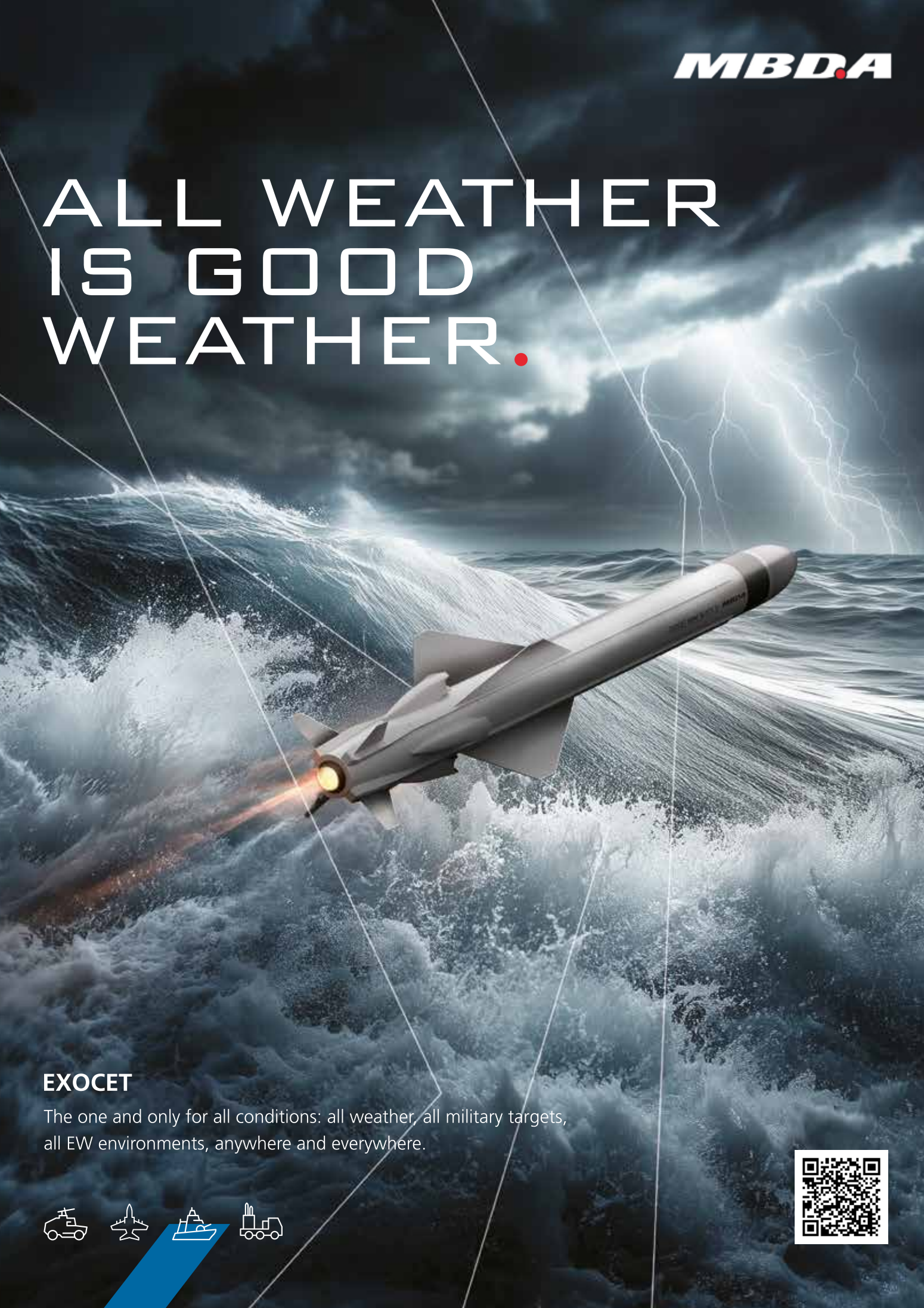
The expanding and elevating levels of naval contest across these theatres, and the increasing availability of new technologies and capabilities, raise the question of how CMS capabilities could be adapted and evolved in response, for example: while current CMS capabilities are state-of-the-art systems, what more can be done with them to enhance their output; what are the likely next-generation developments in CMS capability and integration; and how does CMS capability need to be developed to address emerging threats and integrate new technologies?

Requirements and capabilities

The ongoing Russo-Ukraine war is a very current example of what the future battlefield may look like, with existing and emerging technologies involved in integrated operations. Thus, the war also provides a very relevant illustration of what CMS technology, capability, and operational requirements may be.

Credit: NATO

A REMUS uncrewed underwater vehicle is deployed off Sesimbra, Portugal during NATO's 'Dynamic Messenger' exercise in September 2022. Maritime uncrewed systems can add to the complexity required to build and operate a CMS, but can also enhance CMS capability.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all EW environments, anywhere and everywhere.

"One thing that the conflict in Ukraine has shown is that the future tactical situation is unpredictable," Johan Hägg, Saab's Product Manager for 9LV Combat System Solutions, told *European Security & Defence/Maritime Defence Monitor* in a written interview on 20 September. "There, we have seen a major part of a fleet denied access to a huge sea by small, hastily developed remote controlled or autonomous vehicles."

In this particular instance, the Ukrainian Navy has managed to effect an A2/AD 'bubble' of its own across a large part of the Black Sea by using missiles, unmanned aerial vehicles (UAVs), and – especially – unmanned surface vessels (USVs) to target Russian ships at sea and in port, driving Russia's Black Sea Fleet back across the Black Sea to its own coastal waters.

While Western armed forces and defence industries will work on tackling emerging threats – such as those being demonstrated in Ukraine – within capabilities developed for CMS systems, at the same time they need to keep looking beyond what is known today, said Hägg. A key question, he explained, is: "How do we prepare a CMS for future missions and not just handling today's threats in five years' time?"

MUS will be a central factor in such considerations, Hägg continued; "Uncrewed systems will become increasingly advanced at an accelerating pace. They will carry payloads we currently are not seeing them equipped with. Different uncrewed systems will communicate with the help of new technologies ... [and] thus the autonomous decision loops will get significantly shorter." "This is an environment it would be hard to send crewed systems into. We know that, in MCM operations, the 'removing the operator out of the minefield' doctrine is growing; one thought might be a development move towards an 'operator out of the battlefield' approach," he added.

The arrival of MUS also will see fleet mixes – and their supporting operational infrastructure – change. "Will we see a 'ship ashore'; a CMS/combat information centre (CIC) in a hidden facility, solving tactical missions at sea by uncrewed systems operating in 'hot' zones, whilst crewed vessels are drawn back to supportive roles?" asked Hägg. "Escort duties will be conducted by crewed vessels as long as the merchant ships being escorted are crewed, even though the crewed [naval] vessel might be complemented with uncrewed systems for reach and pre-warning."

In critical maritime regions such as the Baltic Sea, the underwater world will continue to remain challenging, including in coastal waters where the hydrography is complex. This, said Hägg, will prescribe accelerating use of surveillance operations and covert activities.

"Across these scenarios, a CMS is not likely to be the sole solution – but it will be key to co-operative engagement, be that by sub-systems of different kinds, or ships and other assets," Hägg explained. "Leading words like optimisation, decision loops, shared pictures, and 'operator in/on/out of the loop' will put pressure on new [CMS] functionality."

Engineering functionality

The requirement for continuous capability evolution mandates a parallel need for continuous engineering development in CMS systems.

"Continuous engineering is an absolute necessity, as the sub-system developments will be very quick," said Hägg. "You cannot define an uncrewed system for the next ship class, because developments in, for instance, autonomous underwater vehicles (AUVs) are very quick. So, you will have to come up with a way to deal with constant change." Here, he explained, "New standard interfaces, well-isolated application layers, and – notably – new procurement processes to cope with this [fluid] reality will need to be implemented if you want to stay on top of the naval battle."

In terms of new procurement processes, Hägg added that there is a need to find the ways and means of achieving a balance between, and mitigating the competing demands of, peacetime navies' requirements for both cyber security and achieving the necessary operational effects. "The pressure of having a secure system is hampering the flow of data required to achieve the full effect of sensors, weapons, and sub-systems," said Hägg.

Emerging capability

The continuing capability evolution is reflected in the range of emerging technologies that must be integrated into a CMS for the dual purposes of using these technologies in offensive operations and defending against them. Alongside MUS, such emerging technologies include hypersonic missiles and directed energy weapons.

There is also the question of new concepts of operations (CONOPS) that may

Credit: Saab

Saab's Future Operator Workspace is one of the company's emerging technological concepts that integrates the 9LV CMS.

accompany such new technologies, for example the use of swarming tactics with MUS. A CMS system will need to be able to both conduct and counter such CONOPS.

Hägg argued that the arrival of MUS will bring technological requirements that in turn will underline the central role of the CMS, and will present opportunities to take advantage of CMS functionality, particularly through the system's integration of communications capabilities including data collection, analysis, and dissemination.

"The CMS will have an increasing weight in the functional chain, especially when optimising the array of sub-systems developed, in sensor, effector, and communications terms," said Hägg. Here, he explained, uncrewed systems working with each other and/or with crewed platforms will need a co-ordination 'hub' if they are to be able to solve the required task together. A CMS is this 'hub'.

Moreover, the integration of MUS can bring more capability in turn to the CMS. Being connected to MUS systems – sys-

tems that will be present in greater numbers, and deployed more widely across the area of operations – will extend the reach of a CMS system's capability. "The 'tactical range' of a CMS will increase," said Hägg.

Continuing capability developments in turn raise the question of what a CMS needs to do to tackle or harness these developments, including how CMS technology and infrastructure must be adapted. In particular, there are developments that need to be integrated with CMS technologies and infrastructure to enable the use of and defence against such new technologies.

"CMS technologies and infrastructure are in constant change, and the patterns visible today will cater for new threats. The requirements will change of course – more speed, higher accuracy, more decision support etcetera," said Hägg. "The continuous engineering approach will be a necessity to be able to keep on top. This in turn will drive update frequencies, over-the-air changes, and an assured way of compartmentalisation without disturbing operational functions – which is a challenge in itself."

"Given a true open architecture, the integration of new capability is relatively easy," Hägg continued. "Huge dataflows might require major design changes [, although] non-real-time data handling will always be possible to take on as a separate subsystem that will be expandable in itself."

Future integration

Hägg shared some thoughts on ideas for developing state-of-the-art CMS systems to take advantage of the improving integration within 'systems of systems', how other technologies can enhance what can be done with a CMS, and where such a development process might take CMS capability in the near term.

"One idea would be to become increasingly agile on a higher system level, which would require new ways of interaction between manufacturers and procurers," said Hägg. For example, he asked, "Would it be possible to buy, sell, and develop a combat system with framework requirements only, finding another more agile way of agreeing on the effect that the system should bring?"

As regards new technologies that could enhance CMS capability, "artificial intelligence is a maturing technology, and is already in today's CMS systems with different uses. In defined areas, it is highly effective, for instance in [some] sonars, imaging etcetera," said Hägg.

"Unpredictable creativity is a key strength for winning a naval fight, and as yet it is unclear what support a CMS could give in this regard," said Hägg. Yet he highlighted some key development areas. "Let's say a ship contracted today will be delivered in five years' time, within the boundaries of the procurement process established at the outset. We will expect to see [in the CMS] better handling of swarm threats, increasing functionality to handle fast-moving targets, and some kind of handling of multi-static requirements – but no major changes."

Nonetheless, Hägg noted that the 9LV CMS could provide even more capability for ship's companies in the short term, given Saab's position at the forefront of developing naval CMS technologies and effects. ■

Capability growth: naval missiles and gun systems boost surface warfare

Tim Fish

Investment in naval surface-to-surface guided weapons (SSGWs) has fallen behind since the end of the Cold War but recent projects aim to modernise missile capabilities and adapt them for the emerging operational environment. Meanwhile naval gun systems are also proving to offer a useful all-round multi-mission fire support and air defence capability for warships, being able to engage a wide variety of targets. This article explores the latest developments.

An evolving environment

The two main surface-to-surface anti-ship missiles (ASMs) that occupy the inventories of most 'western' naval forces are the US-built Harpoon and the French-made Exocet, both of which were first developed in the 1970s. These weapons were designed for securing the sea lanes of communications across the oceans and optimised for striking targets in a 'blue water' environment with sea-skimming and 'fire-and-forget' capabilities.

However, current naval operations are increasingly being focussed towards the 'green water' littoral environment, which is very different to the open sea. The cluttered environment and presence of more pervasive sensor systems mean that missiles need to be 'smarter', with an ability to find targets in the cluttered coastal environment and overcome ship defences that might include advanced electronic warfare jamming, decoys, gun and missile defences, and even uncrewed systems. Modern missiles may also need to have the capability to attack targets at extended ranges, use tactical waypoints, conduct course changes, maintain two-way communications, have options for target selection, and hit targets on land with more precision.

ASM veterans stay relevant

Despite the changing operational environment, the Boeing Harpoon ASM remains one of the most widely-used anti-ship missiles in the world; currently being in service with over 30 countries. First introduced in 1977, Harpoon's older variants have become increasingly obsolete and vulnerable to jamming; a weakness that is being addressed through production of the latest RGM-84Q-4 Harpoon Block II Plus (+) Extended Range (ER) iteration that is being acquired by the US Navy as an upgrade package. In addition to incorporating a lighter but more lethal warhead that

Credit: US Navy

Boeing's venerable Harpoon, seen here being launched from the cruiser USS Monterey (CG-61) in October 2020, remains in widespread service.

extends missile range to over 200 km by providing more space for fuel, this variant incorporates improved guidance technologies and data links that were not available when older Harpoon ASMs first entered service. Improved targeting information will allow the Harpoon Block II+ ER to find enemy warships hiding along coastal areas where there could be high levels of commercial shipping more easily.

Meanwhile, MBDA also continues to modernise Exocet, the other widely used 'western' ASM. Its latest variant is the MM40 Block 3C, which includes a new 'coherent' active RF seeker from Thales and a digital radio altimeter. These enhancements build on the extended, 200 km range introduced with the previous, turbo-jet powered MM40 Block 3 iteration, which also implemented GPS-based guidance and thereby provided a limited ground-attack capability. The French Navy completed an operational evaluation of the Block 3C missile from the French Navy's *Aquitaine* class frigate FS *Alsace* in September 2023, following on from MBDA's commencement of deliveries of the first Block 3C missiles to the French DGA procurement agency in January 2022. So far the French Navy has ordered 95 new missiles and 45 upgrade kits for the MM40 Block 3. Greece has also ordered the Block 3C as MBDA's first export customer.

Credit: MBDA/Michel Hans

A test firing of an Exocet MM40 Block 3 ASM. The latest, Block 3C iteration, includes a new 'coherent' active RF seeker from Thales and a digital radio altimeter

Credit: Kongsberg

Kongsberg's Naval Strike Missile (NSM) has become increasingly popular with navies seeking a modern ASM capability.

New SSGW entrants

Whilst Harpoon and Exocet remain very popular, other new ASM options have entered the market to address the challenges specific to modern maritime warfare in the littorals. Of these, the Naval Strike Missile (NSM) produced by Norway's Kongsberg is undoubtedly the most significant. In service with the Royal Norwegian Navy since 2012, it has recently seen huge increase in sales as navies worldwide seek to increase their ASM inventories and add new capabilities to penetrate sophisticated ship defences. In many cases, NSM is acting as a replacement for older Harpoon variants.

With a range in excess of 200km, the NSM is designed to be low-observable, with a small radar cross section and a low sea-skimming height. It is subsonic, with a design focussed on high manoeuvrability and stealth to attack a target instead of trying to overcome ship defences through speed. The NSM is fitted with an anti-jamming GPS mid-course guidance system and a dual band imaging infra-red (IIR) seeker with automatic target recognition. The IIR seeker allows the NSM to search for surface ship targets in the terminal phase passively. Most other existing ASMs use an active radar to find enemy ships but this means they emit a RF signal that can be detected and thus allow countermeasures to be deployed against them. Whilst an IIR seeker can be susceptible to bad weather blocking it from receiving signals, Kongsberg argues that these scenarios are rare and are outweighed by the benefits of stealth. The IIR also offers a land-attack capability.

To date, the NSM has been sold to over a dozen fleets, including such 'heavy hitters' as the US Navy, British Royal Navy and Royal Australian Navy (RAN). The missile is being installed aboard American littoral combat ships and future Constellation (FFG-62) class frigates, with some Royal Navy Type 45 destroyers and Type 23 frigates also being equipped to provide an interim ASM capability prior to development of the Anglo-French Future Cruise/Anti-Ship Weapon (FC/ASW). On 22 July 2024, the RAN *Hobart* class destroyer *Sydney* completed Australia's first NSM test firing, paving the way for its use across the country's surface fleet. The NSM is currently available in surface and air (Joint Strike Missile) iterations, whilst a submarine-launched version is under development. A joint programme with Germany for a future SuperSonic Strike Missile (3SM) 'Tyrfing' is also in its early stages.

Meanwhile, Norway's Scandinavian neighbour, Sweden, is pursuing a separate course by developing the RBS15 Mk 4 'Gungnir' ASM. Built by Saab, the Mk 4 is a further development of the RBS Mk 2 and Mk 3 missiles and has a similar missile body to the latter. However, it uses a composite airframe and miniaturised internal components to reduce weight. This permits an increased fuel payload that gives the Mk 4 a range in excess of 300 km. The Mk 4 will be fitted with a Ku-band active radar seeker, anti-jamming GPS, and electronic counter countermeasures (ECCM). It retains some other key features from the Mk 3, including a low (under 3 m) sea-skimming capability and a land attack capacity.

Saab was awarded a contract for the Mk4 variant in 2017. It is due to enter service in the mid-2020s and will encompass both sea-launched and air-launched variants.

The Royal Swedish Navy considers that Harpoon and many other current ASM types are optimised to provide a 'blue water' capability whereas it needs a missile optimised for hitting targets in the Baltic Sea. This is the reason behind the use of an active seeker, as it ensures an all-weather capability. Future options for the Mk 4 include a two-way data link and an additional seeker; either an EO/IR camera or semi-active laser.

Amongst other new missiles under development is the new Brazilian MANSUP ('Míssil Antinavio Nacional de Superfície') ASM. MANSUP will provide an all-weather, sea-skimming ASM with mid-range capability for the Brazilian Navy, replacing the Exocet MM40 Block 1 that is currently in service. Development work should be completed by 2025, in time for it to be installed on the new MEKO series *Tamandaré* class frigates.

Another significant programme is Turkey's ATMACA ASM, which is being produced by Roketsan for the Turkish Naval Forces as an indigenous replacement for the Harpoon. Its guidance system incorporates inertial navigation and GPS guidance, with an active radar seeker being used for final targeting. Reported range is over 220 km. Achieving initial operating capability in 2021, ATMACA is subject to ongoing development that includes use of an indigenous turbo-jet and provision of an (alternative) IIR seeker.

Looking ahead, new capabilities for anti-ship missiles likely include advanced counter-countermeasures and a collaborative tactical capability with other missiles or effectors.

Credit: Leonardo

Leonardo's OTO 127/64 LW (lightweight) medium calibre mounting can fire Vulcano munitions out to ranges of 100 km.

Credit: BAE Systems

In September 2024, BAE Systems announced it had installed the Mk45 Mod 4A naval gun on the first British Royal Navy 'City' class Type 26 frigate, HMS Glasgow.

Gun power pushes the boundaries

Meanwhile, naval guns remain a critical piece of a warship's weapons' outfit that are well suited to littoral operations. Their ability to offer a cost-effective means of providing sustained high-rates of fire using large stores of ammunition that can be easily replenished whilst at sea is a particularly valuable capability for naval forces. Medium calibre naval guns are now largely produced in 127 mm (5 in) and 76 mm (3 in) categories, being supplemented by a wide variety of lighter weapons.

Naval guns can engage targets on land, sea and in the air. In the last-mentioned domain, they are particularly valuable in providing defence against uncrewed aerial threats. Here, their use is more cost-effective than using a limited supply of expensive missiles, which also need to be preserved for engaging more dangerous threats at longer distances. This has been particularly demonstrated during recent naval operations off the coast of Yemen. For example, in July 2024, the Hellenic Navy's Hydra class (MEKO 200) frigate, HS Psara, reportedly used its 5 in (127 mm) Mk 45 Mod 2A naval gun to shoot down two drones launched by the Houthi rebels.

Guided munitions are also extending the range of naval gunfire capability, so that gunfire support can be conducted at longer distances. Ships equipped with 127 mm guns usually require a substantial displacement to manage recoil forces and accommodate the weight of the ammunition magazines and handling devices. This means these types of gun systems are typically reserved for destroyers and frigates. Other calibres such as 76 mm naval guns can be deployed aboard smaller warships, including corvettes, patrol vessels and fast attack craft.

Current 127 mm naval gun systems

The two most common 127 mm (5 in) naval gun systems in use around the world today are the US Mk 45 5 in mounting manufactured by BAE Systems and the equivalent 127 mm naval mount produced by Italy's Leonardo.

Variants of the BAE Systems' Mk 45 gun are in service aboard warships from Australia, Denmark, Greece, Japan, New Zealand, South Korea, Taiwan, Thailand and Turkey in addition to the United States. Its latest iteration is the Mk 45 Mod 4A. The Mod 4 was developed to allow the mounting to fire ammunition at longer ranges than previous iterations, as well as facilitating the possible future use if precision-guided munitions (PGMs) The Mod 4 configuration includes the addition of a longer, 62 calibre barrel (compared with the previous 54 calibre), a strengthened gun mount and an advanced control system that allows the engagement of a wider range of threats, including small drones. It also encompasses changes to the mounting's shape to reduce its radar signature.

The potential use of PGMs in conjunction with the Mk 45 Mod 4 would, for example, mean that fewer rounds would be needed to hit a target, extending the time for which a ship could provide fire support. BAE Systems has been developing a Hypervelocity Projectile (HVP) for both the Mk 45 and heavier calibre US Army 155 mm guns that has also demonstrated counter-UAV and missile defence capabilities in addition to extremely long-range precision fire. Speaking about the HVP, Tate Westbook, Business Development Director, Naval Guns and Missile Launchers at BAE Systems told ESD: "Its manoeuvrability, paired with its high velocity and ability for precision guidance, allows it to engage air threats with minimum response time. With new low-cost air threats that are deployed in swarms, this munition provides an advance layer of protection for the surface fleet."

The Mk45 Mod 4A gun also includes provision for an automated Ammunition Handling System (AHS) that can resupply the gun whilst firing and ensures it can continue firing, whilst also removing the sailors from the most dangerous part of the reloading process. The AHS is being provided to the British Royal Navy and RAN as part of their contracts with BAE Systems to provide Mk 45 Mod 4A mountings for, respectively, their Type 26 and *Hunter* class frigates.

The equivalent, most recent Leonardo OTO 127/64 LW (lightweight) medium calibre mounting can already fire guided munitions in the form of Vulcano ammunition that was developed in partnership with Diehl. Vulcano ammunition is available in Ballistic Extended Range (BER) and Guided Long Range (GLR) variants. These are fitted with different multifunctional fuses, sensors and final guidance components that can extend the range of the gun up to 100 km. The gun can also fire a full range of standard 127 mm ammunition.

Other elements of the OTO 127/64 LW Vulcano system include a fire control system and a modular AHS that can be adapted to various magazine layouts. The AHS loads a feeding magazine that comprises four drums of 14 ready-to-fire rounds that can be reloaded during firing.

The OTO 127/64 LW Vulcano system was first fitted to the Italian Navy's general purpose *Bergamini* variant of the FREMM frigate design and is also being installed in the *Paolo Thaon di Revel* class multirole combatants. It is also currently in Algerian, Egyptian and German service and has been ordered by Canada, the Netherlands and Spain.

OTO 76mm mounting

Leonardo also continues to produce various iterations of its 76/62 gun mounting that began life in the 1960s as the OTO Melara Compact. As previously noted, the 76mm gun offers a lighter calibre system that can be fitted to many smaller vessels. However, it still offers powerful, multi-role capabilities that are assisted by the development of DART (Strales) and Vulcano guided munitions. According to Leonardo, a 76 mm gun utilising DART ammunition and associated fire control has the capability to provide point defence against manoeuvring missiles with a similar effectiveness to a Very Short Range Air Defence (VSHORAD) missile. Alternatively, the use of Vulcano 76mm rounds can allow engagements of shore targets in excess of 30 km with high levels of accuracy.

Leonardo is also evolving various mounting configurations for the 76 mm gun. The latest is the 'Sovraponte' configuration, which stows its ammunition within the mounting's body and thereby does not penetrate the ship's structure. This increases installation options, such as a location on top of a ship's helicopter. The 'Sovraponte' was first installed aboard the lead ship of the *Paolo Thaon di Revel* class, which commissioned in 2022.

Future developments in the naval gun and ammunition sector include new guided ammunition types with additional functionalities that incorporate emerging technologies. Reduction in weight is another area of focus. For example, the development of barrels using aluminium, titanium and composites could help reduce weight but keep structural resistance to the high stresses experienced when firing. Other areas of development include structural calculations (both static and dynamic), control engineering, ballistics, performance analysis, aerodynamics, AHS, and hardware and software management.

Conclusion

The modernisation of surface-to-surface guided missiles and the introduction of new ASM weapons show the renewed focus that is being placed on giving navies effective engagement capabilities in these areas, particularly when operating in littoral regions. New components and technologies will likely increase functionality, giving warships the ability to strike targets even in complex conditions.

Meanwhile the market for heavy calibre naval guns remains significant as naval forces continue to value their all-round utility for air, land and sea engagements. Indeed, this utility is only increasing with the development of new munition options and the need to find an effective defence against UAVs, which are becoming an increasing threat. ■

Credit: Italian Navy

The Italian Navy's ITS Paolo Thaon di Revel was the first ship to be equipped with Leonardo's 76 mm 'Sovraponte' mounting, seen here atop the ship's hangar.

Evolution or revolution: maybe it's a bit of both

Dr Lee Willett

Underwater operations remain a core output that navies and their parent countries use to secure national interests and create international influence. Such operations are, of course, conducted covertly, with submerged platforms: this is the unique selling point, and it endures because the world's oceans remain opaque to sensing technologies trying to see into them from above, on, and below the surface. In contemporary underwater operations, unmanned underwater vehicles (UUVs) have joined submarines as tools for generating this output. With such operations becoming more important as global security becomes increasingly more unstable, the requirements to stay submerged and move at speed underwater have become more important. Yet for submarines or UUVs, there are different reasons and options when assessing why and how to do this.

Broadly, there are two submarine types, defined largely by their power and propulsion systems. While overall operational requirements for both types are generally the same – stay hidden, and move and act quickly and covertly – how they do this is different.

Most of the world's submarines are conventionally powered: using what is generically termed 'diesel-electric' propulsion, these boats – generally known as SSKs – combine traditional submarine 'power supplies' of diesel engines and lead-acid batteries. Today, technologies such as air-independent propulsion (AIP) and Lithium-ion (Li-ion) batteries are added or used instead.

A select number of the world's submarine navies operate nuclear-powered attack submarines (SSNs). These boats generate power and propulsion using nuclear reactors designed for underwater operation. Operating an SSN flotilla is underpinned by significant financial, industrial, and supporting infrastructure investment – a core reason why very few submarine-operating navies opt for SSNs.

An SSN's core capabilities underline, however, why navies and their parent countries pursue submarine capabilities, whether through SSN or advanced SSK programmes. Staying hidden, moving covertly over relatively large distances at relatively high speeds, and conducting various activities unseen where and when required are the main reasons navies invest in submarines. SSKs can generate these outputs too, but not with the sustained submergence, endurance, and flexibility of an SSN.

Credit: Canadian Armed Forces

An SSN – the US Navy (USN) Virginia class nuclear-powered submarine USS John Warner (foreground) – sails with an SSK – the German Navy Type 212A diesel-electric boat U-35 – during the NATO anti-submarine warfare exercise 'Dynamic Manta' in 2022. Nuclear propulsion offers the most sustainable and flexible option for submarine operational output; conventional propulsion offers still significant, but more affordable, capability.

Over the last decade or so, these requirements have become even more pronounced as state-based rivalry has resurfaced around the world. In both the Euro-Atlantic and Indo-Pacific theatres, the first stirrings of this re-surfacing rivalry could be sensed underwater, with the Russian Navy and Chinese People's Liberation Army Navy increasing submarine operations.

Over the same timeframe, what has also surfaced in the military world is the use of uncrewed systems. For navies, UUVs were introduced largely to provide surveillance capability around key locations, like maritime choke points or ports and naval bases; and to conduct mine countermeasures (MCM) operations, enabling ships, submarines, and sailors to remain at a safe distance outside the minefield.

However, as more is learned about UUVs – in terms of what industry can provide, and what capabilities navies require – these roles are evolving. Navies are now looking to use UUVs to conduct surveillance at distance, to operate in an ever-more integrated manner with crewed and other uncrewed platforms in

the underwater and other domains, to carry a wider range of effectors including (potentially) kinetic weapons, and to conduct these tasks with greater speed and sustainability.

For any underwater vessel (SSK, SSN, or UUV), the onboard power and propulsion system is the primary source of such sustainability and speed, alongside the submerged stealth that is the *raison d'etre* for possessing the capability.

Evolution to revolution

When asking the question of whether developments in underwater propulsion are evolutionary or revolutionary, the answer is probably 'both'.

BMT, told European Security & Defence/ Maritime Defence Monitor in a 5 September interview. These options' development trajectory has remained largely constant, Walchester added.

For conventional submarines, diesel-electric capabilities are being enhanced by improvements in battery and AIP technologies. Lead-acid batteries have been the traditional SSK battery type, but new chemistries – notably, Li-ion batteries – are being assessed and used. The Japan Maritime Self-Defense Force (JMSDF) is one such navy leading the exploration of Li-ion battery options.

"It's all about the battery management system and how you keep the battery safe [while] getting the power output you need; it's marrying up the battery chemistry with the safety and the power output in a manner that meets your requirements – because you want power delivered in a certain manner, which suits some chemistries more than others," said Walchester.

Credit: Huntington Ingalls Industries

Pictured is a REMUS 100 UUV, designed for MCM operations. Expanding operational requirements for UUVs – including developing capability to conduct more tasks at greater distance – are prompting assessment of new power and propulsion approaches.

For submarines, whether SSKs or SSNs, power and propulsion systems have generally developed in an evolutionary manner, with improvements made to nuclear reactors, to fuel-based propulsion systems, and also to batteries as more is learned about them underwater and as more developments are made ashore in industry – including in the commercial world.

In the world of uncrewed systems, more revolutionary developments may be found – not only through the accelerating understanding of what can be done with UUVs and how, but what other options exist to do different things with UUV design and technology given the simple fact there are no humans on board.

The propulsion options for underwater vessels may differ depending on the operational requirement, but also on the vessel type.

As regards submarines, "In terms of the options you've got, they're the same that have been there for 5-10 years," Alex Walchester, a senior naval architect specialising in the defence and security sectors at UK-based naval design house

Submarines versus smart phones

Commercial industry plays a crucial role in developing battery technology, particularly through financial investment. "Li-ion and other batteries are being developed for commercial applications: in terms of investment and dollars spent, its order of magnitude is different between what's being developed on submarines and what's being developed just for smartphones, battery banks etcetera," Walchester explained.

For navies, combining technologies can add capability value. "Batteries are always trying to be part of your solution, but AIP might enhance that," Walchester added. "AIP gives you underwater endurance that batteries can't .... The fuel type used in AIP systems is probably far more power-dense than a battery would be, so it allows you to stay submerged for longer."

Technological developments to improve the efficiency of the fuel cells that power AIP systems may also extend a boat's power output and submerged endurance, Walchester explained.

For SSNs, nuclear propulsion technology is a long-trodden, well-established development path. A potential area for change is in the development of different reactor types, said Walchester. Micro-nuclear reactors (MNRs) are one focus area with molten salt reactors (MSRs) being another. Some European navies have begun assessing nuclear propulsion options for surface ships, given growing operational requirements and increasing costs of traditional fuels. MNRs may offer more affordable nuclear propulsion. However, all naval platform design and capability choices bring trade-offs.

"If you go smaller, you're probably not going to get the same amount of power," said Walchester. "In my opinion, with MNRs, you may end up in a place where you've got a system that's similar to an AIP system, but the difference is your AIP system needs to be refuelled." So, in sum, MNRs might not offer the capability of an SSN, but could support a capability step-up for navies seeking to step on from an SSK.

As regards UUVs, power and propulsion developments offer potential for design and capability revolution, said Paul Burke, BMT's senior business development manager for submarines, and a former UK Royal Navy submariner.

"The interesting thing in the last ten years or so is the UUV angle, where you could actually consider more technologically advanced power systems,

because you don't have the people element, so you can take a bit more risk in the propulsion system area," said Burke. For example, he continued, "There's been very little, if any, investigation of how MSRs would work in the maritime or in the underwater environment – but that might be something that could be tested [in UUVs] without threat to human life."

Evolving capability requirements for UUVs will, however, shape the propulsion – and even technological and operational – options that could be considered. For UUVs, Burke explained, "This transition has been happening over quite a few years. As you change from that short-term activity – send something out, bring it back, recharge it easily – to where you want to have something as a capability going out into the deep, doing a long-term activity, it's going to be an endurance issue." This endurance relates to powering not only the UUV, but the sensors, communications systems, and other mission-relevant capabilities.

"There are lots of factors that could be considered to get the right power units in there... There are a whole load of [propulsion capability] options to consider too," Burke added. Looking at how UUV batteries could be recharged, Burke explained: "SSKs must still come up and snort every so often. Why can't you have a long-endurance extra-large autonomous underwater vehicle [XLAUV] that has to surface and stick a solar panel up? .... Can you use plug-in charging points on the ocean floor?"

"There are lots of things that can be thought about for how to maintain a UUV [on station] for a longer period of time," Burke added.

Understanding requirements

Key to many such decisions, said Burke, is for navies to clearly understand and set out what it is they want and need the platform to deliver: this applies to submarines of both types, and also to UUVs. "It all depends on the requirements for that platform .... The question is 'what is the right thing for the task I want to do?'" asked Burke.

"The nice thing about a submarine is it can do loads of things. However, depending on what type of things you want it to do, that addresses your calculus for the propulsion requirement. It's the same for UUVs," Burke explained. Requirements to consider in any such calculation include the endurance, sustainability, and speed needs, plus planned sensor and weapons fits. "Then it's a case of asking 'how do I fit that within the specification?' ... [and] whether it's the best or most efficient option – in other words, financially effective," Burke added.

Such design, capability, and operational requirement choices, including power and propulsion, are perhaps most striking when it comes to submarines. "The nice thing about nuclear propulsion is it gives you multiple options; the nice thing about non-nuclear is it's a lot cheaper, because a lot of the infrastructure needed – even for MNRs – is probably more expensive than conventional-type means of power," said Burke. "So, sometimes it's a cost-benefit decision a country needs to make."

"If you're just looking at submerged endurance, or just want a really high top speed ... there are multiple ways of getting there with conventional propulsion systems," Walchester added.

According to Burke, emerging UK requirements for UUVs may well start to reflect those of its submarine capability – namely, set within governmental and defence strategy requirements, operating UUVs that potentially can do a lot of different things, and can respond at speed to the need to do these things, including at distance.

"Within the UK, we've traditionally had a requirement for being able to operate at range. To achieve that range, you need to have speed, and you need to have endurance, and then be able to deliver multiple types of operations," said Burke. While the UK's optimum underwater solution for meeting these requirements is an SSN, given its multiple sensors and capabilities, a UUV does not fully fit this bill. However, Burke continued, "A UUV can deliver some of the other effects required, like indications and warnings, tripwires etcetera. So, there's definitely capability that could be easily delivered by these longer-range, XLAUV-type capabilities."

To meet such requirements, UUVs will need sustainable, reliable propulsion.

Credit: US Navy

The USN's Nimitz class aircraft carrier USS Abraham Lincoln (left) leads elements of its CSG through the Singapore Straits in August 2024. In the future, CSGs may transit confined waters with XLAUVs picketing out front, sanitising the transit corridor via sensing or strike activities.

Credit: US Navy

The Japan Maritime Self-Defense Force (JMSDF) Sōryū class submarine JS Tōryū is pictured visiting Pearl Harbor in October 2022. The JMSDF is one navy leading the way in exploring new battery technologies for submarines.

Revolution versus reliability

The use of tried-and-tested technologies for submarine propulsion raises a key consideration when assessing options for trying something new with UUV propulsion. While the absence of crew onboard may enable testing of some alternatives, this very absence can impose limitations. The important lesson learned here is reliability, said Walchester.

"As you don't have people there to manage the system or manage defects, your reliability requirement goes up," Walchester explained. "With XLAUVs, when you start incorporating diesel propulsion and snorting etcetera, you start looking at very reliable propulsion systems, and you effectively end up playing it safe."

"There's a safety and battery management aspect .... [It] is something people are aware of in the commercial and naval worlds," he continued. "It's reliability versus capability."

What the commercial world has learned regarding reliability in monitoring and maintaining oil and gas pipelines seems relevant to deploying and operating UUVs at distance. "You have something that just sits there: you don't need to worry about it; it's not going to break down; and it doesn't need a massive, expensive maintenance period," said Walchester.

As UUVs become more capable and usable, there is the added element that they may be seen as less expendable. Deploying a UUV to conduct MCM operations instead of a ship or diver, or to act as an anti-submarine warfare (ASW) picket across a choke point instead of a submarine, underlines an original focus in uncrewed system operational concepts – prospectively trading their loss to save human lives. However, with naval activity increasing and crewed naval platforms expensive to build and operate, UUVs can offer sustainable capability and mass. For example, XLAUVs are viewed as potential forward-deployed sensing pickets to support high-value assets like carrier strike groups (CSGs) on the move, even providing land-attack or anti-ship strike capabilities to sanitise CSG transit corridors.

"You get this juxtaposition with an uncrewed platform: it's new, it's novel, it's cheaper than a submarine, so you want to be able to trial new technologies on it; but at the same time, you don't want to lose it, you don't have people there to adapt to a situation when it goes wrong, and you've possibly got slightly less confidence in the system to adapt itself to overcome any problems," said Walchester. "So, you end up placing quite stringent reliability requirements on your XLAUV, particularly if it's off doing long-distance operations in the North Atlantic where the environment is not always favourable due to poor weather conditions."

Stealth, simple

As with submarines, stealth will remain the primary driver of UUV operational requirements, going hand-in-hand with sensing output to maximise value in the covert capability. "It's the underwater domain, it's submarines and underwater vehicles: they operate underwater for a reason – stealth. So, stealth capability is always very high up in system requirements," said Walchester. "It's what it's there to do, and everything else is effectively there to support that."

The enduring importance of stealth in underwater operations raises the issue of what are the primary questions a navy should ask when assessing power and propulsion options for underwater vessels.

"It's an assessment of the threat, and therefore what you're trying to achieve... It's from high-level strategy all the way down to 'OK, so what'll actually achieve that?'" said Burke.

This assessment, Burke explained, includes whether threats to interests will be surface- or sub-surface-based, whether the requirement is merely to sense the threat (including maintaining long-term surveillance of it) or to consider if – and how – to prosecute it, including whether that is offsetting the threat or physically attacking it. Next comes the question of generating the availability of safe and capable platforms to conduct any required tasks.

Thinking through each factor in this equation drives the propulsion requirements.

There are 'bigger picture' elements to consider here too, Walchester added. These can include how the submarine or UUV must interact with other sub-surface assets and assets in other domains.

There is also real-world operational reality. "If you look at Ukraine and some of the lessons learned... there's what you're doing in peacetime, and then there's – if things go wrong, and you're in a situation you'd rather not be in – if someone is shooting at you, how does the kit degrade over time as elements of your network or fleet slowly degrade, require maintenance, get damaged, or are lost etcetera," said Walchester. "You need to think about the big picture, and then you need to think about the big picture after it's been roughed up a little."

As regards how a 'roughed up big picture' might re-align underwater platform power and propulsion requirements, Walchester said, "I think mass and survivability will become increasingly important, with the requirement for the number of platforms and sensors growing." Here, UUVs will be vital to adding mass in the short term, but still complementing crewed submarines that will continue to bring capability and flexibility that cannot be replicated currently by UUVs, he added. ■

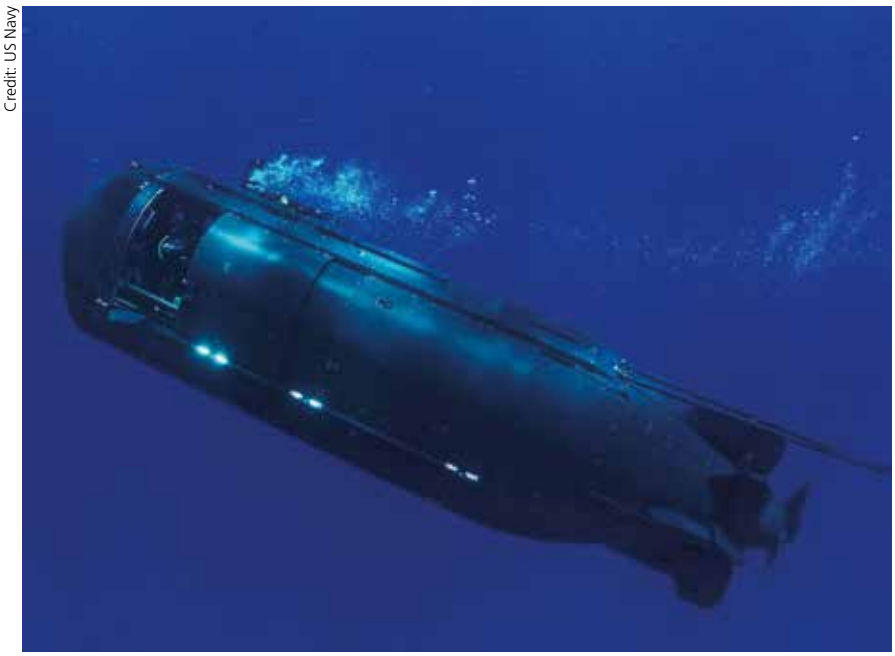
Submersible vessel programmes

Sidney E. Dean

Submersible vessels capable of both surface and underwater operations provide flexible options for Special Operations Forces. They are considerably smaller than conventional attack submarines, and serve a variety of mostly specialised mission types.

Special Operations Forces (SOFs) are the primary users of manned submersibles, which have popularly been referred to as miniature/midget submarines or mini-subs. They are specifically designed for the covert transport of SOFs and their equipment in high-threat or access-denied areas. They are also suitable for direct action and intelligence, surveillance and reconnaissance (ISR) missions. This article examines some of the submersibles in service or under development, focusing largely on current American, British and French designs.

Credit: US Navy



US Naval Special Warfare operators onboard a SEAL Delivery Vehicle (SDV) Mark 11 conduct routine navigation training in 2020 near Pearl Harbor.

United States: SEAL Delivery Vehicle (SDV)

The US Naval Special Warfare Command (NAVSEPCWARCOM) is among the world's leading operators of mini-subs. Since the 1980s the US Navy's Sea Air and Land Teams (SEALs) have relied on the SEAL Delivery Vehicle (SDV) Mk 8 for underwater transportation to their mission objectives; the only other unit to utilise this particular system is the British Royal Navy's Special Boat Service (SBS). The SDV is carried in a dry deck shelter (DDS) mounted atop specially configured attack submarines or ballistic missile submarines (the vehicle can also be launched by surface vessels, but this conflicts with the goal of covert underwater delivery). The 15 tonne mini-sub accommodates a total of six operators including the two-person crew. Reported performance parameters include a 4 knot cruising speed, 18 NM range fully loaded, and 12 hour endurance, with a dive depth of 6 metres. Notably, the SDV is a 'wet' submersible; the divers' rebreathers are attached to the vehicle's life support system while en route, but they are exposed to the water and endure fatigue before even reaching their destination.

The Mk 8's replacement, designated the Shallow Water Combat Submersible or SDV Mk 11, entered service in 2020 and achieved initial operational capability (IOC) in 2022. It was designed by Teledyne Brown Engineering under a 2011 contract with the US Special Operations Command (SOCOM), and produced through to 2024 under two 2019 and 2021 follow-on contracts. The aluminium-hulled Mk 11 is 30 cm longer, 15 cm higher and 1,800 kg heavier than the Mk 8, according to SOCOM briefing documents. Improvements over the Mk 8 include upgraded computers and networking (including the ability to communicate with external manned and unmanned platforms), improved software and user interface, higher accuracy navigation, and addition of bow thrusters for enhanced manoeuvrability. Additions include a sensor mast with an electro-optical periscope, sonar detectors for obstacle and mine avoidance, and a sonar-assisted automatic docking capability. Crew members are connected via both wireless and wired communications interface. While some performance parameters are classified, the Mk 11 is reported to have a range of approximately 36 NM at a cruising speed of 4 knots. Like the Mk 8, the SDV Mk 11 is also being acquired by the British SBS.

United States: Dry Combat Submersible (DCS)

SOCOM has also introduced a second new manned underwater vessel designated the Dry Combat Submersible or DCS. As the name implies, the vessel is fully enclosed and pressurised, permitting the crew and passengers to remain dry, warm and rested during transit. They can wait to don their diving gear until arrival at the egress point, which again contributes to comfort and reduces fatigue during travel. These attributes are expected to have a direct and major impact on mission safety and success by delivering the commandos in fit condition, both physically and mentally.

While many aspects of the DCS remain classified, the known performance parameters offer significant improvement over the SDV Mk 11. These include a reported range of over 60 NM, with a cruising speed of 5 knots and a classified top speed. The submersible is rated for 100 metres depth. Mission endurance exceeds 24 hours. The DCS' capacity is almost double that of the Mk 11, with

a two person crew (pilot and navigator) and room for an additional eight fully-equipped commandos or one metric tonne of cargo.
Two variants designated as DCS Block 1 and Block 2 are planned. The first Block 1 unit was delivered to NAVSEPCWARCOM in 2020 for developmental testing and operational testing. It subsequently reached IOC in June 2023 and full operational capability (FOC) in 2024 according to US Navy Cmdr Jonathan Connelly, program executive officer for the command's maritime undersea systems.
Prime contractor Lockheed Martin RMS developed and built the DCS Block 1 jointly with major subcontractors Submergence Group LLC (Texas) and Msubs Ltd (UK). The DCS Block 1 is based on an Msubs design, the S351 Nemesis, although the design has been modified to meet NAVSPECWARCOM requirements. Construction of the submersibles takes place in the UK, followed by pressure hull inspections by Germanischer Lloyd (now part of DNV GL) in Cuxhaven, Germany. Subsequently the pressure hulls are sent to the United States for final system integration by Lockheed Martin.
Many details of both the DCS' and the Msubs' designs remain classified. External features of the DCS Block 1 and the Nemesis appear very similar, including a length of 12 metres length, a height of 2.5 metres, and a displacement of around 30 tonnes. The pressure hull is divided into three watertight sections: the cockpit is located aft, while the passenger/payload compartment is forward. Above water, personnel access the vessel through a retractable accordion tower located over two hatches in the midships dorsal section. The lock-in/lock-out chamber for entering and exiting the submersible underwater is midships in the lower hull section. The propulsion and steering systems include a shrouded screw with curved blades to avoid cavitation, X-form rudder control surfaces, retractable thrusters forward and aft for fine positioning and transit of tight spaces, and hydroplanes forward. Electricity for propulsion and internal systems is generated via lithium-ion fault tolerant (LiFT) batteries developed by General Atomics Electromagnetic Systems (GA-EMS). According to GA-EMS, LiFT battery technology is designed to provide increased endurance and longer battery lifecycles, while improving safety over conventional lithium-ion battery designs; the modular design reduces the likelihood of uncontrolled and catastrophic cascading lithium-ion cell failure. In the long run SOCOM would like to acquire even higher performance battery systems. To this end it has been investigating the potential of aluminium-seawater (Al-H2O) batteries for the DCS and other underwater vessels. According to L3Harris, the high energy density technology can provide between twice and 10 times the endurance of other battery systems. If eventually applied to the DCS, it could extend the submersible's mission range to several hundred NMs.

Credit: Lockheed Martin

A Dry Combat Submersible departs Lockheed Martin's Palm Beach, Florida facility for open water sea trials, which were completed in March 2023.

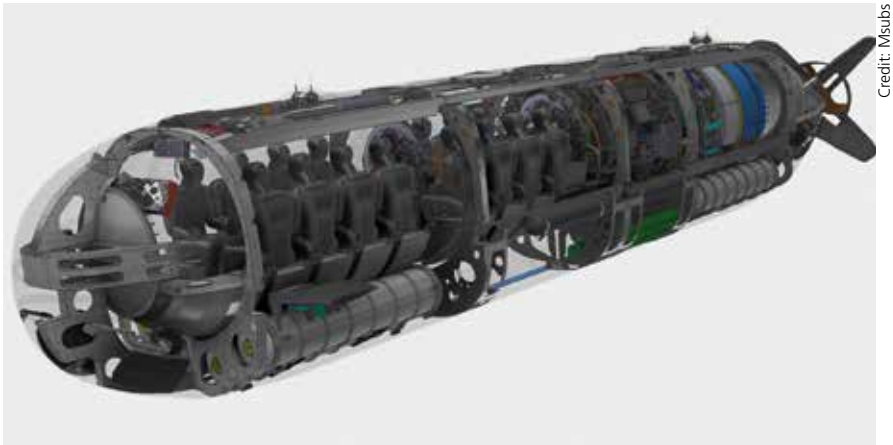
Some key systems have been customised to meet SOCOM requirements. These included the bow-mounted terrain-following/terrain-avoidance sonar for shallow-water navigation, and the radio frequencies countermeasures sensor and library (for detecting, classifying and evading hostile radar). Additional optical and electronic sensors and communications links are mounted on two retractable masts.
To date the US military has received three DCS Block 1 submersibles, with no additional units on order at this time. NAVSPECWARCOM's major remaining concern with the Block 1 is the fact that it is too large to fit inside a Dry Deck Shelter, and therefore can only be launched by surface vessels, either by crane or from a well-deck. Given the submersible's mission range of around 60 NM, the risk that the vessel's launch will be observed is high. The DCS Block 2 configuration, now designated the Submarine Launch Dry Submersible, will be required to be compatible with submarine carriage to ensure stealth. Few details of this variant, which is in development, have been made public. In 2023 SOCOM Acquisition Executive James Smith told reporters he was pleased with the rate of progress. "We're reliant on the Navy for the success of that program and really happy with how the relationship is progressing," Smith said, adding that the US Navy would determine when the new submersible is ready for operational certification.

United Kingdom: S401

Msubs has developed an array of manned submersibles; some smaller and some larger than the S351. This includes the S401, which for the moment is strictly a concept. The 16 metre long vessel would have a displacement of 40 tonnes, and would likely become the largest currently operational mini-submarine if put into production. A modular configuration permits a trade-off between payload or passenger load on the one hand and battery pods on the other, permitting operators to prioritise either the size of the commando contingent or range and endurance. Maximum capacity would permit carriage of 16 combat divers in addition to the pilot. Msubs envisages a default power system option that uses LiFT batteries but offers optional integration of fuel cells or diesel-electric propulsion to extend range and endurance.

United Kingdom: Carrier Seal and Shadow Seal

The Carrier Seal and Shadow Seal watercraft offered by United Kingdom-based James



Credit: Msubs

The conceptual S401 could carry a full 16-member SEAL platoon.

Credit: James Fisher Defence

Unlike many submersibles, JFD's Carrier Seal can be armed when above water.

Credit: James Fisher Defence

James Fisher Defence's Shadow Seal accommodates a two-person crew and two passengers.

Credit: SubSea Craft

This cutaway image shows the Victa's seating arrangement and its waterproof battery chamber.

Fisher Defence (JFD) are optimised for covert transport of combat divers. However, the potential mission profile also includes maritime interdiction, stand-off attack and fire-support, and ISR. Unlike many other submersibles, both are full-fledged multi-domain vessels capable of operating in three modes: surface, semi-submerged and submerged. This permits a high-speed surface approach to the mission zone, requiring transition to underwater operations only when near the target. Deployment options include launching from a surface vessel, deployment and recovery by medium-lift rotary aircraft (sling load), or airdrop onto the ocean surface via tactical transport aircraft. Both are configured as 'wet' submersibles.

The Carrier Seal is 10.5 metres long with a displacement of 4.3 tonnes; with only 50 cm draught, it can manoeuvre almost anywhere. It accommodates two pilots and six combat divers. The agile vessel incorporates a 345 hp diesel engine coupled to a waterjet propulsor for above-water transit and semi-submersed mode. Fully submersed it switches to two, 20 kW Lithium-Polymer batteries which power two electric thrusters. Surfaced, the vessel operates as a speedboat at up to 30 knots with a range of 150 NM.

In semi-submerged and submerged modes the Carrier Seal slows to 4 knots cruise and 6 knots sprint speed or 3 knots cruise and 5 knots sprint, respectively. Range under water is 15 NM. While demonstrating the Carrier Seal at SOF Week 2024 in Tampa, JDF cited a maximum depth range of 30 metres, although the firm's published data sheets have previously stated a range of 40 to 50 metres. Both surface and subsurface range can be doubled by carrying an auxiliary fuel pod and/or extra battery packs.

The Carrier Seal is equipped with several mounts for a variety of weapons, permitting its deployment as a combat boat when needed. To support reconnaissance, surveillance and intelligence missions the vessel can also be equipped with side-scan sonar, remotely operated vehicles and autonomous underwater vehicles.

The firm's smaller Shadow Seal accommodates a two-person crew and two passengers. JDF first showcased the submersible in 2023 at the SOF Week in Florida and the DSEI exposition in London. The firm defines the 8 metre long, 2,500 kg vessel as a tactical diving vehicle or TDV with a maximum dive depth of 24 metres. Surface performance includes a speed of 5.5 knots with a range of 80 NM, while submerged operation reaches 4.5 knots and a 25 NM range.

In September 2023 a JDF press release confirmed that "the Carrier Seal is in operation with a number of the world's navies," without identifying the operators. In 2022 the firm partnered with US-based Blue Tide Marine (BTM) "to provide local demonstration and training services" in hopes of enhancing marketing opportunities in North America.

United Kingdom: Victa

SubSea Craft, another UK-based designer, achieved proof of concept certification for its Victa diver delivery unit (DDU) in July 2023 following extensive sea trials. This paved the way to begin construction of the first production-standard vessel. While the firm hopes to market Victa to the British Special Operations Forces, no acquisition decisions have been reported to date. Following certification, the firm's CEO Scott Verney stated that the firm would continue to evolve and enhance the design to accommodate client preferences and the evolving operational environment.

The vessel is equipped with a Seatek 725 hp diesel engine powering twin propellers, and a high-capacity lithium-ion battery system powering electric thrusters. Victa achieves a top surface speed of 40 knots and a cruise speed of 30 knots, with a surface range of 250 NM; submersed the vessel achieves 8 knots with a 25 NM range, and a dive limit of 30 metres. The transition between surface and subsurface mode requires two minutes. Fly by wire controls and AI-augmented control and navigation systems reduce pilot workload. SubSea Craft intends to develop remote operation and autonomous operation capability in future iterations of the vessel.

The 12 metre long vessel seats eight including the two-person crew. The cabin can be reconfigured to accommodate various mission payloads at the expense of a smaller number of personnel. The mono-hull vessel is constructed of carbon fibre with a composite core. The streamlined form of the enclosed cabin reduces the radar cross-section during surface operations.

While the vessel is fully enclosed during surface operations, the hull is flooded when submerged. While this can have a negative impact on crew comfort, the 'wet' submersible is associated with several advantages, beginning with greater design simplicity and reduced cost (due in part to the lack of organic life support systems). Operationally, the flooded hull provides greater stability and enhanced manoeuvrability compared with the buoyancy issues which can arise with dry submersibles.

Credit: Alseamar

A computer-generated image of divers returning to a Sphyrene SDV.

France: SWUV/PSM3G

France's then ECA Group (now Exail) presented its Special Warfare Underwater Vehicle (SWUV) at the 2014 Euronaval exhibition in Paris. Classified as a SDV, the 8.5 metre long SWUV has a capacity of six, including a two person crew. To date, both Exail and the French Navy have shrouded the system in secrecy, with few structural or capability details being revealed. Performance parameters supposedly include a top speed of 10 knots and a maximum diving depth (depending on source) of between 60 and 100 metres. One of the few official comments was a November 2019 Tweet by then French Naval Chief of Staff, Adm Christophe Prazuck, announcing that he had participated in a dive in the new SDV.

The French armed forces have designated the vessel as the PSM3G or third generation swimmer delivery vehicle. Various media reports agree that it was accepted into service in late 2019, which would be consistent with the timing of Adm Prazuck's demonstration dive. The PSM3G is being acquired specifically for the navy's Commando Hubert SOF combat swimmer unit, although there is speculation that it could also be used by the combat swimmers of the national intelligence service, the Direction générale de la sécurité extérieure (DGSE). The PSM3G can be launched by surface craft or be carried by an 11 metre dry deck shelter on a Suffren class submarine. This grants the divers dry access to the SDV via an airlock from the submarine. Mission options include commando transport, shallow water/coastal ISR, and the underwater transportation and placement of explosives.

France: Coryphene and Sphyrene

In August 2023 the French Navy introduced another new SDV, the Alseamar-produced Coryphene. The 6 metre long SDV provides tandem seating for a pilot and a navigator/systems operator. An additional space behind the navigator accommodates either a third person or an optional retractable optronics mast. The Coryphene reaches speeds of 8 knots and a range of 50 NM (at 5 knots cruising speed). A 1 metre, narrow beam facilitates navigation in cluttered or restricted environments.

Alseamar is also developing the Sphyrene SDV, which is currently at the concept-development stage. Intended primarily for the export market, the 8 metre long Sphyrene will accommodate six divers including its crew. Objective performance parameters include a top speed of 9 knots and a range of 70 NM at 8 knots cruising speed. Like the Coryphene, the Sphyrene can be outfitted with a telescopic optronics mast.

Both SDVs can be deployed from ships, specially configured boats, or from submarine-mounted cradles and DDSs. Both operate as 'wet' submersibles, with crew and passengers receiving a nitrox via the vehicle's life-support system. The submersibles can travel open at depths up to 25 metres; with the access hatches closed, the Sphyrene can descend to 50 metres, while the Coryphene can operate as deep as 100 metres. Both SDVs are equipped with integral sonar with a 350 metre range. Additional navigation and manoeuvring systems include INS and Doppler velocity logging (DVL). Satellite communications ensure connectivity with the mothership or shore stations. The cockpit instrumentation features user-friendly human-machine interface configuration to reduce crew stress and enhance manoeuvrability.

United Arab Emirates: Kronos

The greatest drawback of submersibles is their lack of speed when operating underwater. Highland Systems, a UAE-based start-up founded by Ukrainian engineers, promises to resolve this issue while also enhancing many other performance parameters. The firm publicly presented its Kronos concept at the NAVDEX 2023 exhibition. Externally the 9 metre long, 7.4 metre wide vessel appears to be inspired by a manta ray or a science fiction movie 'death glider'. The designers state that its innovative shape and the composite material overlaying the steel hull are optimised for signature reduction, making the Kronos a stealth vehicle. A hybrid propulsion system includes a diesel engine for surface mode and an electric drive for submerged operations. Highland Systems cites a targeted top speed of 43.2 knots surfaced and 27 knots submerged. This is combined with the ability to manoeuvre and turn sharply at full speed, even under water. The vessel is configured for a standard operating depth of 100 metres, with a maximum critical depth of 250 metres. The design accommodates a single pilot plus 10 passengers. Total mission endurance is given as 54 hours, including 36 hours on the surface and 18 hours submerged, with a 36 hour on board air supply as a safety margin. Recharging the battery and the air tanks requires 90 minutes on the surface. In addition to 10 combat divers, the Kronos can also carry up to six light torpedoes or, optionally, an onboard underwater or aerial drone.

Given the complexity of submersible design, Highland Systems' concept – as presented – appears extremely ambitious. Should even a portion of the targeted performance criteria eventually be met, Kronos would constitute a major leap forward for underwater Special Operations capabilities, and set new baselines for future systems. ■

Credit: Highland Systems

The Kronos concept demonstrator

Propelling the future submarine –

countering new ASW challenges with lithium-ion batteries and air-independent propulsion

Commander Lars Bahnemann

The future submarine operating environment

The water around your submarine is reverberating due to a distant active low-frequency sonar. Every few minutes, the sonar operators report a splash point, a sign that a passive sonar buoy has been dropped by one of the numerous unmanned aerial vehicles (UAVs) out on patrol that relentlessly hunt you 24/7. Your sonar is filled with squeaking, indicating underwater communication between buoys, unmanned surface vehicles (USV) and undetected submerged threats. The last time you raised your scope, you received bearings for at least three radar emitters, possibly UAVs patrolling the area. Thirty minutes after going deep, a swarm of multiple UAVs and at least one USV attempted to hunt you down. You only survived by bottoming and enduring the ordeal of 48 hours of relentless pursuit. You haven't spotted your target for days. As the enemy is aware of your presence, it has possibly been routed away from your position. Intelligence reports suggest enemy satellite coverage has intermittent gaps shorter than ten minutes. Even the faintest periscope wake might be detected by data mining tools on satellite imagery. Your chief engineer reports to you, the commanding officer: "We have battery left for a 15-minute sprint or another five hours of loitering." Raising your snorkel would likely result in imminent destruction. There seems no way around the numerous sensors to gain freedom of manoeuvre. You must stay put under the coastline and wait for a miracle or retreat.

The submarine in this scenario is faced with a dire situation. But it could be the fate of any submarine shortly if technology fails to keep pace with the empowering trends currently seen in anti-submarine warfare (ASW).

Submarines rely on secrecy and cover provided by their operational environment. The intricacies of acoustics make detection by active sonar a resource-intensive task. Recent strides in reducing passive signatures have been remarkably successful, with detection ranges approaching zero. Submarines are invisible if they can evade detection via classic electromagnetic sensors (such as RADAR or electro-optic). They currently enjoy a peak level of freedom, but this is bound to change. Emerging technologies will provide more effective means of detecting submarines in the upcoming decade, even in the most complex environments. The integration of unmanned systems, advanced data processing (such as multi-static sensor systems and data mining) and artificial intelligence (AI) with sensors from all domains and services will provide the future ASW forces with the capability to exploit previously unnoticed signatures – e.g., faint wakes left by the scope or pressure fields. These technologies will help detect, locate and track submarines faster than ever before.

In his ground-breaking article "The Hunt for Full Spectrum ASW",[1] Captain USN Toti described a framework to implement ASW as a joint-force, multi-domain operation (MDO) back in 2014. He defined ten threads along which ASW forces may operate. These threads range from the tactical to the strategic level of war. The tactical-level threads demand mass and are time-consuming, relying heavily on dedicated naval assets. The committed force operates at high risk due to the proximity of the submarine. In contrast, the operational or strategic-level threads require comparatively fewer naval forces and minimise their risk. By utilising joint assets and combining platforms and capabilities present, e.g., UAVs, satellite data and intelligence from cyber and information domain operations, the aim of ASW – denying the enemy the effective use of submarines – can be achieved far more effectively at the operational than at the tactical level in future. Establishing the sensor-to-shooter kill chain makes the employment of conventional submarines extremely difficult, denying the submarine its typical areas of operation, restricting its freedom of manoeuvre and forcing it to take higher risks when using necessary approach routes.[2]

In order to remain relevant, submarines must adapt to the changing ASW environment, outmanoeuvre the opponent and counter the new capabilities. The importance of countering these new capabilities cannot be overstated. On the

Credits: BBC

Figure 1: Schematic overview of the primary components of a submarine power plant.

Author

Commander Lars Bahnemann is a staff officer in the German Procurement Agency (BAAINBw) and responsible for international cooperation in the area of submarines.

1 (Toti2014) Captain William J. Toti "The Hunt for FullSpectrum ASW", The Naval Institute Proceedings, 2014;140;6;1,336.

2 For possible applications and examples, refer to (Lancaster2024) Jason Lancaster "Make ASW Joint: Integrating the Joint Force into Full Spectrum ASW", CIMSEC, 2024; https://cimsec.org/make-asw-joint-integrating-the-joint-force-into-full-spectrum-asw/

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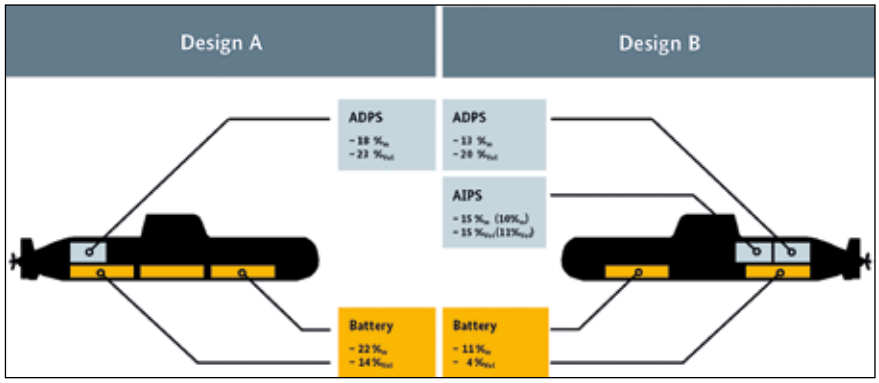


Figure 2: Schematic overview and volume and mass distribution of power plant components for a fictional 2,000--tonne submarine.

one hand, submarines must improve mobility to regain the element of surprise and avoid enemy ASW capability concentrations. On the other hand, they must be able to extend clandestine periods without exposing themselves above the surface. The simplest way to achieve this is by eliminating the necessity for protracted snorkelling and reducing the indiscretion ratio, a key metric in submarine operations that measures the time a submarine can remain submerged without the need to return to periscope depth for snorkelling, even during high-paced movements. Which platform enhancements might help the submarine force overcome this challenge in the upcoming decade?

Technologies at hand

The composition of the submarine's power plant is crucially important, as it determines the indiscretion ratio. Of its four primary components (Figure 1), energy sources and buffers (battery systems) are the most critical. The decisions made in this area will significantly impact the submarine's capabilities and survivability.

The battery is currently the submarine's only source of high electrical power. The transition from the legacy lead-acid battery (LAB) technology to lithium-ion battery (LIB) technology is underway. This shift substantially enhances the usable energy capacity of submarines while enabling sustained maximum power delivery throughout the entire discharge process. The primary concern relates to safety and encompasses the limitation of energy density, currently standing at approximately 175 kWh/m³ at system level when employing the 'safe' LiFePo4 chemistry. It is also known for its stability and low risk of thermal runaway. LIBs exhibit significant growth potential if safety concerns can be effectively addressed. Batteries used in electromobility feature energy densities range from 600 to 700 kWh/m³. Considering the pace of advancement, it may be plausible to anticipate target energy densities for submarine applications to fall within the range of 200 to 300 kWh/m³ in the coming decade.[3] But even then, an LIB with a standard share of submarine displacement will be capable of storing only a fraction of the energy that an energy storage system could store. LIBs may enable prolonged submerged operations at high speeds of up to 20 kn compared to existing designs. Nevertheless, the potential endurance will be limited to hours rather than days. LIBs cannot sustain submerged operations for extended periods and will require additional energy storage. The potential of LIBs lies in their ability to facilitate operations at high speeds and offer new tactical possibilities in volatile situations.

Air-dependent propulsion systems (ADPS) still constitute the fastest method for recharging submarine batteries. ADPS generally use the submarine's diesel engine to generate electricity to charge the batteries. With a volumetric energy density of approximately 10 MWh/m³, diesel fuel remains unrivalled in energy storage capacity. Modern fast-running diesel engines equipped with exhaust gas turbocharging and waste gate achieve power densities of 40 kW/m³. No other energy source can currently match that energy or power density. Ongoing advancements in turbocharging technology and further thermodynamic optimisation promise to increase power density to approximately 50 kW/m³. However, despite these advancements, the potential for reducing the charging time for increasingly larger battery capacities is severely constrained considering the limited space and weight available aboard submarines. The main drawback of ADPS lies in the requirement to raise a snorkel to take in air, restricting

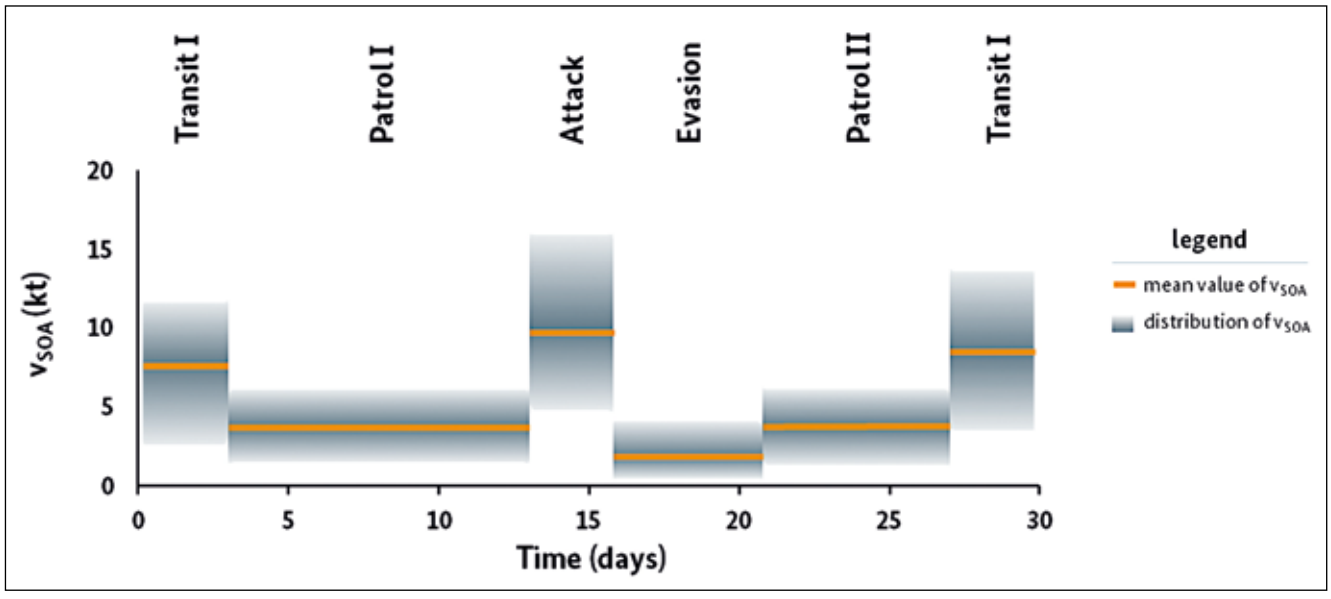


Figure3: Operational profile as baseline of Probability of Detection (PoD) comparison.

3 (Bahnemann2024) Lars Bahnemann "Lithium-Ionen-Batterien auf Ubooten. Ein Paradigmenwechsel in der Unterwasserseekriegsführung?", Europäische Sicherheit & Technik, 2024;5;91-96.

operational use to non-hostile areas and situations where the need for high-speed transit must be carefully weighed against the risk of detection.

Air-independent propulsion systems (AIPS) encompass technologies that convert stored energy into electric energy without requiring an external air supply. Typical systems include the proton exchange membrane fuel cell (PEMFC), the external combustion piston engine (Stirling engines), and the Rankine cycle power turbine (MESMA).[4] These systems typically exhibit a relatively low power output, between 150 and 300 kW at system level.[5] However, their energy conversion efficiency varies, with PEMFC leading at 60%, while the other systems range as low as 25%. The required volume for energy storage also varies widely depending on the exact fuel used. The primary limitation of these systems is their low power output. Current developments do not appear poised to increase their power output substantially in the foreseeable future. Any increase in power density tends to decrease the efficiency of the AIPS, thereby requiring significantly increased fuel and oxidant storage. Moreover, the existing storage technologies are operating at their technical limits, with limited prospects of meeting the specific needs of submarines. While low-power AIPS can sustain submarines on long-submerged patrols due to the fuels' high volumetric energy density, they cannot recharge the battery quickly, with full recharges requiring days rather than hours.

All reviewed systems possess distinct strengths and weaknesses. While the batteries continue to serve as the primary power provider, the ADPS enables quick recharge, and the AIPS provides a low-power, high-energy backbone for the submarine. Therefore, no single technology described will be able to power future submarines in the challenging environment mentioned at the beginning. A combination is essential.

Application to submarines

A review of the current submarine market and procurement programmes reveals two distinct approaches to countering the threat. One approach relies on high-energy LIBs and powerful diesel engines for recharging (Design A). The other approach combines all three technologies to maximise their benefits (Design B). To facilitate a comparison between the two design choices, we shall consider a conventional submarine with a displacement of 2,000 tonnes (Figure 2). The figure illustrates the average distribution of relative displacement per system from multiple submarine programmes and shall act as a baseline for further analysis.

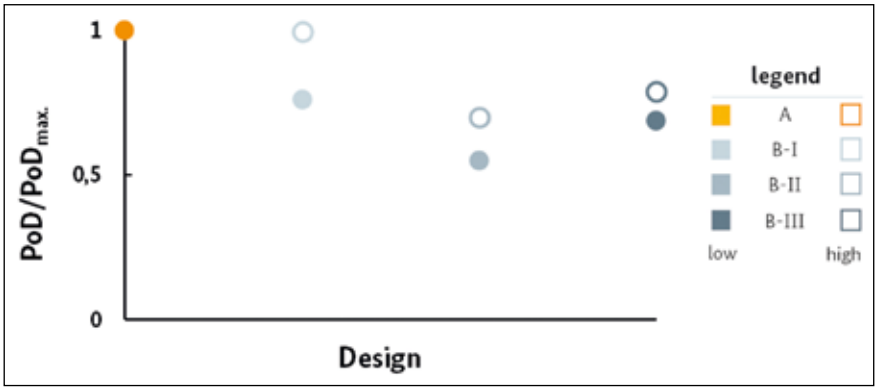


Figure 4: Comparing the Probability of Detection (PoD) during the operational profile in Figure 3 reveals significant advantages for Design B.

The key to making further analysis informative is to address the submarine's survivability in the future operating environment. A simple comparison is the probability of detection against a specific set of ASW sensors after a defined operational profile. Assuming detection can be modelled as a random walk search, with the search rate determined by an artificial sensor combining the characteristics described at the beginning, it is possible to calculate the probability of detection for each submarine design after following the operational profile outlined in Figure 3.

The comparison was made for different AIPS, ADPS, and LIB combinations. Design A represents the LIB-APDS combination with increased charging capacity. Designs B-I to B-III change the AIPS, battery and ADPS ratio. B-I has the smallest AIPS and a larger battery, while B-III has the largest AIPS and the smallest battery, with the ADPS being adjusted according to the battery size. The results presented in Figure 4 show that the integrated approach (Design B) is more likely to go undetected. This holds true even if a possible increase in LIB energy density is considered. The fact that Design B-II achieves the best performance indicates that increasing the AIPS is not a guaranteed recipe for success. Identification of the optimal combination still requires further analysis. Its outcome will not change the final result, though. The combination of battery, ADPS, and AIPS is best suited to avoid detection, survive in the future operating environment, and also allow submarines to remain relevant.

This is mainly rooted in two facts: first, Design A requires a speedy recharge to achieve the low indiscretion rate (IR) necessary to avoid detection. This requires a powerful diesel engine set scaled to the battery system installed on board. Due to the LIB's size, only a massive sacrifice in displacement for the ADPS may reduce the IR effectively. Let us assume it might be possible to achieve a safe LIB allowing 75 MWh energy storage in a 2,000-tonne submarine. This implies an energy density of around 330 kWh/m³, which might be possible to achieve at the end of the outlook period. A recharge with two diesel engines of the latest generation will still take nearly 40 hours. To enable a 4-hour recharge, almost 20 MW of generator power is necessary! Ballooning the displacement share of the ADPS from approximately 5% to 25% is currently impossible, however. Second, while the AIPS is designed especially for quasi-stationary creeping, it may continuously cover the base load of the submarine using up-to-date power electronics and energy management, extending the time submerged even at higher speeds. Furthermore, even though recharging the battery by the AIPS might take an extremely long time, it is possible, thereby allowing the submarine to loiter and recharge during operational pauses after prolonged sprints without snorkelling. Hence, it is crucial to persist in developing and utilising AIPS systems alongside other technologies to optimise the energy configuration on submarines.

To reconsider the scenario presented at the beginning of this article: if you were in command of a Design B submarine, you could confidently answer: "Chief, we will charge the battery via the AIPS for the next 20 hours, ignoring the turmoil. Make a 6-hour sprint along the coastline to the other side of the barrier. Then make another attempt to penetrate the defences." ■

4 (Lus2018) Tomasz Lus „Waiting for Breakthrough in Conventional Submarine's Prime Movers", Transaction in Maritime Sciences, 2019; 04; 37-45.
5 Refer to Lus2018 and Peruzzi2023. (Peruzzi2023) Luca Peruzzi "Developments in Lithium-ion Batteries and AIP Systems for Submarines", European Security & Defence, 2023; 11-12;76-82.

European submarine builders: riding the upturn

Conrad Waters

Europe remains a focal point of submarine construction and technological innovation. The industry placed heavy reliance on securing export orders to sustain their operations during the difficult, post-Cold War years, albeit some rationalisation was inevitable. With a changed political background, many manufacturers are now scrambling to find ways to meet an upsurge in domestic demand as navies seek to rebuild their underwater capabilities. This article looks at the fortunes of the region's current major players.

France: Naval Group

France's Naval Group is arguably Europe's leading submarine manufacturer, being the only European company to have recent experience of manufacturing both nuclear-powered and diesel-electric designs. The focal point of its submarine business is its shipyard at Cherbourg in Normandy, where all French-built submarines are currently constructed. The facility is dominated by the huge, 190 metre long 'Labeuf Hall', which is used for final assembly. Naval Group's submarine activities are supported by an extensive national ecosystem of sub-contractors, amongst the most significant of which are MBDA (weapons), Safran (optronics), Thales (sonar and communications) and Technic-Atome (reactors). Naval Group's ongoing involvement in the production of advanced anti-submarine warships such as the Franco-Italian FREMMs also arguably gives it an advantage in understanding the opponents its submarines will need to combat

Credit: Naval Group

A Suffren class submarine under construction in the 'Labeuf Hall' at Naval Group's Cherbourg shipyard.

Naval Group's submarine activities have two distinct, if closely intertwined elements. One of these is construction of nuclear-powered submarines for the French Navy. The most significant project of recent years has been the 'Barracuda' programme to build a replacement for the Cold War-era *Rubis* class. This has given rise to the construction of six nuclear-powered attack submarines of the *Suffren* class under a series of contracts that were placed from December 2006 onwards. The lead boat was delivered in November 2020 and was followed by her sister FS *Duguay-Trouin* in July 2023. The third member of the class is currently in the course of sea trials whilst work is underway on all the remaining submarines in line with a programme schedule that envisages the final boat being delivered in 2030. The likely near 25 year-long span of construction activity gives a good indication of the size and complexity of the programmes that Naval Group is able to undertake.

The 'Barracuda' class are being followed into production by France's third generation strategic submarine design, otherwise known as the SNLE-3G. Formally launched in 2021, the SNLE-3G programme envisages the numerical like-for-like replacement of France's existing four *Le Triomphant* class boats over the two decades from around 2035 onwards. A first steel-cutting ceremony for the lead unit was held at Cherbourg in March 2024, marking the start of the production phase. The security and continuity in workload enjoyed by Cherbourg's construction activities through France's unwavering commitment to its underwater nuclear deterrent provide a firm foundation for Naval Group's overall submarine business.

Although the French Navy made a conscious decision to phase out its non-nuclear powered submarines after the end of the Cold War, Naval Group has nevertheless managed to remain a leading player in the international market for these boats. A major element in this outcome was the early success achieved by its 'Scorpène' design, which was originally produced in collaboration with what is now Spain's Navantia. The design gained many export contracts and currently remains under licensed production in Brazil and India. To some extent, however, this strong position was subsequently undermined by Naval Group's failure to develop a commercially successful air independent propulsion (AIP) system, reducing its competitive strength in export markets. Another major blow was experienced in September 2021 when Australia cancelled its planned local construction of the group's

Credit: Navantia

Naval Group enjoyed considerable success exporting 'Scorpène' type diesel-electric submarines in partnership with Spain's Navantia. This is the Royal Malaysian Navy's KD Tun Abdul Razak.

'Shortfin Barracuda' design in favour of Anglo-American nuclear-powered submarines under the AUKUS security pact.

Recent developments have been more favourable. Early 2024 saw the announcement of two major export awards that have put the group's international business on a firmer footing. The first success came on 15 March 2024 when the Netherlands provisionally selected the diesel-electric 'Blacksword' variant of Naval Group's 'Barracuda' family for its own replacement submarine programme, partly mitigating the impact of Australia's earlier decision. Later that month, Naval Group also announced that two 'Scorpène Evolved Full LiB' submarines would be assembled by PT PAL in Indonesia under a transfer of technology arrangement. This latter award suggests that progress in lithium-ion battery technology has mitigated the group's relative weakness in the AIP sphere. Given the already-strong domestic demand position, Naval Group's major challenge now seems likely to be driven by the inevitable challenges created in managing the resultant increase in work.

Germany: tkMS

Germany's thyssenkrupp Marine Systems (tkMS) is arguably Naval Group's most significant rival amongst European submarine builders. Its submarine business's current structure traces its origins to consolidation of much of the German naval sector under the ownership of thyssenkrupp in the early part of the current millennium; particularly that of the Howaldtswerke-Deutsche Werft (HDW) shipbuilding company in 2005. Following a previous period of rationalisation, the former HDW shipyard in Kiel is currently the sole location for submarine construction in Germany, employing some 3,100 workers. tkMS claim that this makes the facility Germany's largest shipyard. Like Naval Group, tkMS's submarine business is supported by a strong indigenous supplier network. This includes wholly-owned subsidiary Atlas Elektronik (combat management systems, sonar and torpedoes) and sub-contractors such as Hensoldt (optronics), Rolls-Royce's MTU (diesel generators), and Siemens (electric motors and AIP propulsion).

Credit: tkMS

Construction of the Type 212CD submarine, pictured here in a computer generated image at the Kiel shipyard, is the largest contract ever awarded to tkMS.

tkMS submarine's business is focused on the construction of diesel-electric submarines, mostly also equipped with auxiliary AIP-propulsion systems. Although it has a long track record of supplying advanced submarines to the German Navy – most recently the Type 212 AIP-equipped series – it has typically been more heavily reliant on export contracts than any of the other European manufacturers. Its considerable success in the global market for submarines can initially be traced to the popularity of the well-known Type 209, which was developed in conjunction with the design house IKL as long ago as the 1960s and has remained in production into the current decade. More recently, tkMS has also been bolstered by the widespread acceptance of Siemens' Polymer Electrolyte Membrane (PEM) fuel cell technology for AIP-propulsion. This was first introduced operationally in the Type 212A submarines built for Germany and Italy but, to date, has gained most sales from the export-orientated Type 214 design. The majority of the latter boats have been built by overseas shipyards under licence.

Although tkMS is currently in the course of completing export contracts for Israel ('Dolphin II') and Singapore (Type 218SG), its most important current project is for the new Type 212CD ('common design') class. Derived from but significantly larger than the previous Type 212A iteration, these are being built in Germany for both the German and Norwegian navies under a collaborative programme. A contract valued at EUR 5.5 billion was signed for an initial six boats in July 2021 in what tkMS claimed was its largest-ever award to date. Four of these will be for Norway and the other two for Germany. Their construction will be supported by investment of EUR 250 million in improved production facilities at Kiel. Fabrication of the lead Norwegian submarine commenced in September 2023 for planned delivery in 2029, with completion of the contract expected in 2035. However, Norway's quadrennial Long-term Defence Plan for the period through to 2036 that was announced in April 2024 envisaged procurement of between one or two additional members of the class. Moreover, Germany's 'Vision 2035+' force structure plan envisages the operation of between six and nine submarines in the medium term. As such, it seems that the Type 212CD construction will be extended beyond this date.

The likely growth in the scope of the Type 212CD programme – coupled with further existing and potential export contracts that include a firm order for three additional submarines for Israel – have resulted in questions as to whether the previous process of rationalising tkMS's construction infrastructure has gone too far. In June 2022, it emerged that tkMS had acquired the Wismar shipyard from the insolvent cruise shipbuilder MV Werften as a possible additional location for submarine construction. At present, it is unclear as to the extent to which this intention will be realised amongst reports that Wismar might be re-purposed to construct other types of vessel. Additional uncertainty arises from the planned demerger of tkMS from the wider thyssenkrupp group under a plan revealed in March 2023. As of September 2024, discussions to implement the business's sale were still ongoing.

Italy: Fincantieri

Current Italian submarine construction is carried out by Fincantieri at the Muggiano shipyard near La Spezia in northern Italy. The end of the Cold War saw Italy decide to forego a fully national submarine capability in favour of adopting the German Type 212 design for its future underwater needs under a collaborative programme. This saw limited modifications to what was an existing German programme to meet Italian requirements for Mediterranean operation, leading to the Type 212A designation. Two pairs of these submarines were delivered to the Italian Navy as the *Todaro* class in separate batches during 2006-07 and 2016-17 respectively.

Fincantieri is now in the course of evolving towards re-establishing a fully indigenous submarine design and manufacturing capacity through construction of the Type 212 NFS ('near future submarine') design. This is essentially an Italian

Credit: Fincantieri

Production of Italy's Type 212NFS – a development of the earlier Type 212A design – commenced at Fincantieri's Muggiano shipyard in January 2022

Credit: Navantia

Navantia's lead Type S-80 submarine, Isaac Peral, seen in the course of being readied for float out at Navantia's Cartagena shipyard in May 2021

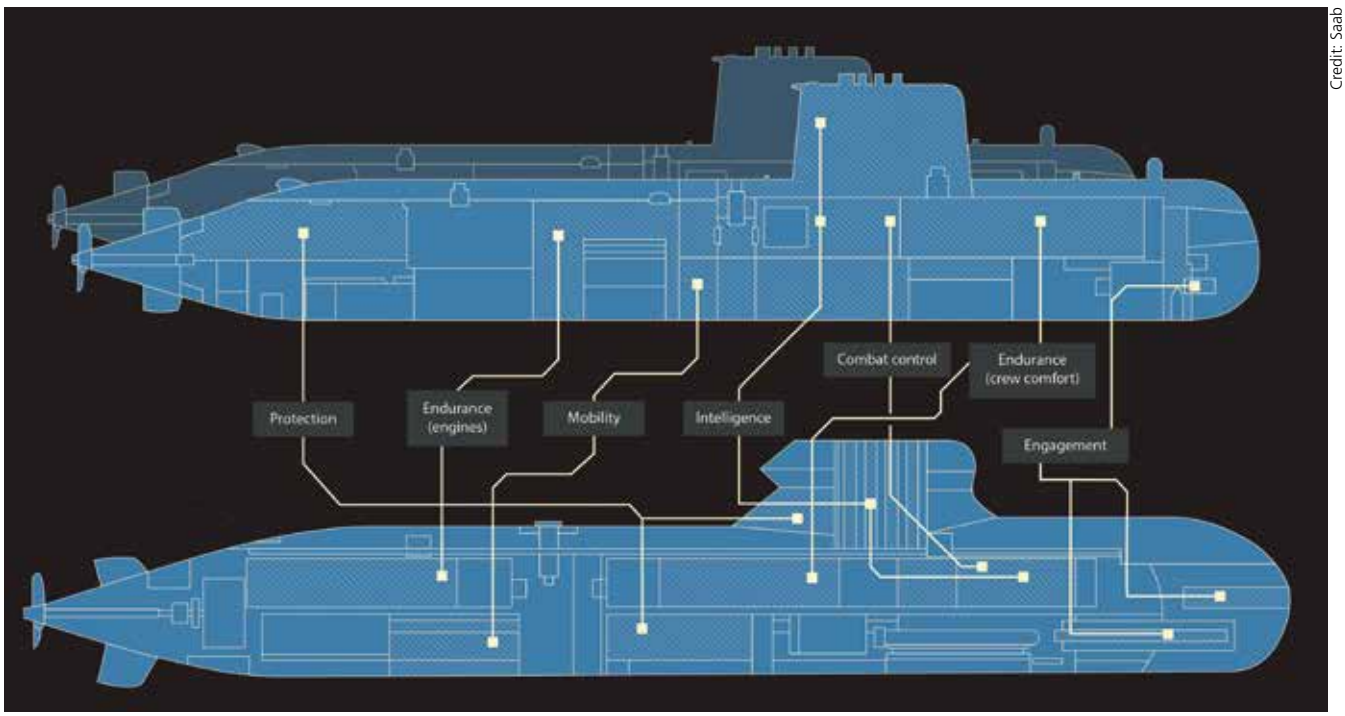
development of the previous Type 212A. Fincantieri signed a contract for two of these new boats in February 2021 and options for an additional pair have subsequently been exercised. Construction of the lead unit commenced in January 2022 to meet targeted delivery in 2027. The design incorporates a number of design modifications produced by the Italian company, which is design authority and prime contractor for the class. The Type 212 NFS also incorporates significant levels of equipment sourced from the Italian supply-chain.

Construction of the Type 212 NFS form part of a phased approach that will subsequently transition to a further-evolved Type 212 NFS EVO prior to production of a fully-national new generation submarine (NGS) in the 2040s. In the interim, Fincantieri has also strengthened its industrial base with the EUR 415 million acquisition of Leonardo's Underwater Armament Systems business in May 2024. Despite this progress, Italy arguably has a less-developed network of component suppliers than many of its European rivals and this could place it at something of a competitive disadvantage. It also has no recent track record of exporting full-sized submarines, leaving the scope of its future activities largely dependent on Italian Navy requirements and funding unless it can break into the wider, international market.

Spain: Navantia

Although Spain has a long track-record of submarine construction, the vast majority of its historic production has been formed of license-produced, overseas designs. The Cold War era saw particularly close collaboration with what is now France's Naval Group; notably with respect to the S-60 (licensed *Daphné*) and S-70 (*Agosta*) classes. This track-record of co-operation subsequently played an important part in Spanish industry becoming a junior partner in a joint venture to produce the export-focused 'Scorpène' design that was finalised in 2001. Spanish-based construction activities for all these submarines took place at the shipyard at Cartagena, which remains the production centre for Navantia's submarine business.

A major change in the Spanish submarine industry's strategic direction took place with the decision to develop the indigenous S-80 class under a programme that received final government approval in September 2003. As well resulting in the breakup of the previous collaboration with France, this exposed Spain to the huge challenges involved in the fully independent design and construction of a complex, modern submarine. According-



Credit: Saab

Saab has used modernisation of the existing Gotland class submarines to pave the way for technologies used in the new A26 Blekinge class boats.

ly, the programme encountered significant difficulties that were most evident in an increase in weight that dangerously impacted reserve buoyancy. The result was a major re-design and hull-extension with the assistance of the United States' General Dynamics Electric Boat (GDEB). This ultimately pushed back delivery of the lead boat, *Isaac Peral,* until November 2023. The other three members of the class remain under construction at Cartagena.

Whilst the S-80 programme has proved a problematic and expensive one, its ultimate implementation has provided Spain with a sovereign submarine design and manufacturing capability that was previously lacking. This has included significant steps in developing the capabilities of an indigenous supply chain. The future of this capacity now depends on the willingness of the Spanish government to fund further submarine orders for the Spanish Navy, as well as Navantia's success achieving export sales. Whilst several opportunities have been pursued, overseas nations demonstrated an understandable reluctance to commit to the company's designs before the lead member of the S-80 class was actually delivered. It should also be noted that Spain likely still has the heaviest reliance on overseas suppliers for submarine components amongst European shipyards, with America's Lockheed Martin (sonar and combat management system elements) and Britain's Babcock (weapon handling system) being amongst key contractors for S-80 construction.

Credit: BAE Systems

The Astute class submarine HMS Anson pictured outside the Devonshire Dock Hall in Barrow-in-Furness, where all British-built submarines are currently assembled.

Sweden: Saab

Sweden is currently in the process of attempting to revitalise its national submarine industry under the ownership and direction of national defence conglomerate Saab. The group acquired the then-Kockums shipbuilding business in 2014 after Kockums' previously successful submarine business has been allowed to atrophy during a period of, first, HDW and, then, tkMS ownership. The acquisition was driven by the Swedish government in reflection of the crucial importance of submarines in Sweden's overall defence architecture.

Since acquiring Kockums, Saab has been working to resurrect indigenous submarine production at the Karlskrona shipyard. The facility has undertaken a series of life-extensions of the three existing *Gotland* class submarines in preparation for construction of the next generation A26 *Blekinge* class, two of which were ordered in 2015. In a sign of the very large amount of work needed to resume Swedish submarine production since completion of the *Gotland* class boats in 1997, it was only in June 2022 that a keel laying ceremony for the lead A26 was held. This challenge is also reflected in a delay in the planned delivery of the initial boat from 2022 to 2027 and an increase in the production contract's cost from SEK 7.6 billion to SEK 12.8 billion (approximately USD 1.3 billion).

Despite these teething problems, the future of Sweden's submarine sector appears to be assured by a continued requirement for domestically produced boats. This is reflected in Saab's receipt of a government contract in December 2023 to conduct concept development studies for future underwater capabilities. These studies likely encompass plans to replace the *Gotland* class during the 2030s with a new design that has sometimes been referred to as 'U-båt 2030'. Saab has also been pitching a series of submarine designs derived from the A26 in the export market but received a major setback in March 2024 when its joint proposal with Damen for the Netherlands' submarine replacement programme was beaten by Naval Group's bid. Whilst Saab continues to pursue other export possibilities, the advantage previously provided by its Stirling AIP technology has arguably been eroded by progress with competitor systems. Given also the economies of scale enjoyed by larger submarine manufacturers, Saab may struggle to achieve export success.

United Kingdom: BAE Systems

British submarine construction is carried out by BAE Systems at its shipyard in Barrow-in-Furness in north-west England. Like France, the British Royal Navy decided to phase out its diesel-electric submarines at the end of the Cold War. In the absence of a competitive diesel-electric design for export markets, this has left Barrow dedicated solely to building nuclear-powered boats. The United Kingdom does, however, have an extensive network of submarine component manufacturers, including Babcock (weapon handling equipment), Rolls-Royce (reactors) and Thales UK (sensors). Some of this equipment has achieved considerable export success with countries such as South Korea and Spain that still lack the ability to produce some submarine components indigenously.

Again in similar fashion to France, the United Kingdom's determination to maintain an underwater nuclear deterrent has underpinned the country's submarine enterprise. However, this did not save the industry from considerable rationalisation at the Cold War's end. Notably, the Barrow-in-Furness workforce fell by over three quarters (from 13,000 to 2,900) in the decade between 1992 and 2002. An associated loss of skills caused significant problems with completing the programme for *Astute* class nuclear-powered attack submarines, for which initial construction contracts were signed in 1997. Five out of a projected class of seven boats have been delivered to date, with the other two in the later stages of construction.

The industry's fortunes have recovered with the need to renew the strategic submarines that form the United Kingdom's nuclear deterrent. Production of the first of a planned four *Dreadnought* class submarines commenced at Barrow in October 2016 under what is known as the 'Successor' programme. The massive project has been costed at GBP 31 billion (plus a GBP 10 billion contingency) and has necessitated the wholescale revitalisation of the shipyard's capacity. This has included extensions to the 260 metre long Devonshire Dock Hall where submarines are assembled, as well as a ramp up of the yard's workforce to a current level of around 13,500 personnel.

Whilst *Dreadnought* class production is already likely to sustain BAE Systems' submarine business throughout the next decade, longer-term production will be assured by the SSN-AUKUS nuclear-powered attack submarines being built for the Royal Navy and Royal Australian Navy under the September 2021 trilateral AUKUS defence security partnership between Australia, the United Kingdom and the United States. All members of the class destined for Royal Navy service will be constructed in Barrow, from where the first boat will be delivered at the end of the 2030s. The project has been reported to require further expansion of shipyard facilities and another increase in workforce to a peak of around 17,000. Although the Royal Australian Navy SSN-AUKUS submarines will be assembled locally in Osborne, South Australia, the British submarine supply chain will benefit from significant business from their construction. Notably, Rolls-Royce will produce the nuclear reactors for all the class at its facility at Raynesway in Derby.

Competition on the Horizon

This short overview of the current European submarine industry reveals a buoyant sector marked by strong increase in demand and associated investment in facilities and the workforce. The industry is also supported by the involvement of major defence and shipbuilding groups with large financial resources and by governments that have displayed a long-term commitment to indigenous submarine manufacture. The position of those manufacturers – BAE Systems and Naval Group – producing submarines that form a critical element of their home countries' nuclear deterrence looks particularly secure.

There are, however, a few clouds on the horizon. In addition to the inevitable strains associated with expanding after a long period of subdued demand, the threat posed by new market entrants cannot be discounted. This is particularly relevant for those manufacturers focused on – or seeking to develop – an export-based business model. For example, Germany's previous support for South Korean and Turkish industry through licensed production of the Type 209 and Type 214 submarines is now seeing both countries starting to emerge as competitors on the world stage. Whilst Turkey has yet to produce a national submarine, its industry has undertaken life-extension work for Pakistan. South Korea is further advanced, having sold submarines to Indonesia and emerged as a realistic contender for many current programmes, not least in Poland. Europe clearly has work to do if the good days of the submarine industry's resurgence are to continue. ■

European surface combatant construction: status report

Conrad Waters

European naval shipyards are enjoying buoyant conditions. Numerous projects for the construction of major surface combatants – destroyers, frigates and corvettes – are now passing through the production stage, often after many years of planning and design development. The challenging international security situation is also driving opportunities for additional sales, both in Europe and across the globe. This article describes the main construction programmes underway and assesses their current status.

United Kingdom

The United Kingdom is undertaking what is currently Europe's largest programme of major surface warship construction. Two separate frigate classes encompassing a total of 13 vessels have been ordered from two companies for completion in their respective Scottish shipyards. At the time of writing, seven of these ships are at varying stages of assembly. The extent of the activity now underway reflects a pause in surface combatant construction after the delivery of the final Type 45 destroyer, HMS *Duncan*, in September 2013 to focus available resources on building the two *Queen Elizabeth* class aircraft carriers. This hiatus has resulted in an increasingly urgent requirement for new frigates as much of the existing Royal Navy escort force reaches block obsolescence.

The larger and earlier frigate project is for eight Type 26 'City' or *Glasgow* class vessels, sometimes also referred to as Global Combat Ships. This programme has a long history dating back as far as the 1990s but only came to fruition when a GBP 3.7 billion order for an initial batch of three ships was placed with BAE Systems in July 2017. This was followed by a GBP 4.2 billion contract for a further five vessels in November 2022, completing the class. The ships displace around 7,000 tonnes and will replace eight Royal Navy Type 23 frigates specifically configured for anti-submarine warfare (ASW) operations. All ships are assembled at BAE Systems' shipyard at Govan on the River Clyde before final outfitting at the neighbouring Yarrow facility. The order for the second batch of ships has unlocked a GBP 300 million modernisation programme across the two shipyards, including a new ship hall that will allow simultaneous assembly of two Type 26 frigates under cover. Whilst this will not be fully completed until 2025, work will be sufficiently advanced for the third member of the class to be assembled within its footprint from late 2024 onwards.

The Type 26 programme has progressed more slowly than initially anticipated due to the impact of Covid-19 and a number of technical problems. This will delay the lead ship's projected entry into operational service from 2027 to 2028. However, the project is now picking up pace, with HMS *Glasgow* in the course of final outfitting at Yarrow before commencing her trials programme in 2025 and the second ship, HMS *Cardiff*, joining her at the yard after being floated out in September 2024. Constituent blocks for the third and fourth Type 26s are also in the course of fabrication. Final

Credit: BAE Systems

The second Type 26 frigate HMS Cardiff pictured at BAE System's Govan shipyard shortly before being floated out.

completion of the ship hall is expected to accelerate build times from the nine years required for the lead ship to as little as five years for the final vessel. This would bring construction schedules broadly in line with international competitors. It is also intended that the interval separating the commencement of work on each ship to be reduced to 12 from 18 months

The other programme is for five Type 31 'Inspiration' or *Venturer* class frigates. These were ordered from Babcock International under a contract valued in excess of GB 1.25 billion in November 2019 and are based on that company's 'Arrowhead 140' design; itself a variant of the Danish *Iver Huitfeldt* class. Displacing about 6,000 tonnes, they will replace those Type 23 frigates allocated to general-purpose duties. Work on the lead ship began in another new, purpose-built ship hall at the group's Rosyth shipyard in September 2021 and assembly of the first three vessels is currently underway. As of October 2024, however, none of these three ships had been launched. The project has also undergone some teething problems, with Babcock being faced to take a total of GBP 190 million of provisions on the fixed-price contract. It seems possible that HMS *Venturer's* planned entry into service in mid-2027 may also be delayed.

Both frigate designs have been subject to export success. The Type 26 design has formed the basis for six (reduced from nine as a result of the February 2024 surface fleet review) Australian *Hunter* class frigates and up to 15 Canadian 'River' class destroyers (formerly known as Canadian Surface Combatants). Official construction of the first Australia ship commenced at BAE Systems' Osborne yard in South Australia in June 2024 and work on an initial production test module for the Canadian project started at Irving's Halifax shipyard during the same month. Meanwhile, the Type 31's 'Arrowhead 140' parent design forms the basis for two Indonesian ships as well as the Polish Navy's new 'Miecznik' or *Wicher* class frigates. Babcock's design was selected for licensed production in 2022, with fabrication of the first of three ships commencing in yet another new ship hall at the PGZ Stocznia Wojenna shipyard in Gdynia in August 2023 prior to formal keel-laying in January 2024. Current plans envisage the lead ship being completed in 2029, with the remainder of the programme following by 2032.

France

French surface combatant construction is focused on the 'frégate de défense et d'intervention' (FDI) project, which is being carried out at Naval Group's shipyard at Lorient in Brittany. Developed as part of efforts to offer a more-cost effective alternative to the Franco-Italian multi-mission FREMM frigates, the EUR 3.8 billion programme was officially inaugurated in May 2015 to replace the existing *La Fayette* class frigates. This was followed by the award of manufacturing contracts in April 2017. Displacing around 4,500 tonnes, the ships offer powerful general-purpose capabilities in a relatively compact hull. One of the project's specific objects was to achieve a more attractive proposition for export sales. The design has often been marketed as the 'Belh@rra' in export campaigns.

Fabrication of FS *Amiral Romarc'h*, the lead French ship, commenced at Lorient in October 2019. She was launched in November 2022 and commenced sea trials in October 2024 in advance of a planned delivery in 2025. Four other members of the class should be delivered between 2027 and 2032. These dates have been delayed from original intentions to prioritise construction of the type's first export order, which was finalised with Greece in March 2022. The three-ship order has a reported cost of EUR 2.3 billion (excluding support and weapons), with the option for the fourth vessel priced at EUR 720 million.

The ships being built under the Greek contract will be known as the Kimon class. Recent press reports suggest that the option for the fourth vessel is likely to be exercised imminently.The class will incorporate detailed differences from their French sisters. Construction of the lead ship began in October 2022 and was followed by launch a year later. A sister, HS *Nearchos*, was launched in September 2024 and work on the third ship is also underway. Greek industry has been involved in the project, constructing blocks for both Greek and French vessels. Reports at the time the contract was signed suggested the first two frigates would be delivered in 2025 and the third in 2026; a schedule that might prove to be optimistic.

Ultimate completion of the FDIs will leave Lorient without an obvious programme of future construction given French naval funding is heavily committed to the PANG aircraft carrier, SNLE-3G submarines and – to a lesser extent – new logistic support ships and offshore patrol vessels. This will leave the yard heavily dependent on securing further export work to maintain continuity of production.

Credit: Naval Group

Sea trials of the lead French FDI type frigate FS Amiral Ronarc'h – seen here during an internal shipyard movement in the spring of 2024 - commenced in October 2024.

Germany

Germany is another European country that has two major programmes of surface construction underway. The most significant is that for six F126 *Niedersachsen* class frigates, previously known as the MKS-180. The project was approved in June 2020 and is being led by the Dutch Damen group. However, physical construction of separate forward and aft sections is being carried out by NVL and German Naval Yards at, respectively, Wolgast and Kiel prior to final fitting out at NVL's famous Blohm & Voss shipyard in Hamburg. The initial approval encompassed four vessels at a cost of around EUR 5.7 billion, including a number of mission modules, but this has subsequently increased to well over EUR 6 billion. Authorisation to exercise the two options was subsequently obtained in June 2024 at an additional estimated total cost, including additional modules, of EUR 3.1 billion. The F126 frigates will replace the four members of the F123 *Brandenburg* class.

The *Niedersachsen* class are large, general purpose frigates of around 10,500 tonnes displacement. Their design encompasses the use of interchangeable mission modules to enhance their operational flexibility. Construction of the lead ship began at the Peene-Werft (Wolgast) shipyard in December 2023 and was followed by a formal keel-laying ceremony in June 2024. Planned delivery in mid-2028 looks a challenging target given delays encountered with other recent German naval programmes. The sixth and final ship is scheduled for delivery in 2034.

Germany is also building a second batch of five smaller, 1,900 tonne K-130 *Braunschweig* class corvettes as part of efforts to utilise shipyard capacity until production of the F126 class has fully ramped-up. Total programme cost was initially estimated at approximately EUR 2.5 billion. The contract for the ships' construction followed delivery of a first batch of five of the type between 2008 and 2013. It was placed with the ARGE K-130 consortium led by what is now NVL and also including German Naval Yards and thyssenkrupp Marine Systems (tkMS) in September 2017. In similar fashion to the F126 programme, sections have been allocated to various yards before final integration in Hamburg. Fabrication of FGS *Köln* – the lead ship of this batch – commenced in February 2019. At this time, her delivery was expected in November 2022.

By mid-2022 it had become apparent that this delivery timetable had slipped, primarily due to problems with combat system integration. Although *Köln* has undertaken preliminary sea trials and been used for initial crew training since late 2023, it will not be until 2025 at the earliest before she enters operational service. The remainder of the class will also be delayed, whilst programme costs have also increased. These difficulties may have contributed to the decision not to proceed with a mooted third batch. Instead, the German Navy's 'Vision 2035+' force structure plan assumes between six and nine of the class remaining in service in the longer term, supplemented by larger numbers of uncrewed surface craft.

Germany also has longer term plans to acquire another new frigate class – designated the F127 – to replace the three air defence ships of the F124 *Sachsen* class. The project is still in the developmental phase but it is likely that the ships will be equipped with the US Navy's Aegis combat management technology. tkMS is heavily promoting a design based on its 10,000 tonne MEKO A400 AMD concept in the hope of regaining its previous prominent place in the German Navy's surface ship

Credit: Damen

Germany's six ship F126 frigate programme is being led by Damen but construction is taking place in German shipyards.

Credit: tkMS

tkMS is pitching its MEKO A400 AMD concept for Germany's F127 frigate programme

construction programmes. In September 2024, it announced a planned joint venture with NVL to pursue the contract in a development that could overturn Damen's previous success in the German market.

Italy

The Italian Navy has an ambitious programme of naval construction underway involving several strands. One of these relates to continued evolution of the FREMM multi-mission frigate design. Ten ships of the type were originally ordered for construction at Fincantieri's integrated shipyard at Riva Trigoso and Muggiano in northern Italy, where production is now drawing to a close on an additional pair of vessels contracted in replacement for two transferred to Egypt to conclude a rapid export deal in 2020. Subsequently, in July 2024, a EUR 1.5 billion contract was signed with the Orrizonte Sistemi Navali consortium of Fincantieri and Leonardo for two of a FREMM EVO variant of the type for delivery in 2029 and 2030. The new ships will incorporate equipment developed since the FREMM programme was first inaugurated, including Leonardo's dual-band 'Kronos' radar.

Another element of the surface combatant programme encompasses the PPA type multi-role offshore patrol vessels of the *Paolo Thaon di Revel* class. Ordered at a cost of EUR 3.8 billion under Italy's 'Naval Law' of 2014, these ships have been completed with varying levels of equipment by Fincantieri's integrated shipyard but are essentially general purpose patrol frigates in all but name. Displacement is in the region of 6,250 tonnes. Fabrication of the lead ship commenced at Muggiano in February 2017, with delivery taking place in March 2022 after a delay of several months that resulted from the Covid-19 pandemic. The launch of ITS *Domenico Millelire*, the final vessel of Italy's seven-ship programme, at Riva Trigoso in July 2024 has brought the initial programme close to its completion. However, again, the sale of two of the vessels overseas will result in a requirement for replacements. The March 2024 export contract encompassed the transfer of the fifth and six members of the class to Indonesia at a reported price of EUR 1.2 billion. Fincantieri also continues to pursue a number of other export campaigns for the type. The Italian Navy is also reportedly close to ordering two new DDX destroyers to replace the existing ships of the *Durand de la Penne* class. Development work on the new vessels, which will be optimised for anti-air warfare, has been underway for a number of years. The completed ships are likely to displace in excess of 10,000 tonnes, rivalling Germany's F126 and F127 classes for the title of Europe's largest surface escorts.

Spain

Spain's Navantia is currently focused on delivering the five F110 frigates of the *Bonifaz* class that will replace the navy's six existing FFG-7 *Santa María* class vessels. Displacing around 6,100 tonnes, the new frigates are general-purpose vessels but have an ASW emphasis. They are equipped with the AN/SPY-7 radar and Lockheed Martin International Aegis Fire Control Loop, which is linked to an indigenous SCOMBA combat management system. A contract reportedly valued at EUR 4.3 billion for the ships' construction was signed in April 2019 after over a decade of developmental work. Assembly is taking place at the group's Ferrol shipyard in Galicia, which hosted a keel-laying ceremony for the first of class in August 2023. As of mid-2024, it was reported that the ship remained on track for a 2028 delivery, with sister ships following her at an annual drumbeat until 2032. The Spanish Navy are reportedly attempting to secure funding for additional units to, at the least, maintain the size of the existing fleet.

Credit: Navantia

Navantia is reportedly making good progress constructing the lead F110 class frigate for the Spanish Navy as part of a five ship programme.

Credit: Fincantieri

The PPA type frigate ITS Domenico Millelire pictured at Riva Trigoso at the time of her launch in July 2024.

The Netherlands and Belgium

The Royal Netherlands Navy and Belgian Naval Component are in the course of modernising their surface fleets through the joint procurement of two pairs of Anti-Submarine Warfare Frigates (ASWFs). The project forms part of a wider programme of joint acquisitions that also includes the rMCM

initiative to acquire mine countermeasures motherships. The ASWF element of the programme is being led by the Netherlands, with Damen acting as prime contractor. Following protracted design discussions, the project received final political approval in June 2023, with construction contracts being signed the same month. In common with other recent Dutch warships, the ships will be fabricated in Damen's shipyard at Galati in Romania prior to final outfitting in Vlissingen. Programme cost has been reported as EUR 4 billion for the first four ships. As suggested by their nomenclature, the ASWFs have a primary ASW orientation, albeit with the addition of powerful general purpose capabilities that could ultimately extend to long-range land attack and ballistic missile defence. Displacement is approximately 6,400 tonnes. A series of equipment selection announcements has followed the contract award but actual construction is not scheduled to begin until 2025. Deliveries are scheduled between 2029 and 2032. In September 2024, the Netherlands announced plans to acquire two additional ships, bringing the total programme to six frigates.

The Netherlands also has a longer-term requirement to replace the existing quartet of LCF air defence and command frigates on a like-for-like basis. It was originally hoped that this might be taken forward as a joint programme with Germany. However, Germany's seeming preference for the Aegis system over Dutch technology makes it likely that this will be taken forward as a purely national project.

Scandinavia

Finland's flagship 'Squadron 2020' naval project involves the construction of four, 4,300 tonne frigate-sized 'corvettes' to replace seven older vessels. The project was formally launched in 2015 after several years of preliminary research and development, this being followed by the award of a construction contract to Rauma Marine Constructions (RMC) in 2019. The detailed design process was far more complicated than originally anticipated and it was only in October 2023 that fabrication began at RMC's Rauma shipyard in the Gulf of Bothnia. This was followed by a keel laying ceremony for the lead ship, FNS *Pohjanmaa*, in April 2024. Work on the second vessel is now also underway. In spite of previous programme delays, it is hoped to commence sea trials of the first ship in 2026 and complete the entire programme by 2029. Programme cost was estimated at EUR 1.3 billion in 2019 but this seems likely to be exceeded.

Sweden is at an earlier stage of fleet renewal. Project definition studies for what was initially intended to be a 'Visby 2' iteration of the existing corvette class commenced in 2021 but subsequent reports suggest the requirement will be for much larger ships similar to the 'Squadron 2020 vessels'. Saab is working on the design of the new ships with engineering support from the United Kingdom's Babcock International under a contract signed in May 2024. Four vessels of what will be known as the *Luleå* class are planned, with deliveries of the lead pair expected by the end of the current decade. Local press reports speculate that the ships' hulls will be built abroad prior to final outfitting at Karlskrona, potentially putting Babcock's Rosyth facility in pole position to play a continued role in the programme.

Credit: BAE Systems

New ship halls and other modernised facilities are springing up across Europe to meet growing naval shipping demand. This is a computer-generated image of BAE System's Janet Harvey Hall at Govan on the River Clyde, which will be completed in 2025.

Concluding Remarks

It can be seen from this brief overview of current projects that Europe's naval shipyards have now left the lean years of the post-Cold War era behind them, enjoying order books stretching into the next decade and, sometimes, beyond. Moreover, additional requirements are already on the horizon, including the British Type 83 and Type 32 destroyer/frigate programmes and Norway's recently announced plans to acquire at least five new major surface combatants. The extent of this demand is providing the opportunity to upgrade often ageing shipyards, with new ship halls and other improved facilities springing up across the continent. If managed correctly, the prospect of a modernised, more efficient European naval sector that is better able to compete against emerging rivals in Asia and elsewhere could be at hand. ■

Credit: Damen

Two Anti-Submarine Warfare Frigates have been ordered by each of the Belgian and Dutch navies under a joint project. The Netherlands has also expressed an intention to order two additional frigates to create a six-ship programme.

The right stuff below the waves

Tim Guest

Combat divers, expertly trained and resilient, rely on a wide range of kit, tough enough to support the execution of typically arduous, covert ops. From rebreathers to compressed gas systems, tactical dive submersibles and more, the gear used by the combat diver enables extreme missions to be undertaken, while ensuring that optimum life support and safety are maintained for the dive teams involved.

This article examines combat diving through expert eyes, touching on overall operational and equipment demands, some of the gear used, and by whom.

Qualified at depth and opening the conversation

Working in one of the harshest environments on Earth, military divers must be highly trained individuals at the peak of human physical and mental abilities, though also relying on critical equipment to support them. With its military diving expertise, subsea specialist company, JFD, announced in May 2024, that former senior Royal Navy (RN) officer, Peter Laughton MBE, had joined the company as its new Head of Military Diving. Laughton was formerly Royal Navy (RN) Commodore in the Middle East, commanding the International Maritime Security Construct and Coalition Task Force Sentinel. After 32 years of RN experience, including many years as a specialist mine clearance diving officer, Laughton will now oversee the ongoing development of JFD's military diving systems, including for Special Operations Forces (SOF) divers, mine clearance operations, and a wide range of other missions. At the time of joining the company, he said, that having relied on JFD life support systems (LSS) throughout his naval career, he was looking forward to transferring that operational understanding to his work at the company.

Credit: JFD

Peter Laughton MBE, new head of military diving at JFD.

Credit: US Army photo/K Kassens

To be able to execute real-world covert missions in high-threat scenarios successfully, combat divers undergo arduous training and must display high levels of competence in their abilities to handle often highly technical combat diving equipment, including their critical LSS. Pictured: competitor in 2024 USASOC Best Combat Diver Team Competition jumps off the tailgate of a CH-47.

ESD took the opportunity to ask Peter Laughton for his qualified insights on all things combat diving and began by touching briefly on how equipment has evolved and latest technologies and innovations have enhanced safety and reliability. According to Laughton, "Combat diving equipment has evolved considerably, and while the fundamentals of a diving rebreather have not really changed, i.e., a counterlung, gas supply, regulator and CO_2 scrubber, what has changed immeasurably are advances in equipment monitoring, both remote and personal, making military diving much safer. Electronics, for example, are now used to strictly control, monitor and alert the diver to changes in the partial pressure of O2 in the diving loop, as well as manage decompression."

On a fairly typical combat diving kit list, essential gear will include a military diving rebreather, as Laughton alluded, to sustain life underwater; an exposure suit of some sort – wet or dry suit – to protect divers from the elements; a face mask and fins; and, in some cases, a diver-propulsion device to allow swimming over greater distances. "There are a range of short- and medium-distance diver-propulsion devices on the market designed to allow divers achieve greater range and operational effect." In addition, and depending on the mission, divers will also carry other ancillary equipment, such as personal weapons,

Author

Tim Guest is a freelance journalist, UK Correspondent for ESD and a former officer in the British Forces.

Credit: JFD

The TRUAS will be capable of carrying a payload of roughly 70 kg of The depth to which TDVs can operate depends on the LSS of the divers onboard. Pictured: Shadow tactical diving LSS, weighs 9 kg, offers a duration of 4–6 hours; maximum depth of Shadow Excursion using nitrox is 30 metres of seawater.

fighting equipment, radios, compasses, and watches. Compressed gas cylinders might also be used instead of a rebreather dependent on the mission.

Preparing for a dive – deep and shallow

Laughton stressed that any form of civilian or military diving is inherently hazardous and, therefore, requires a systematic approach when preparing for a dive or combat mission. Whether scuba, or combat diving, equipment set-up and preparation is fundamental to the safe execution of the mission. No matter the equipment, new or old, safety relies on everything a diver needs for a particular mission being checked and re-checked before deploying. If a diver's equipment malfunctions through incorrect set-up, or general failure of any of the parts, then the mission is potentially compromised. Before every dive, combat divers will check their personal equipment and then conduct a series of other pre-dive checks to ensure the equipment is functioning correctly. This stage includes several in-water checks, such as testing for gas leaks, and then ensuring that all parts of the equipment are functioning as expected. Laughton notes that, "As with any highly technical equipment, which is routinely operated in arguably the harshest environment on the planet, the need for routine and planned maintenance and servicing is essential for both diver safety and mission accomplishment."

On the subject of deep versus shallow dive operations, Laughton emphasised clear distinctions. For example, training – JFD has its own range of ex-military-instructor-led military diver training courses – varies considerably, because the requirement to go deep can introduce much greater risk, as well as the need for decompression, procedures and equipment. Here, the quality of training is critical, especially when operating in such an unforgiving operational environment where mission success can be fundamental to national security. "Going deeper is usually for shorter periods to effect a mission on the seabed, such as mine clearance operations, although this might also be conducted, and necessary, in shallow waters," Laughton said. He added that combat swimmers tend to spend most of

Credit: JFD

Carrier Seal TDV from above showing hatches for rapid entry/exit of boarded passengers and two crew at forward controls.

their time at a shallow depth, but much depends on the mission and they must be prepared to go deeper, if required, for a variety of operational reasons, e.g., when exiting a submarine. The dive equipment for shallow and deep diving can also vary considerably; on deeper dives, for example, gas is used up more quickly, making sufficient back-up gas needed if a diver is to safely reach the surface in the event of an emergency equipment failure of their primary system.

Catching a lift

When it comes to submersibles for combat divers, the discussion moved to Tactical Diving Vehicles (TDVs), which, Laughton said, act as force multipliers for maritime SOF, greatly enhancing operational capabilities. With a re-focus on maritime operations amongst NATO and its allies, as the littoral operational battlespace evolves to meet an increasing range of threats, JFD's new head of military diving stressed that the relevance of TDVs has never been more apparent. These craft are increasingly seen as a vital component of current and future SOF littoral and underwater manoeuvre operations; they bridge critical capability gaps, enhance operational capability, whilst also increasing mission success probability when operating in complex, high-threat littoral environments. TDVs emerge as a viable solution for both discreet and covert littoral operations, and for specialist amphibious reconnaissance and raiding forces that do not have a tactical diving capability, the ability of TDVs to operate in a semi-submerged mode significantly reduces the vehicle's signature, which provides a means of discreet infiltration and exfiltration not offered by conventional surface raiding craft when operating in high-threat areas, thereby reducing the probability of mission compromise. Laughton also said that besides their operability with larger insertion / extraction-support platforms, the long-range capability of TDVs, such as JFD's own Carrier Seal vessel, offer SOF units what he called "an independent, organic, over-the-horizon capability". This not only increases operational flexibility at a unit level, but also enables the employment of multi-mode TDVs without exposing high-value assets, such as submarines and surface ships, to unnecessary risk. He added that for navies that lack submarines capable of supporting TDV operations, these vehicles are a cost-effective alternative, enabling maritime SOF the ability to cross an expanding 'water gap' and conduct operations that would otherwise be beyond their reach. Laughton added that, "The versatility and relatively low cost of TDVs, compared to larger platforms, make them an attractive option for maritime security providing rapid response, coastal defence, and critical national infrastructure protection."

Credit: Dräger

Dräger LAR V rebreather as used by USN SEAL dive teams and other SOF combat divers.

As for the specialist training required for a combat diver to operate such submersibles, Laughton referenced the company's products, saying that training really depends on the size of the TDV, depth requirements, mission complexity, approach and the mission itself. "Our smaller TDVs employ a 'Gameboy controller' approach, for the very purposes of rapid training and ease of use; our larger variants are slightly more complex. However, basic craft handling, which includes diving, surfacing, trim and buoyancy procedures, is very easy." Conversely, he said that extended underwater diving in GPS-denied conditions, and at depth, are another matter and where the core of diver/TDV training would ordinarily focus to ensure that both pilot and co-pilot of a two-man vessel would ordinarily be capable of "flying, or commanding, the craft", by themselves, if required.

The company's own systems, which operate with several unnamed navies, globally, include the Carrier Seal Laughton mentioned; this is an eight-man craft designed at the company's facility in Sweden. Powered by a diesel engine, the 10.45-metre-long, 4,000 kg TDV has a beam of 2.23 m and can carry a payload, including its commander/pilot, driver/co-pilot, crew of six SOF divers, and mission-related equipment, totalling 1,000 kg. The crew sit at the forward controls, passengers sit behind them protected within the hull, but with overhead access panels. For navigation, the TDV's steering information navigation and control system combines data from GPS, gyro compass, depth sounder, obstacle avoidance sonar and doppler velocity log sources to ensure safe passage, and its optronic sensor suite, installed on top of its height-adjustable tactical mast, comprises thermal imaging, colour TV camera, GPS and navigation lights. The TDV can reach surface speeds of 30 kn and achieve a range of 150 NM traveling on the surface, with submerged speeds up to 5 kn and a 15 NM range if submerged; lengthy submerged ops typically require additional batteries. The vessel can also operate semi-submerged, displaying minimum surface signature if the tactical situation requires it, as Laughton alluded. A spare fuel bag and more batteries can also give the Carrier Seal an additional 75 NM range. Typically, after a surface approach to an objective, the final stage of a covert operation would be sub-surface, travelling at 4 kn; as far as the maximum depth the TDV can undertake, this is largely dependent on the LSS worn by the divers onboard.

Of any new tactical submersibles in the JFD pipeline to add to its current range along with the likes of its Carrier, Shadow, Dry Sub/Wet Sub Seal TDVs, Laughton said that, "JFD is exploring future platform enhancements, such as hybrid craft opportunities, enabling manned and unmanned interoperability to enhance versatility for modern day operations." He said that by integrating diver monitoring

technologies and advanced LSS, as well as integrating onboard data systems to provide a unified communication and information platform for divers, this would enhance both mission planning, real-time operational effectiveness, and safety.

Rebreather basics and comparisons

As Laughton highlighted above, the rebreather is probably the key piece of combat diving equipment for SOF covert ops. In recreational or military scuba diving, a more widely used and recognised self-contained, aluminium-cylinder-based, compressed-air, open-circuit, underwater breathing system is used, which, when the diver exhales underwater, releases that exhaled air as bubbles to the surface, which are visible to the naked eye and infra-red, so easily detected by an enemy during a military operation. This is where the compact and relatively lightweight rebreather comes to the fore, as a closed-circuit diving system; as the diver breathes, it scrubs/filters their exhaled breath, removing carbon dioxide (CO_2) and recycling any unused oxygen, though with pure oxygen added as required, back to the diver. No bubbles are released from a rebreather and operatives remain undetected at the surface. Its efficiency in recycling and controlling the use of oxygen offers the added advantage of long-duration dives, potentially up to some four hours at a time, which opens up several operational possibilities, including being able to approach key onshore locations from disembarkation points far out to sea, possibly from a submarine, or other tactical insertion vessel. Buoyancy is another key issue advantaged through the use of a rebreather, unlike in a typical open-circuit, scuba system; in the open-circuit system, the compressed gas pressure is reduced so it fits into the diving cylinder and the diver breathes that air in at a higher volume than it was in the tank. With each inhalation the diver becomes slightly more buoyant, as a result, but with each exhalation he will descend very slightly. Using a rebreather with its closed-circuit system, however, such buoyancy issues do not arise, because between the breathing apparatus and the diver's lungs, gases simply recirculate at a constant volume.
Now let's look at one specific combat diving user group – the US Navy SEALs.

SEAL deal

In the world of combat diving, US Navy (USN) SEALs are often cited, so it's well worth a look to see what categories of open-circuit and closed-circuit diving gear these proficient combat divers – as well as other US SOF diving units – use to conduct their operations.

Credit: USN

USN SEAL combat swimmer swim pair wearing Dräger LAR V rebreather's and using compass navigation method in murky shallows.

Under these two closed and open categories fall three kinds of underwater breathing gear used by SEALs. The first is open-circuit scuba equipment, which typically comprises two aluminium compressed air cylinders, known as Twin 80s, because they each hold 80 cubic feet of oxygen. These can be used in various underwater operations including by divers and crew aboard TDVs. Cylinder size and weight, together with the release of bubbles, as mentioned above, are drawbacks using this system.
The second system is one of two closed-circuit systems used by SEALs and various SOF – the Dräger LAR V rebreather. Suited to shallow-water operations, the relatively small, front-worn LAR V is a closed-circuit scuba equipment, designated the MK 25 by the USN; it uses 100% pure oxygen, recycling expelled breath, filtering CO_2 and adding the pure oxygen to supplement the increasingly, oxygen-depleted, recycled breath, as previously outlined, and eliminating all bubbles to the surface. As a result, this rebreather is suited to covert ops, and can operate down to approximately 20 m; this, however, is less than achievable depths using open-circuit scuba equipment using Twin 80s; dive duration is also affected by depth, water temperature and oxygen consumption rate.
The third type of gear used by SEALs, of which two systems – the MK 15 and MK 16 – are in use, is also a closed-circuit rebreather, although this time they operate using mixed gas instead of pure oxygen. They follow the same CO_2 filtering process as the LAR V, but instead of using pure oxygen to supplement the recycled breath, both these rebreathers dilute the oxygen with another gas – air, Timux, or Heliox – creating a mixture, which maintains a partial pressure of oxygen level, thereby enabling much deeper dives to be achieved, (around 600 msw), than with the Dräger system.
It is worth noting that Dräger now markets the Dräger 8000 rebreather as its most advanced all-purpose solution, which, unlike the LAR V, can be worn on either the front or the back of the diver. The latest system offers typical closed-circuit functionality, or semi-closed-circuit operating that can enable greater depths to be achieved using nitrox. Its design is said to produce very low breathing resistance for the diver, thereby improving their overall breathing performance underwater, all adding to operational effectiveness and safety in the underwater environment where the ability to breathe is a constant challenge. The

Credit: US Army/K Kassens

Equipment checks prior to any combat dive are crucial in minimising the chance of an equipment failure and/or emergency arising. Pictured: 2024 USASOC Best Combat Diver Competition competitor undergoing a dive supervisor pre-inspection prior to validating his equipment.

system has an adjustable lung demand valve, which allows the diver to switch between easy, medium comfort, and harder breathing settings, the latter typically selected when ascending tactically. All components of the LAR 8000 have been designed and tested in accordance with STANAG 2897 Class A, meaning the equipment is a completely non-magnetic diving device.

The company's Panorama Nova Dive full-face mask is recommended for use with the Dräger 8000; the basic mask has a five-point harness to ensure an optimum seal is achieved around the diver's head, with three ports in the mask offering different set-up configurations depending on the rebreather or compressed-air systems to be used, as well as different underwater communication systems that might be employed during a mission. An exhalation valve at the bottom of the mask enables the diver to expel any water that might enter during extreme arduous situations, though under normal operating conditions, the company says water ingress is unlikely. A modified version of the mask can be fitted with a mechanical, low-pressure alarm to warn a diver of low air supply, particularly useful in low visibility when it acts as a precaution against human error.

The company says that its Panorama Nova Dive R mask has been tested the US Navy Experimental Diving Unit (NEDU) and approved by them for use with the Dräger LAR V MK 25 Mod2 rebreather. The approved version has an adjustable, two-position mouthpiece and oral-nasal configuration to reduce the build-up of CO_2.

Best combat diver footnote

Having only recently taken place, in June 2024, mention of the US Army's *'Special Operations Command Best Combat Diver Competition'*, *(USASOC)*, at US Special Forces Underwater Operations school at Fleming Key, at Key West's northern point in Florida, makes a worthy footnote. Underpinning the reliance and care combat divers must have for one another, the competition, according to a statement, is designed to build camaraderie and trust between divers, as well as put an operative's full range of necessary skills – academic, physical, mental, adaptability – to the test, including equipment validations of a wide range of kit, such as rebreathers and gas tanks and all LSS-related gear and peripherals typically used to support extreme, tactical, underwater combat-diving scenarios; operations involving such procedures as airborne insertion and submarine work were also tested. Teams competing were from US Army Special Forces, US Marine Special Operations, and US Air Force Special Operations, with this year's winner the combat diver team from the 10th Special Forces Group of the US Army's Special Forces.

The final point here is about the diver, for no matter the combat diving kit and systems being used, from rebreathers to compressed gas cylinders, tactical diving vehicles, to deployment and insertion by submarine, it is down to the calibre, training, resilience and prowess of the individuals who make up the global SOF combat diver community, that will ensure best use is made of the equipment involved, new or old, and for any mission to be a success.

Knowing there's hope

Tim Guest

Submarine rescue systems, both new and old, along with related, advanced equipment and technologies, offer the undersea world of submariners more reassurance of being rescued from a disabled submarine than ever. Yet, constant training and practice in the use of such systems are required to ensure 'time to first rescue' is minimised.

This article takes a look at pioneering and latest submarine rescue systems in the context of recent developments, their use with allied navies as part of the NATO Submarine Rescue System (NSRS) – as well as how these systems are regularly put to the test on joint naval exercise.

100-year-old concept in use today

There's a piece of equipment, conceived almost 100 years ago, that marks the true beginning of submarine rescue systems (SRS), but which, today, is still in use with the Italian, Turkish and US navies. Their current versions of this simple, though effective and reliable submarine rescue chamber (SRC), have, with some modifications over the years, kept very much to the original design, and the fact that it's still in use makes some historical background more than worthwhile.

Credit USN/ISMERLO

Italian Navy's McCann chamber descending from Mother Ship (MOSHIP) Anteo.

During the 1920s in the US, two submarine accidents, that of the USS S-51/SS 162, lost after a collision in 1925 with the loss of 34 members of it 37-man crew, and the December 1927 sinking of the USS S-4/SS 109 in the waters off Massachusetts following a collision with a Coast Guard destroyer; the tragedy of this latter event was that the crew survived the collision and subsequent sinking, but suffocated while attempts at rescue were being made. Following the first incident, it was Lieutenant Commander Charles Momsen – inventor of the Momsen Lung – who, in 1926, proposed the idea of an SRC to the then US Bureau of Construction and Repair. It was only after the 1927 episode, however, that the initiative gathered further support and began development. It was one Lieutenant Commander Allan McCann, however, who was put in charge of implementing his colleague's design, an important decision, which allowed Momsen time to focus on the development of his 'Momsen Lung', a personal breathing apparatus to enable individual submariners to escape from a disabled submarine at depth.

The first SRC was completed and entered service with the US Navy (USN) in 1930, named the McCann Rescue Chamber, and comprised a closed upper compartment maintained at atmospheric pressure and an open lower compartment flooded at ambient sea pressure. Horizontal bulkheads, watertight hatches, 120 m of steel cable, (which has increased over time), for lowering the capsule, and associated reels, air motors, as well as electric and communications cables, air/CO2 hoses, and crucial rubber gaskets, enabled to chamber to be lowered to a submarine to form a watertight connection under pressure, over the sub's escape hatch. A diver accompanied, or preceded, the capsule to a sub to fasten its haul-down cable to the submarine and help guide the capsule into place. Once mated, water in the capsule's lower compartment clears into its ballast tanks and pressurised air from the lower chamber vents to the surface via the upper chamber. This results in the equalisation of pressure between the rescue chamber and submarine, so the hatches between the two vessels can be opened safely and the crew rescued.

This whole sequence of events was put the test in earnest on 24 May 1939 to save the surviving 33 members of the 59-man crew trapped aboard the USS *Squalus* (SS 192), which had sunk the day before during a training exercise. Lying at a depth of approximately 75 m, it took four trips to bring the 33 survivors to the surface and a further trip to confirm the remaining crew had perished.

Today's versions function in much the same way as outlined above and as used in the Squalus rescue, this age-old, simple McCann SRC, with its dry weight of approximately 9,800 kg, but only 454 kg when buoyant in water; however, it does have its limitations, which make these chambers only suitable for 'simple' rescues, not that any such rescue should be termed such. However, under severe ocean states, or if a submarine is too deep, i.e., below 260 m, or lying at an angle, a McCann SRC will be unable to effect any rescue. Indeed, crew/survivor transfer under pressure (TUP) is also something the system cannot support.

All that said, McCann SRCs remain assets in the submarine-rescue portfolios of the aforementioned three NATO navies, whether aboard dedicated Mother Ships (MOSHIPs), or as air-transportable assets – as in the case of the USN's Submarine Rescue Chamber Flyaway System (SRCFS), when it would be used with a Vessel of Opportunity (VOO), which acts as the MOSHIP, having been pre-identified as a vessel able to handle such

a shallow submarine rescue, with little modification required.
Momsen would, no doubt, have been pleasantly surprised, had anyone told him all those years ago, that his basic rescue bell design would still be in operation nearly 100 years later.

Time is the enemy

But whether a McCann SRC, or other deeper-diving modern submarine rescue vehicle (SRV), no matter the equipment, ensuring that the shortest 'time to first intervention' (TTFI) and 'time to first rescue' (TTFR) are achieved, are the goals of all submarine rescue teams. This makes regular, effective submarine-rescue training essential. For NATO, every three years such training manifests in the form of the Alliance's major, Dynamic Monarch submarine-rescue exercises, with 2024 the year for the latest iteration. Accordingly, Dynamic Monarch 24, (DM 24), duly took place for ten days during September in the cold territorial waters of host-nation, Norway, with the overall exercise led by NATO's International Submarine Rescue Liaison Office (ISMERLO) involving ten Alliance members: Canada, France, Germany, The Netherlands, Norway, Poland, Sweden, Türkiye, the UK, and the US.
Of the many items of equipment used during the exercise, rescue vehicles included: Sweden's URF MkII submersible, which, with its three or four operators, can rescue 35 survivors, effectively, the entire crew of a Swedish SSK sub in a single lift, and from depths down to 450 m. Also operating, the NSRS, which can conduct rescues for up to 15 people at a time down to 600 m. Türkiye also deployed its SRC, a typical McCann chamber, which, while restricted to rescues at shallower depths to 260 m, can rescue up to eight survivors per lift, but operate uninterrupted, 24/7, if necessary and if conditions allow.

Credit: NATO

Turkish McCann Submarine Rescue Chamber from TSC Alemdar MOSHIP.

Among the numerous surface and submarine vessels taking part in DM 24, specialist submarine rescue ships from Norway, Sweden and Türkiye – the NoCGV *Barentshav*, HMSwS Belos, and TCG *Alemdar*, respectively – also participated. The exercise allowed sub-rescue teams from participating countries to share expertise, standardise procedures and operational strategies, test and hone sub-rescue skills, latest equipment, technology and capabilities, and refine the overall interoperability of the systems and procedures involved. The exercise also incorporated scenarios to test multinational medical teams in treating trauma patients inside special decompression chambers on board the MOSHIPS.
During the exercise, under the watchful eyes of Türkiye's Undersea Rescue Commander, Rear Admiral (LH) Eren Günay, Turkish Navy submarine rescue ship/MOSHIP, TCG *Alemdar*, which joined the Turkish fleet on 28 January 2017, worked alongside Sweden's HSWMS *Belos* to conduct rescue operations for the crews of Swedish submarine, HSWMS *Uppland*, and Norway's HNOMS *Utstein* sub. The *Alemdar's* ROV, TCB Istakoz, was also used in a different scenario to search for a DISSUB, again, the Utstein, but this time transferring a life-support package to the sub crew; it can undertake rescue operations to depths of at least 600 m. The Alemdar handles both shallow, (using its McCann SRC), and deep-water rescues.

Credit: Turkish Navy

Turkish Navy ROV vehicle TCB Istakoz during 'Dynamic Monarch 2024'.

The collective effort during DM 24, is aimed at providing sub-rescue support for all Alliance members, but also the wider, allied world, to ensure rescues can be conducted, anywhere, globally, at any time. Indeed, the NSRS itself, which is jointly owned by France, Norway and the UK, aims to be operational anywhere in the world, 96 hours after first alert to a disabled submarine (DISSUB) incident, deploying from its home location in Scotland at HM Naval Base Clyde. Worth noting, that although established by NATO, ISMERLO theoretically supports all submarine-operating nations.
DM exercises typically alternate between warm and cold waters, (DM 21 took place in the eastern Mediterranean), although DM 24 is the first frigid-water exercise for ten years. In this regard, Norwegian Navy Commodore Kyrre Haugen, Chief of the Naval Fleet, commented that as Norway's allies 'get better' at conducting submarine rescue operations in colder climates,

Credit: NATO

Exercise Dynamic Monarch 2024, hosted by Norway, involved various sub-rescue systems used in the NATO Alliance. Pictured: replenishment vessel Main, A515, docked beside the Royal Norwegian Navy's Ula class submarine, Utstein, S302.

Credit: NATO

TCG Aldemar decompression chamber.

"they also get to know our waters. NATO should be prepared to work together towards saving submariners in danger, no matter the area, or what nation the submarine belongs to".

Of DM 24, US Navy Rear Admiral Bret Grabbe, Commander, Submarines NATO, added that the exercise underscored the importance of international cooperation in ensuring all nations are prepared to respond swiftly and effectively to submarine emergencies, with the skills and experiences gained during DM 24 significantly contributing to Alliance naval interoperability and cooperation in sub rescue and other maritime security initiatives.

Tapping into NSRS expertise and insights

And perhaps the most important system of all, exercised during DM 24, was the NSRS, government-owned by the three aforementioned, participant nations, though operated by specialist civilian contractors, including current prime contractor, JFD, in the UK.

For some latest strategic-level, submarine-rescue insights, including about exercises and training, *European Security and Defence/Maritime Defence Monitor* spoke with JFD's product manager submarine escape and rescue systems, Stuart Irwin, who informed this magazine of a growing focus on submarine rescue among navies. This, he said, was partly driven by recent incidents, which have highlighted the importance of safety and the need for a robust rescue plan, but also, in part, due to a recent pivot back to maritime operations and the fact there are currently more submarines operating around the world than ever before. The strategic importance of submarines in both defence and deterrence, especially with new initiatives such as AUKUS, has reflected increased investment and infrastructure support from governments, which transfers to submarine rescue. There is also a continued emphasis on safety, rapid response and international cooperation, he added, as submarine operating ranges and coverage areas expand, driving innovation and enhanced capabilities. For JFD over the past few years, this has driven the completion of multiple new SRV builds and continuing to conduct exercises as part of its long-term, in-service-support contracts. Indeed, the company has now delivered a further three 3rd-Generation SRVs to customers in the Asia-Pacific Region, with focus on such things as improved control systems and navigational instruments; these deliveries have significantly increased the

Credit: ESD/MDM-Tim Guest

JFD's 4th-Gen SRV, Agile, model displayed at DSEI 2023.

Credit: ESD/MDM Tim Guest

JFD's 4th-generation SRV, Agile, at DSEI 2023; artist's impression of air transportability and model.

regional rescue capability, from the Sea of Japan to the South China Sea.

For existing-generation SRVs, Irwin said the company continues to work on enhancement packages to address capability gaps or potential obsolescence issues, including such things as fibre-optic communications system upgrades to enable and/or improve audio and visual communications between the SRV, the dive supervisor, and the bridge commander, thereby enhancing command and control during any rescue; other enhancements include introducing a submariner medical monitoring system, which combines wearable devices, integrated with an array of medical health monitoring equipment and communications to allow comprehensive supervision of all rescued parties throughout the duration of a rescue incident and subsequent treatment.

"Exercises are critical to ensuring both personnel and equipment are fully prepared for real-life rescue operations," Irwin told this magazine. "Regular exercises help validate and refine procedures, as well as improve efficiency, reducing mobilisation times and enhancing coordination between international partners." He said that over the last five years, the company has conducted over 25 exercises under the terms of the global in-service-support contracts it manages.

New generation

Having recently introduced its yet-to-be-built, 4th-genertion SRV to the sector, Irwin said of its earlier-1st, 2nd and 3rd-generation systems that a total of seven have been delivered, globally. "Each generation has been built with longevity in mind and thanks to the ability to continually upgrade and integrate new technology, our first-generation system is still operational and one of the most capable systems in service today." Irwin added that with each new generation there is an obligation to improve.

"Our future generations are built on the proven designs of the past; building on this legacy, our 4th-Generation SRS - Agile - optimises transportability, through its modular configuration and simplified vessel interface, in turn reducing the complexity of the mobilisation process, in turn reducing TTFR." Agile was officially launched at CNE 2023 and later at DSEI 2023 where ESD was given a preview. The company sees the near and mid-term global market potential for the new system driven by such things as the need to replace ageing SRVs, as well as navies with new requirements to support their increasing submarine fleets. Irwin indicated that strong interest in Agile from multiple potential customers has already been expressed. He said the 4th-generation system, once in build, will undergo the same intensive testing and acceptance routines as previous SRVs, including Factory Acceptance Trials (FATS), involving testing at sub-system level using test rigs, pressure chambers and test tanks; Harbour Acceptance Trials (HATS) , involving local, in-water testing of systems in a controlled environment, allowing progressive systems integrity checks and functional testing; and finally, Sea Acceptance Trials (SATS), involving full system deployment at sea, allowing full system capability checks to be conducted at full depth and under typical operating conditions. This normally includes actual interfacing with customer submarines and practice targets.

Agile has a fully redundant Programmable Logic Controller (PLC)-based navigation and control system; it incorporates the latest navigational instrumentation, such as sonar, pinger/receiver, controlled time of departure (CTD) device, doppler velocity log (DVL); its depth capability is dependent on customer requirements, but typically extends to 500–650 metres of sea water. This 4th-generation vehicle also has an increased payload capacity, from 17 up to a possible 22 people in the rescue chamber, without external dimension expansion or weight increase; it also

Credit: SMP

Artist's impression of SMP's new SRV undertaking a sub rescue.

Credit: Turkish Navy

TCB Alemdar submarine MOSHIP.

has a next-generation fibre-optic link for enhanced communications and live video stream, as well as a new deployment/recovery system. New power and control elements for better manoeuvrability and handling in high sea/current states have also been incorporated.

According to JFD's Irwin, no other company has yet released a 4th-generation SRS design. He added that supporting the mobilisation and operation of a submarine rescue and intervention system is a significant endeavour with a wide number of logistical challenges. "Our main design driver is to reduce the TTFR. With limited hours of life support remaining on board a submarine following a distress call, the ability to get a system on location becomes the top priority." Focusing on this, he said that while the support and logistics process is fundamentally the same as for earlier generations, JFD's 4th-generation system's transportability options, reduced interfaces and modular design have enhanced its fly-away capability beyond those of previous-generation systems, ultimately improving the chances of reducing the TTFR. And although existing systems and contracts will remain unchanged, 4th-generation technology upgrades, enhanced procedures, best practice and technical understanding will all be transferrable to the ongoing service contracts maintained by the company.

As for the NSRS, the existing operational model with one SRV, will continue to operate and JFD will continue to support partner nations as per its current contract. "The NSRS must be kept at a high state of operational readiness," Irwin said, "in order to deliver an effective and available submarine rescue capability to the participant nations. We've successfully maintained its availability at a 98% level."

An Indonesian footnote

One recent sub-rescue tie-up beyond the NSRS was announced at DSEI in September 2023 by UK company, Submarine Manufacturing and Products (SMP), in the form of a USD 100-million, three-year-build contract with the Indonesian Government, for the supply of SMP's new SRS, incorporating the SRV-F Mk3 rescue submersible, to the Indonesian Navy. In turn, the navy will host the SRV aboard a new MOSHIP, currently being designed by independent engineering consultancy, Houlder. Once completed, the ship will be delivered to the navy by BTI Defence, Houlder's strategic, regional Indonesian partner, and the SRS, when complete, to the ship.

For the Indonesians, Major General Mohammad Fadjar, MPICT, Director General for Defence Potential at the Indonesian MoD, said: "The realisation of this SRV project marks a new era for the Indonesian Navy in terms of acquiring this critical capability."

In a statement, SMP said its SRS will be UK-designed and manufactured, while construction of the custom-built MOSHIP will take place in region, along with associated training for the navy's submarine-rescue stakeholders. It also said that as a hybrid system capable of deployment to a DISSUB event, either by air, or aboard its MOSHIP, the SRV-F Mk3 can minimise TTFR by reaching a wide range of emergency scenarios across large operating areas. An air-deployed SRV-F Mk3 can also be towed to and from a DISSUB without the need to be handled by a dedicated MOSHIP; the company says "this approach avoids the integration challenges and dependencies associated with flyaway-only, or mothership-only rescue systems". Of its other capabilities, the company statement said the Mk3 can operate at depths of 500 m and carry up to 50 stranded submariners at a time, potentially rescuing all crew members from a DISSUB at once, rather than having to make repeated, dangerous trips. Its new mothership will incorporate a handling system, an advanced TUP system, and a dedicated decompression chamber, so that immediate medical attention and treatment can be provided to rescued personnel.

While celebrating the contract with colleagues on his stand at DSEI 2023, SMP's MD, Ben Sharples, told *European Security and Defence/Maritime Defence Monitor* that the company had recently changed ownership and the new management team had been instrumental in delivering both this win and coming up with an SRV design to meet all the submarine-rescue needs of the Indonesian – and other navies – for years to come, particularly at a time of heightened geopolitical tensions in the waters around the massive archipelago of Indonesian islands and contested waters of the South China Sea.

Worth noting that the deal was announced two and a half years after the loss of the Indonesian Navy's KRI *Nanggala*-402, a West German *Cakra* class, Type U-209/1300 model submarine, with 53 lives lost. This tragedy will, without doubt, have been the major impetus behind the navy's drive to acquire an advanced sub-rescue solution, as part of attempts at wider fleet improvements and modernisation

Last word

While submarine rescues are, thankfully, relatively rare occurrences, knowing that proven, pioneering equipment, as well as the very latest submarine rescue technologies are available, are constantly being improved, and are operated by highly skilled and trained teams and personnel, must surely give solace to submariners who have, at the backs of their minds, the ever-present prospect that they might, one day, find themselves stranded aboard a disabled submarine, at the bottom of the sea. ■

Threats and surface ship survival

Tim Guest

Threats to surface fleet vessels are more numerous and potentially devastating than at any time in naval history, with a ship's survivability a fundamental consideration that begins at the concept and design stages of a vessel's existence.

This article considers some of the threats endangering the survival of today's surface ships and looks at various aspects of ship survivability.

Threats to surface ship survival

In the operationally-active waters of the Black Sea, Russia's war against Ukraine has seen a huge increase in threats to surface vessels, including a considerable rise in the use of autonomous surface vessels never seen before, particularly by Ukraine against Russia's fleet, as well as the use of mines, torpedoes, and Russia's use of cruise missiles against surface ships.

Indeed, test-launching its anti-ship missile capabilities has been a regular undertaking for Russia in the Barents Sea, even before the war; in a latest event, however, on 19 June 2024, it was reported by Russia's TASS news agency that Kalibr and Granit cruise missiles had been launched during naval exercises by two of Russia's Northern Fleet's nuclear-powered submarines – the *Severodvinsk* and the Orel – against surface ship targets some 170 km away and configured to simulate a detachment of enemy landing ships. As one would expect, a statement indicated the live-firing exercise had been completed successfully. Such test launches by the Russians against surface ships highlight the threat posed to allied vessels. Back in October 2021, another such launch saw a Zircon hypersonic cruise missile take around three minutes to cover 450 km at Mach 8, before destroying its surface ship target just about 10 seconds after the missile appeared on the horizon.

And Russia is by no means alone, with China having built up a vast arsenal of anti-ship missiles itself. According to the Center for International Maritime Security in a recent report on China's anti-ship firepower, it cites the YJ-12, YJ-18, YJ-83, DF-21, and DF-26 as the main, or preferred, missiles in the country's anti-ship inventory. Means of delivery sees the former YJ-12 deployed by bombers and coastal launchers, the YJ-18 by submarines and surface vessels, the YJ-83 by multirole fighter jets and smaller warships, with the latter two DF-21 and DF-26 ballistic missiles – the DF-21D nicknamed by some as 'carrier killer' – the country's longest range, land-based anti-ship systems, and launched from mobile launchers.

Credit: USN

Watching the horizon. Today's threats to surface ships will come from all directions, fast, and in potentially high-density numbers. It will require an effective mission architecture for all disparate defensive weapon systems and decoys to work in harmony to defeat such threats... and not simply a pair of binoculars. Pictured: USS Dewey, Philippine Sea Oct 2021.

Indeed, in August 2021, China test fired a DF-21D into the South China Sea, to prove its potential effectiveness against a targeted moving aircraft carrier out to 1,500 km, with the missile traveling at speeds, allegedly, up to Mach 10 during parts of its trajectory, which is certainly in excess of those of Russia's Zircon. Its accuracy is said to be 20 m CEP. DF-21s have terminal trajectories also near the vertical, making them extremely difficult for effective, last-ditch defensive measures by surface ships.

However, adding to the threats from above the surface, it is worth noting that 42 nations around the globe now have submarine capabilities, with over 50 submarines currently on the order books of Asian shipyards. This includes China, with its current tally of 50 submarines, predicted by the Pentagon to expand that number to 80 vessels by 2035, which will pose an immense threat to allied surface vessels operating in the Pacific, especially contested regions such as the South China Sea and the waters around Taiwan. And with air-independent propulsion, conventional submarines can stay below for extended periods making them hard to detect; armed with today's heavyweight torpedoes and effective from

Credit: Lockheed Martin

LRASM is designed to penetrate surface ship defences and destroy vessels from stand-off ranges of some 80 km.

ranges of over 50 km, the threat such submarines pose from below the surface, must also be factored into the defensive mix, if surface ships are to survive.

Thankfully, allied anti-ship systems are also, in play, to threaten the surface ships of any potential adversary. The US Air Force awarded Lockheed Martin a USD 3.2 billion contract for AGM-158C long-range anti-ship missiles (LRASM) as part of a deal that also includes AGM-158B joint air-to-surface standoff missiles (JASSM) in September 2024. Based on the JASSM, LRASM is designed to penetrate surface ship defences and destroy vessels from stand-off ranges of some 80 km. The missiles use precision routing and guidance, navigating from very long ranges, semi-autonomously, to a surface-vessel target, stationary or underway. In early April 2024, four LRASMs were simultaneously flight-tested by the USN and Lockheed Martin in their twelfth integrated test event of the missile, and successfully destroyed their surface target. LRASMs operate from USAF B-1Bs and USN F/A-18E/Fs, as well as F-35s, with a surface-ship-launch variant for use with the vertical launch system used by the USN.

With such missiles hugely expensive, USAF demonstration in the Gulf of Mexico in August 2024 of a low-cost capability to defeat surface vessels from the air is worth noting. Called Quicksink and developed by the USAF Research Laboratory (AFRL) Munitions Directorate at Eglin AFB in Florida, the weapon system is a low-cost, air-delivered method designed to defeat surface ships. In partnership with the USN, the lab operates an ongoing maritime weapon programme to develop anti-ship lethality with air-launched weapons and Quicksink has, according to an AFRL statement, been developed in answer to 'an urgent need to quickly neutralise maritime threats over massive expanses of ocean around the world'.

The system is a Joint Capability Technology Demonstration (JCTD) to defeat maritime surface vessels at a low-cost, with a weapon open systems architecture (WOSA) seeker developed by AFRL to enable precision targeting. The weapon uses an existing guidance kit integrated with the new seeker and methods to achieve the same anti-ship, on-target effects as a heavyweight MK-48 torpedo are being explored, but using less costly, air-launched weapons instead, such as modified 2,000-lb-class, precision-guided bombs. One added benefit of such a capability is avoiding a submarine having to give away its position by launching a torpedo.

This is just a snapshot of the overall threat picture facing surface vessels, without space to discuss the added threats from autonomous vessels, cyber attacks, drone swarms, and fast inshore attack craft, to name but a few. Nevertheless, it is clear that from carrier strike groups downwards, surface ships face more technologically sophisticated threats, and in greater numbers, than ever.

Credit: UK MoD Crown Copyright

Carrier groups and carriers themselves are the highest priority targets for ship-killing weapons. Pictured: HMS QE CSG 21.

Credit: USN

Ship survivability considerations begin at the conceptual design stage, factoring in every aspect of the future vessel, from its hull design and materials such as steel, GRP, or other, to weapon and decoy systems and everything in between. Pictured: eighth Independence-class, littoral combat ship, USS Tulsa (LCS-16), a 418-ft trimaran with a diesel and gas-powered top speed of 47 kn, and including missile defences against swarming fast attack craft, long-range precision strike naval strike missile, and mine countermeasure capabilities.

Survivability considerations

And so, to survivability, which, no matter the vessel type, effectively means not only a ship's ability to both transit through a hostile environment, but also to actively operate in the same domain, if required. It must be able to defend itself and defeat a wide range of threats, remaining afloat and serviceable if attacked and/or damaged, and with a sufficient percentage of its on-board systems remaining operative for it to continue to perform as an effective asset to its fleet. Surface vessels come in all shapes, sizes, and categories, are combatants or non-combatants, include carriers, destroyers, frigates, littoral vessels, patrol craft, auxiliary ships such as replenishment oilers, and more. In just a single carrier strike or battle group, an aircraft carrier will be accompanied by an array of escort vessels, likely including cruisers, destroyers, frigates, as well as several logistics and resupply ships, with the composition of such groups dependant on the navy involved. But all are on someone's target list.

And the structural design attributes of these ships, which will also impact their survivability in one way or another, include some, for instance, being steel-hulled, some monohulled, or maybe of a three-hulled catamaran design. Others are steel-hulled with greater or lesser aluminium alloy substructures in their construction, some are aluminium-hulled, and some, often smaller vessel classes, glass reinforced plastic (GRP). But even before a keel is laid, along with those early concepts and designs, the ship's ultimate survivability will have been at the forefront of the customer's and marine/naval architect's minds and blueprints.

From concept to construct

Indeed, no matter whether a carrier or a patrol boat, destroyer or frigate, parameters impacting a surface ship's survival are set out at a platform's concept stage and will include considerations for delivering optimum manoeuvrability for the design, as well as giving the vessel stealth attributes, perhaps through the inclusion of certain RF, thermal and acoustic technologies. The selection of weapon systems, too, is, of course, a crucial part of the survival matrix and, depending on vessel type, may include guns, missile systems, as well as laser/directed energy weapons (DEW), close-in weapon systems (CIWS), and more.

Then, adding further to a ship's survivability in a threat environment, RF and infra-

Credit: SEA/Cohort

Ancilia trainable decoy launchers counter missile, including hypersonic and ballistic, and drone threats.

Credit: USN

A gathering storm of evolving threats to surface ships will make the effectiveness of their integrated survivability solutions more critical if they are to survive. Pictured: USS Carl Vinson South China Sea, Oct. 2021.

red (IR) jamming systems will be selected, or considered, at design stage, (budgets are the wild cards, which can impact final equipment selections). Intended to jam an enemy's use of GPS guidance datalinks of their incoming weapons, they can, potentially, also impact the altimeters of incoming weapons, such as sea-skimming missiles, resulting in their ending up in the sea before they reach their target.

Decoys are also becoming more prevalent as passive systems to help direct an incoming weapon away from the real platform, but even older, traditional countermeasures, such as chaff-dispensers to distract anti-radar missiles from the target, are expected to have a key role in ship defences and ultimate survivability for many years to come. Beyond these onboard systems, off-board land and air platforms coordinating critically with a vessel, provide technological resilience through the provision of real-time intelligence and support, and include anti-submarine warfare (ASW) aircraft and those on combat air patrol, as well as allied airborne surveillance from AWACS, providing vessels with real-time information on most shore-based, and/or over-the-horizon (OTH) launches and incoming threats, at the earliest possible time.

On their own, all these systems have little chance to make a difference against today's threats, but all of them working together in a coordinated way across a defensive network delivers a comprehensive survivability solution with much greater chance of success. This is where a mission architecture, such as the Combat Systems Highway from UK defence company, SEA, comes in, by providing the backbone to a broader architecture; the system is in service with several navies, including the UK's Royal Navy (RN), where it is used aboard both Type 23 frigates, as well as with some elements of the system on Type 45 destroyers and the HMS QE aircraft carrier. The backbone is divided into a number of functional areas with scalability inbuilt, so that new capabilities, including latest weapon, surveillance and decoy systems, can be added quickly and a ship's survivability can adapt to constantly-evolving threats.

An example of one such system playing a key role in surface ship survivability, is the trainable decoy launcher, Ancilia, from Cohort Group company, Systems Engineering & Assessment (SEA) in the UK. In the pipeline for several years, a GBP135-million contract was awarded to SEA in March 2024, procured for the RN by the UK's Defence Equipment & Support (DE&S) as part of the UK's Maritime Electronic Warfare Programme (MEWP), to progressively update RN surface ship electronic surveillance, electronic warfare command and control, and countermeasures capabilities to 2045.

According to the company, the new decoy launchers will equip Type 31 and Type 26 frigates and Type 45 destroyers and are designed to respond with speed and agility to counter missile, (including hypersonic and ballistic), and drone threats, including in the Red Sea where Houthi missile attacks on shipping are ongoing, including attacks on HMS *Diamond* and HMS *Richmond* in early 2024.

The sister company to SEA, Chess Dynamics, has developed the trainable base for Ancilia, which, with its positioning technology, has been specifically designed to operate accurately, even during high sea states. And where previous decoy and chaff dispenser technology typically required a vessel to alter course and manoeuvre in order to face the direction of a threat, the ability to train Ancilia towards an incoming threat confirms that is now redundant.

Final word

There are a wide range of new and emerging threats to surface fleets, as has been discussed, many of which are more technologically complex than has ever been experienced on the high seas. These developments – together with the convoluted geopolitics of today – have made the maritime environment a much more contested space in which allied navies must operate. Facing such technologically sophisticated threats as anti-ship ballistic and cruise missile systems, amongst others, it is how allied naval forces make use of technology to defend their naval platforms that will enable them to overcome hostile technologies and threats and, ultimately, survive. ■

Warding off new threats

Maritime counter UAV and USV technologies

Sidney E. Dean

Unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs) have emerged as a potent new threat to military ships. This requires a re-evaluation of ship-defence technology and tactics.

For decades anti-ship missiles (ASMs) have arguably posed the dominant threat to surface vessels. However, a new, asymmetrical threat emerged in October 2000 when a small, explosive-laden boat attacked the destroyer USS *Cole* (DDG-67) in the port of Aden, killing 17 crew members and severely damaging the ship. While the *Cole* attack was perpetrated by suicidal terrorists, the same tactic can now be carried out by remotely-controlled or even autonomous unmanned boats laden with explosives or carrying anti-ship or anti-tank missiles. UAVs – including so-called loitering munitions that can transition from a de facto unmanned aircraft to an attack missile – have also provided less-sophisticated combatants a viable tool for holding even highly advanced warships at risk. They are low cost and easy to acquire or produce, and can be launched in mass in an effort to overwhelm defences. Both UAVs and USVs are small, fast and manoeuvrable, making them difficult to detect or target. Even if UAVs are unlikely to sink a destroyer, one or more could render the ship 'hors de combat' by damaging or destroying sensor and communications arrays.

The ongoing standoff between western naval forces and Houthi rebels in the Red Sea illustrates these developments. The Houthis have deployed a broad-based arsenal including anti-ship cruise missiles, UAVs, and explosive-laden USVs to attack both civilian and military shipping. Swarm attacks have included as many as 28 UAVs at one time, requiring the combined efforts of several warships to stop the incoming threat. While the attacks have, to date, failed to penetrate the defences of the military vessels, they have damaged several commercial ships. These include the Liberian-flagged bulk carrier MV *Tutor*, which sank after being struck by a USV (and later, probably, by an ASM) on 12 June 2024. In principle, warships remain vulnerable to such attacks, as demonstrated by a January 2017 Houthi strike on a Saudi frigate south of the Bab el-Mandeb Strait. While the damaged vessel was able to return to port under its own power, two crewmembers were killed.

Credit: US Navy

US Navy helicopters rescued 24 civilian mariners from MV Tutor after the merchant ship was struck by an explosive-laden USV in the Red Sea on 12 June, 2024.

Two multinational missions – the US-led Operation Prosperity Guardian and the EU-led Operation Aspides – have been mounted to secure shipping through the Bab el-Mandeb Straits and the Red Sea. The coalition forces have been forced to adapt their tactics to prevent being overwhelmed by the volume of attacks. Concepts of operation are being revised and optimised. In a way, the Red Sea crisis provides an opportunity to learn and prepare for future unmanned campaigns by significantly larger and more sophisticated state opponents, such as Iran or China. It has become clear that UAV and USV based campaigns will require a combined arms approach utilising a variety of weapon systems, including some which are still in development.

Kinetic weapons

The coalition ships' initial response was to deploy precision guided munitions not only against the Houthi's anti-ship missiles but against all incoming threats. It soon became obvious that this is not an optimal strategy. To begin with, utilising high-performance missiles designed to intercept manned aircraft, cruise missiles and/or ballistic missiles at long range are pure 'overkill' when deployed against small to medium sized UAVs. The cost-ratio calculation of using SM-2 missiles costing USD 1.2 million each against a USD 5,000 drone is justifiable as a short term measure to protect a ship, but is not sustainable as a long-term strategy. Finally, shipboard missile arsenals are finite. A determined enemy can continue to launch unmanned systems until the arsenal of defensive missiles is depleted, forcing the ships to withdraw. Worse, the UAV can be deployed in a calculated strategy to deplete the defensive arsenal, leaving the vessel vulnerable to attack by ASMs or (in the case of a state actor) manned aircraft.

In the Red Sea, coalition vessels quickly began using their deck guns against both airborne and surface targets including both UAVs and USVs. Rapid fire guns such as

Credit: US Navy

USS Carney (DDG-64) fires a Standard Missile (SM) 2 to defeat a combination of Houthi missiles and unmanned aerial vehicles in the Red Sea.

the OTO 76/62 Super Rapid can achieve a rate of fire of 120 rounds per minute. Depending on munition choice, targets can be engaged at up to 40,000 metres distance. The combination of radar and optical precision guidance on the one hand and high-explosive pre-fragmented munitions on the other can place multiple rounds very near a manoeuvring target at considerable distance from the ship. Northrop Grumman is developing a new, manoeuvring 57 mm artillery round designed specifically for the Mk 110 gun mounting used on US Navy warships. Aided by an on-board seeker, the guided high explosive round will continue to autonomously adjust its flight path as it approaches the target, then self-select between proximity detonation or point detonation mode in order to maximise the odds of target destruction. It is designed specifically to defend against fast-moving surface threats, drones, and swarming threats. If surface or aerial threats evade this fire, they can be engaged by close-in weapon systems such as the 20 mm Phalanx Gatling gun and/or heavy machine guns.

Electronic warfare

Shipboard electronic warfare (EW) systems can also be deployed against both UAVs and USVs in order to disrupt radio-control frequencies or satellite navigation. This has proven effective in the short-term in other current drone-intensive conflicts, such as the Ukraine war. However, whether on land or at sea, attackers can utilise various techniques – such as frequency hopping or inertial and optical guidance systems – to overcome EW. As such, it is not a definitive solution.

Directed energy weapons

Directed energy weapons (DEWs) have increasingly been considered the potential optimal solution to shipboard defence against unmanned aircraft, as well as small fast-attack craft, both manned and unmanned. The primary categories of DE systems are lasers and microwave weapons.

US Navy laser programmes: Numerous nations are pursuing high energy laser (HEL) weapon technology for their naval fleets. The US Navy has one of the oldest and largest research and development programmes, although progress has lagged behind original estimates. The maritime environment is particularly challenging for laser weapons as the moist and salt-laden air can interfere with beam cohesion, exacerbating the general difficulty of maintaining beam contact on one spot of a manoeuvring target.

Several different laser systems are currently being evaluated under the umbrella term Navy Laser Family of Systems (NLFoS). The most promising for near-term applications against UAVs and USVs are the Optical Dazzling Interdictor, Navy (ODIN) and the High-Energy Laser with Integrated Optical Dazzler and Surveillance (HELIOS). To date the US Navy has received seven ODIN and one HELIOS system; they are currently installed on warships for evaluation.

ODIN is a purely non-destructive system designed to neutralise UAVs by disabling their optical sensors. The goal is not to destroy the unmanned aircraft but to prevent is from observing vessels and gathering intelligence which could be used, among other purposes, for targeting. In the same vein, disabling its sensors could prevent an explosive laden USV from acquiring a targeting fix on a ship, but additional kinetic measures would still be necessary to destroy the boat and completely eliminate the threat. This underscores ODIN's major drawback; first conceived before armed UAVs and USVs were considered a serious threat, the system is not designed to repel attacks.

HELIOS, by contrast, is a dual-capable system. Its optical dazzler can blind a drone's sensors to prevent targeting, but its 60 kW high-energy laser is also capable of physically destroying a UAV or USV. This would be accomplished by directing the beam against a key element, such as the engine or a hull section, until it catches fire. HELIOS is currently being evaluated aboard the destroyer USS Preble (DDG-88). According to Navy Secretary Carlos Del Toro, the testing has made good progress. "We are at a point now, where... we are a bit beyond the experimentation point," Del Toro said at the Surface Navy Association (SNA) symposium in January 2024. "We will be continuing to do ex-

Credit: European Union Operation Aspides

On 9 March 2024 the French warship Alsace shot down three Houthi attack UAVs using her 76 mm OTO deck gun.

periments [but] over the course of the next year, even less, that will fully flush out how we can employ this incredibly transformative system."

Despite this, US Navy leadership is not entirely satisfied with the state of affairs. "I am not content with the pace of directed energy weapons. We must deliver on this promise that this technology gives us," said Vice Admiral Brendan McLane, head of US Naval Surface Forces, during the same SNA symposium. He is pressing for accelerated fielding of both lasers and high-powered microwave weapons throughout the fleet. Developing these capabilities will be a major effort for the surface force, he said. "I really want to put a lot of effort into accelerating that, because that that gives you so much [capability] when it comes to magazine capacity and speed and distance [for target engagement.]" Secretary Del Toro indicated that funding for DE development will be increased in upcoming budget requests.

European laser programmes:

Other NATO nations are on the same track. In January 2024 the United Kingdom's DragonFire laser directed energy weapon (LDEW) development programme reached a major milestone, achieving the UK's first high-power firing of a laser weapon against aerial targets. The engagement range remains classified, with the Ministry of Defence (MoD) only commenting that the precision required would equate to hitting a coin at a distance of one kilometre. The beam can cut through metal "leading to structural failure or more impactful results if the warhead is targeted," according to a MoD statement. The system had previously proven the ability to track moving air and sea targets with very high accuracy at range.

In April 2024 the MoD announced it was accelerated the fielding of DragonFire with the Royal Navy (RN). The first ships will be equipped with the LDEW in 2027, five years earlier than previously planned. "In a more dangerous world, our approach to procurement is shifting with it. We need to be more urgent, more critical and more global," said then British Defence Secretary Grant Shapps. The UK sees DragonFire as a long-term low-cost alternative to missiles for such tasks as destroying attack drones. In addition to operational effectiveness, expected benefits include simplified logistics through reduced need to stockpile some munitions, and a very low cost per engagement; the MoD estimate less than GBP 10 for a ten-second shot. Presuming the LDEW performs as promised, fielding DragonFire before the end of the decade could place the RN in the vanguard for maritime laser weaponry.

Germany is also pursuing a maritime laser weapon suitable for countering the threat from drones, drone swarms, and speedboats. A 20 kW HEL naval laser weapon demonstrator (LWD) jointly developed by MBDA Deutschland GmbH and Rheinmetall was integrated aboard the frigate FGS *Sachsen* in June 2022 and evaluated at sea over nearly a year. The LWD performed over a hundred test firings onboard the

Credit: Northrop Grumman

Northrop Grumman is developing a manoeuvrable 57 mm round to defend against fast boats, drones and UAVs.

Credit: US Navy

The US Navy has one of the oldest and largest research and development programmes; this photo shows a laser demonstrator trial against a UAV conducted by the amphibious transport dock USS Portland (LPD-27) in May 2020.

Credit: Lockheed Martin

The Lockheed Martin-produced HELIOS laser is currently being evaluated aboard the destroyer USS Preble (DDG-88).

The prototype of the British DragonFire laser weapon has been undergoing successful trials.

Sachsen. As described by the working group, the trials consisted of six campaigns testing the combat effectiveness of the LWD in increasingly complex scenarios, under realistic operating conditions and against different target types. This included detection and tracking (including highly agile targets); the interplay of sensors, command and weapon engagement systems, and effectors; possible rules of engagement; and successful engagement of targets with a high-energy laser beam. Following removal from *Sachsen* in late 2023 the LWD was transferred to the Bundeswehr Technical Centre 91 in Meppen for in-depth evaluation. The test results will inform the development of an operational laser weapon system.

Field testing of the UK's Radio Frequency Directed Energy Weapon (RFDEW) – initially by the British Army – will begin in 2024.

High power microwave weapons: High power microwave (HPM) weapons emit intense pulses of electromagnetic energy which can disable UAVs, loitering munitions, and USVs in two ways. The electromagnetic pulse overloads and damages the on-board electronic components necessary for communications, sensors, and flight control or navigation; aircraft can be forced down, while USVs can be left dead in the water. Additionally, the microwaves generate intense heat within the target, which can melt or distort sensitive components such as circuit boards, antennas and power supplies, also disabling the target. While lasers must focus on one target at a time, and maintain the beam on target for sufficient time to do damage, microwave bursts can be fired either as pulsed-wave HPMs or as continuous-wave HPMs. Pulsed-wave HPMs are narrowly focussed, high-power, short-duration pulses which can provide precise targeting at longer range. Continuous-wave HPMs stream energy over a wider area but have a shorter effective range. They are well suited to area denial missions such as defeating incoming UAV or USV swarms.

Overall, HPMs are considered to have great force-protection potential, especially for warfare scenarios in confined waters which favour operations by smaller unmanned systems, or in a major war scenario against an adversary such as China, which is developing a large and sophisticated unmanned arsenal. The US Navy plans to begin at sea testing of the Meteor HPM in 2026. The weapon is expected to "provide capability with low cost-per-shot, deep magazine, tactically significant range, short time engagement for multi-target approach, dual deception and defeat capability," according to fiscal year 2025 budget documents.

Here, too, other nations are pursuing their own efforts. In May 2024 the UK MoD announced that field testing of the Radio Frequency Directed Energy Weapon (RFDEW) will begin in the summer of 2024. While this testing will be conducted by British Army air defence personnel, the RFDEW is intended for both the land forces and the RN. The weapon is designed to detect, track, and engage multiple targets on land, sea, and in the air at a range up to one kilometre; range is to be increased over time. The RFDEW can defend against drone swarms and is designed for extensive automation, allowing operation by a single person. A single electromagnetic pulse over a wide arc is expected to consume only ten pence worth of electricity.

Overlapping coverage required

A viable, long-term defensive strategy against unmanned aerial and surface attacks will require a combination of kinetic and directed energy systems, deployed to provide layered and overlapping coverage at long, medium and short ranges. Significant research, development and testing efforts relating to weapons in both categories are underway. Smart munitions for ship's artillery will optimise precision interceptions at long to medium range. Scalable high energy lasers will provide flexibility to warn off, disable or destroy threats; they will also offer commanders the option of non-destructive response to perceived threats, if de-escalation or minimising collateral damage are considerations. Microwave weapons will also provide significant flexibility, and enhance defence against swarming threats or attacks emanating from various directions simultaneously. In some scenarios coordinated measures by several defensive systems will be required to ensure that a threat has not simply been disabled but destroyed. Ultimately there will be no 'golden bullet' or optimal end-state; as adversaries continue to refine the capabilities of their offensive systems, fleets will continue to pursue evolutionary and revolutionary UAV/USV countermeasures indefinitely. ■

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