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05
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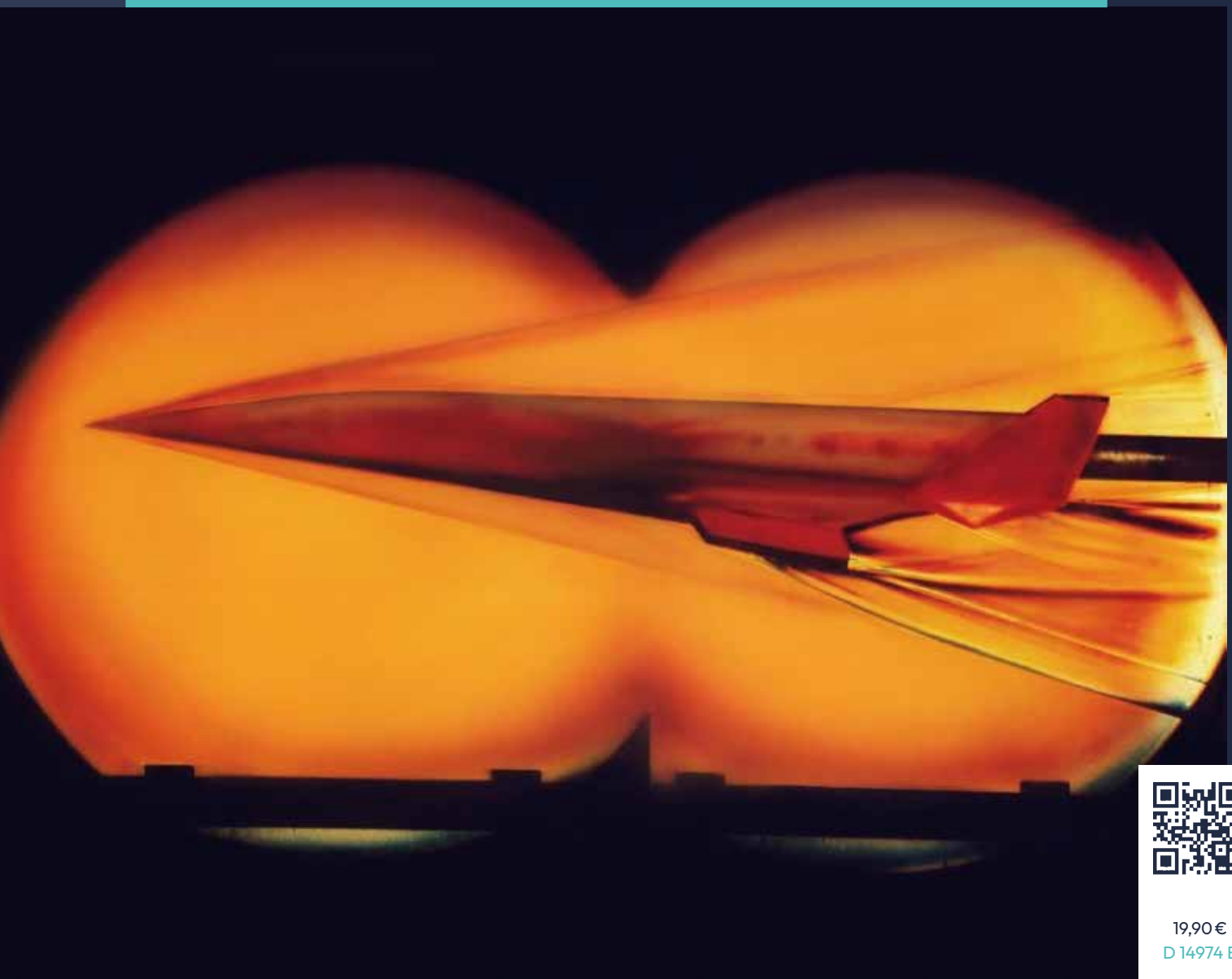
Hypersonic Weapon Programmes



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Why an end to the War in Ukraine remains so elusive

Prior to the 2024 US election, Donald Trump claimed it would take him "one day" to end the War in Ukraine. Yet as the first 100 days of President Trump's second term have slipped by, a peace deal between Kyiv and Moscow still seems like a remote prospect. At the time of writing in late-April 2025, Russia certainly appears intent on keeping the war going, having that month called up 160,000 personnel in their conscription drive, and rebuffed a Ukrainian proposal for even a 30-day ceasefire.

An honest assessment of the situation through the Kremlin's eyes would suggest that there are relatively few incentives for Russia to pursue peace seriously at this point in time. While President Vladimir Putin would no doubt welcome various concessions such as an end to sanctions, diplomatic recognition of Crimea, and the chance for his armed forces to replenish stockpiles, he probably also understands that in reality, things won't be that simple.

A key problem is the limited degree to which the US can offer meaningful incentives without its European allies agreeing to the same. Trump may be able to promise an end to US sanctions, but unless the EU makes a similar promise – which doesn't look likely – this would still leave Russia cut off from key pre-war trade partners in Europe. Much the same goes for diplomatic recognition of Crimea as Russian – the US' unilateral recognition carries less weight than multilateral US and European recognition.

Next, even if sanctions were broadly ended, Russia would not necessarily see a major uptick in trade and investment overnight. While there will no doubt be some businesses who would be willing to recommence trade with Russia, many wouldn't. Even leaving aside the negative optics and potential public backlash of doing so, Russia represents a fundamentally risky business prospect. No business will want to sign a contract with a Russian company, only to have war restart soon after, and find that sanctions have been reimposed and that any agreements signed will not be honoured.

In a similar manner, Europe's two key energy policy priorities are ensuring security of supply, and the green energy transition, neither of which are compatible with a return to dependency on cheap Russian gas. As such, Russia's prospects for reintegration into Europe's energy mix look limited at best. All told, while the war has not been good for Russia's economy and industry – both appear condemned to stagnation, at least for the time being – many of the root causes would likely carry through even after a ceasefire [for a deeper look at the problem, see p88-91 of this issue]; thus providing little economic incentive to stop the fighting.

On the battlefield, there is no obvious propaganda victory to be capitalised upon either. Thus far, the opening months of 2025 have not seen much in the way of battlefield success for Russia – the front lines have moved only slightly since January, with the most notable gain being Russia's near-total recapture of Kursk Oblast, lost to Ukraine's 6 August 2024 incursion. However, this isn't a particularly convincing success story for the Kremlin to be able to spin into a 'mission accomplished', not least because it was only due to Russia's 2022 invasion that the Kursk incursion occurred.

Looking to the war effort, Russia's armed forces appear to be feeling the effects of exhaustion and equipment shortages really start to bite. Many would therefore be tempted to argue that a pause is necessary for its forces to regain offensive potential. This isn't wrong – a pause would indeed give Russia the chance to rest its troops and replenish its stockpiles – yet the exact same goes for Ukraine. In this kind of war, relative gains can often be more valuable than absolute gains.

When speaking to Ukrainians, it is clear most of them fear a ceasefire would give Russia time to rearm and then re-invade more competently in a few years' time. Yet upon closer inspection, Ukraine may get more in relative terms out of a pause to the fighting. For starters, Kyiv is likely to continue to receive some form of military and financial support from Europe in peacetime, not least to deter Russia from another invasion in the future. Additionally, many Ukrainian citizens who fled their country at the war's outbreak may return, boosting the economy and providing a source of fresh potential recruits were war to break out again. Furthermore, depending on how long it lasts, peace could bring Ukraine enough stability to eventually realise its EU accession ambitions, bolstering the country's access to badly-needed funding for development and defence. Russia by contrast will be left to grapple with restoring its battered economy in a difficult economic climate amid currently low oil prices. Collectively, these factors could erode what little relative advantage Russia currently enjoys.

As such, the Kremlin appears to prefer the current situation, bad as it is, over a peace where Ukraine might benefit more from than Russia. The logic at play here can perhaps be best summarised through an old joke:

One day, an old farmer encounters a magical fairy, who offers to fulfil any wish the farmer has, but on the condition that whatever the farmer gets, his neighbour will get double. The old farmer immediately replies: "Take one of my eyes."

Mark Cazalet

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ESD [European Security & Defence]
Issue 5/2025, May 2025,
ISSN 1617-7983
www.euro-sd.com

Published by
Mittler Report Verlag GmbH
A TAMM Media Group company

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Layout & Production
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Production: Lehmann Offsetdruck und Verlag GmbH,
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Cover Photo: A model hypersonic craft undergoing tests in a 50.8 cm (20 Inch) Mach 6 tunnel. [NASA]

Annual subscription rate: €123.80 incl. postage Reduced annual subscription rate for distribution in Germany: €103.80 incl. postage

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Ukraine's European allies work on peace plans while bolstering military support for Kyiv

(pf) The United Kingdom and France convened the first Defence Ministers' Ukraine Coalition of the Willing meeting in Brussels on 10 April 2025 to progress planning to support a lasting peace in Ukraine.

[NATO]

Around 30 nations were hosted by UK Defence Secretary John Healey and French Defence Minister Sébastien Lecornu, with the meeting focusing on how the capabilities of each nation in the Coalition could be best used to support Ukraine's long-term defence and security.

A UK Ministry of Defence press release noted that Healey would tell the meeting, "A couple of weeks ago I visited the UK's Permanent Joint Headquarters, where military leaders from around 30 nations were developing options and progressing plans. I was struck by their sense of historic responsibility to secure the peace in Ukraine and to strengthen European security for all our nations.

"We cannot jeopardise the peace by forgetting about the war, so we must put even more pressure on Putin and step up our support for Ukraine – both in today's fight and the push for peace. Our commitment is to put Ukraine in the strongest position to protect Ukraine's sovereignty and deter future Russian aggression."

The 10 April meeting in Brussels came after UK Chief of the Defence Staff Admiral Sir Tony Radakin travelled to Kyiv with French military chiefs on 5 April to meet Ukrainian President Volodymyr Zelenskyy, Ukrainian Defence Minister Rustem Umerov and Ukrainian military leaders to update and discuss planning.

On 11 April, meanwhile, the UK and Germany co-chaired the 27th meeting of the Ukraine Defence Contact Group, where 50 nations attended and collectively pledged a further EUR 21 billion in military aid to Ukraine.

Despite the efforts of Ukraine's allies, however, along with US efforts to broker a ceasefire, there is no indication that Russian President Vladimir Putin is likely to genuinely move towards a peace agreement.

Operation 'Highmast' gets underway as UK carrier strike group forms for eight-month deployment

(pf) The UK's premier naval deployment of 2025 got underway on 22 April when the aircraft carrier HMS *Prince of Wales* departed Portsmouth, followed a few hours later by the destroyer HMS *Dauntless*.

HMS *Prince of Wales* is leading an eight-month mission of Carrier Strike Group 25 known as Operation 'Highmast', under which series of exercises and operations will be conducted with air, sea and land forces of a dozen allies in the Mediterranean, Middle East, South-east Asia, Japan and Australia.

International by design, the task group will be joined in the English Channel by two Norwegian vessels, the tanker HNoMS *Maud* and frigate HNoMS *Roald Amundsen*, coming directly from Norway, with the Royal Navy frigate HMS *Richmond* and Royal Canadian Navy frigate HMCS *Ville de Québec* sailing from Plymouth. The Royal Fleet Auxiliary tanker RFA *Tidespring*, which has spent much of 2025 in Birkenhead undergoing maintenance and upgrades to prepare for the mission, will complete the strike group in its initial format.

By the end of April Carrier Strike Group 25 will have embarked up to 24 British F-35B Joint Strike Fighters and squadrons of attack, troop-carrying and anti-submarine helicopters, along with unmanned aerial vehicles, all supported by around 750 personnel in the air wing alone.

[Crown Copyright]

The deployment will initially begin with around 2,500 military personnel in total – around 2,100 Britons, 200 Norwegians and a similar number of Canadians and Spanish – but this personnel strength will rise to over 4,500 for some of the key exercises as the force reaches the Indo-Pacific.

Operation 'Highmast' will be commanded by Commodore James Blackmore and his staff from aboard HMS *Prince of Wales*. Cdre Blackmore was quoted in a Royal Navy press release as saying, "I am delighted to lead the UK Carrier Strike Group encompassing sailors, marines, soldiers and aviators from across the UK and allied armed forces. Working closely with partners from across the globe, Operation 'Highmast' will demonstrate credible deterrence and our support to NATO and the rules-based international order.

"This will reaffirm that the UK is secure at home and strong abroad and reinforce the UK's commitment to the Indo-Pacific," the commodore added.

This is the second deployment of a UK Carrier Strike Group in the modern era. The first, led by HMS ***Queen Elizabeth*** in 2021, took place against the backdrop of a world in lockdown due to the Covid pandemic.

SwAF embarks on its first external NATO Air Policing mission

(pf) On 1 April 2025 a detachment of six Swedish Air Force (SwAF) Saab Gripen fighters embarked on the SwAF's first NATO enhanced Air Policing mission from the territory of another ally since Sweden joined the alliance on 7 March 2024.

[Swedish Armed Forces]

The Swedish Gripens, from the SwAF's Norrbotten Wing, joined the Polish Air Force and a detachment of six Royal Air Force Eurofighter Typhoons at Poland's 22nd Air Base in Malbork for the mission.

Since joining NATO Sweden has been contributing to NATO Air Policing missions, but up until now only from Swedish territory.

Speaking during a ceremony at Malbork to mark the beginning of the mission, Swedish Defence Minister Pål Jonson stated, "For the first time ever Sweden is deploying combat aircraft abroad on the NATO enhanced air policing mission.

"This mission is a strong demonstration of cohesion and solidarity among allies and a powerful deterrent against Russian aggression. We are proud that it is our first ever policing mission … and we're also proud to be doing it together with the United Kingdom."

Enhanced Air Policing is part of NATO's Assurance Measures introduced in 2014 after Russia's illegal annexation of the

Norway becomes first F-35 nation to complete its programme of record

(pf) Norway has become the first partner nation in the F-35 Joint Strike Fighter (JSF) programme to complete its programme of record for the jet, Lockheed Martin announced on 1 April 2025.

The JSF fleet of the Royal Norwegian Air Force (RNoAF) was completed with the delivery of the air force's 51st and 52nd F-35As.

Norway selected the F-35 in 2008 and placed an order for its first two aircraft on 14 June 2012. The first Norwegian F-35 was rolled out of Lockheed Martin's facility in Fort Worth, Dallas, on 22 September 2015 and the first three RNoAF F-35s arrived in country in November 2017. The type reached an initial operating capability with the RNoAF in November 2019.

[Lockheed Martin]

The RNoAF's F-35A fleet is mainly based at Ørland Main Air Station in central Norway, although Evenes Air Station in northwest Norway is also used as a forward F-35 base for quick-reaction alert duties and in June 2024 the underground hangars at Bardufoss Air Station, further north, were reactivated for use by F-35s.

Beyond the F-35's service with the US Air Force, Navy and Marine Corps, the type has been selected by 19 other nations. The global F-35 fleet has now surpassed 1,150 aircraft.

British Army trial defeats drone swarms using UK-developed RF DEW demonstrator

(pf) A British Army team has successfully tracked, targeted and defeated swarms of drones in the latest trial of a new UK-developed radio-frequency directed-energy weapon (RF DEW), the UK Ministry of Defence (MoD) announced on 17 April 2025.

The trial was recently completed at Air Defence Range Manorbier in West Wales and was the largest counter-drone swarm exercise the British Army has conducted to date.

During the trial soldiers from 106 Regiment Royal Artillery were able to take down two swarms of drones in a single engagement using an RF DEW demonstrator mounted on a MAN/RMMV HX60

[Crown Copyright]

truck, while more than 100 drones were immobilised using the weapon across all trials.

The project, known as Ealing, has been delivered by Team Hersa: a collaboration between the UK MoD's Defence Equipment & Support organisation and the MoD's Defence Science and Technology Laboratory (Dstl) to develop directed-energy weapons.

Developed by a Thales UK-led industry consortium, the RF DEW demonstrator has been designed to explore the potential of radio-frequency weapons for the UK armed forces. It uses high-frequency radio waves to disrupt or damage critical electronic components inside drones, causing them to crash or malfunction. The system currently has a range of up to 1 km and is effective against targets that cannot be jammed using electronic warfare techniques.

Given that the RF DEW demonstrator only incurs a minimal 'cost per shot', if developed into operational service it could provide a significantly more cost-effective counter-drone weapon when compared to traditional missile- or even gun-based air defence systems.

The UK government has invested more than GBP 40 million (EUR 46.7 million) in RF DEW research and development to date, according to the UK MoD.

The successful trial comes as drone swarms are being increasingly seen in use in frontline combat in Ukraine, with UK Defence Intelligence estimating that in 2024 Ukrainian forces had to defend against attacks from more than 18,000 drones (including bomb-laden unmanned aerial vehicles (UAV) and loitering munitions).

Sweden proceeds with buying 18 new Archer SPHs for Ukraine

(pf) The Swedish government is proceeding with plans to buy 18 new Archer 155 mm wheeled self-propelled howitzers (SPHs) from BAE Systems as part of its 18th support package to Ukraine.

The news was formally announced by Swedish Defence Minister Dr Pål Jonson during a visit to the BAE Systems Bofors site in Karlskoga, Sweden, on 7 April.

Jonson first presented the plan procure the 18 Archer systems for Ukraine on 13 March 2025 in a package worth around USD 300 million (EUR 274 million). Sweden's 18th support package for Ukraine also includes five ARTHUR weapon-locating radars, RBS 70 manportable air defence systems and Tridon Mk2 air defence systems, which comprise a turreted Bofors 40 Mk4 40 mm L70 naval gun, day-night acquisition sensors and a fire-control system mounted on a high-mobility truck.

The Swedish Army originally acquired 48 Archer systems: 24 systems ordered in 2009 and 24 systems, originally intended for Norway, ordered in 2016.

Fourteen systems were then sold to the British Army under an interim artillery replacement programme in March 2023, when it

[BAE Systems]

also emerged that the Swedish government would transfer eight systems to Ukraine.

In September 2023 it was announced that the Swedish Defence Materiel Administration had contracted BAE Systems to supply 48 new Archer systems for the Swedish Army.

The Archer system can fire the BONUS anti-armour munition out to a range of 35 km, conventional munitions out to 40 km, and precision-guided Excalibur rounds to in excess of 50 km. Its automated magazines can hold a mix of different ammunition types and modular charges needed to support any particular fire mission.

Bulgarian Air Force receives its first F-16 Block 70 fighter

(pf) The first Bulgarian Air Force Lockheed Martin F-16 Block 70 fighter arrived at the country's Graf Ignatievo Air Base on 13 April 2025, signalling the beginning of F-16 operations in Bulgaria.

Bulgaria has ordered a total of 16 F-16s, having signed an initial letter of acceptance (LOA) for eight F-16s in 2019 and then a second LOA for an additional eight jets in 2022. The first eight aircraft will be delivered by the end of 2025.

The 16 F-16 Block 70s will replace the Bulgarian Air Force's current fleet of 12 Soviet-designed MiG-29s.

The F-16 Block 70 standard features the Northrop Grumman APG-83 active electronically scanned-array (AESA) radar,

[Lockheed Martin]

advanced avionics, an extended structural service life of 12,000 hours and critical safety features like the Automatic Ground Collision Avoidance System (Auto GCAS). Since its integration into the US Air Force in late 2014, the Auto GCAS "has been instrumental in saving 13 pilots across 12 F-16 incidents, exemplifying the aircraft's unparalleled safety and performance standards", Lockheed Martin noted.

While many European air forces are retiring their F-16 fleets in favour of procuring the Lockheed Martin F-35 Lightning II Joint Strike Fighter, Lockheed Martin says it still has a backlog of 114 F-16 Block 70/72 jets to be produced in Greenville, South Carolina, for all of its customers, with a total of 26 of the type delivered to date.

A number of Lockheed Martin's international customers are also upgrading their current F-16 fleets to the equivalent F-16V standard.

First Spanish A330 Multi-Role Tanker Transport aircraft enters service

(gh) The Spanish Air and Space Force has commissioned its first A330 Multi-Role Tanker Transport (MRTT) aircraft under a contract for three such aircraft signed in November 2021.

According to an Airbus announcement on 11 April 2025, the aircraft was delivered from the A330 MRTT aircraft conversion centre in Getafe and will be operated by the 45th Air Force Wing from Torrejón de Ardoz airbase near Madrid.

[Airbus]

Spanish Defence Minister Amparo Valcarce praised the aircraft as "a contribution to strengthening the European pillar in NATO - a system that gives us the confidence to reliably fulfil our commitments".

The A330 MRTT for the Spanish Air and Space Force is equipped with a state-of-the-art hose-and-drogue refuelling system, has a flight endurance of more than 18 hours and has a range of 16,000 km.

According to Airbus, the A330 MRTT is the only new-generation tanker and strategic airlifter currently available and operational. Its large basic tank capacity of 111 tonnes enables it to successfully carry out aerial refuelling missions without additional tanks. Thanks to its wide-body fuselage, the A330 MRTT can be used as a transport aircraft capable of carrying up to 300 troops or a payload of up to 45 tonnes. In addition, the aircraft can be configured with a dedicated medical evacuation (medevac) kit, allowing the installation of different stretcher modules and intensive-care stations.

The second and third Spanish A330 MRTTs are currently undergoing conversion at Getafe.

Horizon frigate MLU programme completes critical design review

(pf) Naviris and Eurosam have completed the first critical design review (CDR) for the Horizon Mid-Life Upgrade (HRZ MLU) programme, Eurosam announced on 4 April 2025.

[Naviris]

The announcement is a pivotal moment for the Franco-Italian frigate programme as it officially marks the transition from the design phase to the production phase.

Originally delivered between 2009 and 2011, the Horizon-class ships – the Italian Navy's *Andrea Doria and Caio Duilio* and the French Navy's *Forbin* and *Chevalier Paul* – are set to undergo their MLU between 2026 and 2030. The upgrade aims to ensure that the ships will remain equipped with state-of-the-art technology and enhanced capabilities, extending their operational lifespan while preserving and expanding their performance.

Awarded in July 2023 by Europe's Organisation for Joint Armament Co-operation (OCCAR), acting on behalf of the French and Italian nations, the HRZ MLU contract is led by Naviris (a 50/50 joint venture created by Italy's Fincantieri and France's Naval Group) and Eurosam and is supported by both Fincantieri and Naval Group as well as key partners such as Leonardo, Thales, SiGen and MBDA.

The HRZ MLU programme addresses key national requirements focusing on the development, production and integration of Eurosam's Aster-missile-based Principal Anti-Air Missile System (PAAMS) as well as advanced electronic warfare systems, providing enhanced new capabilities and performances against the most modern threats while resolving obsolescence issues and updating systems to ensure continued reliability and effectiveness.

All upgrade activities are programmed to be concluded by 2030, according to Eurosam.

Sweden confirms it will acquire four C-390 airlifters from Embraer

(pf) Sweden has officially committed to acquiring four C-390 Millennium multi-mission airlifters from Embraer, the Brazilian aerospace manufacturer announced on 1 April 2025.

The announcement, which secures the necessary production slots for the Swedish aircraft, was made on the first day Brazil's 2025 LAAD defence and security exhibition in the presence of Peter Sandwall, state secretary to the Swedish Defence Minister Pål Jonson, and Bosco da Costa Junior, president and CEO of Embraer Defense & Security.

Sweden and Brazil signed a letter of intent (LoI) on 9 November 2024 under which Sweden indicated its interest in buying C-390 airlifters while Brazil stated that it plans to procure additional Saab Gripen E/F fighters.

[Embraer]

The Swedish Air Force has an urgent need to replace the five C-130H Hercules (Tp84) transport aircraft and one KC-130H (Tp84T) tanker that it still operates out of an original fleet of eight C-130s delivered from the 1960s.

Sweden is the sixth European nation to select the C-390, along with Austria, the Czech Republic, Hungary, the Netherlands and Portugal. As well as entering service with the Brazilian Air Force in 2019, the C-390 has also been ordered by South Korea.

Hanwha Aerospace to provide 87 more chassis for Polish Krab SPHs

(pf) South Korea's Hanwha Aerospace and Polish company Huta Stalowa Wola (HSW) have signed a contract over the supply of tracked platforms for 87 more Polish Krab self-propelled howitzers (SPHs), Hanwha announced on 7 April 2025.

Under the contract, which is valued at around USD 280 million (EUR 256 million), Hanwha Aerospace will supply Krab tracked platforms between 2026 and 2028. The contract also includes the supply of powerpacks for the Krab SPH, which is a 155 mm/52-calibre SPH designed and manufactured by HSW that uses the chassis of Hanwha's K9 Thunder SPH.

The signing ceremony was held at the headquarters of HSW in Stalowa Wola, with the attendance of high-profile representatives from both companies.

[Hanwha Aerospace]

Hanwha originally signed an agreement to supply tracked platforms for the Krab SPH in 2014, which followed by a second agreement in 2023. The latest contract is thus the third such agreement.

Poland originally ordered 120 Krab SPHs; 78 of these were delivered by 2022, of which 54 were donated to Ukraine, while delivery of the remaining 42 vehicles was postponed. Forty-eight Krabs were then ordered on 5 September 2022 and another 96 were ordered on 23 December 2024.

Patria signs supply agreement to provide NEMO mortars for Hungarian Lynx IFVs

(pf) Patria has signed a supply agreement with Rheinmetall subsidiaries Rheinmetall Landsysteme and Rheinmetall Hungary for the delivery of at least 24 Patria NEMO mortar systems, the Nordic defence system provider announced on 9 April 2025.

The mortars are intended for integration into a new variant of the Lynx KF41 infantry fighting vehicle (IFV) to be delivered as part of Hungary's Zrinyi defence modernisation programme.

The Patria NEMO is a remote-controlled, turreted 120 mm mortar system capable of both direct- and indirect-fire missions. It can also fire on the move and execute multiple-round simultaneous-impact (MRSI) fire missions that allow up to six rounds to hit a target at the same time.

Rheinmetall successfully conducted a trial integration of a NEMO system into a Lynx KF41 in September 2024. Tests focused on evaluating technical compatibility and validating the system's integration into the vehicle. The results confirmed that the system can be seamlessly incorporated into the platform, expanding the Lynx's operational capabilities.

The integration of the Patria NEMO turret into the Lynx KF41 platform is a significant step in meeting requirements of the Hungarian programme.

[Patria]

Joint company formed to take MGCS programme forward

(pf) The next step has now been taken in the Franco-German Main Ground Combat System (MGCS) programme, the companies associated with the project jointly announced on 17 April 2025.

Following approval by the German Federal Cartel Office, KNDS Deutschland, KNDS France, Rheinmetall Landsysteme and Thales legally incorporated the 'MGCS Project Company GmbH' on 10 April 2025 in Cologne, appointing Stefan Gramolla, a colonel in the German Army Reserve, as its managing director.

After the upcoming negotiation of a contract with the Federal Office for Equipment, Information Technology and In-Service Support of the Bundeswehr (BAAINBw), which is acting on behalf of the two nations through a Franco-German Combined Project Team (CPT), MGCS Project Company will be responsible for implementing the next phase of the programme as the industrial prime contractor. In particular, it will consolidate the concept and the main technological pillars of the system.

Launched as an initiative of the French and German governments in 2017, the MGCS project aims to replace the Germany's Leopard 2 and France's Leclerc main battle tanks (MBTs) by 2040.

However, rather than simply producing a successor MBT, the MGCS programme is expected to deliver a multi-platform ground combat system solution, incorporating both manned and unmanned vehicles, that replaces the capabilities offered by the traditional MBT.

Hanwha Aerospace to join GA-ASI in addressing the global UAV market

(pf) US unmanned aerial vehicle (UAV) manufacturer General Atomics Aeronautical Systems Inc (GA-ASI) and South Korea's Hanwha Aerospace have agreed to collaborate on the development and production of UAVs for the global defence market, GA-ASI announced on 8 April 2025.

The joint effort follows the successful completion of a major flight demonstration in November 2024 when the two companies launched a GA-ASI MQ-1C Gray Eagle STOL (short take-off and landing) UAV from the Republic of Korea Navy (ROKN) amphibious landing ship ROKS *Dokdo* (LPH-6111) as it was underway at sea off the coast of Pohang, South Korea.

The Gray Eagle STOL is the only medium-altitude, long-endurance UAV with the ability to operate without a catapult or arresting gear from fight deck-equipped warships such as amphibious ships and aircraft carriers. It additionally enables true runway independence by operating from unimproved fields and makeshift runways. The 2024 Gray Eagle STOL demonstration with the ROKN paved the way for GA-ASI and Hanwha to sign their new agreement to jointly invest in and pursue new UAV business opportunities.

[GA-ASI]

Hanwha Aerospace produces numerous defence systems but does not currently have a UAV portfolio. However, the company plans to invest more than KRW 300 billion (EUR 0.18 billion) in development and production facilities for Gray Eagle STOL and other UAV engines, to expand research and development activities, and to provide production infrastructure in both South Korea and with GA-ASI in the United States.

UVision expands loitering munition portfolio by acquiring Trim Robotics

[Trim Robotics]

(pf) The US arm of Israeli loitering munition (LM) specialist UVision Air has acquired Trim Robotics, which develops highly manoeuvrable next-generation rotary-wing unmanned aerial vehicles (UAVs)/LMs.

The acquisition, which was announced by UVision on 7 April 2025, strengthens the company's portfolio by integrating its Hero series of LMs with Trim's innovative quadcopter-based LM system, which UVision calls the QuadiKaze system in its press release but which is called the Peregrine system on the Trim Robotics website. This is a dual-frame rotary-wing LM system that offers "unprecedented aerodynamic efficiency and enhanced flight performance", according to UVision.

Unlike conventional rotary-wing solutions, Trim's design integrates a dual fuselage to ensure superior in-flight control and optimised attack trajectories with a high angle of attack. The system thus bridges the gap between the limited manoeuvrability of traditional attack quadcopters and UVision's advanced fixed-wing Hero series of LMs.

Embraer and Denel sign MoU in relation to KC-390 collaboration

[Embraer]

(pf) Brazil's Embraer and South African company Denel have signed a memorandum of understanding (MoU) to strengthen their strategic partnership, with a particular focus on Embraer's KC-390 tanker-transport aircraft.

The MoU was signed on 3 April at the 2025 LAAD Defence and Security exhibition in Rio De Janeiro, Brazil, by Chris Boshoff, group executive and CEO Aerospace of Denel, and Fabio Caparica, vice president of contracts at Embraer Defense & Security. The agreement outlines the framework for a potential future collaboration on the KC-390 Millennium aircraft, with a focus on aerostructures manufacturing, maintenance, repair and overhaul activities.

The South African Air Force has been cited as a potential customer for the KC-390.

Mach beyond: The technical edge of hypersonic missiles

Sam Cranny-Evans

As multiple countries race to develop and deploy hypersonic missiles, questions remain about their cost-effectiveness and actual battlefield impact. This analysis explores the technical realities behind hypersonic glide vehicles and hypersonic cruise missiles, examining whether they can truly deliver on their promised capabilities.

Militaries around the world are clamouring to develop hypersonic missiles for conventional strike missions. The US, China, Japan, the UK, and France are all working on various hypersonic missile development programmes that are each at different stages – from concept studies to advanced experimental test launches, and reportedly in-service missiles. The Japanese MoD even indicates that its Hyper Velocity Gliding Projectile (HVGP) Block 1 – which is still undergoing tests – is in low-rate initial production. Russia reportedly deployed its 3M22 Zircon hypersonic cruise missile (HCM) against Ukraine in early February 2024, at least the remains of one of the missiles bears the designator 3M22. Russia's Zircon strikes against Ukraine may mark the first use of hypersonic missiles in anger. Moscow has also deployed the Kh-47 Kinzhal, an aeroballistic missile that is technically hypersonic, but falls outside those considered here. China of course regularly parades the DF-17 with its DF-ZF large hypersonic glide vehicle (HGV), indicating that it is an in-service capability.

The US had had multiple hypersonic missile research & development (R&D) efforts to meet the needs of its various service branches. The Army's main effort is the Long-Range Hypersonic Weapon (LRHW), a ground-launched HGV which is expected to be fielded by the Army's Multi-Domain Task Forces in the next few years. In tandem with LRHW, the US Navy is developing the Intermediate Range Conventional Prompt Strike (IR-CPS), which is effectively a naval variant of LRHW, with both being based on the same Common Hypersonic Glide Body (C-HGB) design. The US Navy was also previously developing an air-launched near-hypersonic cruise missile, known as the Offensive Anti-Surface Warfare Increment 2 (OASuW Inc 2), also known as Hypersonic Air Launched Offensive (HALO), until the Navy cancelled the project in early April 2025, citing cost concerns and overall programme performance. The US Air Force (USAF) meanwhile is working on the Hypersonic Attack Cruise Missile (HACM), which as the name suggests, is an air-launched HCM.

China's DF-17 employs a hypersonic glide vehicle and is thought to be nuclear capable. [Yí Yuán Jū, via Wikimedia Commons; CC BY-SA 4.0]

Outside of the US, France is developing the ASN4G, a near-hypersonic cruise missile designed for nuclear payloads, and the UK has initiated its own hypersonic R&D programme in cooperation with the US and Australia with the stated aim of fielding a missile by 2030.

Many of these capabilities are nascent. With the exception of China's DF-17 and Russia's 3M22 Zircon and Avangard, none of them are currently in service; and yet, search Linke-

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dIn for the phrase 'hypersonic' and you could be forgiven for thinking development in this area is more or less complete. Many articles and posts suggest that hypersonic missiles as a concept are completely new, that militaries discovered the key to hypersonic flight in 2010 and that they have since made rapid progress in developing them. Articles proclaim 2025 to be a breakthrough year for hypersonic technology, that hypersonic missiles are already revolutionising naval defence, and that the future of defence is hypersonic. With so much expectation placed on hypersonic missiles and their proclaimed war-winning capabilities, this article examines their underlying technology and operation in greater detail to get a sense of what these missiles are, and are not, going to do. But first, a little history.

Not a new frontier

"For approximately four decades, the hypersonic community had a difficult and somewhat dichotomous relationship with the military," Dr Richard Hallion, Senior Adviser for Air and Space Issues, Directorate for Security, Counterintelligence and Special Programs Oversight wrote in 1998, for a volume titled 'The Hypersonic Revolution; Case Studies in the History of Hypersonic Technology'. It is worth quoting Dr Hallion in full:

"Military officials concerned with force-structure requirements and combat operations recognized that hypersonics might have some merit, but the serious technological challenges (first involving rocket propulsion and re-entry protection and then, over time, more complex challenges, particularly air-breathing propulsion), and the pressing needs to develop more conventional fighters, bombers, and missiles to confront a highly aggressive Soviet state, often encouraged deferring work on hypersonics in favor of a "replacement strategy" emphasizing developing more traditional kinds of aircraft, missile, and other weapon systems."

The volume including Dr Hallion's contribution is 916 pages long and freely accessible. It charts attempts and studies designed to develop hypersonic vehicles and weapons from the early 1900s. It includes Eugene Sänger from Austria, who developed a concept for a rocket-propelled aircraft that he thought could reach speeds of Mach 13. Mach 13 refers to an object travelling at 13 times the speed of sound, which is 1,235 km/h at sea level. Sänger was suggesting that using a high lift-to-drag ratio, his craft could reach speeds of 16,000 km/h in 1934. This is not to say that Sänger was successful, but does stand as an indication of the length of time that there has been interest in hypersonic flight. Perhaps unsurprisingly, Nazi Germany worked on some rocket designs with a close to hypersonic flight, such as the A-4B, a derivative of the V-2 ballistic missile with gliding wings designed to increase its range. The A-4B was actually tested in 1945, reaching Mach 4 before one of its wings broke up.

It is safe to say that we are not living through a new frontier in hypersonic missiles. It is more accurately a period of hypersonic evolution. The drivers of this evolution are many and complex. Russian and Chinese air defence networks are advanced and capable, and the relative failure of Russia's conventional cruise missiles to penetrate Ukraine's air defence network indicates that those are weapons with potentially limited utility. It is also interesting to examine the change from Dr Hallion's initial assessment in 1998, where the cost of hypersonic missiles was deemed so great, that it would detract from the pressing development of conventional platforms that were needed to confront the Soviet mass.

It could be argued that the current hypersonic evolution is driven by the inversion of that paradigm. Conventional platforms in the early 1990s were comparatively much cheaper than their modern day equivalents. An F-22 was estimated to cost around USD 135 million per aircraft in 2022, with the F-35 coming in at roughly USD 80 million per jet the same year (though previous lots cost more), and the future F-47 projected to cost "multiple hundreds of millions of dollars" per aircraft, according to former Secretary of the Air Force Frank Kendall speaking to Congress on 27 April 2022. For comparison, an F-16 was estimated to cost around USD 30 million in 2017, and USD 15 million in 1998. So, costs were increasing as Hallion and his team published their work on hypersonics, but they had not reached the present levels, whereby even the US Government is looking at fairly modest fleets of some of its future conventional capabilities.
So, if costs are limiting the ability to build mass, then MoDs have to ensure that their weapons at least reach the target and have the desired effect. In short, the cost of conventional

There have been many iterations of hypersonic missiles. Here, a B-52 carries a testbed of the AGM-183A Air-launched Rapid Response Weapon (ARRW). The programme was cancelled in 2023 after multiple failed tests, representing another attempt to develop hypersonic weapons that failed to yield the desired results. [USAF/Giancarlo Casem]

platforms and weapons, combined with their potential vulnerabilities, have made the fielding of hypersonic missiles seem desirable. Added to this, the recent intensive development of key technologies that make them viable means that fielding them is now a realistic goal.

Defining hypersonic missiles

There are two primary types of hypersonic missile that are both relatively well-known, but it is worth a brief explanation: Hypersonic boost-glide vehicles (HGVs) are a type of missile that is boosted along a conventional ballistic trajectory before being released from a booster. The glide vehicle, which is typically unpowered, then continues to its target at hypersonic speeds using momentum, aerodynamics, and gravity, manoeuvring on its way. The second is air-breathing hypersonic cruise missiles (HCMs), which are similar in concept to a conventional cruise missile, albeit typically using a rocket booster to boost them to supersonic speeds, at which point a scramjet engine takes over to provide sustained thrust to hypersonic speeds for the rest of their flight.

Hypersonic missiles are often defined by their speed, which must exceed Mach 5 or 6,175 km/h. However, this is not all that defines them, they also need to be manoeuvrable and have specific flight profiles. Both types require air to function and manoeuvre, which differentiates them from ballistic missiles.

Hypersonic glide vehicles

This section focuses on the HGV, the technologies that they need, likely uses, and their limitations. Boost-glide vehicles are launched using a conventional rocket booster, which accelerates vertically and into an arc towards the target. At an altitude roughly between 40 km and 100 km, the glide vehicle detaches from the booster and descends back towards the Earth. It then begins to gradually lose speed, and performs a pull-up manoeuvre to properly orientate itself and gain equilibrium. The separation from the booster and pull-up manoeuvre both impart immense forces to the glide vehicle, the separation in particular requires a stable release or the vehicle risks an unstable flight. The post-separation portion if flight is known as the glide phase, and is worth examining how it differs from a conventional ballistic missile.

Conventional ballistic missiles are powered for the initial phase of their flight, in the same way that a boost glide vehicle is, they then proceed under the momentum imparted by the booster, with no further propulsion. In the case of tactical ballistic missiles (TBMs), short-range ballistic missiles (SRBMs) and to a slightly lesser extent medium-range ballistic missiles (MRBMs), the flight path is mostly shaped by gravity and air resistance. With longer-range classes such as intermediate-range ballistic missiles (IRBMs) and intercontinental ballistic missiles (ICBMs), air resistance plays a comparatively smaller role, as these classes spend a majority of their flight time in space, outside of the atmosphere. In any case, they also follow a similar, arcing, ballistic trajectory determined by gravity. You can visualise this by throwing a rock or ball high into the air – once it has left your hand, that ball follows a ballistic trajectory. Many classes of ballistic missiles will typically reach hypersonic speeds, however, as they are unable to change their flight path, their trajectory can be modelled, allowing them to be intercepted.

While interception is possible, this does not make it easy; Russia's use of the 9M723 Iskander-M SRBM in Ukraine shows the limits of this theoretical framework. While Ukraine's interception rates of cruise missiles are reportedly high – around

This graphic, originally published in the USAF's Airman magazine and later made available via DVIDS, shows how a hypersonic boost glide vehicle separates from its rocket booster. [USAF/Travis Burcham]

80% – its interception of 9M723 Iskander missiles is much lower. Over the course of two attacks in 2024, one in March and August, Ukraine intercepted just one of the 18 9M723s launched at it, and one of the 10 Kh-47 Kinzhals. It is one of the contentions of the US Congressional Budget Office, which has assessed that ballistic missiles would be as survivable as hypersonic missiles.

The design of the glide vehicle is very important, as once it has conducted the pull-up manoeuvre, it uses aerodynamic lift to continue its flight and extend its range. In the final portion of its flight, known as the terminal phase, the glide vehicle descends towards the target. The range and speed of a glide vehicle is shaped by the lift-to-drag ratio (this is simply the lift divided by drag), with the vehicle ideally able to generate sufficient lift to remain aerodynamically stable and capable of manoeuvre while taking on as little drag as possible from air resistance. This means that as the glide vehicle loses speed, it must drop to lower altitudes and thicker air that can provide enough lift to keep the missile flying – though this causes it to lose more speed as air resistance increases. So, the higher that the missile starts its descent glide, and the faster it flies, the further it can travel. A missile that releases at an altitude of around 47 km and travels at 6 km/s (Mach 17) could glide for more than 7,000 km, according to one computer simulation. It would take that simulated missile around 35 minutes to reach that range. As is the case for all missiles, any manoeuvres conducted during flight will use up available energy, reducing speed and overall range.

CONEMP leads the design

The final velocity of the boost phase becomes very important for an HGV, especially within the envisaged concepts of employment (CONEMP) that are driving their development. In short, the driving theory is that Russian and Chinese layered air defence and long-range strike capabilities would force the US to launch some of its effects outside of their reach. Those effects need to be fast to succeed. So, as the final velocity of the boost phase, along with release altitude, decides how far the glide vehicle will travel, it is critical that this element of the design functions properly.

However, very high speeds create design challenges for the vehicle itself. As the glide vehicle begins its glide phase and travels towards its target, extreme levels of heat must be dissipated without damaging the outer glide body. Furthermore, the deceleration and formation of a plasma sheath

- **The HGVP being developed by Japan is intended to strike Chinese naval vessels in the event that they attempt to invade Japan. [Japanese MoD]**

The US Army's Rapid Capabilities and Critical Technologies Office, in collaboration with the US Navy Strategic Systems Programs, completed a conventional hypersonic missile test in December 2024. Both services were using the Common-Hypersonic Glide Body. [US DoD]

around the missile body can interfere with radio frequency (RF) communication such as GPS, or sensors such as radar seekers, making accurate guidance of the missile extremely difficult. Although, it is worth noting that these challenges are far greater for terminally guided ballistic missiles, according to James Acton from the Carnegie Endowment for Peace.

"For a boost glide vehicle, this means that it will need a heat shield, typically made of carbon fibre or graphite, which can be quite heavy," Dr Iain D. Boyd, Director of the Center for National Security Initiatives at the University of Colorado Boulder, told ESD during an interview. The materials used for heat shields are an ongoing area of research as different approaches are sought, but whatever material is used, it must be able to withstand ablation. "Ablation occurs because the air around the vehicle gets so hot that it breaks down chemically, and becomes oxygen which is incredibly corrosive as they oxidise carbon very rapidly," Dr Boyd explained. "Ablation will physically change the shape of the heat shield, although some ceramic heat shields may provide better resistance to this effect," he added.
Heat is not only a problem for the material that the missile is made of, it makes traditional guidance and target engagement difficult, too. Typical seekers such as optoelectronic TV or thermal seekers may not work under extreme heat, or would require specialised transparent housings allowing them to view the target area. Likewise radar would struggle to identify the target while the glide body is at high speeds. This drives reliance on accelerometers and gyroscopes, which must also be adjusted and improved to meet the extreme forces imparted during hypersonic flight.

There is one final challenge for the design of HGVs – which is also relevant to HCMs – and that is the warhead. Speaking on the current design challenges for hypersonics, Dr Boyd said, "Packaging is difficult because the vehicles are very slender, and there isn't a lot of payload space. You can create more space, which leads to a bigger vehicle, which then costs more to launch." Ultimately, the size of a glide vehicle is limited by the diameter of the booster, which in turn is limited by the launch platform. Consider the US Army's LRHW, for instance, which must be launched from a dedicated transporter erector launcher (TEL), capable of fitting two LRHW launch containers side-by-side. Moreover, the geometry of a boost glide vehicle must be optimised to maximise the lift-to-drag ratio, which does not necessarily mean a lot of space for an explosive payload.

Much is often made of the kinetic energy of a hypersonic glide vehicle, which could be significant to destroy many targets. A 450 kg glide vehicle travelling at Mach 5 would transfer 661 megajoules of kinetic energy upon impact. This is enough energy to lift the UK's 65,000 tonne Queen Elizabeth class aircraft carrier one metre off the ground. Kinetic energy alone might be enough to destroy a large, emplaced radar, such as some long-range or over-the-horizon designs. However, it would require a very precise hit and ideally would include an explosive payload to increase the damage against the target, guaranteeing the desired effect. As a result, the kinetic element of a hypersonic glide vehicle should not be overstated – it would require very high levels of accuracy to be an effective tool.

There are a range of hypersonic glide vehicle programmes underway around the world; these are summarised in Table 1.

TABLE 1

Hypersonic glide vehicle (HGV) programmes

Country	Project name	Capabilities	Status
China	DF-17 armed with DF-ZF HGV.	Believed to be nuclear and conventional capable. Top speed of Mach 10 and range of 2,500 km.	In service.
France	V-MAX	Testbed, achieved speeds greater than Mach 5.	In trials and development.
Japan	Hyper Velocity Gliding Projectile	Conventional warhead with a range of 500-900 km for Block 1.	In development.
Russia	Avangard	Nuclear and conventional warhead capable. Top speed of around Mach 20 and range exceeding 6,000 km.	In service.
USA	LRHW/IRCPS (C-HGB)	Range exceeding 2,700 km (est.).	Due to enter service in next few years.

Hypersonic cruise missiles

▲ **Despite being a testbed hypersonic vehicle, the X-51 Waverider is reflective of the design of hypersonic cruise missiles. The shape is intended to help drive airflow into the scramjet. However, it also constrains the available space that can be used to carry a payload. [USAF/Chad Bellay]**

While HGVs seek to maximise speed and manoeuvrability to reach their target, relying on the inability of air defence systems to intercept the boost phase of most missiles. Their unpowered design means that they must leverage altitude and aerodynamics to attain the ranges necessary to meet force requirements. HCMs function differently, they are powered weapons, typically operating with a rocket booster to propel the missile to supersonic speeds, at which point they use a scramjet engine to reach hypersonic speeds and provide sustained thrust. Most tests appear to involve integration onto a jet aircraft, providing a boost to the initial starting speed of the launch, as well as representing the expected host platform for most weapons in this class. The Hypersonic Attack Cruise Missile (HACM), under development in the US, for example, is designed to be used by the F-15E Strike Eagle, and expected to be eventually integrated with other platforms including B-1 Lancer, B-2 Spirit, and B-52 Stratofortress. Under the SCIFiRE partnership, Australia also plans to operate HACM, to be launched from its F/A-18F Super Hornet aircraft, and the Royal Australian Air Force's (RAAF's) SCIFiRE page also suggests the weapon may come to be integrated with the country's E/A-18G Growler, F-35A Lightning II, and P-8A Poseidon aircraft.

HCMs, much like HGVs, must deal with a significant amount of heat. "With scramjets, the thermo-management problem is different from a boost glide vehicle: You have heat outside the vehicle and heat inside the vehicle from burning propellant. This is typically solved by lining the point between the engine and the body with special materials," Dr Boyd explained. He added that an HCM travelling at Mach 5 experiences very different environmental factors to an HGV travelling at Mach 20. This means that while heat shielding may still be required on the missile's exterior, it may not need to be as extensive or advanced as that fitted to an HGV.

The most important element of a hypersonic cruise missile is its engine. The typical approach is a supersonic combustion ramjet (scramjet) engine. Scramjets are a difficult technology to master. Pratt and Whitney, for instance, started work on a

▼ **This graphic, originally published in the USAF's Airman magazine and later made available via DVIDS shows how a hypersonic cruise missile is launched. [USAF/Travis Burcham]**

scramjet for hypersonic flight in the 1960s, revisiting it again in the 1980s as interest surged in space flight, and once more in 2001. Although flight tests have been conducted with a scramjet, they are prohibitively expensive; the X-51 Waverider which flew with scramjet engines from Pratt and Whitney Rocketdyne is estimated to have cost some USD 300 million, providing just four test vehicles for flights, three of which failed.

Scramjets work by compressing airflow at supersonic speeds into the engine where it is mixed with fuel like hydrogen or regular jet fuel and ignited. The ignited fuel generates an enormous amount of heat and highly pressured exhaust gasses that are passed through a nozzle at the rear of the engine generating propulsion. The airflow must be at supersonic speeds for the scramjet to work, which is why the missiles are generally designed to be launched from an aircraft already flying close to the speed of sound, with at least one rocket booster providing initial acceleration. The X-51 Waverider used the rocket booster from an ATACMS missile, which took it up to Mach 4.5 before the scramjet was ignited and the booster jettisoned.

The Avangard may represent Russia's sense that its conventional nuclear arsenal may not be survivable against America's more advanced missile defences. [Russian MoD]

Several HCM designs employ a missile body design known as a 'waverider', which has a very slender nose with the scramjet located underneath the missile body. As the flight speeds are lower than with HGVs, it is possible to fit optical systems and other sensors enabling the missiles to find their targets, Dr Boyd explained. Moreover, depending on the exact speed and altitude, can result in either no plasma sheath developing, or a plasma sheath with lower electron density than that of much faster vehicles such as HGVs. This should mean that RF communication could be possible depending on the missile's height and speed. However, at the same time HCMs are usually smaller than HGVs – typically a few hundred kilogrammes – a good portion of which is taken up by the scramjet and its fuel. Like other missile designs, speed and range requirements lead to proportional increases in size, weight, and cost. So, the faster and further the missile is required to fly, the bigger and more expensive it will be. At least one of these facets is problematic when the cruise missile is designed to be launched from a relatively small fixed-wing jet. So, there is a compromise between range and speed, and a jet's ability to carry and deploy the missile. This leads to ranges for cruise missiles generally in the 400–1,000 km region, with payloads of around 150 kg.

As a weapon system, HCMs are generally suited to engaging high-value targets such as naval vessels and potentially certain ground-based missile launchers if sufficiently accurate targeting data can be paired with seekers capable of locating their targets. HCMs offer very high speed strikes compared to conventional cruise missiles, which could prove very valuable in penetrating an adversary's air defence network. However, the effects of those missiles getting through are not guaranteed. Known HCM programmes are summarised in Table 2.

TABLE 2

Hypersonic cruise missile (HCM) programmes

Country	Project name	Capabilities	Status
China	Lingyun-1	Unknown.	In development.
France	ASN4G	Near-hypersonic missile to be armed with a nuclear payload.	In development.
Russia	3M22 Zircon	Hypersonic anti-ship/land attack missile	In service.
South Korea	Hycore	Hypersonic missile for land, air, and sea with a range up to 1,000 km.	In development.
UK	HVX	Hypersonic demonstrator programme launched in 2022.	Demonstrator programme.
USA	HACM	Estimated to have a range of 500 km, with 150 kg payload.	In development.
USA	OASuW Inc 2 (HALO)	Near-hypersonic cruise missile with anti-ship warhead.	Cancelled.
USA	MoHAWK	Further testbed designed to improve hypersonic technologies.	Testbed.

Caution: Effects not guaranteed

During the 2003 Iraq War, US and coalition forces deployed 19,948 guided munitions from the air, according to data published by the Air Force Magazine. This constituted 68% of the munitions used, the majority of them were relatively close-range guided bombs. When US and allied forces conducted long-range strikes against Syrian facilities associated with chemical weapons in 2018, they launched a total of 103 missiles at just three targets. Russia has launched some 12,000 missiles and drones at Ukraine, according to figures released by Ukraine's Air Force. All of these examples show that the number of missiles and guided munitions to achieve an effect at scale is much greater than a handful or the low hundreds. This is important for hypersonic missiles because there are two things that we can say about them with relative certainty, despite few actually being in service: First, they are expensive to design, to test, and to build, which means they will be expensive to use. Based on indications from the US Army and US Navy around the C-HGB, the Congressional Budget Office estimated that a procurement of 300 missiles would have a per missile cost of USD 41 million, and a total programme cost over 20 years of USD 17.9 billion. The challenge here is that this would represent just 300 missiles that may potentially only be suitable for engaging large fixed infrastructure and static targets.

Second, there is the issue of their payload. Russia has deployed glide bombs weighing up to 3,000 kg in Ukraine with guidance kits. These have proven effective in destroying singular, relatively large buildings with a single munition, even when they do not strike the building directly. However, with a relatively lower payload, a hypersonic strike may not deliver the same results from an imprecise strike. Even with a precise strike, the relative lack of payload may mean that the strike may not deliver the desired results in some tactical scenarios. Altogether, this means that hypersonic missile stocks are likely to be limited in number because of their cost, whilst only offering improved chances of penetrating air defences, and not necessarily guaranteeing the desired effect against their intended targets. In addition, if it is only possible to deploy relatively few hypersonic missiles because of their immense cost, a defender might choose not to worry about them, focusing instead on the bulk of conventional cruise and ballistic missiles being used at the same time.

In conclusion, missile strikes generally require some mass to achieve effects that are truly war-winning and difficult for an adversary to recover from. Hypersonic missiles are designed to address the problem of improved air defences, however, they are doing so at such immense cost that they may impose an opportunity cost on maintaining higher numbers of conventional capabilities, whilst also not necessarily guaranteeing effect on target.

Briefing: Key Czech and Slovakian procurement programmes

Martin Smisek

Both the Army of the Czech Republic (Armáda České republiky; AČR) and the Armed Forces of the Slovak Republic (Ozbrojené sily Slovenskej republiky; OS SR) are currently undergoing the most extensive modernisation since their creation in 1993. The following overview presents the most important recent procurement projects.

Czech Republic

Air Force

The most expensive armament project is and will remain the acquisition of 24 F-35A Lightning IIs for the 211th and 212th Tactical Squadron at Čáslav air base, with the first six aircraft to be delivered in 2029. As the Czech Ministry of Defence (MoD) accelerates the instalments in 2025, the next two F-35As will be delivered in 2030. The remaining 16 aircraft will be completed in tranches of four per year between 2031 and 2034. The contract also includes the delivery of an initial supply of ammunition consisting of AIM-9X Block II Sidewinder and AIM-120C-8 AMRAAM air-to-air missiles as well as GBU-53/B StormBreaker and GBU-31/B JDAM (with BLU-109C/B penetrators) precision-guided bombs. The full operational capability (FOC) of Lightning IIs is expected in 2035.

▲ The Czech Air Force's F-35A aircraft are due to be delivered from 2029 to 2034, with FOC anticipated in 2035. [USAF/Airman 1st Class Joshua D. King]

On 25 October 2024, the Ministry of Defence awarded Embraer a contract for the delivery of two C-390 Millennium transport aircraft for CZK 11.3 billion without VAT. The first of these in the basic configuration is scheduled for delivery in late 2025. The second fully equipped C-390 is scheduled for delivery in late 2027 or early 2028. The first delivered aircraft will then be continuously upgraded to full standard. Along with the aircraft, the MoD has ordered additional equipment such as the Modular Airborne Fire-Fighting System II (MAFFS II), an in-flight refuelling module, a patient transport module, including an intensive care unit, additional fuel tanks for extended range, a self-protection system, forward arming and refuelling point (FARP) fuel dispensing system, search and rescue (SAR) operations module, as well as a GPS repeater for special forces. Both aircraft will be operated by the 24th Transport Air Force Base at Prague-Kbely.

In June 2024, deliveries of eight UH-1Y Venom helicopters and four AH-1Z Viper helicopters to the 221st Helicopter Squadron at Náměšť nad Oslavou air base were completed. On 14 August 2024, a contract with the US was concluded for the overhaul and upgrade of another six AH-1Z and two UH-1Y helicopters originally operated by the US Marine Corps (USMC), and provided to the Czech Republic under the Foreign Military Financing programme. These helicopters will be modified to the same standard as the first 12 newly-manufactured ones. According to the latest schedule, these Venoms and Vipers should be delivered in late 2027 and early 2028 respectively. In 2024, additional munitions have been ordered for the H-1 helicopters, including up to 70,000 Hydra 70 rockets with M151, M229, M274 and WTU-1/B warheads along with an unspecified number of APKWS II guidance kits (maximum 600 sets) and AGM-114R Hellfire II anti-tank guided missiles (maximum 200 units).

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The first Deployable Passive ESM Tracker (DPET) surveillance system of the 532nd Electronic Warfare Battalion at the Drone Shield 2024 experimental exercise. [Czech Armed Forces]

Air defence

The purchase of eight IAI EL/M-2084 MMR radars ordered in December 2019 is facing major delays. According to the original schedule, the last radar was to be delivered in April 2023. However, only three radars had been shipped by February 2023. As of November 2024, due to technical problems, only four EL/M-2084 MMRs were regularly operated by the 262nd Radiotechnical Battalion, with the remaining four pending resolution of the technical difficulties.

In October 2021, the MoD ordered four batteries of the SPYDER-MR air defence missile system. By mid-December 2024, most of the components for the first and second batteries had been delivered to the Czech Republic. The first battery was completed by March 2025 and subsequently took part in company trials. The operational evaluations are expected to be conducted in autumn 2025. The full operational capability of the complete system is planned to be achieved by 1 January 2028. Within the framework of the SPYDER PII research project, a solution for the integration of the information from the Deployable Passive ESM Tracker (DPET) surveillance system for fire control of the SPYDER-MR is being developed.

Elsewhere, the Czech Army's 25th Anti-Aircraft Missile Regiment is set to receive 16 very short-range air defence (VSHORAD) vehicles based on the SVOS MARS 4×4 protected patrol vehicle (PPV).

Armoured vehicles

In 2024, work continued on a project to deliver CV9030 MkIV tracked vehicles for CZK 59.7 billion including VAT. The first complete new IFV for the Czech Army (AČR) will be officially rolled out in the middle of 2025. In parallel, the development of the ambulance variant started in VOP CZ. At the end of 2024, work was underway on the production of a mock-up of the ambulance variant. A prototype of the complete vehicle is to be delivered in 2026. VOP CZ is also developing supporting mobile workshops on the Tatra 815-7 8×8 as part of the contract. A total of 29 workshops in three versions have been ordered. The first batch of ten CV9030 MkIV IFVs is due to be delivered to Czech units in November 2026. By 2030, AČR should own all 246 vehicles in seven variants.

As compensation for Czech aid to Ukraine, Germany donated 28 Leopard 2A4 tanks to the Czech Republic. In July 2024, the MoD signed the final agreement for the transfer of an additional 14 Leopard 2A4s and one Büffel armoured recovery vehicle (ARV) worth approximately CZK 4.5 billion. The first tank from this delivery was to be shipped to the Czech Republic at the end of 2024, with the remaining main battle tanks arriving by April 2025. The Büffel is expected to be delivered by early 2026. On 3 December 2024, the MoD awarded a contract for the purchase of an additional 14 Leopard 2A4s with the price of the contract worth CZK 3.98 billion excluding VAT. The tanks will be delivered by the end of 2026. In total, the 73rd Tank Battalion will have 42 Leopard 2A4 tanks and two Büffel 3 recovery vehicles. In the meantime, preparations are underway for the purchase of the latest Leopard 2A8 tanks (maximum of 77 vehicles), including derivative combat support vehicles.

The Czech Army's 25th Anti-Aircraft Missile Regiment shall receive 16 light armoured vehicles armed with RBS 70 NG missiles, mounted on the MARS 4×4 manufactured by SVOS. [SVOS]

At the time of writing, the MoD was preparing to contract around 20 additional TITUS vehicles in command and staff/communication versions (KOVVŠ/M2 and KOV VVŘ variants). In March 2025, the public tender for 4×4 universal armoured wheeled vehicles was launched. The number is expected to be in the low hundreds, with deliveries to take place between 2026 and 2032.

Artillery

The purchase of 62 CAESAR 8×8 CZ self-propelled howitzers (SPHs) is currently facing a delay of some 18 months. Additional requirements for the C4ISTAR architecture have led to postponements, so the first two prototypes are not due to be completed until March 2025. The operational evaluation in the Czech Republic is planned to take place in the summer of 2025. While two artillery workshops based on armoured Tatra 815-7 8×8 are currently under production, the MoD is going to order 26 ammunition supply vehicles for CZK 1.1 billion. Each of these is composed of a Tatra 815-7 8×8 cargo bed truck with an armoured cab and a loader crane as well as an off-road trailer based on the Tatra FAST II. Moreover, Vojenský technický ústav (VTÚ) will deliver 15 LOV-VČ platoon commanders' vehicles for CZK 1.3 billion and ten LOV-REKO topographic survey vehicles worth around CZK 1 billion to the 13th Artillery Regiment. Both types are based on the Iveco Defence Vehicles LMV.

Intelligence

On 14 January 2025, Space X's Falcon-9 rocket carried the first Czech military spy satellite, SATurnin-1, into orbit. The satellite, developed under the GOLEM X programme by the Czech state-owned aerospace research institute VZLU AEROSPACE, has a span of 87 cm after the solar panels are extended. The satellite main body has dimensions of 32 × 22.5 × 22.5 cm, and weighs approximately 14 kg. SATurnin-1, which is composed only of components developed exclusively in the Czech Republic, will be operated by the Satellite Centre of the Military Intelligence. Due to its pioneering nature, its mission in space will be predominantly scientific and research in nature, with a focus on advanced technologies for remote photographic surveillance of the Earth.

In December 2024, the STRATOM development project was completed; STRATOM is a high-altitude 'pseudo-satellite' surveillance balloon developed to augment the AČR's

▲ **The SATurnin-1, the first Czech military spy satellite, was launched on 14 January 2025. [VZLU AEROSPACE]**

intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) capabilities. STRATOM was designed by the Czech company STRATOSYST and intended for surveillance; it will serve as a medium- and long-term continuous source of information for the area under surveillance, which will be predominantly the territory of the Czech Republic. The system will acquire optical data of the surveilled area in extremely high resolution in the form of photography and live video. At the same time, the device will have the ability to serve as a communications node in the event of a failure of conventional communication services, and a relay station for data from satellite systems, which will be received by its terrestrial segment.

The STRATOM high-altitude ISTAR balloon is based on the SkyRider solution that can 'anchor' at an altitude of 25 km for up to six months. [STRATOSYST]

Communications and electronic warfare

The MoD plans to acquire four types of L3Harris radio stations totalling 4,264 units, worth CZK 4.6 billion. Within the framework of the MILSATCOM project, the AČR will receive two Large Enterprise Terminals for satellite communication from the US. The procurement of both terminals and the construction of related infrastructure will cost some CZK 5 billion.

During autumn 2024, the 532nd Electronic Warfare Battalion obtained the last of two DPET passive surveillance systems based on the VERA-NG, each transported on five Tatra 815-7 8×8 trucks with armoured cabs and multi-lift MSH-165-SCA hook lifts. Moreover, the MoD ordered three PLESS passive over-the-horizon direction finding systems, also developed by the Czech company ERA. The PLESS can detect, locate, identify and track air, land and naval targets with a focus on slow-moving or stationary platforms. The AČR will receive one stationary and two mobile systems worth CZK 2.3 billion. The MoD is also buying eight ES-RA systems for electromagnetic surveillance and electronic warfare (EW) coordination; these are based on the Tatra 815-7 8×8 with armoured cab and box-body superstructure in the same fashion as the STARKOM jammer. The overall value of the contract is CZK 3.8 billion.

Logistics

The most expensive contract in the logistics segment, awarded in July 2024, is the framework agreement for the purchase of up to 872 Tatra 815-7 trucks in three configurations (6×6 cargo bed, 8×8 cargo bed, 8×8 MSH-165-SCA hook lift) with a maximum value of CZK 13.35 billion. The minimum quantity of trucks to be acquired is 98 vehicles, which should be delivered by September 2031. Moreover, the framework agreement allows NATO partners to join, which was already used by Slovakia. Another important modernisation project

Under a framework agreement, the Czech and Slovak armies will receive several hundred Tatra 815-7 (Tatra FORCE) trucks of the latest generation by September 2031. [Tatra Trucks]

is the acquisition of mobile workshops based on the chassis of Tatra trucks. Based on a framework agreement, VTÚ will produce an undisclosed number of vehicles up to the maximum overall price of some CZK 10 billion; the deliveries will take place between 2025 and 2031.

Slovak Republic

Air Force

The most expensive Slovak armament project is the purchase of new supersonic fighter aircraft. In December 2018, the MoD ordered 12 F-16C and two F-16D Block 70 Fighting Falcons, including training, supporting equipment and armament, valued at EUR 1.58 billion. The contract includes six AN/AAQ-33 Sniper XR targeting pods, ammunition for the M61A1 guns, 28 AIM-120C-7 AMRAAM air-to-air missiles, 324 Mk 82 bombs, along with 150 GBU-38/B JDAM, 12 GBU-12/B Paveway II and 150 GBU-12/B Paveway II Plus guidance kits. Under a separate contract, 98 AIM-9X-2 Sidewinder air-to-air missiles were ordered. The aircraft will be introduced into the inventory of the 1st Tactical Squadron of the 81st Wing at Sliač air base. As the reconstruction of this airfield was not completed on time, the aircraft will initially operate from Kuchyňa air base. In July and December 2024, the first three F-16Cs were flown there with six more 'Vipers' due to be flown to Slovakia by August 2025. Delivery of the last aircraft ordered is currently expected in the first quarter of 2027.

▲ **Among the candidates for the Slovak Air Force's new jet trainer is the L-39 Skyfox by AERO Vodochody AEROSPACE. The Czech CLV flight training centre has operated the Skyfox since February 2025. [AERO Vodochody AEROSPACE]**

Meanwhile, the situation of the jet trainer fleet has reached critical proportions. The 2nd Tactical Squadron of the 81st Wing currently has the last two airworthy Albatros trainers – one L-39CM and one L-39ZAM. The preferred replacement is the L-39 Skyfox, but details of the possible purchase of new jet trainers have not yet been made public.

The 46th Wing at Kuchyňa currently operates two C-27J Spartans and seven L-410 Turbolets. In December 2024, the Slovak government decided that this fleet would be replaced by four C-390 Milleniums (three definite and one under option) and two twin-engine medium-range business jets for 15 passengers. Two or three L-410s will remain in the inventory and will be used mainly for aircrew training.

The 1st Helicopter Squadron of the 51st Wing at Prešov operates nine UH-60M Black Hawks. To save costs as much as possible, these helicopters were initially delivered without defensive armament or any missile approach warning system (MAWS) and radio warning receiver (RWR) self-protection systems. The M240H door machine guns were shipped in 2024 and the OS SR will receive the ballistic protection system for these Black Hawks during 2025. In the future, the helicopters are planned to be fitted with self-protection equipment and a weapon subsystem enabling the use of rockets and missiles. In 2025, two UH-60M SOF helicopters will be delivered under an intergovernmental agreement from June 2021. This pair of Black Hawks will already come equipped with an optronic infrared (IR) sight, M134D-H machine guns and an AN/AAR-47 self-protection system.

During 2024, the replacement of Mi-17M helicopters operated by the 2nd Helicopter Squadron of the 51st Wing was addressed. A US government offer to supply surplus AH-1Z Vipers was rejected and instead, a contract worth EUR 150 million was awarded to

ACE Aeronautics for 12 refurbished UH-60L Black Hawks in December 2024. The helicopters will be delivered with 12 Fulcrum Modular Effects Launcher (MEL) four-station configurable lightweight armament wing kits, 18 Arnold Defense M261 rocket pods and 12 aircraft survivability equipment kits.

Air defence

Like the Czech Republic, Slovakia has decided to bet on Israeli radars from IAI/ELTA Systems. In March 2021, the Slovak government concluded a contract for the delivery of 17 radars (six EL/M-2084M-MMR; five EL/M-2084S-MMR; and six EL/M-2138M sets) for EUR 123 million including VAT. According to the contract, Elta Systems is to complete deliveries during 2025. However, at the time of writing, not a single radar has been delivered to the 2nd Air Force Brigade.

In August 2024, the government approved the purchase of six batteries of the BARAK MX system for EUR 554 million for the 11th Air Force Brigade. The armament will include all available missile types. The first components of the BARAK MX system should arrive in Slovakia at the end of 2025 and the first battery is expected to achieve initial operational capability (IOC) in 2026. One battery consists of a fire control centre, a radar and three launchers, each carrying eight missiles. An option for two more batteries can be exercised in the future. Slovak companies should participate in the production of parts of the radar and the final assembly of the missiles; in the latter case, VOP Nováky will assemble the missiles from imported components.

Although the Polish Piorun was selected as the successor to the Russian 9K38 Igla (SA-18 Grouse) Man-Portable Air Defence System (MANPADS) as early as 2023, no agreement has been concluded for their purchase so far.

Armoured vehicles

In 2025, the Slovak Armed Forces (OS SR) await the delivery of 160 JLTVs (110 M1278A1 HGCs with M153 CROWS weapon stations and 50 M1278A1s with manned turrets). Within the Slovak land forces, these vehicles will be used to equip the 65th Reconnaissance Battalion and the newly-established 25th Motorised Battalion.

The Slovak MoD has also restarted a project for new 4×4 multi-purpose armoured vehicles. To find a suitable type of local origin, the MoD has ordered a total of nine vehicles in three different configurations from three Slovak suppliers at the end of 2024: the Gerlach from Zetor Engineering Slovakia, the PATRIOT II from MSM Land Systems, and the HRON from DefTech. After comparative trials, the OS SR intends to order at least 400 vehicles of the chosen type. It can be assumed that their evaluation will not start before late 2025, and the test results and the production order will come during 2026 at the earliest.

In August 2022, the MoD ordered 76 Patria AMV XP 8×8 armoured vehicles in three variants for the units of the 2nd Mechanised Brigade – the 21st and 22nd Mechanised Battalions. The prototype of the IFV variant was scheduled for delivery in the second quarter of 2024, with the vehicle subsequently taking part in a military parade in Banská Bystrica in August 2024. AMV XP deliveries are slated for completion in the first quarter of 2027.

The project for the delivery of 152 CV90 MK IV tracked combat vehicles for the 1st Mechanised Brigade – 11th, 12th and 13th Mechanised Battalions – is also underway. According to plans made last year, the first vehicle could be ceremonially handed over in May 2025, with inspection trials starting at the end of that year. Vehicle deliveries were scheduled to be completed in the second quarter of 2029.

The MoD is also in search of a new main battle tank (MBT); solutions under consideration include the Leopard 2A8 and K2PL tanks, and even the CV90120 fire support vehicle (FSV) – though the latter is not an MBT. However, the selection of a specific type has not yet been announced.

The Slovak Armed Forces are set to receive 160 JLTVs for the 65th Reconnaissance Battalion and 25th Motorised Battalion. [US Army/Chin-U Pak]

The Slovak Ministry of Defence is considering the possible acquisition of 16 EVA M2 155 mm SPHs. [KONŠTRUKTA – Defence]

Artillery

The OS SR is still waiting for the last eight ZUZANA 2 SPHs from a contract for 25 units awarded to KONŠTRUKTA-Defence in 2018. These guns have been physically produced but were shipped to Ukraine by January 2023. Their replacement for the OS SR was supposed to be completed by the end of June 2024, but due to various issues, this did not happen.

The MoD is also considering the acquisition of EVA M2 155 mm SPHs from KONŠTRUKTA – Defence, and a batch of AM120 120 mm self-propelled mortars from ZTS – ŠPECIÁL.

Logistics

In December 2024, Slovakia joined the Czech Ministry of Defence's framework agreement for the delivery of Tatra 815-7 trucks in three configurations. Based on the concluded amendment, the OS SR should receive 870 6×6 cargo bed vehicles for EUR 383 million excluding VAT and 437 8×8 container carriers with MSH-165-SCA hook lifts for EUR 325 million excluding VAT by 2031, with deliveries in several stages.

The MoD also plans to gradually purchase new passenger road and offroad vehicles; up to 821 could be purchased by 2027 for an estimated value of EUR 40.63 million.

Marketing Report: EVPÚ Defence

EVPÚ Defence to unveil new drone countermeasures at IDET

As drones become more prevalent and pose greater threats on the battlefield, the need for effective countermeasures has never been more urgent. EVPÚ Defence, known for its customisable security and defence technologies, has responded to this growing need by expanding its portfolio to include hard-kill solutions designed to counter drones and other aerial threats.

The hard-kill solutions feature two new additions to the GLADIUS line of remote-controlled weapon stations, specifically developed with a strong focus on detecting and neutralising aerial threats, including fairly small, fast-moving drones. The first of these two new GLADIUS configurations is designed to mount two FN MAG (or NATO equivalent) 7.62 mm machine guns with two 750-round ammunition boxes. In addition to an advanced fire control system, it features a fully independent electro-optical sight with high-sensitivity sensors optimised for both day and night operations, and provides an automatic tracking capability. Equipped with a radar and utilising small-calibre ammunition, this configuration excels in urban environments and offers a cost-effective solution for close-range drone engagements.

The second configuration incorporates a powerful 30 x 113 mm cannon capable of firing proximity-fuzed or high-explosive ammunition. It also integrates a radar and a sophisticated electro-optical sight, both of which move independently from the gun carriage. Both versions offer modular construction, compact design, and excellent stabilisation, making them suitable for a wide range of stationary and mobile platforms - from buildings and infrastructure to armored vehicles and naval vessels.

A close-in view of a GLADIUS operator workstation. [EVPÚ Defence]

Both GLADIUS configurations will be displayed at the IDET international defence and security exhibition in Brno, Czech Republic, from 28-30 May 2025, at stand no. P-075.

Nurol Makina: A company specialised in Defence and Security

Technological advancements play a pivotal role in safeguarding nations and ensuring peace in the ever-evolving landscape of defence and security. One company that stands at the forefront of innovation in this sector is Nurol Makina, with its diverse range of cutting-edge products making a significant impact worldwide. Specialising in 4×4 armoured vehicles, Nurol Makina has demonstrated its commitment to excellence, providing state-of-the-art solutions to meet the evolving needs of defence and security forces worldwide.

▲ The NMS-L, a lighter variant of the NMS 4×4. [Nurol Makina]

Global Presence

Users

Nurol Makina's influence extends far beyond its headquarters in Türkiye, with its distinctive products being utilised in diverse regions across the globe. Attaching great importance to research and development, Nurol Makina has created a wide product range that provides superior performance and meets various scenario and task requirements in different terrain and weather conditions of Africa, Asia, and the Middle East, Europe, and South America.

Companies/Operations

The company, which has recently made a difference by making a name for itself in Europe and other continents, has entities in Hungary and the United Kingdom.

Nurol Makina's family of vehicles for conventional warfare

The capabilities of Nurol Makina's armoured vehicle families exceed low-intensity conflict requirements, which is the typical operational domain for 4×4 armoured vehicles. With increased surveillance and firepower capabilities complementing its distinctive tactical, operational, and strategic mobility and protection features, the product line encompasses a spectrum of combat, combat support, and combat service support variants that are capable of operating in modern conventional warfare theatres. In addition to air defence and anti-tank capabilities, the fleet facilitates effective utilisation in high-intensity conflict zones through armament options including 25 mm and 30 mm automatic cannons, 120 mm mortar, and loitering munitions, among others.

Armoured vehicles

Nurol Makina's prominent product groups is its cutting-edge armoured vehicles. Thanks to their unparalleled protection and mobility capabilities, these vehicles instil confidence in security forces and demonstrate exceptional performance in high-risk environments. Nurol Makina's armoured fleet encompasses not only Combat vehicles but also Combat Support and Combat

▼ The extended wheelbase (EWB) variant of the Ejder Yalçın 4×4. [Nurol Makina]

Service Support variants, all of which are founded on advanced technology and have the capacity to integrate emerging technologies, thus establishing new benchmarks in the global defence industry.

Since its initial production, the flagship Ejder Yalçın has participated in numerous intense conflicts. Despite being subjected to repeated attacks involving hundreds of kilograms of improvised explosive devices, the personnel on the vehicle have been able to continue to fulfil their duties without even suffering severe injuries, and Türkiye should be genuinely proud of this exceptional vehicle.

NMS 4x4 is a vehicle that attracts attention with its design and is advantageous for security forces thanks to its scalable ballistic protection level. Armour steels can be replaced by simply removing the screws with a simple tool, without any preparation or extra effort in the field. Imagine that you have such a vehicle that not only has STANAG 4569 Level 1 ballistic protection but can also adapt to the evolving threat by increasing its protection level.

▲ **The extended wheelbase (EWB) variant of the NMS 4×4. [Nurol Makina]**

Unmanned Systems

Unmanned systems, crucial for augmenting combat effectiveness while minimising casualties, particularly in initial engagements, have become indispensable elements of the contemporary battlefield. In this context, Nurol Makina has demonstrated considerable success in integrating such systems into its armoured platforms with a forward-looking approach. These systems range from drones and loitering ammunition to remotely controlled IED destruction arms. Through these efforts, Nurol Makina provides its users with reconnaissance, surveillance, and precision strike capabilities. By virtue of these endeavours, Nurol Makina accumulates the knowledge and experience required for autonomous systems, which are one step ahead and stand out in the competitive defence industry.

Strategic Partnerships

Nurol Makina's commitment to global security is further exemplified by its strategic partnerships with various countries and defence organisations such as the UN and NATO countries. Working in harmony with large global companies as solution partners is an essential skill. From the user's point of view, such features are noteworthy. Collaborations with international entities, as mentioned, have facilitated the transfer of technology and knowledge, contributing to the strengthening of defence capabilities on a global scale. Such partnerships exemplify Nurol Makina's dedication to fostering cooperation and collaboration, in order to support building a safer world.

Innovation and Adaptability

Nurol Makina's present accomplishments stem from the extensive research and development initiatives undertaken in the preceding years. Continuously following technological advancements, emerging technologies, evolving threats, and lessons drawn from conflict zones, Nurol Makina persists in investing in future capabilities to remain prepared for the next challenge, not the last. These encompass Autonomous Driving, Intelligent Detection Systems, Target Identification and Threat Detection, Preventive Maintenance, Communication and Control Systems, Adaptive Armour and Protection, and Energy Efficiency and Optimisation.

Conclusion

Nurol Makina's products have become synonymous with reliability, innovation, and effectiveness in the global defence and security landscape. As the company continues to make strides in technological advancements and forge strategic partnerships, its impact in the defence industry is undeniable. Nurol Makina's commitment to providing cutting-edge solutions underscores its role as a key player in shaping the future of defence and security, contributing to a safer and more secure world for all. It is, therefore, a talent that authorities should consider when choosing their product.

▼ **The extended wheelbase (EWB) variant of the Ejder Yalçın 4×4. [Nurol Makina]**

SITREP: The modernisation of Spain's land forces

Robert Czulda

Spain is pursuing an ambitious modernisation programme for its land forces, aiming to ensure they meet the demands of future battlefields by 2035. However, financial constraints may hinder these plans. So far, there are no indications that Spain will increase its defence spending.

Funding military modernisation requires substantial financial resources, and Spain is not among the leaders in this regard. In 2024, Spain allocated approximately 1.28% of its GDP to defence – one of the lowest figures in NATO. This is somewhat understandable, given that Spain is geographically distant from Russia and faces no immediate conventional military threats. Instead, its most pressing security challenge is the surge in illegal migration from North Africa, which continues to break records. According to official reports, a record number of 64,000 migrants reached Spain in 2024, including over 43,000 migrants who arrived in the Canary Islands. On the other hand, Spain's low defence spending raises questions about its credibility as an ally and its overall usefulness within NATO.

A Spanish M109 A5E SPH conducts night firing during the Gazola 25 Exercise. The country's land forces are gradually modernising, yet questions regarding the sufficiency of its defence spending remain. [Ejército de Tierra]

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Despite its low defence expenditure, Prime Minister Pedro Sánchez reaffirmed his support for the EU's 'ReArm Europe' defence initiative in mid-March 2025. He argued that the current international climate — marked by Russia's threat to Central and Eastern Europe and evolving US policies — presents an opportunity to reindustrialise Spain and the continent. During his visit to Finland on 12 March 2025, Sánchez reiterated his commitment to increasing defence spending to 2% of GDP by 2029.

However, at present Sánchez's statements appear to be little more than rhetoric. On the international stage, he has declared a willingness to raise defence spending, fully aware that such an increase is unlikely. At the same time, he has assured the Spanish public that any potential boost to the defence budget will not come at the expense of his social programmes. He also lacks the support to push an increase to defence spending through Spain's parliament, where he does not hold a majority. Furthermore, defence spending hikes have faced resistance from both Sanchez' coalition partners as well as opposition parties, who have question both the feasibility and timing of his proposed budget increase.

Spain's Fuerza 2035 modernization programme

In January 2024, Spanish Defence Minister María Margarita Robles emphasised the need for more advanced technologies to ensure that the Spanish military meets the demands of modern warfare. At the heart of this effort is the Fuerza 2035 programme, a long-term initiative aimed at transforming the Spanish Armed Forces (Fuerzas Armadas de España), with a planning horizon extending beyond 15 years. The Fuerza 2035 project was officially launched in 2018 by the Spanish Ministry of Defence, with concrete implementation efforts beginning in subsequent years.

Fuerza 2035 focuses on the land forces (Ejército de Tierra), aiming to modernise their structure, equipment, and operational capabilities. However, the other branches — the Air and Space Force (Ejército del Aire y del Espacio) and the Navy (Armada Española) — are also undergoing technological modernisation and structural, as well as doctrinal transformation. Ejército de

Tierra is set to evolve from the 'Force of the Possible' (Fuerza Posible) in 2018-2024 to the 'Advanced Force' (Fuerza Avanzada) between 2024 and 2030, before ultimately becoming the 'Force of Superiority' (Fuerza de Ventaja) between 2030 and 2035. The Fuerza de Ventaja stage is expected to provide operational superiority, ensuring full integration of modern systems, interoperability with allies, and readiness for future challenges. The future Ejército de Tierra will leverage artificial intelligence (AI) and a wide range of unmanned systems, including unmanned aerial vehicle (UAV), and unmanned ground vehicle (UGV) platforms — from micro-UAVs to medium-altitude long endurance (MALE), and high-altitude long endurance (HALE) UAVs, along with strike UAVs.

The Fuerza 2035 programme is based on the assumption that the future security and defence environment will undergo significant changes. A key aspect will be increased competition between states, while non-state actors will continue to proliferate. To achieve their objectives, some adversaries will extensively utilise the latest technologies, avoiding direct confrontation. However, the possibility of a high-intensity conventional conflict cannot be ruled out.

The Spanish military is expected to be capable of operating successfully across the entire spectrum of conflict, from supporting civil authorities to engaging in non-linear battlefields and high-intensity urban combat against conventional enemies. The force will be highly expeditionary and maintain a high state of readiness, with a reduced personnel footprint thanks to the integration of new technologies.

Spain's ground forces aim to integrate a range of unmanned systems as part of modernisation plans. [Ejército de Tierra]

Spain has been developing the Brigada 2035 concept to create technologically advanced ground forces with the combat power, protection, and capabilities necessary to operate in future conflict scenarios. This unit serves as a reference model for Spain's future land forces. The 'Rey Alfonso XIII' Brigade of the Legion, based in Almería, has been designated as the Experimental Brigade (BRIEX) 2035. This unit is responsible for analysis, lessons learned, and the development of concepts, doctrines, and procedures.

Brigada 2035 will consist of 2,800–3,000 soldiers, organised into three Combat Groups (Grupos de Combate), capable of independent operations, and a Brigade Troops Core (NTB - Núcleo de Tropas de Brigada), serving as the brigade's central command and support structure. Each Combat Group will be the size of a reinforced infantry battalion. Brigada 2035 will also include an artillery group (Grupo de Artillería), an engineering battalion, a logistics group, a cavalry group, an intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) unit, a communications unit, and other specialised units. The NTB will play a crucial role in integrating and coordinating all operational support units necessary for conducting joint warfare within the brigade.

Tanks

Regarding armoured units, Spain operates both Leopard 2A4 and Leopard 2E tanks. The latter is an upgraded export variant of the Leopard 2A6. Spain currently has 219 Leopard 2Es, produced between 2001 and 2008, but due to their age, they no longer fully meet the requirements of the modern battlefield. As for the 2A4 variant, these tanks were acquired through the Programa Coraza 2000, designed to replace the French AMX-30 as well as US-made M47 and M48 tanks. Approximately 79 A4s are in active service from a total of 108 tanks that were originally bought from Germany in the late 1990s — first leased and later purchased. In 2012, around 50 Spanish 2A4s were placed in storage due to financial constraints, while 29 were recently transferred to Ukraine.

Spain currently has 219 Leopard 2Es, produced between 2001 and 2008, but due to their age, they no longer fully meet the requirements of the modern battlefield. [Ejército de Tierra]

Madrid plans to modernise its existing Leopard 2E fleet by 2029. The majority of the Leopard 2E fleet was produced locally by Santa Bárbara Sistemas between 2003 and 2008 – though the initial 30 tanks were produced by the then-KMW (not KNDS Deutschland) at its Munich facility – and features improvements such as the LINCE battle management system and thermal imaging optics developed by Indra. Planned upgrades will enhance command, control, communications, firepower, mobility, protection, and maintenance. The tanks are expected to receive a laser warning receivers, upgraded optoelectronics, multispectral camouflage, an improved main gun (presumably the Rh120 L55A1), an active protection system (APS), and a remote weapon station (RWS). The upgraded Leopard 2E+ is expected to remain in service until the future Main Ground Combat System (MGCS) becomes available.

Madrid plans to modernise its existing Leopard 2E fleet by 2029. Planned upgrades will enhance command, control, communications, firepower, mobility, protection, and maintenanability. [Ejército de Tierra]

Beyond the Leopard 2E modernisation programme, the Ejército de Tierra is preparing to phase out its obsolete Leopard 2A4s. These are expected to be replaced by the Leopard 2A8, a variant still under development by KNDS Deutschland. The 2A8 builds upon the Leopard 2A7 and, according to the manufacturer, features enhanced armour protection for the hull front and turret face, which can be supplemented with various optional packages, including a roof armour package. The 2A8 is armed with the Rh120 L55A1 120 mm smoothbore gun, offering increased pressure (700 MPa) compared to the earlier Rh 120 L55 model (670 MPa). This can be supplemented by an optional RWS. A key upgrade is the integration of the Trophy APS, which has also been tested on the 2A7 variant. The 2A8 retains the 1,119 kW (1,500 hp) power pack of earlier variants, supplemented by a 20 kW auxiliary power unit (APU) to permit a 'silent watch' capability and ultracapacitors.

The armoured forces modernisation plan was officially announced in January 2025 during the International Armoured Vehicles Conference 2025 (IAV 2025) in Farnborough, UK. Spain also intends to replace its current support vehicles, including armoured engineering vehicles (AEVs) and armoured vehicle launched bridges (AVLBs), based on the M60 platform. Madrid is actively seeking to maximise the participation of the Spanish defence industry in both projects – the modernisation of the Leopard 2E and the acquisition of the Leopard 2A8.

Armoured vehicles

One of the key modernisation programmes for Spain's land forces remains the production of a new multi-role wheeled platform. The VCR (Vehículo de Combate sobre Ruedas) Dragón, an 8×8 wheeled vehicle family based on the GDELS-Mowag Piranha V design, expected to replace Spain's ageing wheeled armoured

▲ **Image shows a demonstrator for the VCI (IFV variant) of the Dragón 8×8 during tests. [TESS Defence]**

vehicles. Specifically, Dragón will phase out two vehicle types designed by the now-defunct company Pegaso in Barcelona: the BMR-M1 (6×6) and the VEC/VEC-M1 (6×6). The former, with a fleet of nearly 700 units, has been in service with the Spanish Army since the late 1970s, while the latter (340 units) is only a few years younger.

The Dragón is presented by both the Spanish military and the local defence industry as a flagship project. It is not only intended to provide the armed forces with a modern vehicle in multiple variants, but also to serve as a crucial component in the growth of Spain's defence sector. In short, the Dragón is expected to become a cornerstone of Spain's future military (Fuerza 2035). Undoubtedly, it has the potential to achieve this, as it is the most modern wheeled vehicle ever fielded by the country. The manufacturer highlights its versatility, high resistance to explosive devices, mobility, modular armour, and autonomy, allowing it to operate independently for over 48 hours.

The Dragón will be available in six variants (down from the 13 variants originally planned), including an infantry fighting vehicle (VCI), a cavalry reconnaissance vehicle (VEC), a fire observation vehicle (VCOAV), a battalion command post vehicle (VCPC), an armoured recovery vehicle (VREC), and a combat engineering vehicle (VCZ). While Spain has yet to decide whether the DRAGÓN family will be equipped with an active protection system (APS), all variants will be fitted with advanced electronics, including onboard mission management systems developed by Indra.

Production of VCR Dragón vehicles for the Spanish Army began in late 2021, although initial plans had projected deliveries starting as early as 2014. In reality, the first batch was completed only on 20 December 2022, when the GDELS-Santa Bárbara Sistemas (GDELS-SBS) factory in Alcalá de Guadaíra, Andalusia, delivered seven serial production vehicles along with five technology demonstrators in three different variants. The first production tranche includes 348 vehicles, with a contract value exceeding EUR 2 billion, originally scheduled for completion by 2027. However, this is only the beginning — due to the need to replace all ageing vehicles, Madrid has planned two additional tranches: 365 vehicles between 2026–2030 and 287 vehicles between 2031–2035, bringing the total planned investment in the Dragón programme to EUR 3.8 billion.

It is already clear that the original schedule will not be met. In 2024, Tess Defence (the consortium responsible for manufacturing the VCR Dragón) was supposed to deliver 94 vehicles, yet not a single unit has been handed over to the Ejército de Tierra. According to Spanish sources, the vehicles failed to meet operational requirements. Reported issues include excessive weight, which exceeds the payload capacity of the A400M transport aircraft, and dimensional constraints. In September 2024, Madrid-based newspaper *La Información Económica* reported that the Spanish Ministry of Defence fined Indra, SAPA, and GDELS-SBS EUR 9 million for delays. Defence Minister Margarita Robles has voiced her "great concern" over "the lack of progress and the level of compliance" in the Dragón programme.

Other vehicles

One of the key modernisation projects is the second phase of the Pizarro tracked armoured vehicle programme. During Phase I, Spain procured 144 vehicles, including 123 Pizarro IFVs in the VCI/C (Vehículo de Combate Infantería/Caballería) configuration and 21 VCPC (Vehículo de Puesto de Mando) command post vehicles. Phase II aims to equip the Spanish Army with additional vehicles, including specialised variants for engineering units. While Spain initially planned to acquire 212 vehicles, financial constraints ultimately reduced the total number to 117, comprising 81 VCI/C IFVs and 36 VCZ (Vehículo de Combate de Zapadores) engineering combat vehicles.

▼ **One of the key modernisation projects is the second phase of the Pizarro armoured programme. Phase II aims to equip the Spanish Army with additional vehicles, including specialised variants for engineering units. [Ejército de Tierra]**

Deliveries under Phase II began in December 2015 with the delivery of 10 VCI/C Pizarro Fase II vehicles. In December 2023, the Ejército de Tierra received its first batch of six VCZ Castor

tracked engineering vehicles from GDELS-SBS; this was followed by a further four in December 2024. The deliveries were part of a contract for 36 vehicles for Spain's sapper units, under Pizarro Phase II. The Castor is based on the ASCOD 2 platform (related to the original ASCOD used for Ulan/Pizarro) and is powered by an MTU 8V 199 TE20 turbocharged diesel engine developing 537 kW (720 hp), produced by Navantia Motores, coupled to a SAPA SG850 automatic transmission.

The Fuerza 2035 programme also envisions a Phase III. According to official documents, additional infantry and cavalry vehicles will be acquired, with enhanced capabilities to integrate ISTAR data, unmanned systems, and network connectivity with other vehicles and dismounted units. However, official technical specifications and delivery schedules for Phase III have not yet been published.

By the end of December 2024, the Ejército de Tierra received an additional four VCZ Castor engineering vehicles. The Castor is based on the ASCOD 2 vehicle family. [Ejército de Tierra]

The same lack of details applies to another component of Fuerza 2035 – the introduction of an entire family of unmanned ground vehicles (UGVs). These will include weapon carriers, chemical, biological, radiological, and nuclear (CBRN) reconnaissance vehicles, medical evacuation platforms, troop and cargo transporters, engineering vehicles, and armoured recovery vehicles (ARVs). Research in this field is being carried out under the ESCORPION programme, which aims to develop a family of remotely operated wheeled and tracked UGVs. Notably, in 2021, reports emerged about a collaboration between GDELS-SBS and Sener Aeroespacial to develop a remote driving system for Pizarro vehicles, both in combat (VCI/C) and engineering (Castor) configurations. This innovation would allow operations in hazardous environments without exposing soldiers to direct risks.

In contrast, more details are available regarding the replacement of Spain's fleet of M113 tracked vehicles, of which approximately 1,000 remain in service. Madrid plans to acquire the VAC (Vehículo de Apoyo de Cadenas) tracked support vehicles, to be manufactured by the TESS Defence consortium. The VAC is based on the ASCOD 2 platform, and in its first phase, 394 vehicles will be acquired in multiple specialised variants, including self-propelled mortars, armoured personnel carriers (APCs), command vehicles, fire support vehicles, medical evacuation vehicles, and technical support vehicles. The VAC will also incorporate an active protection system (APS) and share several electronic systems with the VCR Dragón family.

Artillery

Spain has very ambitious plans for modernising its artillery. According to Fuerza 2035, Brigada 2035 is expected to have an organic artillery group consisting of three batteries of 155 mm calibre guns, either towed or self-propelled, with a range exceeding 50 km, along with one battery of multiple-launch rocket systems (MLRSs) with long-range and high-mobility capabilities, providing a range of 120-130 km. By 2035, fire support capabilities are expected to extend up to 500 km, based on guided hypersonic rockets and missiles. Spain also plans to acquire tactical radars, various drones (including loitering munitions), and mobile acoustic location networks. Purportedly, electromagnetic guns, and hypersonic missiles are also under consideration.

In 2024, Madrid announced a project to purchase 145 self-propelled howitzers (SPHs). The acquisition will include 36 wheeled and 109 tracked howitzers. The goal of this programme is to replace the US-made M109 tracked SPHs currently in service. Spain presently has approximately 96 M109 A5E SPHs and various towed guns, including 82 GDELS-SBS 155/52 APU-SIAC (155 mm) and 56 L118A1 (105 mm). In late 2023, GDELS-SBS was awarded a EUR 15.7 million contract for the maintenance of its 155/52 APU-SIAC guns. A full upgrade and repair programme will cost over EUR 36 million.

Spain expects to replace its in-service the US-made tracked M109 A5E SPHs, presently numbering approximately 96. [Ejército de Tierra]

Regarding the procurement of 145 new howitzers, these are expected to have barrel lengths between 47 and 52 calibres, with a range exceeding 40 km using base-bleed ammunition. It is worth noting that in mid-2024, GDELS–SBS announced the reactivation of its ability to produce large-calibre gun barrels. This move responds to the increased demand for artillery systems. The barrels will be produced again at the Trubia facility, owned by GDELS-SBS.

In 2023, Spain signed a EUR 700 million contract with Israeli company Elbit Systems to acquire a single PULS MLRS fire module. This purchase is part of the SILAM (Sistema Lanzador de Alta Movilidad) programme, which aims to acquire MLRS capable of striking targets at ranges up to 300 km. Spain will receive 12 mobile launchers, 12 munition supply vehicles, ten command-and-control vehicles, two technical evacuation vehicles, and six reconnaissance vehicles. In terms of munitions, apart from 216 training rounds with a range of 15 km, Spain will acquire 288 rockets with a range of 35 km, 112 rockets with a range of 150 km, and 64 rockets with a range of 300 km. The ammunition procurement will cost EUR 414 million.

At the same time, Spain's land forces are increasing their capabilities through the acquisition of mortars. Madrid will purchase 84 EIMOS 81 mm mortars from Rheinmetal Expal Munitions for EUR 150 million (the contract also covers maintenance and training), with deliveries due to be completed by 2027. The EIMOS system, which can be mounted on a standard 4×4 vehicle, will be used by all branches of the Spanish military.

Air defence

Future Spanish forces will be equipped with very short- and short-range air defence systems (V/SHORAD), including anti-aircraft guns capable of targeting helicopters and small UAVs at very low altitudes. In order to enhance air defence capabilities, Fuerza 2035 plans to introduce hybrid cannon/missile self-propelled anti-aircraft gun and missile (SPAAGM) vehicles on an 8×8 wheeled platform, and potentially using a 35 mm cannon armament. The system will feature its own radar, optical tracking, and targeting systems, making it suitable for defence against aircraft, helicopters, UAVs, and even various missiles.

In May 2024, Kongsberg was awarded a contract worth EUR 410 million to deliver the NASAMS II+ air defence system. This is a fairly recent variant which will enable, among other improvements, the use of AMRAAM-ER missiles with a range of 40 km. The purchase aims to fill the gap left by divestment of MBDA's SPADA 2000 system, which was sent to Ukraine. Currently, Spain has four NASAMS batteries, with two launchers per battery; in May 2024, Madrid requested a EUR 45 million modernisation programme for the system. At the same time, Spain will procure a replacement for its I-HAWK systems, which were also donated to Ukraine. By July 2024, Madrid requested PATRIOT PAC-3 MSE missiles and related support equipment. Spain will be the 15th PAC-3 MSE user, with a contract worth EUR 2.4 billion.

The Portuguese Army's modernisation ambitions

Victor Barreira

As part of the Military Programming Law 2023-2034 approved in July 2023 the Portuguese Army (Exército Português) is undergoing a major modernisation effort aimed strengthening its capabilities in several key domains.

Pictured: a Portuguese Leopard 2A6 firing. The Army is looking to modernise its tank fleet, along with many other capability areas. [Exército Português]

The operational structure of the Portuguese Army is principally comprised of the Rapid Reaction Brigade, the Intervention Brigade, the Mechanised Brigade, the General Support and Military Emergency Forces, and three overseas infantry battalions.

Despite limited budget resources and procurement constraints and issues, the army, headed by General Eduardo Manuel Braga da Cruz Mendes Ferrão and with approximately 11,000 personnel, has managed to successfully implement several acquisition programmes in recent years.

The Military Programming Law 2023-2034 seeks to invest EUR 5.57 billion to modernise the Portuguese military. However, this figure is scheduled to be updated in 2027. The EUR 800 billion 'ReArm Europe' plan, unveiled by the European Commission on 4 March 2025, could help Portugal accelerate its acquisition ambitions.

AUTHOR

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Of the EUR 5.57 billion, a total of EUR 1.236 billion is scheduled to be spent to build the next-generation Portuguese Army, by introducing capabilities over several key domains such as protection, firepower, digitisation, command and control, survivability, situational awareness mobility, and connectivity, to enable the army to be ready to operate and fight. The Army is simultaneously seeking to further develop capabilities such as cyber defence, simulation, and electronic warfare (EW) and to gradually introduce unmanned systems. A breakdown of the Portuguese Army's scheduled annual spending on modernisation is detailed in Table 1.

TABLE 1

Breakdown of the Portuguese Army's scheduled annual spending on modernisation

Amount budgeted (EUR millions)	Year
90	2023
70,6	2024
75.8	2025
95.8	2026
63.2	2027
85.8	2028
102.1	2029
129.8	2030
132.9	2031
123.3	2032
136.1	2033
130.2	2034

The equipment modernisation for the Army seeks investment in 12 capacities consisting of 99 projects and sub-projects by 2034. These are broken down in Table 2.

TABLE 2

Breakdown of the Portuguese Army's scheduled spending (2023-2034) by capability

Amount budgeted (EUR millions)	Capability
119	Command & Control (C2)
98	Light Forces
405	Medium Forces
26.9	Heavy Forces
21.4	Defence of Archipelagos
7.5	Special Operations
41.9	Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR)
4.8	Land transport
159.2	Protection and survivability
113.8	Logistic support
90.2	Emergency military support
130.2	War stocks

Included in the modernisation programme is EUR 50 million aimed at acquiring helicopters for protection, evacuation, and support roles; EUR 55.4 million for the modernisation of Leopard 2A6 main battle tanks; EUR 6 million for micro- and mini-unmanned aerial vehicles (UAVs); EUR 8.2 million to acquire counter unmanned aerial systems (C-UAS) between by 2034; EUR 297.7 million for the upgrade of Pandur II 8×8 armoured vehicles between 2026 and 2034; EUR 13.6 million to acquire a tracked infantry fighting vehicle fleet to replace the M113A2 carrier as part of the VCI-L (Viatura de Combate de Infantaria de Lagartas) project; EUR 119.5 million to acquire field artillery systems; EUR 126.5 million to procure C2 equipment; as well as EUR 90.2 million for ammunition by 2034.

The acquisition of major weapon systems by the Portuguese Army are principally established by the Forces Planning Division (Divisão de Planeamento de Forças), while the procurement procedures are conducted by the NATO Support and Procurement Agency (NSPA) through the signature of sales agreements, and by the Logistics Command (Comando da Logística). Over the previous year, the Portuguese Army has significantly increased acquisitions through the NSPA.

Other hardware in domains such as C2, ISTAR, logistics support, medical support, space, and cyber defence, will be received as part of joint capabilities projects run by the Ministry of National Defence and the Armed Forces General Staff.

Key procurements

C4ISTAR

To modernise, strengthen, and complement the existing SIC-T communications system, the Army has recently purchased a tactical deployable communication and information system consisting of 16 communications modules. A total of 21 signal shelters were purchased by the NATO Communications and Information Agency (NCI Agency) on behalf of the Portuguese Army, according to a EUR 33.1 million contract awarded to EID on 8 July 2024. Delivery of the first modules is scheduled to take place in 2025, the Army told ESD. The SIC-T solution consists of different node types and a set of associated elements designed to deliver information technology services to users over different domains.

▲ **The Portuguese Army is looking to acquire new tactical UAVs to complement the RQ-11 Raven B DDL system. [Victor Barreira]**

The deployable ISTAR capability of the ISTAR Battalion of the Rapid Reaction Brigade has been significantly increased with the acquisition by the NSPA of four shelters based on standard 6 m (20 ft) ISO containers from Lavorazioni Elettroniche e Meccaniche (LEM), along with associated trailer-mounted power generator sets. The shelters principally accommodate a telescope mast, workstations, peripherals, and PRC-525 radios. The mobile ISTAR system will be further strengthened with the acquisition of UAVs and various sensors.

Other recently-introduced equipment included RQ-11 Raven B DDL UAVs, PRC-525 tactical radios, along with TRC-4000E and TRC-4000 high-capacity line-of-sight radios.

Artillery

The year 2024 was particularly significant for the modernisation of the Exército Português, with a contract awarded for self-propelled howitzers (SPHs), under a framework cooperation agreement signed on 26 October 2024 between the Directorate General for National Defence Resources (DGRDN) and the French Direction Générale de l'Armement (DGA). The contract, worth approximately EUR 270 million, is for the acquisition of up to 36 KNDS France CAESAR MkII 6×6 155 mm SPHs by 2034, to be supplied through the European Defence Industry Reinforcement through Common Procurement Act (EDIRPA) fund. The plan to acquire the CAESAR MkII was further confirmed through a Letter of Intent signed on 28 February 2025 in Porto.

Portugal is looking to purchase up to 36 CAESAR MkII 6×6 155 mm L52 SPHs. [KNDS]

The Chief Executive Officer (CEO) of KNDS France Nicolas Chamussy, told ESD on 28 February that negotiations are underway to deliver CAESAR MkIIs to the Portuguese Army. The CAESAR MkII principally includes the Arquus Armis 6×6 tactical truck armed with a 155 mm L52 gun, muzzle velocity radar, an inertial navigation system (INS), and C2 system.

Alongside this, efforts are underway to add the NELI ballistic calculation and aiming system from Integrated Defence Solutions and Exail Advans Lyra inertial navigation system to the M119 Light Gun 105 mm towed howitzer of the 10.5 Towed Field Artillery Group (GAC 10.5 Reb) of the Rapid Reaction Brigade. The field artillery capability received some improvement thanks to the procurement of Newcon Optik LRB 6K tripod-mounted laser rangefinder binoculars and Instro Precision iFires integrated targeting systems with the Elbit Systems CORAL-CR tripod-mounted thermal imager.

Air Defence

To strengthen its depleted ground-based air defence (GBAD) capability, Portugal purchased the Thales ForceShield Compact ground-based Very Short-Range Air Defence system (VSHORAD) to replace the obsolete M48A2E1/M48A3 Chaparral missile launchers within the Air Defence Artillery Battalion of the Intervention Brigade and the Air Defence Artillery Battery of the Mechanized Brigade.

The EUR 39 million contract awarded by the NATO Support Procurement Agency (NSPA) to Thales on 23 October 2024 principally included the supply of three RAPIDRanger mobile missile launchers based on the URO VAMTAC ST5 4×4 vehicle platform, the Thales GroundMaster 200 radar and ControlView C2 System (this radar/C2 package collectively referred to as 'ControlMaster 200' (CM 200) by Thales), as well as two portable weapon terminals for the existing Stinger man-portable air-defence system (MANPADS), and Thales F@stnet HD VHF radios.

The RAPIDRanger is fitted with the Lightweight Vehicle Mounted Turret (LVMT) from Ultra, and houses a 360° two-axis gyro-stabilised optronic sight and is armed with four missiles (two per side), with compatible munitions comprising the Thales STARStreak high-velocity missile and the Thales Lightweight Multirole Missile (LMM; also known as 'Martlet'). The vehicle also accommodates a C2 workstation, communications, navigation equipment, as well as the ControlView Compact C2 system.

Thales ForceShield Compact GBAD system for Portugal includes the RAPIDRanger mobile launch vehicle (pictured), capable of launching Starstreak and LMM missiles. [Thales]

The Thales GM200 Multimission Compact (MM/C) is an S-band multi-beam active electronically scanned array (AESA) radar, using Gallium nitride (GaN) technology. It has an instrumented detection range of 250 km, and can support engagements out to 100 km. The radar is capable of detecting and tracking fixed-wing and rotary-wing aircraft, UAVs, loitering munitions, cruise missiles, artillery rockets, artillery rounds, and mortar bombs. It has an embedded Mode 5 identification, friend or foe (IFF) interrogator, and in Portugal's configuration, is integrated with the ControlView Compact C2 system; this configuration is marketed as 'ControlMaster 200' by Thales.

The ForceShield system will be fully delivered to Portugal in October 2026 for acceptance tests and live-fire exercises, Thales told ESD. The contract includes an option for a fourth RAPIDRanger system, a second CM200 unit, and two additional portable weapon terminals.

Portugal has recently joined the multinational European Sky Shield Initiative (ESSI) to purchase a medium-range air defence system, thus complementing the incoming RAPIDRanger system. The ESSI seeks to coordinate the procurement and interoperability of air-defence systems among its members to protect against the threat of Russian missiles and drones.

Portugal previously acquired the deployable integrated air defence artillery command and control system SICCA3 (Sistema Integrado de Comando e Controlo para a Artilharia Antiaérea). The SICCA3 consist of Teknel's shelter-based fire detection centre and tactical operations centre equipped with MIL-STD

subsystems, two Kerax 4×4 high-mobility trucks, and related trailer-mounted power generator sets and equipment. The Portuguese ForceShield Compact will include the necessary interfaces for a future integration to the existing SICCA3 system.

Light vehicles

Portugal plans to acquire a new tranche of 4×4 light armoured tactical vehicles to complement the existing 139 VAMTAC ST5 vehicles of the Rapid Reaction Brigade acquired from UROVESA (URO Vehículos Especiales) through the NSPA in July 2018 worth EUR 27.3 million. The fleet, consisting of 107 multirole vehicles, 12 special operations vehicles, 13 medical support vehicles, and seven command post vehicles, was received between 2019 and 2021.

Portugal received 139 VAMTAC ST5 4×4 light armoured tactical vehicles as part of its VTLB project for the Rapid Reaction Brigade. [Victor Barreira]

Additionally, the NSPA is currently carrying out a EUR 19.9 million tender on behalf of Portugal to acquire up to 12 self-propelled mortars (armed with a 120 mm mortar), based on the VAMTAC ST5 4×4 platform. The Army is also looking to add several upgrades to the VBL/VB2L lightweight armoured reconnaissance vehicle fleet of the Reconnaissance Squadron of the ISTAR Battalion. Other recently-incorporated equipment included Hilux 2.4 D4 4×4 utility vehicles; Q-150D 4×4 multi-purpose airborne vehicles; and MRZR D2 4×4 all-terrain vehicles.

Medium-weight vehicles

The Army is seeking to carry out a mid-life upgrade (MLU) of its Pandur II 8×8 vehicle fleet of the Intervention Brigade and simultaneously add a lightweight remote medium-calibre weapon station to several of the infantry carriers. Portugal fields 112 infantry carrier vehicles, 16 command post vehicles, four reconnaissance vehicles, eight ambulances, seven recovery vehicles, 30 infantry fighting vehicles, five anti-tank carrier vehicles, and six communications vehicles meet the wheeled armoured vehicle requirement, the Army told ESD. Pandur IIs are currently deployed to the Central African Republic (CAR) and Romania.

The infantry carrier and the infantry fighting configurations were recently equipped with a multifunctional tablet to run the Portuguese-made EyeCommand Battlefront battle management system. Additionally, Rohde & Schwarz SOVERON VR5000 and HR5000 radios and EID ICC-201 intercoms have been purchased recently, worth EUR 2.5 million for Pandur II infantry carrier and command post vehicles that will take part in an EU battlegroup. Furthermore, seven M151 Protector remote weapon stations fitted to Pandur II infantry carriers are being modernised with new optics.

Portugal is taking steps to upgrade the Pandur II 6×6 fleet of the Intervention Brigade. [Victor Barreira]

Heavy vehicles

The Army is looking to add a slew of upgrades to the existing fleet of 34 Leopard 2A6 tanks of the Battle Tanks Battalion and the Reconnaissance Squadron of the Mechanised Brigade, by adding a new fire extinguishing system, and an ultra-capacitors (ultracaps) kit to the electrical system, an auxiliary power unit (APU), air conditioning unit, a thermal imager for the driver, and an electric turret and gun control system with digital stabilisation.

Since the tank fleet was received from Royal Netherlands Army surplus in 2008-2009, it was equipped with the PRC-525 radio system, ICC-251 intercom, and the DT10-M multifunctional rugged tablet for the EyeCommand Battleground battle management system.

In return for the delivery of three MBTs to Ukraine in 2023, the German MoD and the Portuguese MoND agreed that Germany would finance the maintenance by KNDS Deutschland of 14 Leopard 2A6 in service with Portugal. Additionally, A tank platoon of five Leopard 2A6s has been integrated with the Spanish Army-led NATO Multinational Battlegroup in Slovakia since July 2024.

In terms of other efforts, the Portuguese Army is looking to procure armoured recovery vehicles (ARVs), armoured vehicle launched bridges (AVLBs), and mobile assault bridging systems.

Logistics and transport

The Army is receiving a fleet of medium tactical logistics trucks acquired through the NSPA to Spain's Technology and Security Developments (TSD). The contract is designed to meet the Medium Tactical Vehicles project (VTM) and consists of 47 MAN Truck & Bus TGS 18.440 BBCH 4×4 signal shelters carriers (and 15 modular protected cabs) for the tactical communication and information system SIC-T (Sistema de Informação e Comunicações Tático), and 61 MAN Truck & Bus TGS 26.440 BBCH 6×6. Of the 61 6×6 trucks, 28 are configured for general transport without an armoured cab, 13 for general transport with an armoured cab, 16 container carriers with a HIAB X-HiDuo 072 loader crane, and four with the HIAB MULTILIFT hooklift system for a 6,000-litre water tank. Deliveries are scheduled to be completed in March 2026, the Army told ESD.

recovery trucks. The Army is also working to procure general-purpose unarmoured 4×4 tactical trucks, as well as 6,000 litre unarmoured 6×6 water tank tactical trucks. Additionally, the Army is looking to procure three retrofitted Sikorsky Aircraft UH-60 Black Hawk utility helicopters, with an option for a fourth.

CBRN

The Army has strengthened its chemical, biological, radiological, and nuclear (CBRN) capabilities by acquiring a mobile CBRN decontamination system and a mobile Biological, Chemical and Radiological laboratory. Both are housed in standard 6 m (20 ft) ISO containers, mounted on a FMX420 6×6 truck equipped with the Palfinger PH T17S hookloader.

Portugal is receiving a new fleet of 4×4 and 6×6 armoured and unarmoured tactical logistics trucks. [Victor Barreira]

The VTM project is part of the wider Family of Tactical Vehicles (FVT) programme that includes acquiring a fleet of logistics trucks, as well as tractor trucks, ultra-lightweight tactical vehicles, ambulances, general-purpose transport trucks, dump trucks, water tank trucks, fuel tank trucks, and recovery trucks, to replace existing trucks gradually.

The VTM's cabin comes equipped with a towing winch, mounting brackets for assault rifles, the EID's PRC-525 software-defined tactical multi-band radio with the EID MT-525S single radio system mount and a detachable remote console, and a mount system for a rugged tablet running a Portuguese-made battle management system.

Other recently-incorporated equipment included ACTROS 2041, CF85.460, CF85.510, TGX18.420, FMX540 and FMX420 tractor trucks, along with AFMX520 dump trucks and FMX380

The Army is also working to procure four light tactical armoured vehicles for the CBRN reconnaissance and explosive ordnance disposal (EOD) roles.

Special Forces

As part of the Plan for the Implementation of the Special Operations Force (PIFOE), the Army boosted the material capacity of its special operations troops, thanks to a variety of equipment received over the past years, including HK416A5 and HK417A2 assault rifles; AXMC, M107A1, and G28E precision rifles; STF/12 Compact shotguns; MP5 KA4 submachine guns, M2HB-QCB and FN MAG machine guns; HK269 and GMG grenade launchers; M72 rocket launchers; Sportsman MV850, MRZR 2, MRZR D2 and MRZR D4 all-terrain vehicles; VAMTAC ST5, ANAFI USA UAVs; MOSKITO TI target acquisition and surveillance devices; Galaxy S20 TE mobile devices with Android Tactical Assault Kit (ATAK);

Defender 130 TD4 4×4 assault vehicles; AN/PVS-21 night vision goggles; PRC-148 JEM and PRC-525 radios; Carl Gustaf M2U weapons; and the C-Guard Slider portable modular jammer.

Dismounted soldier systems

A key modernisation effort, worth EUR 42 million, seeks to strengthen the firepower, situational awareness, command and control and survivability of the dismounted soldier by 2026. This programme, known as the Soldier Combat Systems SCS (Sistemas de Combate do Soldado) consists of the lethality, survivability and command, control, communications, computers and intelligence (C4I) projects.

The lethality element of the project principally resulted in the acquisition of 15,000 FN SCAR-L STD 5.56 × 45 mm assault rifles, 850 FN SCAR-H STD 7.62 × 51 mm assault rifles, 2,000 FN40GL Mk2 40 × 46 mm grenade launchers, 1,000 FN MINIMI Mk3 5.56 mm light machine guns, 400 FN MINIMI Mk3 7.62 mm general-purpose machine guns, 300 Supernova Tactical 12-gauge shotguns and 3,910 G17 Gen5 FS personal defence weapons, CompM4 red dot sights, VCOG 1-6 × 24 and ACOG 3.5 × 35 scopes, THERMIS MK2 thermal scopes, Vario-Ray LP laser light modules, Spear A2 flashlights, Trilobyte helmet lights, and Nexus Bird LR observation and reconnaissance devices.

The C4I project was met with the acquisition in November 2021 to Portuguese tactical communications specialist EID of a range of equipment, including the SOVERON

The SCAR-L 5.56 × 45 mm weapon has become the standard assault rifle in the Portuguese Army. [Victor Barreira]

HR5000 handheld multi-band radio, the TWH-104R personal role radio, ComTac XPI headset, TWH-101W1 wireless push-to-talk unit, DSI-104 integrator, battery, as well as the Bittium Tough Mobile 2 tactical smartphone to run the Eye-Command Groundforce battlefield management system.

The survivability element is being met by local companies and includes acquiring clothing, ballistic protection helmets, combat boots, ballistic protection vests, assault bags, individual first aid kit, knew and elbow pads, battle belts, and more.

A number of soldier equipment items have been acquired between 2024 and 2025 through separate contracts awarded by the Logistics Command to local companies as part of the SCS project, including ballistic protection helmets, tactical gloves, ballistic vests, protection eyewear, individual first aid kits, combat clothing, tactical and dump pouches, combat belts, and ammunition holders.

Other recent incorporation of equipment included Carl-Gustaf M3 84 mm recoilless rifles, along with 75 Carl Gustaf M2s modernised to the M2U standard; GMG 40 mm automatic grenade launchers (AGLs); and AN/PVS-14 night vision monoculars.

The Army also seeks to a obtain a tactical infantry simulator; two ground surveillance radar systems; along with 6,107 ballistic protection helmets with side-mounted STANAG 4694/MIL-STD 1913 rails and universal night vision goggle (NVG) shroud. Other items sought include an anti-tank guided missile (ATGM) system, various micro- and mini-UAVs, loitering munitions, and counter-UAV (C-UAV) systems.

R&D efforts

The Portuguese Army is also taking measures to strengthen Research and Development and Innovation activity (R&D+I) to assist in the service's modernisation and simultaneously support the local Defence Technological and Industrial Base (DTIB).
A key R&D+I project is the AMIDA-UT (Automated Modelling, Identification and Damage Assessment of Urban Terrain) worth EUR 4.9 million. The project is part of the EU's Permanent Structured Cooperation (PESCO) mechanism and seeks to develop modular and scalable software capable of delivering automated target detection and identification, structural damage survey, prediction for CBRN contamination, and digital terrain analysis, all by 2027.

Another R&D+I effort calls for delivering automation and electric propulsion capabilities to the M113A2 troop carrier and developing UAVs, counter-improvised explosive devices (C-IED), UAVs, unmanned ground vehicles (UGVs), and loitering munitions.
The Army is relying on the Recovery and Resilience Facility temporary instrument of the EU Commission, to fund several projects, such as the construction and refurbishment of military housing and education infrastructure. It is also increasing the perimeter protection of the Commando Regiment by installing CCTV systems and utilising autonomous UAVs through the use of 5G technology.

Coupling up: Articulated all-terrain vehicles

Jim Backhouse

Since 2020, there has been a flurry of activity in the global market for military-specification articulated all-terrain vehicles (ATVs), with contracts for close to 1,000 new vehicles signed and several more programmes approaching the threshold of contract award. This article explores the factors encouraging this demand, how the vehicles are evolving to meet customer requirements, and whether this niche capability has the potential for wider adoption beyond specialist units.

The concept of articulated steering for tracked military vehicles is not a recent innovation; designs employing this method had been proposed and experimented with even before the first tanks entered service during the First World War. However, it is only during the Cold War that the class of vehicles we would recognise as tracked articulated all-terrain vehicles (ATVs) began to be adopted for military service. While their exact form varies depending on the design, these vehicles generally consist of two halves known as 'units', each of which has its own pair of tracks. These units are connected together via an articulated joint in the middle of the vehicle, which allows the units to turn left or right and – depending on the degree of freedom in the articulated joint – also pitch up and down relative to one another. As suggested by their classification as ATVs, their initial military adoption was encouraged by their increased mobility in soft terrain compared to conventional tracked vehicles with just one pair of tracks. Since they still maintain this advantage over conventional tracked vehicles and because demand for mobility in challenging terrain is increasing, there remains a small yet healthy market for articulated ATVs.

Two pairs are better than one

The advantages in mobility conferred by articulated steering have their roots in a fundamental design constraint afflicting tracked vehicles. Leaving aside the handful of vehicles that can steer by warping their tracks, in order to be able to steer a tracked vehicle with one pair of tracks, it must be fitted with a transmission that allows it to 'skid steer' or – in other words – vary the speed of one track relative to the other so that the vehicle turns in the direction of the slower or stopped track. For this system to work effectively, the ratio of the track length in contact with the ground to the distance between the centre of each track must remain within a range of between 1.0:1 and 1.8:1, although in practice most tracked military vehicles sit between 1.5:1 and 1.8:1. If this ratio is exceeded, the resistance to turning the vehicle caused by the friction between the slower track and the ground will make steering exceedingly difficult if not impossible. Similarly, if the ratio is lower than 1.0:1, it will be difficult for the vehicle to travel in a straight line without constant steering corrections.

▲ **The unarmoured BAE Systems Bv 206 is the archetypal articulated ATV. Vast numbers of these remain in military service and are likely to need replacing in the near future. [Crown Copyright 2022]**

This ratio imposes limitations on the overall length and width of conventional tracked vehicles. In turn, this means that larger, heavier conventional tracked vehicles suffer from an increasingly higher nominal ground pressure (NGP) because it is impossible to sufficiently increase the length of track in contact with the ground (and hence its surface area) to compensate for the increased weight of a longer, wider vehicle. Although NGP is a crude measure of the interaction between a tracked vehicle and the terrain, a higher NGP typically corresponds with reduced mobility across soft terrain with a high moisture content, such as deep snow, swampy bogs or marshland, and dense mud. This is because the increased pressure causes the soil to shear, which risks the vehicle sinking into the terrain and becoming bogged down. Moreover, as the tracks require sufficient traction on the terrain to be able to steer, this can complicate steering on soil that is more prone to shearing, as the track that is turning faster will struggle to get a grip and slip on the terrain, potentially leading to the vehicle stalling and becoming bogged down.

On the other hand, articulated ATVs are not subject to the dictates of this steering ratio. Instead, steering for these vehicles somewhat resembles that of a normal car steering along a curved path, with turning achieved by angling the front pair of tracks in a different direction to the rear pair. This means that articulated ATVs can be longer and narrower than a conventional tracked vehicle. The length of track in contact with the ground can also be longer, reducing the vehicle's NGP relative to its weight. Furthermore, articulated ATVs require less traction to be able to steer, which further reduces their susceptibility to bogging down. The upshot of this is that tracked ATVs will have superior tactical mobility in soft terrain. An additional advantage enjoyed by some articulated ATVs is that if the joint connecting the two units can vary in pitch, the front unit can be raised to increase its vertical obstacle crossing capability.

TABLE 1

Comparison of Selected Tracked AFV Mobility Specifications

Specification	BvS 10	Bronco 3	M113A3	MT-LB	FAMOUS ATV	ACSV G5
Payload (kg)	5,500 (APC)	6,000-8,000	N/A	2,500	3,500	8,000
Nominal Ground Pressure (kg/cm2)	0.25	N/A	0.59	0.44	0.33	N/A
Gradient (%)	100	60	60	60	60	60
Side Slope (%)	70	30	N/A	30	N/A	30
Vertical Step (m)	1	1	0.7	0.61	N/A	1.1
Trench (m)	2	2	1.67	2.41	2	2.3
Turning Radius (m)	11	12	N/A	1.25	N/A	N/A

Despite these advantages, the compromises involved in using articulated steering have militated against the adoption of articulated ATVs for most tracked military vehicle requirements. Firstly, unlike some conventional tracked vehicles, articulated ATVs are unable to perform a pivot turn, in which the vehicle rotates about its own centre point by rotating each track in opposite directions. This increases their turning radii and reduces their manoeuvrability in confined spaces, such as dense urban terrain. Secondly, the use of an articulated joint adds complexity and cost to the vehicle (though this may be offset by the lack of a complicated steering system within the transmission). Thirdly, the division of the vehicles into two halves may constrain the carriage of payloads with dimensions and weight that exceeds the envelope of one of the units. Finally, the articulated joint is difficult to protect against ballistic threats in a weight-efficient manner. Although there have been trials with articulated tanks in the past, vehicles developed for roles that require a high level of ballistic protection such as infantry fighting vehicles (IFVs) and main battle tanks (MBTs) have therefore generally eschewed articulated steering.

The US Army has ordered the unarmoured Beowulf derivative of the BAE Systems BvS10 for its CATV programme. [US Army photo/John Pennell]

A healthy market

These drawbacks notwithstanding, articulated ATVs continue to be in demand. Between 2021 and 2024, contracts worth a combined total of USD 1.87 billion were signed for the procurement of 984 new vehicles, along with the upgrade and overhaul of a further 800 legacy vehicles.

In terms of value, the largest contract was for the multinational Collaborative All-Terrain Vehicle (CATV) programme. Awarded to Sweden's BAE Systems Hägglunds in December 2022, its initial USD 760 million contract covered the delivery of a total of 436 armoured BvS10s, of which 236 were destined for Sweden, 140 for Germany, and 60 for the UK. Germany subsequently ordered an additional 227 vehicles under the same programme's framework agreement in April 2023. Independently of this programme, Sweden ordered a further 167 BvS10s between 2021 and 2022. The other notable procurements in this period concerned US Army orders for its Cold Weather All-Terrain Vehicle (confusingly also named CATV) programme, for which the unarmoured Beowulf variant of the BvS10 was selected. Following an initial order for 110 vehicles in August 2022, 44 more were ordered in December 2024. The programme could ultimately see up to 163 vehicles purchased from BAE Systems, although this figure was finalised before the reactivation of the Alaska-based 11th Airborne Division in 2021.

Although less information is available in the public domain, Russia and China are also active in this sector of the market. Russia utilises the GAZ-3344-20 Aleut, an unarmoured vehicle that has comparable specifications to the earlier generations of the BAE Systems' product range. Deliveries of the unique Vityaz DT-10 and DT-30 series of vehicles have also been documented since the full-scale invasion of Ukraine in February 2022. With a payload capacity of 10 and 30 tonnes, respectively, these vehicles can accommodate a substantially higher payload than any comparable Western articulated ATV. This also enables them to

TABLE 2

Tracked Articulated ATV Contracts 2021-25

Customer Country	Prime Contractor	Vehicle Type	Contract Award (Year)	No. of Vehicles Ordered	Contract Value (USD Millions)
Sweden	BAE Systems Hägglunds	BvS10	2021	127	236.6
Sweden	BAE Systems Hägglunds/A	BvS10	2021	40	50.0
Germany, Sweden & UK	BAE Systems Hägglunds	BvS10	2022	436	760.0
USA	BAE Systems Land & Armaments	Beowulf	2022	110	278.2
Germany	BAE Systems Hägglunds	BvS10	2023	227	400.0
Sweden	Nordic Terrain Solutions	Bv 206 [Upgrade]	2023	800	80.3
USA	BAE Systems Land & Armaments	Beowulf	2024	44	68.0

be adapted to a wider range of purposes, which have included the 2S39 Magnolia 120 mm turreted mortar carrier and variants of the Pantsir and Tor air defence systems. An experimental DT-BTR armoured version, fitted with a BM-30-D unmanned turret armed with a 2A42 30 mm cannon, has also been developed and was still undergoing trials as of April 2024, according to a report aired by Krasnaya Zvezda.

Thanks to its 30-tonne payload, the Russian Vityaz DT-30 series of vehicles can be used as the basis for heavier systems, such as the 9A331MDT-1 (pictured) or 9A331MDT-2 transporter, launcher, and radar (TLAR) vehicles within the Tor-M2DT air defence system. [Alexey Tarasov]

China's People's Liberation Army Ground Force (PLAGF) is reported to have acquired the Guizhou Zhanyang Power Heavy Industry JM8, with deliveries documented as early as 2018. The Sichuan Jinji Special Equipment Technology Co Ltd also claims to have delivered the ZJ01 variant of its Monitor Lizard family of articulated ATVs to elements of the People's Liberation Army (PLA) and was marketing the vehicle in February at IDEX 2025. Reliable information on production volumes and contract details for these Russian and Chinese platforms is not available through open sources, but it appears that production is directed towards meeting domestic requirements, with neither country's platforms having had any documented military export successes.

TABLE 3

Opportunities for Tracked Articulated ATV Procurement

Country	Programme Name	No. of Vehicles Required	Programme Value (USD Millions)
Canada	Domestic Arctic Mobility Enhancement (DAME)	130-170	69.6–173.3
India	Articulated All-Terrain Vehicle (AATV)	18	N/A
Italy	Full All Terrain Vehicle (F-ATV)	450	1,330.7
Netherlands	Future Littoral All-Terrain Mobility Tracked Vehicle (FLATM BV)	50-100	54.1-270.7

Demand for articulated ATVs looks set to increase over the next ten years as a number of additional programmes progress into the contract award phase. Of which, the most lucrative could potentially be Italy's F-ATV programme, which is anticipated to procure up to 450 vehicles worth more than USD 1 billion according to the Italian MoD's 2024-26 budget planning document. This has been identified as an opportunity by BAE Systems and ST Engineering, with the latter revealing in March 2025 that it has teamed up with Italian companies ARIS and Leonardo to offer licensed production of the Bronco 3 in Italy. However, the Italian Army has so far only committed to funding a EUR 4 million two-year study phase for the programme, indicating that final quantities and funding allocations may yet change.

Other notable opportunities include the FLATM BV project in the Netherlands, which was originally part of the CATV programme but withdrew on the basis that it did not require an armoured vehicle to replace its Bv 206 and BvS 10 fleet. Canada is also seeking a replacement for its old Bv 206s, with the requirement having grown from 100 vehicles in 2019, up to 153 in 2021, and now to as many as 170 vehicles. There are strong indications that programmes to replace articulated ATVs could also emerge in Finland and Norway, while operators in Asia may also seek to renovate their fleets by 2030.

Specialist tools

Three main trends are apparent from these programmes. First of all, when compared to the dearth of activity in the period between 2015 and 2020, there has been an uptick in demand for articulated ATVs since 2021. This has been driven by preparations for increased strategic competition in the Arctic and along contested mountainous border regions in Asia, coupled with a growing eagerness to replace obsolescent legacy fleets. For example, the US Department of Defense (DoD) published an updated Arctic Strategy in July 2024, which specifically mentioned the need for adapted and specialised equipment capable of providing mobility in Arctic conditions.

Secondly, this class of vehicles remains a niche capability procured in relatively small numbers for specialist formations with unique operational requirements, rather than as a general-purpose tracked military vehicle used by conventional mechanised and armoured formations. Furthermore, the procurement of these vehicles is typically tied to the replacement of older types rather than acquiring a new capability. By way of example, the UK procurement of the BvS10 under the CATV programme was specifically linked to use by the Royal Navy's Littoral Response Group amphibious taskforces in the Arctic. Likewise, the US is procuring a relatively small quantity of Beowulfs to replace the Bv 206-based Small Unit Support Vehicle (SUSV) employed in Arctic operations. Sweden is perhaps the one exception, having used the BvS 10 for a broader range of roles, including as the launcher for its IRIS-T SLS-based Eldenhet 98 (EldE 98) air defence system.

Thirdly, BAE Systems is so far the dominant player in this sector of the market, having beaten its main competitor ST Engineering for every known non-Singaporean procurement opportunity since 2015. BAE Systems' dominance may be helped by its favourable position as the incumbent supplier in nearly the entire global market open to Western suppliers, with BAE Systems claiming to have manufactured 12,000 units of its Bv-family as of early 2025. Indeed, the only major exception to this pattern is Singapore, which has selected the domestically-developed Bronco 3 as its Next Generation Armoured Tracked Carrier. Another factor that is likely to lead to further success for BAE Systems is the economies of scale and the benefits of interoperability encouraged by the multinational CATV programme, which lessens the burden for countries that would otherwise have to pay higher costs for a small, bespoke fleet of vehicles amidst increasing competition for funding.

Less successfully, BAE Systems attempted to pitch its BvS10 family as an alternative for the APCs, IFVs, and support vehicles used by mechanised formations at DSEI 2023. Claiming that the vehicle can negotiate 80% of the globe's terrain, the company has suggested that its "hypermobility" could increase survivability by making mechanised formations more versatile and thus less predictable to the enemy. While there so far appears to be no signs that this vision has been embraced by its customers, the war in Ukraine has called into question the survivability of some heavier, more expensive IFVs in a battlespace characterised by pervasive surveillance technologies and with a constrained area of operations for vehicles that rely on a vulnerable logistical tail, cannot swim across water, and struggle to negotiate challenging terrain such as marshes or woodland.

The UK Royal Marines operate the BAE Systems BvS10 Viking, seen here in its mortar carrier guise. [Crown Copyright 2025]

Open to all roles

BAE's leading market position has been secured by two product ranges: the armoured BvS10 and its unarmoured derivative, the Beowulf. This approach is mirrored by ST Engineering, which offers the armoured Bronco 3 and the unarmoured ExtremV. In January 2025, the Finnish company Sisu also introduced a derivative of the Bronco 3 known as the GTT. Sisu states that this version has components commonality with the Sisu GTP 4×4 protected patrol vehicle (PPV) that has been procured by Finland and Sweden, although it has not provided further details on the extent of this commonality.

When comparing the existing offerings in the armoured and unarmoured space with their predecessors, one of the main trends is an increase in their payload and overall gross vehicle weight (GVW). For example, BAE Systems' earlier Bv 206S armoured vehicle had a payload capacity of 1,550 kg and a GVW of 7,000 kg, which grew to 2,800 kg and 11,300 kg, respectively, on the original version of the BvS 10. Further increases in payload capacity to between 6,000 and 8,000 kg, and GVW to between 16,000 and 18,000 kg were achieved on the later BvS 10 Mk IIb, representing up to a 416% increase in payload compared to the Bv 206S. This reflects broader trends in military vehicle development, where pressures to integrate increased passive and active protection, heavier weapon systems, additional sensors, and more networking capabilities are driving GVW upwards and necessitating vehicles with greater growth potential than was necessary in the past.

Complementing this trend, BAE and ST Engineering are offering their vehicles with open architectures, good power generation capacity, and built-in modularity so that they can be customised for a broad set of customer requirements. This is demonstrated by the ability to swap out the rear unit of the Bronco 3 in 30 minutes, enabling one vehicle to be re-roled for purposes such as APC, ambulance, mortar carrier, and engineering vehicle. An option for fitting ISO twist locks is also available and appears to be employed on the Sisu GTT, which can accommodate a 3 m (10 ft) ISO container weighing up to 5 tonnes on its rear cargo platform.

Introduced in January 2025, the Sisu GTT is based on ST Engineering's Bronco 3 design. Various modules or a 3 m (10 ft) ISO container can be installed on the rear module's flatbed. [Sisu]

Despite these developments, armoured articulated ATVs remain lightly armed and armoured compared to dedicated tracked IFVs, especially in their base configurations. Neither the BvS 10 nor the Bronco 3 has been demonstrated with a turreted weapon station armed with a medium-calibre cannon typically, as is typically fitted to an IFV. Furthermore, the basic ballistic protection of the BvS 10 Mk IIb displayed at DSEI in 2023 was stated to be equivalent to NATO STANAG 4569 Level 2, with further increases to Level 4 standards of ballistic protection requiring valuable payload capacity to be consumed by a ceramic armour kit.
Following the developmental current of the wider military vehicle market, there is also experimentation with adding unmanned capabilities and hybrid drivetrains into tracked articulated ATVs. In March 2019, ST Engineering presented a version of the Bronco 3 with an unmanned rear module equipped with a hybrid-electric drive that could be remotely operated up to a range of 20 km. One operational benefit of such a configuration may be to reduce the risk to operators of high value tactical targets such as air-defence systems or radars, as the crew could separate themselves from the system by operating it from the front unit.

Hybridisation has also been trialled in the High Mobility Land Platform (HiMoLaP), which German company FFG presented to Germany's defence procurement agency in June 2021. This was fitted with a form of mild hybridisation in which an electric motor was used to provide a boost to the conventional drivetrain, but full hybridisation is mentioned as a potential offering for the vehicle. If this technology can be matured to a state where it is sufficiently reliable for military requirements in extreme weather conditions, it is likely that it will be adopted for use on articulated ATVs, as the potential for hybrid vehicles to export power offboard will be especially useful for supporting operations in austere environments.

An expanding niche?

This ongoing development and the continued demand for articulated ATVs indicates that they remain valuable niche capabilities for militaries requiring mobility in environments characterised by soft terrain. Peering into the future, the main question is whether they can also capture part of the market for general-purpose tracked AFVs. With many militaries still operating vast numbers of ageing, lightly armoured tracked vehicles such as the M113 and MT-LB in support roles, these will need to be replaced in some form. Articulated ATVs offer one option for this, but they are likely to face competition from other low-cost, lightweight tracked vehicles, with Patria's FAMOUS ATV being one notable recent example of this. Faced with the need to increase mass, militaries may also be more inclined to accept the compromise of worse tactical mobility in soft terrain and consider cheaper wheeled vehicles for these requirements. Even though articulated ATVs still have the advantage of many superior mobility characteristics over these competitors (see Table 1), their prospects of success will hinge on whether military requirements evolve to place greater emphasis on tactical mobility at the expense of other factors such as cost or protection. So far, however, there is little sign of the change in mindset necessary to justify their acquisition outside of specialist roles.

Are you deceiving me?

Dr Thomas Withington

Battlefield electromagnetic deception is a vital means to sow doubt into hostile decision-making, and force enemies to divide their assets; tactics that are at the heart of the Spartacus initiative.

The United States Army's First US Army Group, better known as FUSAG, was a formidable outfit: FUSAG contained two armies, the British 4th and the US 14th. These two formations contained four corps and three independent divisions between them. Deployed across eastern and south-eastern England, FUSAG had an ostensibly simple, but major, objective. The force would invade western Europe across the Pas-de-Calais, the narrowest part of the Channel between the United Kingdom and France. At a mere 33 km (17.8 NM), this route made sense. It was the quickest way for the Allies to attack the western flank of Fortress Europe.

A dummy Sherman tank, of the type used by FUSAG. [US National Archives]

Early on the morning of 6 June 1944, troops from Australia, Belgium, Canada, Czechoslovakia, France, Greece, The Netherlands, New Zealand, Norway, Poland, the United Kingdom and the United States thundered onto the continent as Operation Overlord was launched. This was not the Allies' first invasion of the continent. The liberation of southern Europe had commenced on 9 July 1943 with Operation Husky, the amphibious and airborne invasion of Sicily. With this huge operation, the Allies' Nazi adversaries knew that the invasion of Western Europe was underway. FUSAG's build-up was impossible to keep secret as its staging areas in the east and south-east of England were full of materiel. The airwaves were abuzz with FUSAG's radio traffic as preparations unfolded. Axis double agents scored major intelligence coups, sharing details of FUSAG's activities and planning with their German handlers. The Allies' adversaries had no choice but to take the First US Army Group seriously, after all, it was commanded by 'Old Blood and Guts', General George Patton. In his biography of Gen Patton, Alan Axelrod wrote that he was a general the German High Command feared and respected. FUSAG was primed, locked and loaded, ready to play a major role in Overlord which was great, apart from the fact that it did not exist.

FUSAG was part of a larger deception campaign mounted by the Allies to confuse their enemy regarding the likely shape of the invasion and its potential location. The First US Army Group was formed as part of Operation Quicksilver, a major component of the wider Operation Fortitude deception effort, which had six distinct parts: Quicksilver-1 focused on disseminating the existence of FUSAG through the double agent network. Quicksilver-2 was the creation and transmission of the fake radio traffic which would be expected to accompany a formation of this size preparing for attack. Quicksilver-3 focused on creating fake materiel and bases in FUSAG's supposed staging areas in England. Quicksilver-4 would see the allies performing attacks against targets in and around the Pas-de-Calais to prepare the battlefield for FUSAG's arrival across this stretch of water. Quicksilver-5 would show preparations such as landing craft embarkation performed in and around Dover on the northwestern coast of the Pas-de-Calais. Quicksilver-6 used night lighting to simulate the appearance of FUSAG working all hours to ensure that preparations were ongoing. FUSAG did not disappear once Overlord got underway. Instead, the deceptions continued into September 1944, three months after the invasion had commenced, to convince Berlin that the events in Normandy were but a side show. It was imperative to convince the German High Command that the Allies' 'Schwerpunkt' (point of main effort) was still the Pas-de-Calais.

Fake it 'til you make it

Using radio traffic for deception has never gone out of fashion as a tactic, as it has much going for it. Firstly, it is relatively inexpensive from a personnel and equipment perspective to achieve. All you need are a few radios to move false traffic between them, and personnel to draft and disseminate this. False traffic can be used for elegant double-bluffs. Such deception can be transmitted on protected, encrypted channels. Should the enemy be successful in breaking into this traffic, they may feel they have stumbled on an intelligence goldmine. Mixing fake and real traffic hands the enemy a dilemma: Which traffic should be distrusted and which should be ignored?

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Tracking down hostile radios provides valuable intelligence on enemy force disposition and movement, but are the signals real or fake? [USMC/Pfc Bishop Williams]

Fake traffic can relate to genuine past, present and future events. Suppose an enemy first person view uninhabited aerial vehicle (UAV) sees two Blue Force infantry fighting vehicles (IFVs) moving down a road towards a Red Force position. The radio traffic reiterates that the objective for the squad of Blue Force troops is to clear Red Forces from a local railway station. The traffic also shares that the squad is to capture a signal box 1 km or so further down the line. Both these missions now seem contradictory. Is the signal box or the railway station the objective? What if both targets are the objective? How should the Red Force prepare? Should it redeploy some of its troops to protect the signal box, but risk reducing the railway station's defences? What if neither the signal box, nor the railway station are the real objectives? Ultimately, what should the Red Force believe or discard?

As the FUSAG plan underscored, radio traffic can be simulated to create entire army-size formations with all their attendant and complex tactical networks and backhaul trunk communications at the operational level. Moreover, fake traffic does not need to be confined to voice communications. Land forces are as reliant, if not more so, on data, thanks to digital command and control (C2) and battle management systems. Fake zeros and ones can be as devastating in the discord they can sow as deceptive radio chatter. Mixing fake and real traffic on the battlefield creates an additional problem: Electronic warfare (EW) cadres use communications intelligence (COMINT) to locate and identify troops and deployments on the battlefield. Find a radio and you find a soldier, as the adage says. You may also find a platform, weapons system, sensor or base, given the preponderance of radio connectivity not only within armies, but all military forces.

Identifying a radio's signal parameters can tell you a lot about that transceiver, and hence a lot about the user and/or asset it equips. Perhaps an electronic support measure (ESM) equipping a COMINT unit has detected a cluster of signals spread over an area of roughly 1 km2 (0.38 square miles). The signals are transmitting on frequencies of between 2.4–2.4835 GHz. The ESM's antennas triangulate the source of the transmissions, indicating they are around 7 km (4.4 miles) away. Having ascertained the frequencies, the ESM determines the signals have a strength of around -114 dB when they arrive at the COMINT antennas. An accompanying signal on a frequency of 157 MHz with a received signal strength of -108 dB has also been detected. The COMINT cadres will be able to deduce by ascertaining the frequency, geographical concentration of the signals and their strength that they have, with some degree of confidence, detected a squad of troops using their Personal Role Radios (PRRs). The single 157 MHz signal seems to be from the squad commander's handheld radio. The fact that the signals are mobile and comparatively spread out indicates that that the soldiers have dismounted and are moving. Matching a signal's characteristics provides a good indication of who, or what, is using a radio to transmit these signals. All this information is ascertained without even needing to break into the actual radio traffic.

Thus, it becomes immediately clear that faking such transmissions could yield significant tactical, and in the case of FUSAG, operational and even strategic, benefits. Let us return to our 2.4–2.4835 GHz -144 dB, and 157 MHz -108 dB signals the ESM detected from roughly 7 km away. For all intents and purposes, the COMINT cadres have detected a dismounted squad, and their commander, with their accompanying ESM. This information is shared with their commanders to inform them that the red force squad has dismounted and is mobile. The ESM has derived the coordinates of the enemy which are also shared. Commanders now must decide how the red force squad will be engaged. Should a call for fires be made to engage them with artillery? Are Blue Forces nearby which can engage them? Should the PRRs, and the squad network they inhabit, be engaged with jamming? Would it make sense to attack the squad's C2 system with cyber effects? Perhaps all these effects should be used synchronously or sequentially? The riposte will absorb and expend personnel, materiel and time. Expenditure is productive if it achieves effect, but wasteful if it achieves nothing and all battlefield resources

USMC logo for the Signals Intercept and Electromagnetic Warfare Course, Alpha Company, 1st Radio Battalion. Battlefield signal interception and deception have only increased in importance with the adoption of networked warfare. [USMC/Sgt Amelia Kang]

are ultimately finite. Deception helps generate waste. What if the PRRs are fake? What if there is no deployment of dismounted squad troops? Resources used to engage this fictitious unit have been wasted.

The PRRs, and the single handheld, were not radios at all. They were decoys transmitting similar signals mounted on small uninhabited ground vehicles moving in patterns indicative of dismounted soldiers. Time and treasure have been wasted on a deployment that never occurred. To make matters worse, while this fictitious unit was being engaged, an actual dismounted tactical action was happening nearby, but it was never noticed. Those latter troops exhibited exemplary emissions control (EMCON). Robust EMCON ensured that radios were never used and the COMINT cadres took the bait.

I'm Spartacus

Deception clearly provides significant tactical benefits, and hence potential tactical advantage. This has not been lost on the United Kingdom Ministry of Defence (MoD), which has launched the Spartacus programme, with the ministry's Defence and Security Accelerator (DASA) responsible for the programme. In its own words, "DASA finds and funds exploitable innovation to support UK defence and security quickly and effectively." DASA's vision is "to have strategic advantage through the most innovative defence and security capabilities in the world". The organisation is backing the Spartacus initiative developed by a UK-based consultancy company called PhoenixC4i. The company says that Spartacus "provides commanders with the ability to mimic C2 systems, increasing uncertainty as to where the true target is". As well as mimicking C2 radio emissions, Spartacus can be used to generate multiple emitters, which could be deployed in such a fashion as to replicate the locations of radios typically used by deployed land formations.

Reports have noted that Spartacus has already undergone trials at the Army Warfighting Experiment (AWE). The AWE is a regularly-occurring British Army effort to evaluate key technologies. The most recent AWE occurred in October 2024 and focused on urban warfare, according to the MoD. The ministry says the AWE's stated goal is "to inform investment decisions and find capabilities suitable for rapid exploitation." Spartacus is an apt appellation for this capability. Stanley Kubrick's 1960 epic Spartacus featured a now-legendary scene. When Roman soldiers are attempting to find the eponymous slave who has led a rebellion against their rule, they tell the defeated slaves they can avoid death if they give up Spartacus for crucifixion. One by one the slaves step up and announce that they are Spartacus. The Romans realise that they will never find the man they seek and simultaneously witness the slaves' resolve. Like their namesake rebels, the Spartacus decoys will all claim to be a desired emitter. An oft-quoted analogy in EW is that trying to find the signal of interest can be trying to find a needle in the haystack: What do you do when you have to find a pin in a pile of needles?

PhoenixC4i told the author that three products constitute the Spartacus family; Air, Echo and Coeus, which are currently at Technology Readiness Levels (TRLs) between Three and Eight. The UK's Science and Technology Facilities Council denotes TRL-3 as the successful demonstration of a proof-of-concept. TRL-8 denotes that an actual technology has been completed and qualified through test and demonstration. The three products are being incorporated into a product called Digital Deception in a Box (DDIAB). DDIAB provides tactical level brigade and/or battlegroup with "radio frequency and infrared deception." All the development of these products is being performed inhouse by the PhoenixC4i. The decoys are designed to "mimic a battlegroup command post." Alternatively, the decoys can electromagnetically replicate an event such as an obstacle crossing. Another option is to distribute decoys widely to "provide more coverage around the battlespace". Decoys can be controlled via standard cell phone networking or "any bearer of opportunity if planned". PhoenixC4i is now awaiting any decision by the British Army, and the UK MoD, to move ahead with procuring Spartacus as a programme of record. Should this occur, "the capability can be productionised very quickly" according to PhoenixC4i.

Decoy technologies have come a long way since the days of FUSAG. Nonetheless, the architects of that brilliant deception would instantly recognise the principles at play in Spartacus. As history shows, fooling your adversary can sometimes pay unimaginable dividends.

▲ The basic constituent parts of the Spartacus architecture are shown here on this workbench during a British Army exercise. The system uses relatively little in terms of hardware. [PhoenixC4i]

▲ Spartacus can be used for an array of electromagnetic deception tactics from simulating the radio traffic and electromagnetic signature of a battlegroup headquarters to mimicking specific tactical actions. [PhoenixC4i]

Undoing Babel's curse: The challenge of integrating allied air and missile defence systems

Dr Sidharth Kaushal

NATO faces a complex challenge: how to rapidly enhance its air and missile defence capabilities while ensuring integration across disparate systems developed by various countries. This analysis explores how divergent approaches to integration can be reconciled to create effective multi-layered protection against sophisticated aerial threats.

A Standard Missile-6 (SM-6) Dual II with Software Upgrade (SWUP) is launched from the USS Preble (DDG 88) off the coast of the Pacific Missile Range Facility in Kauai, on 28 March 2024. While several NATO members have developed sophisticated air and missile defence capabilities, integration at the Alliance level remains a challenge. [MDA]

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In the wake of the conflict in Ukraine, the subject of integrated air and missile defence (IAMD) has seen a surge of interest within NATO. Projects such as the German-led European Sky Shield Initiative (ESSI), which has the stated aim of coordinating and accelerating the procurement of air and missile defence systems are illustrative of this newfound prominence. A potential surge in the capacity for IAMD at the disposal of NATO's European members has the effect, however, of making questions regarding the integration of capabilities at the Alliance level an even more pressing consideration. Gaps in the integration of capabilities have long been considered consequential by both military practitioners and analysts and a growth in the scale of NATO's IAMD which may be driven by the procurement of heterogenous off-the-shelf capabilities will potentially increase the complexity of this challenge. It is thus of considerable importance to analyse how the Alliance's IAMD capabilities can simultaneously be grown at pace and made coherent.

Visions of air and missile defence procurement and coordination

Broadly speaking, there are two approaches to the generation of additional capacity for air and missile defences within Europe. The first approach, exemplified by the ESSI, emphasises the procurement of off-the-shelf capabilities, many of which will be non-European in provenance. This has the potential to allow European states to leverage the defence industrial capacity of states including the US, South Korea and Israel, among others – a decided advantage in a context where pipelines for the production of complex weapons will likely remain congested for some time.

However, this comes at a cost with respect to both security and integration. While many of the systems which can be procured from Allied nations can be linked to other Allied platforms through networks such as Link 16, low-latency data sharing for tasks such as cooperative engagement requires higher-frequency (and often bespoke) datalinks. Moreover, the battle management software employed by different systems is often not compatible, as was illustrated by the long-standing challenges related to sharing data between Aegis and non-Aegis vessels within NATO. Finally, there have been residual debates regarding the security implications of linking non-NATO platforms into Allied networks, which caused the German procurement of the Israeli Arrow-3 to be a subject of some controversy.

The second approach, proposed as an alternative by nations such as France, focuses on the production of IAMD capabilities within Europe, with projects such as HYDIS2 and TWISTER, two PESCO projects focused on delivering counter-hypersonics via a space-based tracking layer and an endoatmospheric interceptor. The advantages of this approach must be juxtaposed with lead times to deliver capability and potential challenges with respect to achieving economies of scale.

Relatedly, there are several conceivable approaches to IAMD at the NATO level. Per one analysis, these approaches can be grouped into three camps – an integrationist approach based around functional specialisation at the national level and the centralised development of C2 capabilities, a European-led procurement effort, and a federated architecture.

▲ **Artist's impression of an MBDA AQUILA interceptor (being developed under the HYDIS2 project) engaging a hypersonic glide vehicle (HGV) type target. [MBDA]**

The first approach, while arguably a rational one from a military standpoint, raises important questions regarding national sovereign capabilities. A European-led effort has both the strengths and pitfalls already described. An improved version of the status quo with improvements to Alliance-level capacity for the provision of recognised air pictures, for example, would be less constraining but would also limit the degree to which any system could be described as being truly integrated – which will be a particular challenge against complex manoeuvring targets such as hypersonic threats. On the other hand, the engagement of certain targets is likely to become an all arms challenge in which sensors not necessarily held by air defenders are relevant. An example of this might be the classification of unmanned aerial vehicles (UAVs) which will increasingly depend on acoustic sensors in tandem with radar. As such, a degree of system level heterogeneity should be expected in any case.

▶ **An Aster-30 B1 NT being launched during a test at Biscarrosse DGA Essais de Missiles on 8 October 2024. [DGA]**

The best way forward is, ironically, to do away with integration as a catch-all term. Rather than speaking of an integrated air defence network it might be more reasonable to describe parallel integration efforts which focus on the sensors and effectors most relevant to specific parts of the threat spectrum. This is counterintuitive given the emphasis placed on creating a single seamless system in most discussions of IAMD. However, as illustrated by programmes such as the US Air Force's Airborne Battle Management System, an excess of ambition can doom integration efforts. Moreover, despite there being truth to the idea that clearly-defined parts of the threat spectrum which could be distinguished by speed and altitude are being challenged by the emergence of capabilities such as hypersonic threats, which operate at the seams of a stovepiped system, there are still parts of the threat spectrum which share few sensors and effectors. For example, few capabilities are relevant to both counter-UAV (C-UAV) and ballistic missile defence (BMD). Similarly, the requirements for latency and sensor fusion differ across parts of the threat spectrum, with tasks such as BMD depending on low latency and a limited number of radar-based sensors while tasks such as C-UAV involve a larger number of sensors but less stringent requirements.

The imperative, then, is not to do away with integration but rather to group capabilities into parallel lines of effort defined in terms of criteria such as network latency, range and altitude categories. This in turn can enable a hybrid approach which will prove better-suited to NATO's needs than a single approach to force development and Alliance-level integration.

Different approaches to creating architectures

Broadly speaking, there are several types of architecture which can deliver an integrated system of systems. The first involves the setting of specific requirements that link individual systems to one another in well-defined kill chains. An example of this would be the US Navy's Naval Integrated Fire Control-Counter Air (NIFC-CA), which was built around five pillar programmes (JLENS, Aegis, F/A-18, E-2D and SM-6), into which specific requirements were inserted by the NIFC-CA

programme office in order to create well-defined kill chains (for example between F/A-18 and Aegis). The approach taken with NIFC-CA did not confer upon the programme office the capacity to procure, merely to set standards. This approach created a system that was difficult to scale given the very specific standards introduced into each programme, but it nonetheless created an effective Navy-wide network for achieving specific tasks.

The utility of this approach is most likely to be felt when the number of systems relevant to a task is not likely to radically increase. An example of such a task is BMD. The sensors needed to track exoatmospheric targets with resolution sufficient to enable interception by a kinetic kill vehicle either outside the atmosphere or upon re-entry are typically highly bespoke systems such as the X-Band AN/TPY-2 Radar used by the THAAD system, or the ELM-2080S Super Green Pine L-band radar which supports the Arrow-3 system. Moreover, a relatively limited number of systems carry BMD effectors capable of engaging medium-range ballistic missile (MRBM) and intermediate-range ballistic missile (IRBM) targets. Presently among European countries it is only the Aster-30 B1 NT which provides a counter-MRBM capability in the maritime domain, with SM-6 filling this role for the US Navy, while a handful of land-based capabilities also offer this.

Against IRBMs such as the Oreshnik, the number of available systems is likely to be very limited. By way of an example, the US fields 9 THAAD batteries across the whole force. For BMD at the theatre level, then, the likelihood of national solutions emerging is slim – the choice between national capabilities and multilaterally developed systems is an entirely artificial one. In such a context, where nations and publics can credibly be presented with a choice between hanging together or hanging alone, an approach comparable to that of NIFC-CA may be entirely feasible despite the political challenges which can sometimes undercut integration. Since there are undeniable advantages to lessening dependencies on non-European states, in areas where solutions can only be developed at a pan-European level (and thus the issue of national sovereign capability is less pressing), an effort to co-develop capabilities indigenously as proposed by France, or at least impose stringent standardisation requirements comparable to those used in NIFC-CA, is entirely reasonable.

A second approach to integration is backwards integration via the mechanism of service-oriented architectures (SOAs). An example is BMD Flex, a software package developed in order to link Aegis and non-Aegis destroyers together. BMD Flex is based on an SOA, and can use service application programming interfaces (APIs) to draw data from one system into another, even if they were not designed to work together. This approach does not necessarily scale, however, given the number of APIs used. An optimal role for a service-oriented architecture is drawing together areas of IAMD where a specific system may have utility against a target which occupies a different part of the altitude spectrum from the one which the sensor is normally optimised against. As an illustrative example, BMD sensors might be integrated into a future counter-hypersonics capability through a service-oriented architecture.

The final approach, which offers the greatest architectural flexibility, is a publish-subscribe model. Publish-subscribe models do not require the source code of a system in order to operate – the broad structure of the data suffices. These models rely on message brokers to translate data across formats based on translation layers. The advantage of this approach is that it can allow the integration of systems never intended to work together at scale. For example, in a July 2021 test at White Sands Missile Range a US Army PATRIOT battery was cued by feeds from a US Marine Corps AN/TPS-80 G/ATOR radar and F-35 despite not being specifically built to integrate with these systems. However, in order for this to be achieved, a U-2 Dragon Lady had to act as a gateway and data had to be translated at an Integrated Battle Command System (IBCS) engagement operations centre. This speaks to one of the challenges of looser systems – complexity is imposed by the need to move data across networks which operate at different levels of sensitivity. For instance, Multifunction Advanced Data Link (MADL) terminals, upon which F-35 depends, are only carried upon a small number of platforms by design. As a rule, system complexity increases exponentially rather than linearly with the addition of a new network node (the so called N-squared problem).

A Patriot Advanced Capability-3 (PAC-3) Cost Reduction Initiative (CRI) missile is launched during a July 2021 Integrated Battle Command System (IBCS) flight test at White Sands Missile Range. [PEO Missiles & Space/Darrell Ames]

Furthermore, the requirement to translate data across multiple formats requires centralised processing nodes – which may themselves be targeted. Finally, the larger a system becomes the larger and more complex data packages within it become, in order to route data through a larger network – which in turn drives even greater requirements for centralised processing. Lean data formats exist, but these formats typically pose a challenge for encryption (since encryption requires data to be broken into smaller packets).

Where the loose coupling associated with publish-subscribe models might offer the greatest value, then, is when high latency is acceptable as the cost of sensor fusion at scale. This will be especially true against slow and low-flying targets such as UAVs, as well as subsonic cruise missiles given that the comparatively low speeds of the targets somewhat loosen the demand for latency while the task of tracking elusive targets against clutter and complex terrain raises the premium on sensor fusion.

Different integration approaches which eventually converge

An answer to the question of how European IAMD capabilities should be cohered, then, might be provided by an approach which treats different parts of the threat spectrum differently in terms of the type of integration sought and the method of delivering it employed. Against air-breathing targets such as the 3M-14/3M-54 Kalibr and Kh-101 cruise missile families, as well as one way attack (OWA) UAVs, a procurement approach focused on rapid procurement (even at a cost in heterogeneity) as well as backward integration through publish-subscribe models may prove optimal. Subsonic targets represent the most viable means of attack which Russia can employ at scale for the next decade, since the production of missiles such as the Oreshnik IRBM is likely to be constrained by capacity limitations. Even if Russian production capacity for IRBMs increased to 40 a year – which was the number of 15Zh45 IRBMs used with the RDS-10 Pioneer system (NATO reporting name: SS-20 Saber), the USSR could produce with its much greater industrial capacity – it would be some time before Russia had a large IRBM arsenal.

The ESSI, with its focus on off-the-shelf systems thus adds greatest value against more immediately challenging aerial threats. Moreover, latency requirements against high subsonic threats are comparatively limited. Indeed, some subsonic threats will require the integration of sensors not organic to the air defence network in an all-arms effort. In this context, backwards integration through publish-subscribe models of a heterogenous mix of capabilities is an entirely viable approach as has been demonstrated in Ukraine, which has cohered a broad mix of Western and non-Western capabilities.

By contrast, the tracking of MRBM and IRBM targets might represent an area where requirements can either be inserted into programmes as NATO standards or, should standards be improperly applied, a smaller number of systems can be backwards-integrated via a SOA approach.

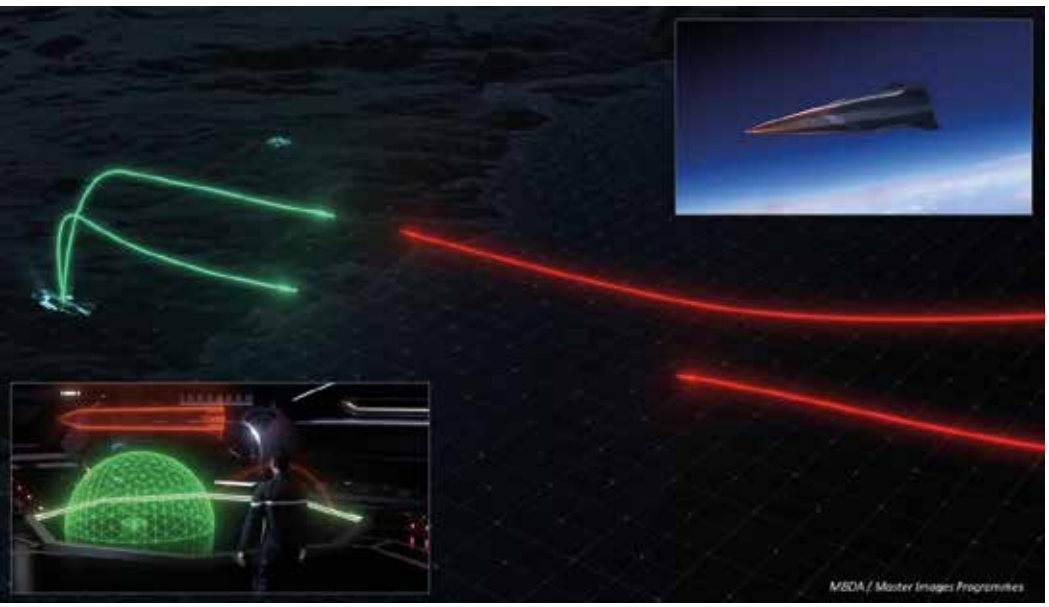
Finally, there is likely to be more commonality between the tracking of hypersonic threats and ballistic targets with respect to the relevant sensors, particularly space-based sensors, as well as effectors. For example, HYDIS2 is meant to deliver both a counter-hypersonic capability and a BMD capability. As such, since there is a more integral relationship between these parts of the defensive architecture and since both involve small numbers of exquisite capabilities, counter-hypersonics and BMD at the theatre level can be cohered via a SOA approach.

As such, there might be two parallel and overlapping approaches to air defence: an off-the-shelf approach to targeting air-breathing threats cohered using publish-subscribe models; and a longer-term effort against MRBMs and hypersonic glide vehicles (HGVs) which could either be standardised and pursued as a European effort or aligned via SOA solutions.

Such a system, it might be objected, leaves stovepipes between air and missile defence. However, this is only partially true. First, as mentioned, the sensors and effectors relevant to theatre BMD and air defence do not often overlap. Moreover, a BMD system which was tightly coupled could still be linked to a loosely coupled air defence network, but could not draw on data from this network. However given that only a limited number of sensors are relevant to BMD, it is unclear that this represents a considerable loss of capability. For example, few GBAD systems could provide useful tracks against an intermediate ranged target. As such theatre BMD capabilities could still provide early warning and tracks against tactical targets (for example SRBMs) for systems primarily built to deal with air breathing threats which might also have a tactical BMD role.

Conclusion

A successful approach to delivering a European air and missile defence capability will have to balance conflicting imperatives. In order to do so, the threat must be broken into its constituent parts. This runs counter to the logic of integration, which tends to encourage analysts to view threats as a gestalt. To be sure, integration remains highly important but a plurality of parallel integrations, each tied a different approach to procurement, might best balance Europe's conflicting imperatives.



A conceptual illustration of an AQUILA interception against HGV targets. [MBDA]

If it floats, it fights: Containerised naval munitions

Sidney E. Dean

Containerised missile systems could significantly increase the number and type of vessels capable of attacking enemy warships as well as land targets.

Two decades ago, the US Army and US Navy began developing the non-line-of-sight launch system (NLOS-LS, aka 'Rocket in a Box') as a modular firing system housing 15 vertically launched 280 mm rockets in a container. The Army planned to mount the system on flatbed vehicles, while the Navy hoped to add much-needed firepower to the Littoral Combat Ship (LCS). By 2011, both services had terminated the programme over technological setbacks and poor performance.

First launch of a SM-6 missile from the Mk 70 PDS aboard USS Savannah (LCS-28) on 24 October 2023. [US Navy/Lt Zachary Anderson]

Around that same time (2010), the Russian firm Concern Morinformsystem-Agat introduced the Club-K concept of deploying Kalibr family cruise missiles on launchers installed inside shipping containers. This immediately raised concerns that rogue states or even terrorist groups could deploy the technology on cargo vessels and launch surprise attacks on western ports. While there is no evidence that the Russian system – which has been offered internationally by Rosoboronexport – has ever been operationalised, reports of containerised Chinese missile systems being developed surfaced in 2016. By 2019, more specific reports "indicated that China was [developing] a variant of the YJ-18 long-range cruise missile that can be fired from standard shipping containers loaded on Chinese-flagged merchant vessels", wrote US Navy Captain (ret.) and JAG-officer Raul Pedrozo in International Law Studies (vol. 97, 2021). Pedrozo added that "the Chinese missile system is similar to the Russian Klub-K container missile system."

Containerised munitions

The concept of containerised naval weapon systems is currently gaining traction with several Western nations. They can be secured to open deck spaces on any vessel, from naval auxiliaries to merchant ships and to larger unmanned surface vehicles (USVs). Since the containerised weapon systems are self-sufficient and include integrated fire control systems, they can be quickly loaded onto ships and operationalised with minimal reconfiguration. The number of combat-capable vessels can thus be increased at very short notice. When the requirement for the additional strike capability is over, the ships can quickly return to their original mission configuration.

The concept is particularly suited for navies which need to increase the number of combat-capable platforms at an affordable cost and over a short timeframe. The US Navy, in particular, has been adamant about the need for distributed maritime operations (DMO), especially in expansive theatres of operations such as the Indo-Pacific. To date, long-range anti-ship and land-attack missiles remain the prerogative of dedicated surface combatants ranging from corvettes to cruisers. While powerful, these sophisticated vessels are available in limited numbers. Enabling additional missile launch platforms would permit dispersed attacks against enemy naval groups and land targets, increasing the potential to inflict damage while also straining enemy defences. Potential platforms include lightly-armed warships with open deck space as well as auxiliary vessels including cargo craft. Leasing or purchasing merchant vessels to serve as containerised missile carriers is another option.

While the vessels equipped with containerised munitions would be slower and less robust than dedicated major combatants, modern standoff weapons could be launched from sufficient range to minimise risk; dispersal of firing platforms would also make enemy counter-strikes more difficult. In this

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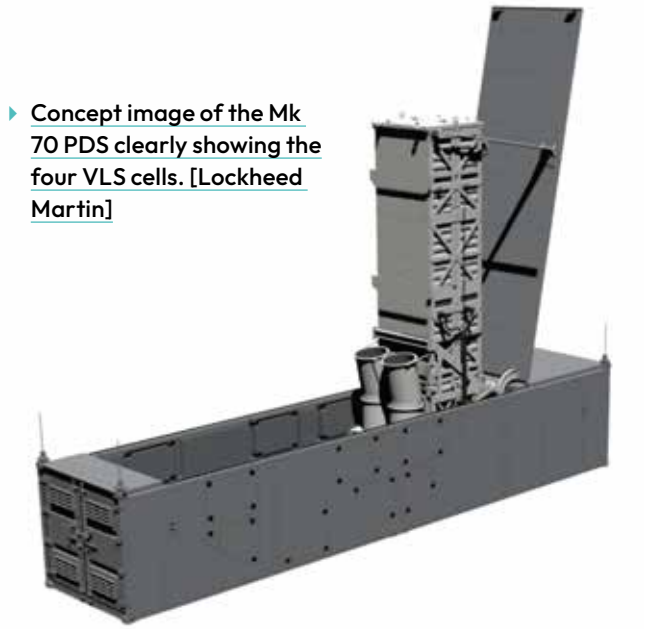
context, it should be noted that the containerised weapons concept includes the option of equipping vessels with air defence missiles as well as loitering munitions optimised against surface threats, adding a force protection element.

US Navy – Mk 70 Payload Delivery System

The US Navy has chosen to equip the *Independence* class and *Freedom* class littoral combat ships (LCSs) with the Mk 70 mod 1 Payload Delivery System (PDS). Developed by Lockheed Martin, the Mk 70 PDS is incorporated into a 12 m (40 ft) ISO container with four Mk 41 VLS cells and a launch erector system placed within the container. In principle, any munition capable of launching from a deck-embedded VLS cell aboard a cruiser or destroyer can be loaded into the Mk 70. To date, the launcher is certified for the SM-6 missile and the Tomahawk Land Attack Missile (TLAM). Additionally, Lockheed Martin tested the launcher with the Patriot PAC-3 MSE surface-to-air missile (SAM) in May 2024, downing a cruise missile representative target.



Concept image of the Mk 70 PDS clearly showing the four VLS cells. [Lockheed Martin]

The US Navy first tested the Mk 70 PDS in 2021, launching an SM-6 missile from the USV testbed Ranger, and followed up on 24 October 2023 by launching an SM-6 missile from the USS Savannah (LCS 28). In December 2024, then-Secretary of the Navy Carlos del Toro confirmed that the Mk 70 PDS is operational on the first LCS, with plans to equip "many" LCS units with the new system. The move is part of the over-the-horizon weapons system upgrade which seeks to provide both classes of LCS with a significant offensive maritime strike capability. It augments the ships' Kongsberg Naval Strike Missile (NSM), which has a of over 185 km (100 NM) range. Raytheon's multi-mission SM-6 Block 1 officially achieves a range of 241 km (130 NM) and can engage both aerial and surface targets, though unofficial estimates postulate a higher range extending to 370-463 km (200-250 NM). The TLAM family's Block V variant is estimated to achieve ranges above 1,667 km (900 NM) range; in addition to land targets, the Block V Tomahawk will be able to combat surface ships once the Maritime Strike Tomahawk enters service.

The Navy has not categorically stated how many Mk 70 PDS would be carried per LCS, but in 2024 Lockheed Martin presented a concept showing three systems (for a total of 12 VLS cells) on the flight deck of a Freedom class vessel. The drawback of this full load-out on an LCS would of course be the inability to conduct helicopter operations as long as the containers are in place, a restriction that would not be as significant on ships with larger decks.

According to Lockheed Martin, the Mk 70 (which is also configured for truck-launched operations for the US Army) "enables rapid deployment of [mid-range precision fires] offensive capability to non-traditional platforms and locations". It could be deployed in the future on any vessel with sufficient free deck space – including amphibious ships, Expeditionary Support Base units or large unmanned surface vessel (USV) – to provide them with powerful anti-ship, land-attack or air defence systems. This would enhance force protection for these otherwise weakly-armed vessels, while expanding their offensive options. Being containerised, it can also be truck-mounted and landed (via Ro-Ro ramp or landing craft), making it a 'dual-use' weapon employable from ship or shore and back again within one deployment.

SH Defence – CUBE System

Danish firm SH Defence offers the CUBE System which promises enhanced modularity and flexibility for multi-mission vessels. The many mission module options in the CUBE System portfolio include 6 m (20 ft) and 12 m (40 ft) ISO containers housing anti-ship missiles (ASM), torpedoes for anti-submarine warfare (ASW), and loitering munitions.

Concept of a CUBE System container with ready-to-fire UAVs and loitering munitions. [SH Defence]

Like the Mk 70 system, the Danish weapon modules can be carried on deck. Alternatively, ships preconfigured with recessed mission bays can carry CUBE containers internally. The weapon container/launchers slide into place through external hatches and are replaced when expended or operational requirements change. According to SH Defence, exchange of modules can be completed within four hours in port. Depending on the vessel configuration and the munition in question, weapons can be launched vertically or laterally, from the deck or via retractable hatches in the ship's side.

The USMC displays a containerised Hero 120 launch system on the long-range unmanned surface vessel (LRUSV) in April 2023. [USMC/Sgt Kealiiholokaikeikiokalani De Los Santos]

RNLN Multifunction Support Ships

The Royal Netherlands Navy will arm its new Multifunctional Support Ships (MSS) with containerised missiles. The 28 × 8.5 m aft deck can accommodate a variety of containers, with concept images showing four 6 m (20 ft) ISO containers side-by-side, in addition to two stacked containers for electronics and control systems. As of early 2025, it is expected that the containers will be bolted to the deck, although other options – including the SH Defence CUBE system – could still be applied. The MSS is intended as an escort for the *De Zeven Provincien* class air defence frigates, and will provide additional firepower to protect the primary combatant (and other vessels) from missile and unmanned aerial vehicle (UAV) saturation attacks. The frigates will provide targeting data and command and control (C2) for the MSS's weapons. The primary weapon for the MSS will be the IAI Barak ER SAMs which can defeat aircraft, cruise and short-range ballistic missiles at ranges up to 150 km and altitudes up to 30 km. These will be supplemented by the IAI Harop long-range loitering munition which can strike land targets to support amphibious operations.

Concept of the Royal NL Navy's Multifunctional Support Ship with weapons containers on the aft deck. [RNLN]

In addition to the container configurations displayed on the RNLN concept images, IAI also markets additional weaponised container concepts, including the All-Capabilities Defence Container (ACDC) concept (armed with four Mini Harpy loitering munitions and eight short-range Rotem L loitering munitions). The ACDC can be bolted to the deck of any vessel capable of accepting commercial shipping containers, and is intended to add self-defence capabilities to less-heavily armed ships. In addition to the aforementioned weapons, it integrates a one- or two-person operations room as well as a mast with radar, communications and optronic sight.

Rheinmetall Containerised Launch System

In 2024, Rheinmetall, in collaboration with UVision, presented its own concept of a containerised launch system consisting of 126 cells for Hero-120 loitering munitions. The image showed a truck-mounted version. The container had no top, and was subdivided into three arrays with 42 cells each. Each cell had its own cover which the loitering munitions could penetrate during launch. While the displayed configuration was vehicle-mounted, the system appears well suited to installation aboard a suitable naval vessel. Rheinmetall itself has praised

the Hero-120's ability to easily integrate into existing naval C2 and target-acquisition systems, "[bringing] highly affordable solutions to the growing challenges of the complex naval arena". Potential operational scenarios include launching offensive swarms to overwhelm defences of an enemy vessel (including 'blinding' a major warship through a saturation attack against its sensors) or counterattacks to neutralise incoming UAVs/USVs or manned fast inshore attack craft (FIAC) operating in swarms. The subdivision of the container implies that the system can be mounted in containers of various size, with different numbers of effectors, to accommodate smaller and larger vessels as well as different operational scenarios.

The Hero 120 carries a 4.5 kg warhead and achieves a range of over 60 km and endurance of 60 minutes. The US Marine Corps (USMC) chose the loitering munition on 2021 to equip various platforms, including the long-range unmanned surface vessel (LRUSV). While the USMC terminated the rapid prototyping initiative for the LRUSV, the USMC did publish photos that year showing the unmanned vessel with an eight-cell launcher, demonstrating the feasibility of rapidly and flexibly equipping boats with removable missile containers.

IAI – LORA

Israel Aerospace Industries' long-range artillery (LORA) tactical ballistic missile was first introduced at Eurosatory 2006, and is thought to have entered service with the Israel Defense Forces (IDF) in 2007. IAI cites minimum/maximum ranges of 90 km to 430 km (49 NM to 230 NM). It was originally designed as a truck-mounted mobile weapon system with four sealed missiles per containerised launcher.

▾ **Test launch of the LORA missile at sea in 2020. [IAI]**

In June 2017, IAI carried out a seaborne test launch of the missile by securing a launch truck on a cargo vessel's deck. According to the IAI press release, "the missile was launched from an operational system that consists of a command trailer and ground launcher. Following the launch, the missile has navigated its course to the target, striking the designated target with high precision." In 2020, IAI followed up on this test, firing two missiles from a ship in the Mediterranean Sea, precisely striking two separate floating targets located at a distance of 93 km and 398 km (50 NM and 215 NM) respectively, from the launch vessel. According to IAI, the LORA is not considered an anti-ship weapon, but is configured to strike ground targets "deep in enemy territory" from land or sea.

Special considerations

Special legal aspects must be considered with regard to housing long-range weapons in civilian-appearing cargo containers. This is irrelevant when the missile containers are mounted on clearly designated warships such as the LCS or the MSS. However, some analysts have proposed quickly and cheaply expanding war fleets by acquiring merchant vessels and arming them with containerised missiles. One argument made in this context is that such vessels would be able to sail in or near conflict zones (including through chokepoints) with little risk of detection, as their silhouette would blend in with commercial traffic. However, unless the vessels are clearly designated as combatants, such a practice could quickly enter a legal grey zone. As Captain Pedrozo emphasised, only warships and military aircraft may exercise belligerent rights during an international armed conflict (IAC) at sea. "Other vessels, such as naval auxiliaries and merchant vessels, even when carrying out support services for the naval forces, are not entitled to engage in belligerent acts during an IAC, but they may defend themselves, to include resisting attacks by enemy forces." Conversely, non-belligerent vessels may not be targeted as long as they refrain from belligerent acts.

Again citing Captain Pedrozo, merchant vessels can legitimately be converted into warships, but they must be clearly designated as such through external markings and be publicly registered in the list of warships. They must also be under direct command of military officers. In addition to respecting the rule of law, this would also preclude an opponent categorically targeting merchant vessels prophylactically under the assumption that they might be disguised belligerents. While most Western maritime powers would be expected to broadly comply with international norms regarding openly distinguishing between military and civilian vessels, in China, which maintains the world's largest merchant fleet, a 2016 law requires merchant carriers to support "strategic projection" by the armed forces. Given past instances of disregard for international norms by China, such as various threatening acts toward other navies in the South China Sea, some analysts worry that the country might deploy unmarked merchant vessels as missile platforms. Whether designated or not, the sheer size of China's power projection potential will require a major and timely expansion of armed platforms by western nations. Given budgetary constraints and the long lead-time for military shipbuilding, this goal seems most readily achievable through systematic procurement of non-traditional vessels for military purposes.

Powered respirators: Wave of the future?

Dan Kaszeta

CBRN respiratory protection is intended to give the user safe and clean air to breathe. Various approaches to achieving this end have both advantages and disadvantages. A major problem is that the disadvantages, in certain situations, end up with the user being dead, disabled, or seriously injured. Lots of engineering has gone into respiratory protection to make sure this does not happen, but the subject of how to protect soldiers and emergency responders from inhaled CBRN threats needs, in this correspondent's mind, a bit of a fresh look.

An Airman with the 127th Civil Engineer Squadron participates in a gas mask fit test at Selfridge Air National Guard Base, Michigan, on 14 October 2023. [US ANG/ Senior Master Sgt Dan Heaton]

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Two main types of respiratory protection

Let us examine two prevalent but different types of respiratory protection. Most military-style protective mask can be described as 'negative pressure air purifying respirators'. Some militaries use the word 'mask' (USA) while others (such as the UK) use 'respirator', but this article will use the terms interchangeably. Regardless of term, filter masks/respirators seal to the wearer's face, with straps around the head. When the wearer inhales, there is, briefly, a state lower air pressure inside the mask and lungs. This negative pressure is enough to draw in air through a filter, which uses various methods and materials to let in breathable air but stop particles, vapours, gases, and aerosols. When the wearer exhales, the positive pressure of exhalation forces the exhalation air out through simple valves.

This type of mask has advantages and disadvantages. They are cheap to make, which is valuable as an army may procure a million units or more. Good filters may last a month in a toxic environment, depending on variables. They are relatively easy to wear, so it may only take an hour or two of training for a soldier. Filter masks are lighter than other forms of respiratory protection. But filter masks make a number of design compromises in order to achieve their mission. Filters only take things out of the air, and it cannot give the wearer enough oxygen when there is insufficient oxygen in the ambient air. Not everything can be easily filtered. Carbon monoxide and some other toxic chemicals, some rare and exotic, are difficult to cheaply filter. Breathing through a filter provides resistance, and sometimes users can struggle. If breathing resistance is too high in a physical situation where the wearer is breathing quite heavily (for instance, combat), the mask becomes a danger as well as a burden. Most importantly, the protective value of such a mask depends on how well it seals up. Masks only come in a few standard sizes, and people's faces vary in shape. Things like hair and helmet straps can get caught in a seal. A poor fit or the slightest breach in the seal means that during the negative pressure phase of operation, the act of inhalation will pull threatening materials into the mask through the small breaches, as the resistance will be less than breathing through the filter.

The other type of protection is a type we have all seen worn by firefighters. These are often referred to as self-contained breathing apparatus (SCBA). They have a facepiece that is, in many ways, very similar to filter-based masks, but they can be described as 'positive pressure supplied air respirators'. The breathing air comes generally from a tank worn on the

back, or occasionally, in occupational safety settings, a long supply hose. Such devices have a regulator that supplies air at positive pressure. When you inhale, the small pressure difference is enough to trigger the regulator valve, which floods the facepiece with air at a small positive pressure difference.

The advantages and disadvantages of SCBA are many. It provides breathable air in environments where there may not be enough oxygen to sustain life, or substances that are difficult to screen out with a filter. The smallest leak in the seal or breach in the mask results in pressurised air filling the space between the face and the facepiece, pushing hazards out. As a result, exact fits are less important. They also provide far less breathing resistance than a filter mask. On the other hand, their disadvantages are as notable as the advantages. An air tank is heavy and only supplies a limited duration of air – when they run out, they are truly out. Filters, on the other hand, last a long time. SCBA systems are typically designed for 30-45 minutes of time, and that time may also need to be used for getting to and from the hazardous area decontamination after coming out of a hazardous situation. In CBRN environments, these systems are good for a quick entry to collect samples, rescue victims, or mitigate a hazard, but time constraints mean that serious extensive work plans require numerous entries and exits, logistics for air tank replacement, and rotation of personnel. This is why filter respirators are used in military environments, and SCBA is only seen among specialist CBRN technicians in military settings.

Traditional firefighting Self-Contained Breathing Apparatus (SCBA) provides a high degree of protection but does not last long enough for military operations and is generally considered too heavy. [USAF/Eric M. White]

Protection factor

We are all, by now, familiar with the concept of a protection factor for sunscreen. Respiratory protection also has a concept known to the safety regulators as 'assigned protection factor' (APF). The APF is the degree to which a particular respirator is likely to reduce the level of respirable hazard to the wearer, based on numerous factors. APF is set by regulators based on studies, but the real protection factor on a given day may be higher or lower based on factors such as having the wrong size mask, how tight the straps are, hair stuck in the seal, or damage to the facepiece. There is entire market segment of fit validation equipment that tests the protection factor of a particular person wearing a particular respirator on a particular day.

APFs are used for general regulatory determinations about which category of protection is required for a particular occupational safety environment in the civil workplace. When you start comparing APFs between military filter masks and SCBA, the difference is stark. In the USA, regulators evaluate well-fitted filter masks as having an APF of 50. This means that the respiratory hazard is reduced by a factor of 50 on average. On the other hand, the APF of a pressure-demand SCBA is rated at 10,000 – a 200-fold improvement in protection. It should be noted quite strongly that many manufacturers claim that their masks have a much higher protective factor, when properly fitted and tested, than the default APF. This is undoubtedly true and much technical literature backs this up. Yet such statements must also be balanced against field conditions, where soldiers may have been accumulating dirt and facial hair (which can interfere with a fit), mistreating their PPE, and possibly wearing their respirator the wrong way.

When it comes to chemicals (or biological matter) with high levels of danger in high concentration, is an APF of 50 really good enough? We can work a very basic scenario, although it will require some number-crunching. Looking through one available study, an explosion of a cylinder of Chlorine gas (much like that dropped by Bashar al-Assad's helicopters in Syria, most notably during 2018) can create a modest area of a concentration of 1,000 parts per million (ppm) and a much larger area where concentration may be 30 ppm, depending on confinement, wind and other conditions. For a person who

A crew member is fitted for a gas mask aboard aircraft carrier USS *Harry S. Truman* (CVN 75), on 16 July 2015. Fit and field conditions can greatly impact the 'real' APF, which may vary from the 'boilerplate' protection figure. [US Navy/MC3 L.C. Edwards]

is unprotected and remains in the gas, the 1,000 ppm concentration could be fatal and the 30 ppm concentration would be enough for minor injury, serious cough, and eye irritation. In other words, enough to keep a soldier from fighting very well. For a person wearing a respirator with an APF of 50, that 1,000 ppm zone would be reduced to 20 ppm, still quite irritating, possibly temporarily incapacitating, but not lethal. That 30 ppm zone would be reduced to 0.6 ppm, still enough for a dry throat and some eye irritation. For the person wearing SCBA with an APF of 10,000, the threat is reduced to negligible.

In a practical military setting, one can envisage scenarios where an APF of 50 is just not good enough, especially with materials that are far more toxic than Chlorine. To be honest, given the state of current masks, an APF of 50 probably understates the average NATO mask, but field conditions and industrial hygiene laboratories are different from each other. Many militaries, and the CBRN professionals in them, engage in both honest interlocution and some degree of hand-waving to say that the safety and health regulations and standards developed for industrial health and safety or first responders are not the same as for the military environment. To a certain extent, they are right. However, a filter mask is not an SCBA and the brutal truth is that military filter masks are designed to help the bulk of the soldiers survive and escape, but certainly not all of them. This correspondent argues that this situation is simply not good enough.

Fixing the problem

One way to fix the problem is to make masks better. Industry has been doing that for a long time and the existing generation of filter respirators is much better that the Vietnam War-era masks that this correspondent was using decades ago. Yet the conceptual flaw remains. User error and field conditions mean that a negative-pressure often mask fails in a mode that lets hazards in every time the user breathes. This is obviously a bad thing. In addition, there will always be some percentage of the population that will not easily wear one of the handful of sizes available and will struggle to get a good fit.

At the other end, SCBA are too large, too heavy, and run out of air too quickly, so they are not suitable for combat missions, except for perhaps some sort of special operations raid on a laboratory complex. Some hybrid approaches are available. For air crew and combat vehicle crewmen, there have long been specialist masks that plug into a supplied breathing air system and operate in a positive pressure way as long as the crewman is plugged in. However, these are a minority of use cases. Some SCBA systems have been developed that have a back-up filter and the operator can switch between supplied air and filter. (This correspondent used one such system from InterSpiro (USA) for five years.) Yet such systems, while useful in certain operational niches, rely on an air bottle that is too big for military use.

One possible answer is to use a device that is, in many ways, an intermediate category between air purifying and supplied air devices. The so-called Powered Air Purifying Respirator (PAPR) uses an electric motor to blow air through the filter, either all the time or when turned on by the user. The respiratory protection specialists who calculate those dreaded APFs think much more highly of such devices. Several US reference documents give full-facepiece PAPRs an APF of 1,000; so twenty times as good as an unpowered filter respirator and one-tenth as good as an SCBA. The primary reason for this is that small breaches in the seal result in filtered air exiting through such breaches rather than unfiltered outside air entering every time a user inhales. Various small defects and malfunctions, such as an outlet valve jamming, fail to a safe mode of operation rather than an unsafe mode. Further, breathing resistance is reduced or eliminated because air is being pushed through the filter by the motor, not just the user's lungs. By operating at positive pressure, getting an exact fit is not as critical and someone with an oddly-shaped face and a marginal fit can still derive protection. Simply stated, a blower motor and a few minor tweaks inside the mask can improve the protective factor by over on order of magnitude, with nothing like the weight or expense of SCBA.

Powered Air Purifying Respirators (PAPRs) strike a balance between traditional negative pressure respirators, and SCBA, providing superior protection to the former while being less bulky and allowing longer-duration operations than the latter. [USAF/Senior Airman Ryan Mancuso]

PAPRs are not without their disadvantages. Motors can break, batteries die, and they are heavier than regular filter masks. But they are not anywhere near as heavy as SCBA and if a blower fails or battery dies, the mask can still work like an older filter mask. They will make some noise, but modern engineering can work on that issue. Battery life is also an issue, but that can be worked on as well.

The marketplace

There are rumblings in this market sector. PAPRs have been made and used in civilian settings for some decades. Many of the major manufacturers have produced PAPRs. Some are now made for military specs, while others could be easily modified for military procurement. Avon Protection (UK) makes several PAPR systems for military and paramilitary use. Scott Safety (US, a division of 3M) has a robust product line-up, with many emergency response products that could easily find a military niche. Air Boss (Canada) has adapted a long-standing civil product line for military use. Dräger (Germany) has civilian PAPRs, but given its expertise, could probably field a military product if such demand existed. Mira Safety (USA) is pushing hard in this field and is one to watch. It has been several years since I have done a full survey of respiratory protection for this magazine. It will be interesting to see how much of the marketing effort is given over to PAPRs in a year or two.

In conclusion, using a powered air purifying respirator for military CBRN protection is a useful approach and one that builds on existing product lines. What needs to change is on the demand side of the equation. Once CBRN defensive doctrine adapts a bit, procurement officials may be convinced be that the PAPR's advantages, particularly a 20:1 improvement in protective factor, outweigh the disadvantages. If a 20:1 improvement in body armour or small-arms ammunition came along, MoDs around the world would be falling over themselves to adopt it. Having scanned the entire CBRN defence horizon for some years now, as a career specialist in this field it seems clear that this is the most likely sub-segment of CBRN defence where a relatively small change can make a big difference.

A PAPR shown as part of USMC Alert Contingency Marine Air-Ground Task Force (ACM) issued equipment, during exercise Habu Sentinel 16 at Marine Corps Air Station Iwakuni, Japan, on 8 June 2016. [USMC/Sgt Jessica Quezada]

Protection, platform, system – the path to today's combat helmets

Tim Guest

From simple steel constructs of the twentieth century, the combat helmet has seen a comprehensive evolution in design, materials, and manufacturing on its journey to reach the advanced systems protecting soldiers today.

▲ **Pictured: French Chasseurs Alpin from the 27th Mountain Infantry Brigade trialling the new standard-issue F3 helmet during Exercise Cerces 2021, prior to the helmet's unveiling at Eurosatory in mid-2022. [Armée de Terre]**

This article looks at certain helmet basics and manufacturing advances, some recent examples portraying how they have become more than just helmets, and also shares feedback from a leading maker about the manufacturing path, processes and considerations; the article concludes with a look at the role of original equipment manufacturer (OEM) partnerships in the helmet system ecosystem.

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Protection = survivability

The combat helmet today relies on the use of advanced materials, including aramids such as Kevlar, as well as ultra-high molecular weight polyethylene (UHMWPE) composites. They are processed and engineered using advanced manufacturing techniques to produce some of the most effective combat headgear ever developed. UHMWPE is predominantly (with some exceptions) today's preferred material of use, due to its extremely long molecular chains which serve to transfer impact loads more effectively through the material than other composites. As a result of using such materials, levels of ballistic protection in modern helmets meet some of the most stringent US National Institute of Justice (NIJ) standards, against which most Western ballistic protective equipment – helmets, body armour – are measured. Together with a full understanding of the biomechanics involved in impact-induced head injuries encountered in battle, manufacturers have been able to select the most appropriate advanced composite materials and ballistic fabrics, and process them in ways that optimise their energy absorption and impact resistance material characteristics, thereby optimising levels of protection and wearer survivability.

Headgear evolution in action

To illustrate the kinds of advanced-end product entering service and incorporating the latest understanding of materials and manufacturing techniques, it is worth looking at a few examples of new helmet systems. In the US, with many

▲ **Pictured: Galvion pressed helmet shells. Aramids and predominantly UHMWPE composites, are processed and engineered using advanced manufacturing techniques to make today's latest helmet systems. [Galvion]**

years of outstanding performance from its previous helmet variants, including the Integrated Head Protection System (IHPS), the Advanced Combat Helmet and the Enhanced Combat Helmet, the US Army has been introducing its new, Next-Generation Integrated Head Protection System, (NG-IHPS), from makers Gentex Corporation and Avon Protection. While it continues to be made of UHMWPE composites, just like its predecessors, its composite construct has been engineered to offer improved protection against projectiles and shrapnel, despite also being some 40% lighter than previous helmets. As a 'system', the NG-IHPS comprises retention and suspension elements, a helmet cover, and frontal bracket with a three-bolt night vision goggle (NVG) baseplate, (as opposed to the single-bolt baseplate of predecessor IHPS). Its overall design also allows the integration of communications equipment, hearing protection, and heads-up displays. Importantly, structural integrity of the helmet shell has been maintained in manufacturing by not drilling to affix the chinstrap retention system, which is boltless. Integration of a mandible protector has also been factored into the new helmet system, over 190,000 of which are expected to be delivered by the end of 2028.

In France, a juggling act seems to have been going on between the use of aramid composites and UHMWPE composites for the latest helmet design, with the new F3 ballistic helmet, (part of France's Félin future soldier systems), being made with aramid-based fibre materials, while previous helmets had already been made of UHMWPE; this came as a surprise to some in military circles, who saw the use of aramid for the F3 as a backward step, the polyethylene composites already viewed across industry as the more advanced material with better ballistic-protection capabilities. Indeed, UHMWPE was employed in the earlier Spectra F2 helmet, which, while not proof against full metal jacket (FMJ) high-velocity rifle rounds, as a fragmentation-resistant helmet its performance has been highly effective, as well as its ability to protect against such other NIJ standard threats as a 9 mm FMJ bullet, with an impact velocity of 426 m/s. Nevertheless, the F3 is now standard issue, and its Kevlar composite structure also, reassuringly, provides similar levels of ballistic protection against shrapnel and 9 mm projectiles as the F2; its exterior design, however, differs considerably from previous helmets, with a significant increase in the payload capacity through new side attachments and rails for attaching tactical equipment, devices and sensors, such as NVGs. Whatever the F3's longevity, it is understood from reports that UHMWPE is being considered for future designs beyond the F3.

While other modern helmet systems have entered the market, space preludes their mention here, except for a brief look at the family of 4th-generation Hjelm systems introduced in late 2018 by Norway's NFM Group. Its two latest family members are the Hjelm HC 120MT/multi-threat, and Hjelm HC 160F/fragmentation, helmet systems, introduced in late 2023. Some of the technological and manufacturing innovations in these and other Hjelm systems include the company's Frec-2 pressing technology, which bolsters the structural integrity of the shell while maintaining a lightweight profile, and NFM's use of Koroyd's impact-management technology, which uses welded tubes on the inside surface of the shell, that crumple instantly and consistently when impacted. This ensures that maximum forces are absorbed in a controlled manner by the collapsing tube matrix, thereby allowing only a minimal amount of energy to be transferred to the wearer's head.

Pictured: Batlskin VIPER A1 Special Edition helmet. The Batlskin Viper A1 is a high-cut ACH shaped aramid helmet; the special edition specifically developed for a regional Middle Eastern customer in coyote brown includes a custom camo helmet cover, bespoke bag, as well as Galvion's modular suspension system to provide comfort, stability and good air circulation. [Galvion]

Thoughts from industry

For some qualified insights into latest helmet manufacturing and design developments, ESD turned to Galvion, a supplier of helmets to several NATO members, as well as having provided helmets in support of Ukraine and recently in the news with a mid-February 2025 order from a Middle Eastern customer for 35,000 units of Viper and PDxT variants of its Baltskin helmet system.

Senior vice president of the company's tactical head solutions, Richard Coomber, reiterated how helmet solutions have moved from the purely passive products of the past, to becoming platforms supporting capabilities such as comms, NVGs, and other sensors. Looking back a few decades, he said that changes started with a transition from the use of aramids to the use of UHMWPE as the main ballistic material for the helmet shell, which has increased protection and reduced weight; this has been followed by the integration of visors and maxillofacial protection and now, increasing levels of 'smarts' such as power, data and computation systems' integration. Coomber noted, *"Users and programmes will move through this spectrum of advances at different speeds, depending on their overall mission sets, threats, and budgets, so it will certainly be a faster transition for some than others. Our philosophy is to have options that have an 'upgrade' path, with solutions available to support all our customer groups, regardless of how fast or slow they want to adopt technology."*

Construction considerations

Coomber added that at their most basic, helmet shells are constructed of layers of materials, that are compressed into

the helmet shape, with the general shell shape designed to facilitate comfort, impact and ballistic protection, but with various cuts, or styles, such as high, mid, or full-cut, available and offering different degrees of head coverage, wearer situational awareness and weight. Traditionally, helmets have also adopted a bolted design, using five bolts to attach accessories, various rails, such as Picatinny rails, mounts and fixtures, to the helmet to facilitate capability integration; these bolts pass through a drilled or lasered hole and are ballistic in design. Alternatively, a 'boltless' design can be used, where a series of anchors are bonded to the inside and outside of the shell, removing the need for bolts and maintaining the helmet's ballistic integrity in areas where bolts would otherwise be present.

Pictured: Helmet scanning during the manufacturing process; advanced methods and processes ensure optimum ballistic protection levels are achieved from latest materials and designs. [NP Aerospace]

When it comes to a user/end customer selecting a helmet, three main factors must be considered: weight, protection and cost. Ultimately, each user has to prioritise two of these factors and the third will, simply, follow. For instance, selecting a helmet that's lightweight with high levels of protection will typically mean higher cost; choosing a low-cost unit, but with high levels of protection will mean a heavier helmet; similarly, a lightweight, low-cost option may well require a sacrifice on the level of protection provided. Nevertheless, by using the most advanced materials and manufacturing processes, various constituents can typically be hybridised by makers to deliver the right balance of protection, weight and cost to meet most user requirements.

However, at the same time it is a mistake, according to Coomber, to assume that the most advanced helmets can protect against the most dangerous of threats. Whilst it is possible for some types of helmets using the most advanced materials and processing techniques to stop rifle rounds, though likely with higher cost and weight considerations involved, a better use of funds by a potential user might be to consider adopting a helmet that incorporates NVGs and communications into a more lightweight construct, making the wearer more agile and with quicker reaction times. However, if protection is still the customer's key focus, some composite helmets that meet NIJ IIIA levels of ballistic protection can stop handgun ammunition, such as 9 mm FMJ at 426m/s, but will not stop high-velocity rifle rounds. That said, there are some excellent materials and solutions, which Coomber said will stop some rifle rounds, though not all. It is worth noting that when balancing risks and rewards, with rails, accessories and sensors all taking up helmet real estate, the weight of peripherals such as NVGs and cameras becomes a major factor adding load to the head system and placing stress on the wearer's neck, shoulders, and spine. Whereas some helmet systems have previously, (and some still do), use weights at

Pictured: Galvion's Caiman helmet system upgraded fitband; the importance of user feedback from the USMC led to a new, more robust fitband dial. [Galvion]

the back to counterbalance devices such as NVGs on the helmet's front, Coomber insisted this is inefficient. *"Centre of gravity, overcoming moments of inertia, and stability, are all factors that are evaluated in good helmet design. And while the simplest way to counterbalance an NVG on the front of the helmet is to use a counterweight on the back, it also happens to be the most wasteful approach when you're talking about the limited and valuable real estate on a head system. Far better to replace that counterweight with a battery, sensor or other on-head capability, that adds an operational benefit over just its weight."*

Importance of user feedback

Helmet design today requires consideration beyond just protection from threats and while a soldier's helmet should ideally be comfortable and stable, protective and light, it's no longer just about these considerations alone. Coomber said Galvion always gathers extensive user feedback to inform its product development and updates, citing recent improvements to the company's APEX liner system as a case in point, where upgrades, which came about as a direct result of work with the US Marine Corps, include a more robust fitband dial for its Caiman helmet, additional comfort pad options, and stronger camlocks to adjust harness fit.

Coomber said, "We're now talking about a head sub-system that is intimately connected to the eyes and ears through which communications and visual augmentation systems can pass information and analysis, along with that additional information flowing directly to the soldier." He elaborated, "the dangers of physical and cognitive overload become real. With more equipment and tech being added to the helmet sub-system, the choices and trade-offs made must enhance mobility, accuracy, decision-making – they have to make the soldier more efficient." Coomber explained, "So, it's critical to gather user feedback to understand where those lines are – when technology and information stop supporting the soldier and, instead, distract or overwhelm. There's a whole new layer of complexity to the feedback loop now, making user feedback essential, not just desirable."

NSPA helmet numbers exceed 200,000

As the discussion wrapped up, Coomber was able to inform ESD, that as of end March 2025, orders for Caiman helmets to date through a contract with the NATO Support and Procurement Agency (NSPA; the Alliance's main logistics and procurement entity), have now exceeded 200,000, including a wide range of accessories, and with a significant portion having already been delivered. While the exact numbers of these helmets apportioned to each NATO member country involved remains confidential, he reconfirmed Norway, Finland and Sweden as the first countries to place orders through the NSPA framework contract. Moreover, since the award was first made in December 2022, Coomber noted "inside and outside of the NSPA mechanism, other nations have adopted our products, accessories and maintenance plans and we expect the volume to increase further throughout the life of the contract".

OEM partnering exemplar

Having mentioned Galvion's Viper helmet earlier, it is worth noting that this had previously been chosen, at the end of 2020, as the new helmet – Helm SpezKr schwer – for the German Special Forces, with Rheinmetall Soldier Electronics, the in-country contracting entity manufacturing the helmet, as Galvion's OEM partner. The framework contract will have delivered some 20,000 helmet systems by the time it concludes later in 2025, although a two-year contract-extension option is possible.

Pictured: Galvion's Caiman helmet, which is now also being made at the company's new facility in Poland. [Galvion]

Beyond Rheinmetall's OEM partnering, Galvion has relationships and facilities to meet the likes of the NSPA NATO member requirements, that include the establishment of a new European Caiman helmet system production facility in Gdansk, Poland in September 2023, now fully operational, and another OEM production partnership forged the same year and similar to the Rheinmetall arrangement, but this time with UK body-armour specialist, NP Aerospace. This partnership is now helping meet the needs of European NATO members with Caiman helmet systems, as well as Galvion's Cobra Plus helmets for the UK's Virtus programme.

The partnering choice of NP Aerospace makes sense, considering it already designs, tests, and makes its own high-performance ballistic helmet shells using advanced composites, and works closely with the global helmet OEM community; its Ontario, Canada facility is also a relative stone's throw from Galvion's HQ on the New Hampshire coast of the US. NP Aerospace, which made the first Kevlar composite helmet for the British Army as far back as 1979, has recently introduced a seamless helmet shell design some 25% lighter than previous shells, without, it says, losing any ballistic performance, and at the same time increasing manufacturing efficiency and capacity as a result of the helmet shell's ergonomic properties. NP Aerospace has its own ISO 17025 UKAS-accredited laboratory and ballistic firing range on site, where it tests its helmet shells and ensures international ballistic performance standards, such as NIJ requirements, are met.

With its manufacturing facility in the UK and production-assembly plant in Ontario, NP Aerospace's OEM contracts see it produce over 6,500 helmet shells a month, as well as meeting its own product manufacturing needs. The company's own LASA AC915, for example, is the latest ultra-lightweight, high-cut, tactical ballistic helmet, which meets NIJ 0106.01 standards, and uses the company's own hybrid UHMWPE ballistic helmet shell to provide high-level ballistic (for instance, a 9 mm FMJ at 436 m/s), fragmentation (for example, a 16 grain sphere at >620 m/s), flammability and blunt trauma protection.

Pictured: NP Aerospace's AC915 helmet is an ultra-lightweight, high-cut, tactical ballistic helmet, which meets NIJ standards. [NP Aerospace]

NP Aerospace's experience and manufacturing processes for its own products, coupled with its support for Galvion, merely highlight how OEM partnerships in the helmet-manufacturing ecosystem underpin the production and supply of some of the latest helmets for NATO customers and beyond.

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Ready and relevant: JEF shines light into CUI grey zone to deter sub-threshold threats

Dr Lee Willett

Despite continuing politico-strategic turbulence in trans-Atlantic relations surrounding the on-going Russo-Ukraine war, NATO remains the standalone multinational military structure for deterring high-end military threats to Western European security. Yet with the war being 'fought' strategically by Russia through using hybrid activities in various regions, domains, and contexts across the Euro-Atlantic theatre, multinational structures other than NATO play a crucial role in deterring threats and escalatory risks at the sub-conflict-threshold level. At sea, one such multinational structure is the UK-led, 10-country, Joint Expeditionary Force (JEF).

In recent years, JEF has increasingly focused on maritime matters, due to its geographical area of responsibility (AOR) – the High North, North Atlantic, and North and Baltic sea regions – and the threats assessed in this area, especially since the war broke out in 2022.

Broadly, JEF is designed to provide robust, multidomain, multinational deterrence presence in Northern Europe. It generates non-NATO activity in the air, on land, and at sea to counter sub-threshold threats to member interests across its AOR that would not necessarily precipitate a NATO-led response. The 10 JEF member states – Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, the Netherlands, Norway, Sweden, and the United Kingdom (as framework country) – all hail from this region.

Since being established in 2014, JEF's maritime presence has been prominent, and increasingly so since 2022. Such maritime presence is crucial in deterring sub-threshold threats in a domain that, by geopolitical definition, is perhaps more open to 'grey zone', 'hybrid', asymmetric activities, being broadly accessible without the same physical national borders found in the land domain.

The Finnish Navy fast attack craft FNS *Hanko* and the UK Royal Navy (RN) Type 23 frigate HMS *Richmond* conduct patrols in the Baltic Sea in support of Joint Expeditionary Force (JEF) CUI security tasking. Through its 'Nordic Warden' activity, JEF is bringing regional member states together to build CUI security. [Finnish Navy]

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Moreover, the North Sea/Baltic Sea region is laced together by maritime links. For example, the 10 JEF states – plus other regional countries like France, Germany, Poland, and Russia – all rely on maritime trade for daily supply and economic development. This maritime trade is manifested in shipping traffic that transits from the North Sea, through the Skagerrak/Kattegat straits, and across the Baltic to the Gulf of Finland. In the context of the Baltic having become – again, by geopolitical definition – the northern maritime flank of the Russo-Ukraine war, the sea lines of communication (SLOCs) that transect it and connect it to the North Sea have become 'strategic SLOCs'. With the heavy shipping traffic present across the Baltic and North seas, these 'strategic SLOCs' are very visible in politico-economic terms, being important for both maritime trade and security reasons. In the latter context, NATO and JEF will wish to support Baltic State, Finnish, and Swedish interests at and from the sea; Russia will also wish to access the North Sea from Kaliningrad and St Petersburg. So, such Baltic Sea 'strategic SLOCs' are – once more, by geopolitical definition – contested.

The Baltic and North Seas, plus their surrounding countries, also host another form of 'strategic SLOC' that generates daily supply and economic development – the network of critical undersea infrastructure (CUI) pipelines, cables, and other nodes that connect the resident countries to each other and to elsewhere to deliver energy, information, and other resources.

It may or may not be coincidental that the strategic importance of seabed SLOCs and of the Baltic Sea is such that, in the context of the Russo-Ukraine war, a series of CUI-related incidents has occurred in the Baltic since September 2022. The most recent incidents (in October 2023, November 2024, and December 2024) raised political and public awareness in Western European countries regarding the risk to CUI, but also prompted debate about whether such incidents – involving damage mostly to cables (but also pipelines) possibly being caused by ship anchors being dragged at speed along the seabed – were attributable to 'shadow fleet' ship activities. Such rogue vessels are used by rogue states to surreptitiously support efforts to evade sanctions, for example: they seem to operate at sea with automatic identification system (AIS) signals turned off and ashore with ownership paper trails cut off.

If such damage was done deliberately, for example to disrupt Western energy and data flows, this would be an archetypal illustration of the use of 'hybrid' tactics in the 'grey zone' below the conflict threshold, yet with intended strategic-level effects. Thus, responding to such an immediate threat and building near- and longer-term deterrence against it, without necessarily risking escalation, is a perfect task for JEF to tackle. JEF is aimed at sub-threshold threats: and the CUI risk is just that.

"Maintenance of security and stability for the North Atlantic region remains our key tenet," Captain Dan Thomas – a UK Royal Navy (RN) officer posted as Assistant Chief of Staff (ACOS) Operations at the UK's Standing Joint Force Headquarters (SJFHQ), Northwood, UK – told ***ESD*** in a 22 April 2025 interview: "Everything we're doing as JEF now and indeed in the 10-year plan must be complementary to NATO, it must reinforce national defence plans, which in turn play into the NATO regional plans and the family of plans therein." He noted, "everything is designed from the outset to be complementary because why wouldn't it?"

Regarding CUI itself, Capt Thomas continued, "If we're looking at security and stability, then protection of anything which has got 'critical' in the title is absolutely paramount." He added, "the CUI issue within the Baltic – but also wider into the North Sea, which is in our AOR too – is absolutely critical".

Warding off threats

JEF, through its maritime presence and wider response capability, has been tackling the CUI threat under what has developed into the 'Nordic Warden' series of operational activities. As the CUI incidents continued, the catalyst for JEF action was defence ministerial direction to look at the CUI risk writ large across JEF's AOR, particularly in the Baltic. JEF CUI-related activities have been conducted on two occasions; in June 2024, with a task group deployment into the Baltic; and in January 2025, following the December 2024 Baltic CUI incident, when the EstLink2 power cable connecting Estonia and Finland, plus several internet cables, were damaged.

The Norwegian Coast Guard vessel NoCGV Barentshav (W340) during the Nordic Warden 24 exercise, with an oil rig and maritime patrol aircraft (MPA) visible in the background. [Norwegian Armed Forces]

'Nordic Warden' response activities are enhanced today by an artificial intelligence (AI)-based software system from US company Palantir, which in this instance was used to help track potential CUI threats and monitor shipping by assessing AIS and other ship positioning data to calculate risks posed by certain vessels (including known 'shadow fleet' ships) entering certain areas of interest.
In a UK Ministry of Defence (MoD) statement in January 2025, Defence Secretary John Healey said the system is "a major innovation which allows us the unprecedented ability to monitor large areas of the sea with a comparatively small number of resources".

NATO itself has a live CUI security activity underway in the region – 'Baltic Sentry', which similarly was set up following the December CUI incident. 'Baltic Sentry' integrates two NATO standing naval forces (SNFs), various surveillance assets from seabed to space, plus NATO, regional, and national naval platforms and command structures to provide multid-

The RN frigate HMS *Richmond* – pictured here in late 2024, returning from a Red Sea deployment – spent a large part of that year leading a JEF CUI deployment to the Baltic. [Crown copyright 2024]

omain surveillance and deterrence presence. NATO's focus at the higher end of the threat and operational spectrums is underlined by the fact that Standing NATO Maritime Group 1 (SNMG1) –
NATO's North Atlantic-based high-readiness maritime task group – is leading 'Baltic Sentry', working with high-end capabilities including (for example) F-35 Lightning II fighter aircraft and submarines.

JEF fits neatly into this overall framework, including in a supporting and enabling manner. According to the MoD statement, "The JEF action reinforces existing and planned NATO responses." It added that 'Nordic Warden' was activated under JEF protocols designed to provide response options to be used to protect member state and NATO alliance interests against such threats.

Response options

Known as the JEF Response Options (JROs), these protocols were drawn up following the war's outbreak in February 2022, as JEF moved to strengthen the sub-threshold, non-NATO security contribution it could make for Baltic region allies and partners. According to JEF, the JROs are "planned integrated military activities designed to enhance multilateral capabilities, reassure countries, deter overt aggression, and complement NATO, throughout the continuum of competition to conflict". The JROs are based around: the requirement to act quickly to build deterrence, through increasing co-ordinated, collective capability; addressing military (including hybrid) threats; deterring malign actions; and supporting – and sometimes being sequenced with – NATO's enhanced vigilance activities to provide persistent response.

The JROs are part of a two-fold JEF operational response framework, providing proactive options alongside other, more persistent activities. The JROs enable JEF member states to opt in to what are surge activities designed to prepare and shape a theatre for a wider response, although should the deterrence impact of such a surge succeed then the JRO can be stood down, a 2024 JEF newsletter explained.

"We've got in the region of 70 JROs that go across the conventional domains and now increasingly into the hybrid domain," explained Capt Thomas, noting, "they give our political and military leaders choice, based on pre-planned joint response options that we've developed as frameworks … to get after specific activity."

Alongside the 'Nordic Warden' series – and emphasising JEF's role across sub-threshold and into crisis contexts – other JEF operations, activities, and exercises encompass various air, land, maritime, and joint activities, including: 'Baltic Express', JEF's maritime JRO series, which includes a forthcoming activity involving escort of strategic assets into the Baltic Sea from the North Atlantic, with six JEF countries contributing platforms (ranging from corvettes and patrol boats, to destroyers and frigates, to maritime patrol and 'fast jet' aircraft), C2, maritime operations centres (MOC), and civilian agency support; 'Razor Edge 25', which features operational activities designed to test the UK's joint force contribution to JEF requirements in the Baltic and High North regions, including testing some JRO concepts; and the multi-JEF member 'Tarassis 25' activity, a six-week period of operations set for the end of 2025, that will test assigned forces and an expanded SJFHQ staff in JRO contexts, including relating to the Russian threat.

Drawn up in 2022 and based around robust military judgements, the JROs have since been matured, including quite swiftly in some areas, Capt Thomas explained: "They've been refined – or we're starting to refine many of them – based on actual, tangible activity, which is a really big step forward." This certainly is reflected in the CUI context.

JEF first activated a JRO in December 2023, to respond to the CUI risk and following a defence ministerial-level decision

taken in November 2023 (itself occurring in the wake of the October 2023 CUI incident). Under this JRO, JEF established a focus on North Atlantic, North Sea, and Baltic Sea presence to counter CUI threats, including conducting the June/July 2024 CUI activity in the Baltic – the first time JEF had generated a maritime force to deploy on CUI tasking.

Ships began deploying to the region in late 2023 to support the JEF CUI focus with precursor activities, including the UK Royal Navy (RN) anti-submarine warfare (ASW)-focused Type 23 frigate HMS Richmond. The JRO ran for four weeks across June and July 2024. From across the JEF members, more than two dozen ships plus almost a dozen supporting aircraft came together, with assets deployed across 2.59 million km2 (1 million square mile) maritime area stretching from western UK and western Barents Sea waters, but particularly through the North Sea and into and across the Baltic. Although not a NATO activity, the operation aimed to bring deterrence against the CUI threat through maritime security presence and surveillance, including to support NATO's enhanced vigilance activity requirements. JEF tasks included patrol at sea and in the air with particular focus on securing offshore assets, sharing intelligence, monitoring Russian ship activity, and building a multi-domain maritime picture.

In a statement published during the operation, JEF said "CUI vulnerability can allow an adversary to use hybrid warfare techniques to destabilise targets by circumventing the methods of standard warfare."

Illustrating how JEF countries contributed units to meet presence, surveillance, and deterrence requirements, the Royal Norwegian Navy (RNoN) frigate HNoMS Fridtjof Nansen and Skjold class corvette HNoMS Gnist deployed off Norway to secure the Goliat oil field and Nyhamna gas facility, respectively; in the Baltic, Estonian Navy, Finnish Navy and Border Guard, and RN ships worked together. Assets remained under national command, but with JEF co-ordinating activities from SJFHQ.

According to JEF, almost 100 intelligence reports were raised and shared during the deployment, leading to 33 commercial vessels being tracked in areas ranging from Norway's western approaches to the eastern Baltic. The overall effect was to build situational awareness, share information, and communicate JEF member state intent.

In a statement released when the JRO concluded, JEF highlighted several factors underpinning the activity's success: the importance of consistent liaison with numerous NATO headquarters to align messaging and emphasise mutual interests; contributing to national interests while complementing NATO's work; and operating and co-operating effectively in a busy region and operational environment.

"'Nordic Warden 24' was a shift from being reactive to being proactive," said Capt Thomas. While JEF previously had been responding to incidents, the more proactive approach was designed to build deterrence, including through compiling a more comprehensive 'patterns of life' picture. "It was about having a coherent effect, having surveillance, looking at maritime domain awareness (MDA), and building an understanding of what activity was going on within the Baltic Sea region," Capt Thomas added.

The range of assets generated through an up-front 'force sensing' process – namely, seeking a generic sense of what forces countries may have available – also gave the JEF planners the opportunity to more effectively apply assets and their outputs to particular areas of interest.

The Royal Norwegian Navy's (RNoN's) Skjold-class ship HNoMS *Gnist* conducts CUI deterrence and security patrols off the Nyhamna gas facility, western Norway during a JEF JRO deployment in 2024. [Norwegian Armed Forces]

The RNoN frigate HNoMS *Fridtjof Nansen* deploys around Norwegian CUI sites in 2023. The frigate also worked under JEF tasking to conduct similar deterrent patrolling in Norwegian waters in 2024. [Norwegian Armed Forces]

'Nordic Warden 25' was done slightly differently. The specific focus again was CUI, with SJFHQ responding within 24 hours to defence ministerial calls to counter the continuing CUI threat, as evidenced by the November and December 2024 incidents. Working closely with the commercial sector, the JEF planners drew up a list of 24 named areas of interest spanning the North Sea, Norwegian Sea, Baltic, and Gulf of Finland. The aim here, Capt Thomas explained, "[Was] essentially to target where we thought international CUI was most vulnerable, and then being able to do something about it".

What differed this time, however, was the need to work in tandem with NATO's 'Baltic Sentry' CUI activity. This prompted perhaps three primary differences from 'Nordic Warden 24'.

First, given that all JEF members are NATO members and with 'Baltic Sentry' covering a similar aim and area – to deter Baltic CUI risks – but focused on visible, higher-end deterrence presence, priority for contributing physical platforms was given to 'Baltic Sentry'.

Second, JEF delivered significant value instead for both 'Nordic Warden' and 'Baltic Sentry' through generating greater autonomy in the at-sea surveillance and analysis function by introducing its software system from Palantir into operational activities for the first time.

Palantir's system was used to help generate enhanced real-time MDA and recognised intelligence and operational pictures, with participants able to feed in and draw on the open source and intelligence data it uses, explained Capt Thomas. "The system would monitor everything we wanted to monitor. It would alert us if there was something we would be interested in," he said. Enabled by record, playback, imagery, and analysis functions, and with data including ship names, tracks, and port visits, Palantir's software "gives you this really good picture of what's going on," he added.

The 24 identified areas were 'geo-fenced', with Palantir's software providing information on vessels of interest in each area and parameters that could point to suspicious activity outside of routine 'patterns of life'. Subject matter experts then determine if any activity flagged automatically by the system is suspicious or not, with the determination and supporting information shared with JEF countries and NATO. "Then we decide whether we'd want to have an effect, based on that," said Capt Thomas.

With the volume of shipping traffic in the region, the amount and complexity of CUI, and the number of sensors and other information sources collecting data, AI plays a critical role within Palantir's software. "[It] allows the system to interrogate the huge amount of data and present it in a way that's digestible for the human to then make a decision," said Capt Thomas. "We're harnessing the power in order that, for the operator, it's easier to see what's going on."

Third, integration with other stakeholders – especially NATO Allied Maritime Command (MARCOM), as the operational-level command for 'Baltic Sentry' – was more crucial than usual. 'Baltic Sentry' is the overarching, 'umbrella' construct under which all national and multinational activities targeting the Baltic Sea CUI risk since January have been held. Capt Thomas explained that the NATO and JEF activities were complementary. This complementarity, and overall output effect, was enhanced by the similar but slightly different AORs: 'Baltic Sentry' was Baltic-focused; 'Nordic Warden' had a wider AOR, including out into the North Sea and North Atlantic. JEF's already-established close integration with NATO commands was both reflected and reinforced. Operational co-ordination

JEF's participation in activities and operations in regions ranging from the Arctic to the Baltic underlines its growing impact on Northern European security, acting as a 'spoke' in the regional security 'wheel' built around the NATO 'hub'. In early 2024, JEF forces were deployed to support the opening stages of NATO's alliance-wide, joint force, multi-domain 'Steadfast Defender' exercise, with this presence proving out JEF's operational concept by demonstrating its deterring or shaping role in the pre-conflict phase, depending on how it is needed to support NATO requirements in peacetime, crisis, or conflict. JEF's development pathway includes plans to link its own exercise and wider operational activity series more closely with the alliance's 'Steadfast' series, said Capt Thomas.

JEF is being developed around a 10-year campaign plan, Capt Thomas explained. "That aims to [assess] where we are going, where NATO is going, and where we have to continue to develop to stay relevant – to stay at the cutting edge of doing what JEF set out to do in the first place."

and coherence and information and intelligence sharing between the JEF and MARCOM headquarters (along with Commander Task Force [CTF] Baltic – the German Navy's new tactical maritime headquarters, which was conducting tactical control of 'Baltic Sentry' ships operating under MARCOM command) was very good, Capt Thomas added.

Operationalising effect

The 'Nordic Warden' CUI activities and their impact on an issue garnering high-level politico-strategic attention underlined the demonstrable effect JEF continues to have on regional security, particularly with the increased level of integrated operational activities it is conducting.

"We're absolutely pushing the planning horizon out to make sure we are 'match fit', to make sure we're absolutely integrated into the national exercise and defence plans, but potentially – and more importantly – into the NATO series of exercises to ensure what we're doing is absolutely complementary," Capt Thomas continued.

Although JEF passed its full operational capability milestone in 2018, it still seeks to enhance its operational outputs. "We continue to morph, we continue to practise, we continue to rehearse alongside with NATO, in order that we stay relevant and agile, and ready to do what JEF needs to do in terms of security and stability, particularly the North Atlantic and Baltic region," Capt Thomas concluded.

JEF navies have been working together to build regional deterrence presence for several years. Pictured are JEF ships conducting the 'Baltic Protector' deployment back in 2019. [Crown copyright 2019]

Five frontline innovations from Ukraine

Sam Cranny-Evans

The war in Ukraine has evolved rapidly into a brutal battlefield that has outstripped the ability of the established defence industries in both Russia and Ukraine to meet all equipment needs. This has led to a thriving ecosystem of frontline innovations. This article looks at five that are particularly interesting and assesses their impact.

Counter-drone corridors

In February 2024, images and videos were posted on Telegram showing Russian soldiers driving through net tunnels erected in the Bakhmut area. The tunnels were designed to protect vehicles and personnel from Ukrainian drone strikes behind the frontline. The Ukrainian armed forces had embarked upon a deliberate strategy in 2024 of isolating Russian units by striking up to 30 km behind the contact line. They developed and employed a mixture of heavy bomber drones such as the Vampire, which can carry a TM-62 anti-tank mine, and lighter first-person view (FPV) drones to disrupt the flow of vehicles moving back and forth between bed-down locations and forward fighting positions. This was combined with conventional artillery to the extent that Ukraine was effectively isolating frontline units, limiting their ability to rotate forces, resupply, or conduct coordinated offensive manoeuvres.

▲ The Ukrainian Vampire unmanned aerial vehicle (UAV) shown here is also known as 'Baba Yaga'. It is a heavy bomber drone capable of flying at night and carrying large anti-vehicle mines behind the frontlines. This type of tactic is driving the development of counter-drone corridors. [Ukrainian MoD]

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Russian engineers then began to develop counter-drone corridors, seemingly as a frontline innovation. The corridors are built by erecting poles up to 5 m in height along the roads to be protected. The sides of the roads first need to be cleared of mines and unexploded ordnance before this can be done, much of which was left over from the battle for Bakhmut. Wire is strung between the poles and used to support netting that forms either a corridor or high walls. Russian engineers have experimented with the types of netting, according to a March 2025 article published by Izvestia. Earlier videos showed nets made of nylon cord with small openings. Later videos and images show netting similar to fishing nets, made of synthetic fibres such as monofilament nylon. These nets were harder to see on a drone's camera, Russian engineers claimed. Once established, the engineers would be focused on repairing and maintaining the nets, as attempted attacks or other events would create tears or damage to the netting.

The approach is part of a wider effort amongst Russian units in that area to reduce Ukraine's drone strike efficacy. Other measures include the use of specially equipped soldiers referred to as 'drone busters', who stand guard whenever drones are detected, ready to intercept them.

Are the nets worth the effort? Ukrainian soldiers seem to have taken a dim view of them, and they can likely be quickly destroyed using thermite-armed drones or by various other means. However, as part of a layered system of defence, which includes electronic warfare (EW), established hides along the roads, and 'drone busters', they likely improve the survivability of Russian units moving along those roads, which can otherwise be poor.

Drone busters

Before Russia's 2022 invasion, images emerged of Russian special forces moving into the trenches somewhere in the Donbass region of eastern Ukraine. They were equipped with a sniper rifle, commercial quadcopter drone, and an anti-drone gun

Ukrainian soldiers practice counter-drone engagements with Hatsan Escort BTS-12 semi-automatic 12 gauge shotguns. [Ukrainian MoD]

that used jamming to degrade the control link between a drone and its operator. Those soldiers were already aware of the risk posed by Ukraine's drones, which had come to fill the artillery gap created by the 2014 Minsk Agreements.

Those soldiers foreshadowed what was to come in Ukraine following the 2022 invasion. Early adaptations to the threat of small drones focused on EW, with the occasional abortive attempt to shoot them down using medium calibre cannons and even short-range air defence missiles. EW proved effective, and remains so, however, regular firmware updates and frequency changes helped operators to somewhat mitigate its effects, and the rapid growth of FPV drones seems to have helped reduce the impact of GPS-jamming and spoofing (which reduced the effectiveness of various other munitions) to some extent. However, as the war has come to focus on small sections of infantry, often isolated, new innovations have emerged. The drone buster is a term that has been used by Russian journalists to describe soldiers equipped with a shotgun, drone detector (either a simple signal detector or direction finder), and occasionally a drone jammer. However, soldiers that are similarly equipped have been seen fighting in both forces.

The type of shotgun employed varies enormously; some drone busters carry the military Saiga-12, a Kalashnikov pattern 12-gauge semi-automatic shotgun, typically with an eight- or ten-round box magazine, though smaller box magazines and larger drum magazines are also available. However, it is more common to see drone busters armed with break action and pump action shotguns, the former often appearing to be sporting designs like the TOZ-34 over-under shotgun. Often, drone busters also carry a standard assault rifle such as the AK-74 fitted with a collimator sight that provides a back-up option should the shotgun fail to bring the drone down. This may be a more common outcome than one might think. The kinetic energy of shotgun pellets declines rapidly with distance; this can be mitigated by using larger-grade shot, but this then reduces the number of pellets over a given area. So, poor cartridge selection, and inexperience in using a shotgun, which produces a different shot pattern to a rifle, could lead to failed interceptions.

The drone buster arsenal is completed with the addition of a drone jammer, which is often procured from China. One example includes the Harpy CKJ-1704 backpack drone jammer. The Harpy is designed to suppress drone signals over a radius of 2,000 m and can provide up to four hours of continuous jamming. It is claimed to provide 300 W output and to be effective against frequencies between 430 and 960 MHz. A drone detector, which monitors radio frequency (RF) signals, provides the final element of the drone buster kit.

This approach to drone defence appears valid and takes into consideration the elements needed to provide the greatest chance of a successful intercept. Refinements could be made, for instance shotguns equipped with red dot sights and purpose-built cartridges such as the Anti-Drone Long Effective Range (AD-LER) 12-gauge cartridge from Norma. However, this innovation generally appears to offer at least some defence against a threat that is otherwise very difficult to counter.

The 'Turtle tank'

In 2021, prior to the invasion, tank units of Russia's Southern Military District were observed with strange-looking cages installed over the roofs of their T-72B3s. Speculation swirled in the West as onlookers pondered the cage's ability to degrade and fool the FGM-148 Javelin anti-tank guided missile. The reality was far less ambitious. For some years – since 2017 at least – Ukrainian units had used small drones to deploy grenades and mortars against Russian and separatist paramilitary forces in the East of the country. This was well-known to the Russian units sitting on the other side of the border, and so they developed the drone cages to try and protect their tanks, starting a trend that has spread around the world. Israeli Merkava IV tanks were observed with their own drone cages as they entered Gaza in 2023; the Chinese People's Liberation Army (PLA) has released footage of Type 99 tanks fitted with the PLA's own interpretation of the concept. Across the sea, Taiwan has shown an M60 fitted with an array of cages, and Vietnam modified a T-55, while India did the same with some of their T-90 tanks.

The drone cage structure appeared on Russian tanks some time before the invasion of Ukraine, prompting some analysts to erroneously speculate that they were intended to counter Javelin. [Russian MoD]

As the war has progressed and the FPV threat developed, the 'cope cages' as they had come to be known, provided less and less protection. This was a big problem for Russian units, which were increasingly required to conduct offensive operations from late 2023, and also developing a growing reliance on their tanks to fill in for the artillery that was lacking ammunition. Eventually, 'turtle tanks' began to appear with the first types

appearing around April 2024 in social media posts. In short, Russian forces would take a tank – even the ostensibly well-protected T-90M – and build a crude shelter around it.

The shelters can be built from various materials, typically including some form of wire cage or mesh as the base structure that is used to build a house around the vehicle. Wood panels and other materials like corrugated or sheet metal are then added to the cage structure, limiting the crew's ability to rotate the turret, as well as their situational awareness and mobility too. They were built in workshops along the frontline, and many other examples emerged quickly after the first version was observed. EW equipment is often found on the vehicles, as well as mine rollers or ploughs. "We are creating tanks that will go ahead to clear mines and attack the enemy," one Russian soldier said.

Ukrainian soldiers pose with a captured Russian 'turtle tank', which appears to be a T-62 fitted with an extensive structure designed to reduce the probability of a successful strike. [Armyinform]

The compromises in visibility and combat efficacy were likely acceptable to the Russians as they mitigated against the effects of FPVs, with various such tanks reportedly surviving multiple hits. In one operation in Krasnogorovka near Avdiivka, a turtle tank was used to deliver an assault section onto a Ukrainian position, which it did successfully before withdrawing. It was eventually destroyed in its hide. Ukrainian news outlets report that the tanks were largely effective and resistant to FPVs, which were the primary form of lethality available to Ukrainian forces at the time. US aid had stalled at the time and was stuck in a deadlock in Congress, which meant Ukraine had few anti-tank missiles and artillery available to deal with the tanks. Eventually, chains of mines were used to disable them and successive FPV strikes to destroy them. However, one turtle tank reportedly survived more than 40 drone strikes, according to Russian news outlets.

The turtle tank sets out to address a very specific set of interrelated challenges. In a typical offensive operation, Russian forces would expect an extensive artillery and air assault preparation with continued availability throughout the offensive. This would destroy enemy positions and suppress its fighters, making the advance easier, and providing time for mine clearance. However, with an ammunition shortage biting the Russian forces too, they could not rely on overwhelming firepower to clear the route ahead for them. This in turn meant that sending engineering assets to clear a minefield would be very likely to fail, as the Ukrainian forces had found in their own offensive the year before. If a vehicle was immobilised by mines, FPVs would ensure that it could not be recovered. So, the turtle tank provided a solution; enough protection to get through the minefields whilst absorbing FPV strikes.

Interceptor drones

Air defence became a serious problem for Ukraine as it depleted its stocks of munitions for its Soviet-era air defence systems. The consequences of this have ebbed and flowed with the availability of Western air defence systems, as well as additional missiles procured from abroad for Ukraine's Soviet-era systems.

This still from the Ukrainian MoD captures the moment an interceptor drone draws close to a Lancet loitering munition. For a long time, Ukraine lacked an effective response to the Lancet, and although it still remains capable, solutions such as interceptor drones are helping to balance the scales somewhat. [Ukrainian MoD/Azov Brigade]

However, as Russia's production of cruise and ballistic missiles, as well as the Shahed family of one-way attack (OWA) drones increased, Ukraine appeared to focus its limited air defence resources on defending population centres. This created openings for Russian reconnaissance drones to range deep behind the frontlines searching for targets, leading to particularly lethal strikes with the Iskander-M short-range ballistic missile (SRBM) system. In some cases, the Russian reconnaissance-strike complex was able to identify air defence systems and ammunition convoys in time for a missile engagement. The strikes enabled Russia to further compound the other advantages that it was building, such as the increased production of glide bombs.

To help counter the almost ubiquitous Russian reconnaissance drones, which include the Z-16 series from Zala Aero and Orlan-10 from STC, Ukrainian units began engaging them

kinetically with FPV drones. Video footage that shows an FPV approaching a class 2 fixed-wing drone from behind is now a relatively common sight on the social media channels of the Ukrainian MoD. The tactic expanded, and videos soon emerged of small class one drones physically crashing into each other to try and bring the adversary drone down. In another video, a Russian drone armed with a stick collides with a Ukrainian Baba Yaga with unclear results. However, the damage to the stick indicates that the video was probably not its first outing.

Over time, Ukraine appears to have become quite proficient at bringing Russia's larger reconnaissance drones down using smaller FPVs. This is likely an important element of the air defence ecosystem, helping save missiles and other even scarcer systems for interceptions of high-threat systems such as missiles, fixed wing aircraft, and helicopters.

Molniya

The final innovation considered here is the Molniya family of fixed-wing OWA drones with FPV guidance developed by Russian forces that has grown in use. The best way to describe Molniya is to say that it is a minimal viable concept for a drone.

It uses light and readily-available materials such as aluminium poles, plywood, and low-quality electronics. Russian media outlets indicate that it is assembled with tape and glue prior to launch. Despite its seemingly flimsy design, however, the original Molniya-1 has been used quite effectively and modernised to the more robust Molniya 2 design, distinguished by its two wing-mounted propellers instead of a single nose-mounted propeller, and sometimes also by its use of an aerodynamic fairing around the central portion of the craft.

These OWA drones can be armed with various payloads, with the Molniya-2 having been observed being fitted with two thermobaric warheads from the RPO-A Shmel', and the TM-62 anti-tank mine, which carries explosive equivalent to 7.5 kg of TNT. Their cheap construction and range of around 40-50 km mean that they can be used in large numbers, somewhat mitigating their lack of accuracy. A TM-62 can be enough to collapse a building, and in this role the Molniya family helps make up for the lack of other fire support systems.

Adaptation, innovation, survival

Leon Megginson, Professor of Management and Marketing at Louisiana State University, stated in 1963 that, "it is not the most intellectual of the species that survives; it is not the strongest that survives; but the species that survives is the one that is able best to adapt and adjust to the changing environment in which it finds itself." This quote (often misattributed to Charles Darwin, although it was originally made by Megginson while summarising his interpretation of Darwin's ideas in 'The Origin of Species') neatly sums up the situation in the Ukraine war. A cycle of frontline innovations, some happening in as little as six weeks, has led to a violent and lethal battlefield where soldiers are constantly having to adapt to survive.

The Molniya-1 OWA UAV is shown here in stills from a video released by the Russian MoD. [Russian MoD]

The demilitarisation of chemical weapons

Dan Kaszeta

Since the dawn of chemical warfare in the First World War, various countries in the world made large quantities of chemical warfare agents (the toxic chemicals themselves) and chemical munitions (the weapon systems to dispense them). Only a portion of these weapons were used on the battlefield and no country has a declared arsenal of chemical weapons now, although a few arms control hold-outs might have a few stashed away. Where did they go? The answer is both interesting and alarming.

It is nearly a fool's errand to try to calculate how many tonnes of chemical warfare agents were manufactured during the 110 years since their first major battlefield use at Ypres in World War I. Many records are still secretive, but the quantity has to be well into the hundreds of thousands of tonnes of agents and accounts vary considerably. Many accounts mistakenly confuse munition weight (the weight of a filled bomb or shell) with agent weight (just the weight of chemicals), and many countries also ended up with unfilled munitions at the end of wars, thus further complicating the accounting.

The US once managed a vast stockpile of chemical warfare agents. All are now destroyed. [US Army]

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The end of wars, the obsolescence of a particular chemical agent or delivery system, the end of the Cold War, and the worldwide adoption of arms control treaties, principally the Chemical Weapons Convention (CWC) adopted in the 1990s, gave impetus to the destruction of both chemical agents and munitions, both filled and unfilled. The process of disposal gradually became known as 'chemical demilitarisation' and it has taken on many forms over the years. This article relies more heavily on US demilitarisation efforts, as they are exceedingly well-document in the public domain, unlike efforts in other places. The American experience heavily documented many of the technical and environmental problems, leading to an extensive body of knowledge in this otherwise arcane field.

Chemical demilitarisation has been harder than getting rid of other classes of weapons. Swords can be literally turned into ploughshares if someone wanted to do it, and tanks and battleships can be scrapped for metal. Tonnes of nerve agent or similar chemicals, however, present different sorts of problems. The vast majority of chemical warfare agents and munitions were developed with a view towards battlefield use, but not with any sort of idea how to get rid of them when no longer needed. Some chemical warfare agents will leak or degrade, but others could easily last many decades in undisturbed intact munitions. On top of the problem of weapons no longer wanted or needed, there are issues with lost or abandoned chemical weapons. Ships sink, entire countries go out of existence, and chemical weapons fail to function, and so sit alongside other unexploded remnants of warfare.

Out of sight, out of mind

The first approach taken was burial. Both Western and Eastern fronts in the First World War saw extensive use of chemical weapons. The initial impetus was to leave potentially unexploded defective weapons buried in situ, often out of lack of any better idea. Given the technology of the time, this was, if not a good idea, a 'least bad' idea in many people's minds. The legacy of such decisions in 1918 and 1919 still rears its head, with chemical artillery shells still occasionally turning up in fields in France and Belgium.

Larger quantities of chemical munitions were simply buried in trenches. This was very much an approach taken by the Japanese at the end of the Second World War in China, as they were retreating in haste and their government no longer existed. China was by no means the only exemplar of such haste. The US Army, for example, buried numerous munitions just outside Washington DC only to be uncovered by construction in the leafy neighbourhood of Spring Valley in the 1990s, leading to

an expensive clean-up effort that dragged on for many years. These instances cannot be considered a demilitarisation strategy in themselves, and merely deferred the problem for later generations.

Get in the sea!

Up until the 1960s, environmental impact was not foremost in the mind of governments seeking to get rid of munitions. The easiest course of action for getting rid of larger quantities of chemical weapons was to sink them in the sea. It is likely that the most widespread disposal effort, at least up until about 1970, was disposal at sea. Even at the time, these disposal operations were considered the least bad of poor options, but not ideal.

Sulfur mustard containers being pushed off a barge and dumped into the Atlantic Ocean in 1964. [US Army]

People could be forgiven for imagining that 'getting rid of chemical weapons in the sea' was basically pouring the chemicals straight into the water. This did not happen at any significant level. Dumping of whole munitions (for instance, chemicals inside a shell or bomb) did happen, but the state of the art for sea disposal was to place the munitions in surplus ships and then sink those vessels. For example, Operation Sandcastle saw the British military get rid of 71,000 captured German bombs filled with the nerve agent Tabun in 1955 and 1956. These were loaded on superannuated merchant vessels and sunk in the North Atlantic at a depth of 2500 m.

The most transparent and best-documented chemical demilitarisation campaign has been the US Army's fifty-year effort to get rid of its Cold War chemical arsenal. President Nixon, for all his faults in other areas, was an earnest proponent of arms control and an advocate for chemical and biological disarmament. Long before the US military decided to fully rid itself of chemical weapons in the 1990s, there were numerous items that were no longer fit for purpose. The US Army, which was the custodian of all the US chemical weapons, started disposal operations quite early on, and gradually scaled them up. The US had a series of such operations called Operation CHASE which gloriously stood for 'Cut holes and sink 'em'. For some of the more dangerous US weapon systems, such as the infamously unsafe M55 nerve agent rocket, the US would put the rockets in steel boxes and fill the boxes with concrete, encasing the rockets in dense blocked of concrete, before loading them on ships. These ships would be sunk in deep sea, at a depth of thousands of metres.

Operation CHASE started to get significant opposition from residents and local politicians as, invariably, rail and road operations to move the chemical weapons from landlocked storage depots to sea ports raised the prospect of accidents or incidents. Sober risk assessments showed that transport was the most dangerous aspect of the operation, and increasing public concern for the environment meant that this programme ended. The last Operation CHASE sinking took place in August 1970.

Neutralisation or incineration

The Cold War drew to a close with vast arsenals of chemical weapons in the Soviet Union and the United States, with smaller stockpiles in several other countries. In the United States, the ending of sea disposal happened at the same time as President Nixon's halting of chemical weapons production and a general pivot away from chemical warfare as a military doctrine. Various panels of scientists and chemical engineers contemplated the disposal problem and considered two approaches, neutralisation and incineration. Neutralisation adds chemicals to the warfare agents to degrade them into substances that are less dangerous. Incineration uses very high temperatures to cause the molecules to fall apart into much safer molecules.

The US had considerable experience using neutralisation with Sulfur mustard (so-called 'mustard gas') and Sarin, but only very limited experience with VX. Mustard could be mixed with chemicals such as monoethanolamine, but this would leave a sludge of by-products, some of which were almost as much of a disposal hazard as the original. Sarin was considered easier to destroy, and many hundreds of tons of Sarin were treated with sodium hydroxide. While effective, the chemical reaction was technically reversible, and some Sarin re-formed out of waste products, meaning that the waste would have to be incinerated anyway.

Johnston Atoll Chemical Agent Disposal System (JACADS) on 1 November 1990. During the 1990 joint US-West German 'Operation Steel Box' known as 'Aktion Lindwurm' (ENG: ' Operation Golden Python') in German, over 100,000 chemical weapons were removed from West Germany and shipped to the Johnston Atoll for destruction. [USAF/SSgt Val Gempis]

The US then pioneered high-technology high temperature incineration. A National Academy of Science study concluded that incineration was the only truly safe method. The method had much to recommend it, in that none of the decomposition products had any chance of re-forming back into warfare agents, the effluent could be easily monitored, and the emitted exhausted gases were well down the list of environmental hazards. Both in quantity and composition, the emitted compounds were far less damaging than a coal power plant, particularly the power plants of the era.

At first there was a pilot plant in Utah to pioneer various concepts, then, at vast expense, the large Johnston Atoll Chemical Agent Disposal System was built in the mid-1980s. Johnston Atoll is a US possession in the Pacific, some 1500 km southwest of Hawaii. One of the USA's most remote places and with no local population to remonstrate, it had become the resting place for US chemical weapons withdrawn from Okinawa in 1971. These weapons were later joined by US Army chemicals withdrawn from Germany. By 1990, by the time the disposal incinerator went on line, Johnston Atoll had 262 tonnes of Sulfur mustard, 1197 tonnes of Sarin, and 383 tonnes of VX. It took a long time, but by 2000 the chemicals had been destroyed

The USA also had vast amounts of chemical weapons stored at eight sites in the continental USA, and had originally planned to ship them to Johnston Atoll. However, concerns about safety in transport nixed the concept, especially since some of the weapons were leaking. The laborious process of building destruction plants at those 8 sites and took decades. The entire campaign was beset by myriad delays too numerous to detail here. Some delays were technical; the M55 nerve agent rocket was a fiendish devil to destroy. A varied blend (local politics being very different across the US chemical weapons estate) of local activism and environmental litigation combined legitimate concerns, distrust of the Federal government, low probability worst-case scenarios that rightly alarmed the local populace, and the occasional conspiracy theory all combined to drag the programme out considerably. Ironically, environmentalism delayed the end of the US chemical weapons programme. The Federal government responded with a mix of dithering and diplomacy, lavishing large grants to the nearby communities mostly in the form of the Chemical Stockpile Emergency Preparedness Program. Many a local fire or police department benefited from Washington's largesse. Incineration progressed at six of the eight storage sites, being completed in 2012, well over budget and well behind schedule.

Not everyone was happy with incineration. It was occasionally likened to simply burning in the open, although the high-tech methods were far from that, and decades of entrenched debate had sometimes devolved into hyperbole. In two locations, Pueblo, Colorado and Lexington, Kentucky, incineration was so vociferously opposed that the Army re-investigated neutralisation and under the label 'Assembled Chemical Weapons Alternatives' used more advanced chemical techniques than those available in the 1970s when the problem was previously considered. Although the programme was delayed and more expenses piled up, the last of the US chemical weapons stockpile was destroyed in 2022. The X (formerly Twitter) account of the Program Executive Officer for Assembled Chemical Weapons Alternatives provided a fascinating level of detail of the last years of this effort.

Finding CW in other places

The US experience is by no means the only one. Russia went to great lengths to destroy the old Soviet arsenal. In better political climes, this was heavily aided by US technical grants and expertise under the Cooperative Threat Reduction programme. Regardless of lingering doubts raised by

Workers remove air filters from Static Detonation Chamber Unit 3 at the Pueblo Chemical Agent-Destruction Pilot Plant on 11 March 2025, in preparation for an Unventilated Monitoring Test. [PEO ACWA]

▲ **Chemical Weapons stockpile in Russia before destruction by Defense Threat Reduction Agency (DTRA), photographed 20 July 2011. [DTRA]**

incidents like the attempted assassination of Sergei Skripal with a nerve agent, thousands of tons of chemical agent were destroyed under international supervision.

Old or abandoned chemical weapons do crop up from time to time in places like France, Belgium, and China, left over from the World Wars. Specialist destruction facilities have been built to deal with such munitions when they are found. Albania found an old stockpile and did the right thing by declaring it. A small destruction plant was built and some USD 48 million spent to rid Albania of this unwanted legacy. Elsewhere, South Korea very quietly got rid of some chemical weapons at some point, although the programme was shrouded in secrecy. India declared and destroyed a small stockpile. An international effort led to the demilitarisation of a small Libyan programme.

Sometimes things still are not destroyed in an ideal way. US Army soldiers destroyed large quantities of Saddam Hussein's chemical weapons at a storage complex in Khamasiyah, Iraq, in 1991. It was thought that ample quantities of high explosive would destroy the chemical agents, but the efficacy of the demolition was doubtful and the exhaust plume has been closely correlated to many medical problems. (This is discussed in more detail in the article on *Burn Pits and Toxic Residue of War*, forthcoming in this publication).

Syria acceded to the Chemical Weapons Convention after being caught using Sarin in 2013. A quantity of Sulfur mustard, some of it evidently quite old, and many tonnes of precursor chemicals were declared and offered up for destruction. Destroying them amidst an ongoing civil seemed problematic, but no country wanted to take the worst of the chemicals. The Organisation for Prohibition of Chemical Weapons (OPCW) and the USA, with some funding from the UK, deployed a merchant vessel, the MV *Cape Ray*, equipped with two 'Field Deployable Hydrolysis Systems' that used chemistry not dissimilar to that used in Pueblo, Colorado. The *Cape Ray* neutralised Syrian mustard and some nerve agent precursors while at sea in the Mediterranean. Syria's ultimate compliance with chemical demilitarisation will only be determined after a full accounting of the former Assad regime's chemical programme, now that the Assad regime is out of power.

There are future prospects in this area. Old munitions continue to turn up in Western Europe, China, and a few have turned up elsewhere over the years. At some point, the world may need to deal with possible chemical stockpiles in Egypt (possible, albeit possibly small or old), Israel (a total unknown), and North Korea (unknown but possibly quite large). None have made declarations to the OPCW. One can envisage a wide variety of geopolitical scenarios in which demilitarisation efforts for newly-declared or discovered chemical stockpiles may be relevant. Chemical demilitarisation has slowed down considerably, but it is by no means irrelevant.

▼ **The MV *Cape Ray* (T-AKR 9679) in the Mediterranean Sea, on 4 August 2014 [US Navy]**

Chaos at the Pentagon

Peter Felstead

While US President Donald Trump often appears to thrive in sowing discord, the current chaos at the US Department of Defense (DoD) cannot serve any decent purpose – and comes with significant strategic risk.

▲ US Defense Secretary Pete Hegseth pictured at the Pentagon on 2 April 2025. Hegseth's actions so far have kept the White House spin doctors busy. [US DoD]

With US President Donald Trump having announced in early April 2025 that he planned to set the 2026 US defence budget at a record-breaking USD 1 trillion (EUR 870 billion), a prerequisite for overseeing such a vast sum would appear to be a highly efficient Department of Defense (DoD) with a clear and unified purpose.

Yet less than 100 days into Trump's second presidential term the US DoD is reeling from one crisis to the next amid multiple firings, astonishing lapses in security and Pentagon staff being threatened with lie detector tests to stifle any leaks to the press. A major reason for the current disfunction is a relatively obvious one: the qualifications for serving in the Trump Administration are not experience and professional capability, but absolute loyalty to Trump's political agenda. In this regard the current US secretary of defence, Pete Hegseth, epitomises the current situation.

AUTHOR

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Dogged in the wake of his nomination by reports of excessive drinking, abuse of women and a clear lack of executive and political experience, Hegseth squeaked through his confirmation hearing on 25 January 2025 only through the rare intervention of the US Vice President, JD Vance, to break a 50-50 tie in the Senate vote. While there were clear reservations about Hegseth's suitability on both sides of the political aisle, the former Fox News anchor sported exactly what Trump required: a background of military service (with a hint of Christian nationalism), but above all absolute fealty and an eagerness to wage a 'war on wokism' within the US military.

The 'war on wokism'

Trump and Hegseth lost no time in firing senior US commanders whose leadership or appointments they viewed as having strayed too far in terms of diversity, equity, and inclusion (DEI) initiatives.

On his first day in office, in fact, Trump fired the commandant of the US Coast Guard, Admiral Linda Fagan, who in June 2022 became the first woman to lead a US military service. Then, on 21 February, the chairman of the Joint Chiefs of Staff, US Air Force (USAF) General Charles 'CQ' Brown was unceremoniously ushered from his post via a Trump message on social media. Hegseth separately announced the same day that he was replacing Chief of Naval Operations (CNO) Admiral Lisa Franchetti and USAF Vice Chief of Staff General James Slife.

▼ US Defense Secretary Pete Hegseth signing a memorandum on 3 March 2025 to revert Fort Moore in Georgia back to its original name of Fort Benning. Hegseth's 'We the People' tattoo, visible in this photograph, is an opening phrase in the US Constitution, but Hegseth also has other tattoos that draw on militant Christianity associated with The Crusades. [US DoD]

Both Gen Brown and Adm Francetti had served in the US military for four decades; Gen Brown is a former fighter pilot who was appointed as the USAF's first black chief of staff by Trump in August 2020, while Adm Francetti commanded the US Sixth Fleet, two carrier strike groups and US Naval Forces Korea before becoming the first woman appointed as CNO in November 2023. Gen Slife, who had served in the USAF since 1989, is a former commander of Air Force Special Operations Command. Both Gen Brown and Gen Slife, as four-star officers, have been replaced by three-star officers.

Meanwhile, a campaign was afoot to reverse the previous Biden Administration's renaming of nine US Army bases previously named after Confederate generals of the American Civil War. On 10/11 February 2025 Hegseth directed Fort Liberty in North Carolina to be restored back to its original name of Fort Bragg, while on 3 March Hegseth directed Fort Moore in Georgia to be reverted back to its original name of Fort Benning. On both occasions the US DoD – though not Hegseth in his social media posts – was at pains to point out that these bases were being renamed after US Army heroes of the 20th Century, rather than the slavery-endorsing Confederate leaders they were originally named after. Presumably some unfortunate staffers within the Pentagon are now having to come up with another seven US Army heroes who share the same surnames – Gordon, Hill, Hood, Lee, Pickett, Polk and Rucker – as the Confederate generals those bases were originally named after.

The 'Signalgate' fiasco

While the re-renaming of US Army bases can be seen as a waste of time and money that has little to do with the Trump Administration's professed goals of emphasising the warfighting effectiveness of the US military, Hegseth has now been involved twice in potentially exposing classified military information.

On 15 March 2025, US Central Command (CENTCOM) initiated a large-scale operation consisting of precision strikes against Iran-backed Houthi targets across Yemen. Prior to the attack commencing, however, US National Security Advisor Michael Waltz inadvertently copied in a US journalist, *The Atlantic* Editor Jeff Goldberg, into a group chat among senior Trump Administration officials on messaging app Signal in which Hegseth noted in some detail the operation being executed. The events were subsequently reported by Goldberg in a 24 March piece published in The Atlantic.

This appeared to be a major security breach that contravened a number of US security laws and regulations, yet in the wake of the revelation numerous Trump Administration officials denied and obfuscated over the extent of the incident. On 24 March, Hegseth's initial response was to attack Goldberg's credibility and to state that "Nobody was texting war plans and that's all I have to say about that."

In a subsequent 24 March interview with CNN, however, Goldberg defended the claims made in his article, "No, that's a lie. He was texting war plans. He was texting attack plans, when targets were gonna be targeted, how they were gonna be targeted, who was at the targets, when the next sequence of attacks were happening."

A videograb from WBNS 10TV footage of US Defense Secretary Pete Hegseth arriving in Hawaii on 24 March 2025 when he claimed that "Nobody was texting war plans" on Signal in relation to the Houthi strike on 15 March. [WBNS 10TV]

On 26 March, following numerous denials from Trump Administration officials that any war plans had been texted, The Atlantic published a full transcript of the controversial Signal chat. In it, Hegseth posted the following outline of the US strike plan:

"1215et: F-18s LAUNCH (1st strike package)"
"1345: 'Trigger Based' F-18 1st Strike Window Starts (Target Terrorist is @ his Known Location so SHOULD BE ON TIME _ also, Strike Drones Launch (MQ-9s)"
"1410: More F-18s LAUNCH (2nd strike package)"
"1415: Strike Drones on Target (THIS IS WHEN THE FIRST BOMBS WILL DEFINITELY DROP, pending earlier 'Trigger Based' targets)"
"1536 F-18 2nd Strike Starts _ also, first sea-based Tomahawks launched."
"MORE TO FOLLOW (per timeline)"
"We are currently clean on OPSEC"
"Godspeed to our Warriors."

"If this text had been received by someone hostile to American interests – or someone merely indiscreet, and with access to social media – the Houthis would have had time to prepare for what was meant to be a surprise attack on their strongholds," The Atlantic wrote. "The consequences for American pilots could have been catastrophic."

It then emerged on 21 April 2025 that Hegseth had shared detailed plans about military operations against the Houthis on a second Signal group chat, this time one he had set up himself that included his wife, brother and lawyer. The group chat was reportedly set up during Hegseth's confirmation hearing in January, included more than a dozen people and was continued to be used by Hegseth after he was confirmed.

Amid this latest controversy a number of Pentagon advisors in Hegseth's orbit disappeared from their jobs. John Ullyot, the former top DoD Spokesperson, announced his resignation on 16 April, while on 18 April three top staffers at the Pentagon were fired: Senior Adviser Dan Caldwell, Deputy Chief of Staff Darin Selnick and Chief of Staff to the Deputy Defence Secretary Colin Carroll. Hegseth's Chief of Staff, Joe Kasper, then announced he was leaving that position for a new role in the Pentagon.

Ullyot is a fully pro-Trump official who was sidelined amid controversies over the purging of supposedly DEI content from military websites, while Caldwell, Selnick and Carroll were all accused of leaks: an assertion they strongly deny.

In a 20 April opinion piece for the US news website ***Politico***, Ullyot wrote, "It's been a month of total chaos at the Pentagon. From leaks of sensitive operational plans to mass firings, the dysfunction is now a major distraction for the president — who deserves better from his senior leadership."

Ullyot also defended Caldwell, Selnick and Carroll, asserting that "Defense Department officials working for Hegseth tried to smear the aides anonymously to reporters, claiming they were fired for leaking sensitive information as part of an investigation ordered early this month. Yet none of this is true."

Despite claiming to be a "longtime backer" of Hegseth, Ullyot nevertheless wrote that the US defence secretary *"is now presiding over a strange and baffling purge that will leave him without his two closest advisers of over a decade — Caldwell and Selnick — and without chiefs of staff for him and his deputy. More firings may be coming, according to rumors in the building. In short, the building is in disarray under Hegseth's leadership."*

of records retention protocols, Ullyot suggested in his Politico opinion piece that "it's hard to see Defense Secretary Pete Hegseth remaining in his role for much longer". That might not come to pass – at least in the short term – unless Hegseth himself resigns, given that, having overseen the railroading through of his appointment in the face of considerable opposition, Trump would have to concede to having made a mistake in doing so. On 21 April, when asked about Hegseth's position, Trump stated, "Pete's doing a great job. Everybody's happy with him."

That said, as numerous casualties within the first Trump Administration have demonstrated, senior officials in Trump's orbit only have his complete support until they don't.

The wider picture

All of the discord and disfunction at the Pentagon could be regarded as a comical sideshow if it was happening in a vacuum, but it isn't. The war resulting from Russia's invasion of Ukraine in February 2022 continues to rage, despite Trump claiming numerous times pre-election that he could end it in 24 hours. The economic meltdown that Trump claimed would happen should his presidential rival Kamela Harris be elected is, indeed, happening – as a result of Trump's self-instigated tariff

US President Donald Trump at his first Cabinet meeting on 26 February 2025, flanked by Secretary of State Marco Rubio (left) and Secretary of Defense Pete Hegseth. [White House]

With regard to the 'Signalgate' debacle, Ullyot claimed that Hegseth "followed horrible crisis-communications advice from his new public affairs team, who somehow convinced him to try to debunk the reporting".

Writing that this was "just the beginning of the Month from Hell", Ullyot detailed further PS disasters: ***The Wall Street Journal*** and other outlets reporting that Hegseth brought his wife, a former Fox News producer, to two meetings with foreign military counterparts where sensitive information was discussed; the Pentagon setting up a top-secret briefing by the Joint Chiefs of Staff on China for Elon Musk, the Tesla-owning Trump senior advisor who still has extensive business interests in China (a meeting subsequently cancelled by the White House); the Pentagon purges; and then details emerging about Hegseth's second Signal chat group.

Noting that Hegseth now faces an inspector general investigation into a possible leak of classified information and violation

war. Meanwhile, US relations with some of its erstwhile closest allies, as a result of both the US response to the situation in Ukraine and the imposition of US tariffs, is at perhaps its lowest level since before the Second World War. Indeed, a major fallout of the first 'Signalgate' incident was the revelation of how much contempt senior figures in the Trump Administration – most notably Hegseth and Vance – hold for their supposed European allies.

Beyond the eroding of allegiances forged in the grim endeavours of previous wars, the greatest danger from a dysfunctional Pentagon is nothing less than strategic. With the Trump Administration packed with appointees whose prime qualification for their positions is absolute loyalty to the Trump agenda, and with the US defence secretary devoid of senior advisors as of late April 2025, there is a growing likelihood that bad strategic decisions will progress unchallenged. If that were to materialise, the consequences could be felt far beyond US borders.

Diversifying Armenia's defence: Shifting alliances and military modernisation

Eduard Arakelyan and Dr Karena Avedissian

Armenia's defeat in the 2020 Nagorno-Karabakh war, followed by Azerbaijani offensives on Armenian territory and Nagorno-Karabakh in 2022 and 2023, marked a turning point in the country's defence strategy. These conflicts exposed critical weaknesses in the Armenian army, which remained largely reliant on outdated Soviet and Russian weaponry. This dependence on Russian arms and logistical support proved inadequate in the face of modern warfare tactics, revealing vulnerabilities and necessitating a strategic reassessment of Armenia's approach to defence and security.

Despite the lessons of the 2020 war, Armenia initially continued sourcing arms from Russia, even signing a major arms contract with Russia in 2021. However, two key events forced Yerevan to rethink its military partnerships. First, Russia's prolonged invasion of Ukraine exposed serious flaws in its defence industry and weapons production. Second, Azerbaijan's large-scale offensive in September 2022 targeted Armenia's internationally-recognised territory, attacking civilian areas and occupying border regions. When Armenia sought assistance from its allies – particularly the Russia-led Collective Security Treaty Organization (CSTO) – for assistance, it was met with indifference, reinforcing the unreliability of these alliances.

These events made it clear to Armenia that continued reliance on Russian arms supplies was becoming increasingly unsustainable. Following Azerbaijan's September 2022 attacks,

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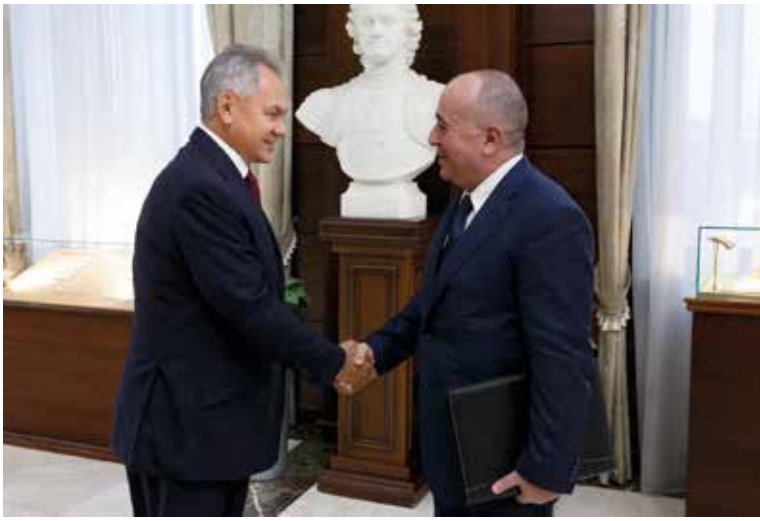

Former defence ministers Sergei Shoigu (Russia) and Arshak Karapetyan (Armenia) after signing a defence contract in August 2021. [Armenian MoD]

Armenia actively sought military cooperation with other countries, particularly India and France, to secure alternative sources of weaponry. Since then, diversifying arms supplies and military equipment has become a cornerstone of the country's defence policy. This strategic shift became even more urgent after Azerbaijan's September 2023 attack on Nagorno-Karabakh, which led to the mass displacement of the resident Armenian population, leading Armenia's Prime Minister Nikol Pashinyan to accuse Azerbaijan of conducting ethnic cleansing. This outcome further solidified Armenia's determination to reduce its military dependence on Russia.

Since late 2022, India and France have emerged as Armenia's primary arms suppliers, providing nearly the entire range of weapons and equipment necessary for the country's defence. Both countries remain open to further deliveries of critical weaponry, and Armenia has become the largest foreign client of India's defence sector. India was the first country Armenia turned to under its new defence initiatives, aiming to modernise and diversify its military capabilities. Armenia's efforts are now primarily focused on securing partnerships for the supply of advanced weaponry and ammunition, ensuring reliable logistics, and reducing its dependence on Russia – a country that has proven unable to provide adequate arms and support, particularly in Armenia's ongoing confrontation with Azerbaijan.

In recent years, India has made significant strides in expanding its military industrial capabilities through the 'Make in India' initiative, successfully developing and mass-producing military equipment at competitive prices. Armenia's procurement of Indian-made weapons serves to some extent as an endorsement, helping to establish India's growing presence in the international defence market

At the same time, India continues to maintain its position as the world's second-largest arms importer (after Ukraine), with its imports constituting 8.3% of global arms trade from 2020–2024 according to SIPRI. The country's defence acquisition strategy remains diversified, with major procurement relationships maintained with France, Israel, and Russia.

India

According to open sources, since late 2022, Armenia and India have signed several defence contracts encompassing a wide range of weaponry and military systems. These agreements include the acquisition of 214 mm Pinaka multiple rocket launch systems (MLRS), Konkurs anti-tank guided missiles (ATGMs) – which were produced in India under Russian license – as well as mortars, and various types of ammunition. Additionally, the contracts cover MArG 155/39 self-propelled howitzers (SPHs), ATAGS 155/52 towed howitzers, anti-drone systems, and Akash surface-to-air missile (SAM) systems. Indian media reports indicate that Armenia is also considering acquiring Indian missile defence systems.

▲ The Advanced Towed Artillery Gun System (ATAGS), a 155 mm howitzer developed by India's DRDO for enhanced firepower and mobility. [Tata Advanced Systems]

Unconfirmed reports from Indian sources suggest that Armenia has also received offers for more advanced systems, such as Pralay short-range ballistic missiles (SRBMs), BrahMos and BrahMos NG supersonic cruise missiles, ATGMs, various other types of ammunition and undisclosed weaponry. Additionally, India may offer upgrades for Armenia's four Su-30SM multirole fighters, originally purchased from Russia in 2019. These upgrades would involve equipping them with Indian avionics, radar systems, and missiles, including Astra beyond-visual range air-to-air missiles (BVRAAMs) and Smart Anti-Airfield Weapon (SAAW) precision-guided glide bombs. Reports indicate that Armenia has already approached India with a request for this modernisation to enhance the compatibility of its aircraft with Indian air-launched weaponry.

A potential drawback of Armenia's procurement of Indian combat systems is that some of India's newly developed military equipment – particularly the MArG 155/39 SPHs and ATAGS 155/52 towed howitzers – has not yet been officially adopted by the Indian Army. As a result, Armenia is acting as a launch customer, and given the geopolitical situation in the region, it may become the first country to deploy these systems in combat. The true effectiveness of these weapons, along with their strengths and potential weaknesses, can only be fully assessed after their use in real battlefield conditions.

While expert estimates of Armenia's current and planned contracts with India range from USD 1 billion to USD 2 billion, the Indian Ministry of Defence has confirmed that arms purchases already paid for by Armenia have reached USD 600 million by the beginning of FY2024–2025. This growing partnership signals strong potential for future defence cooperation between the two countries, with possibilities extending beyond arms sales to include joint exercises, technical partnerships, and defence industry investments.

As India continues to expand its defence sector, it is prepared to export a broad range of its military products to Armenia. Additionally, there is a possibility that India may grant Armenia long-term credit line as a major and reliable defence client. A key component of this partnership could involve joint production and technological collaboration. India may further develop defence ties with Armenia not only through direct exports, but also through localised production, which would require manufacturing certain components of Indian weaponry in Armenia and transferring military technologies on mutually beneficial terms.

Such an arrangement would allow Armenia to achieve its strategic goal of diversifying its defence partnerships and reducing its dependence on Russia. At the same time, India would gain a reliable partner in advancing its 'Make in India' industrial policy while strengthening its geopolitical influence in the region.

France

Defence cooperation between France and Armenia took a significant step forward in 2024 with the visit of French Defence Minister Sébastien Lecornu to Yerevan. This collaboration was formally initiated in October 2023, when the first agreement on arms supplies was signed. In December 2024, the two countries solidified their partnership by concluding

a Defense Cooperation Program for 2025, outlining plans for closer security cooperation. Armenian Defence Minister Suren Papikyan highlighted that the cooperation spans multiple critical areas, including arms supplies, training of Armenian military personnel, advisory and intelligence support, and broader defence initiatives.

▲ **Armenia's Defence Minister Suren Papikyan and French Defence Minister Sébastien Lecornu after signing a contract on the delivery of CAESAR artillery systems in June 2024. [Armenian MoD]**

According to the signed memorandum of understanding (MoU) and open-source information, Armenia is acquiring a broad package of weapons and military equipment from France. This includes 50 Arquus Bastion 4×4 protected patrol vehicles (PPVs), three Thales GM200 radars capable of detecting aerial targets within a 250 km radius, night vision devices and thermal imaging equipment such as binoculars and goggles, various models of sniper rifles from PGM Précision, as well as MBDA Mistral very short-range air defence (VSHORAD) missiles.

Further strengthening its military capabilities, Armenia signed a contract with France for 36 CAESAR 155/52 SPHs, scheduled for delivery by September 2025. Negotiations are ongoing for additional arms supplies, including air defence systems, artillery, anti-drone systems, and anti-tank weapons specifically tailored to meet the operational needs of the Armenian Army.

Beyond arms acquisitions, a key pillar of this cooperation is military education, training, and consulting—areas where Armenia had previously been entirely dependent on Russia. France has committed to training Armenian officers and junior command personnel, marking a significant shift in Armenia's defence orientation. As part of this initiative, five Armenian officers have been sent to the prestigious Saint-Cyr Military Academy, with plans to expand the cadet training programme in the coming years.

While the financial details of current and future defence agreements remain undisclosed, the growing partnership with France signals a major shift in Armenia's defence strategy. Looking ahead, the prospects for cooperation could extend beyond arms deliveries to include defence industry modernisation, enhanced military training programmes, and the potential development of a long-term strategic security partnership between the two countries.

Other partners

Armenia is also expanding its defence ties with a range of other countries. Over the past year, the Armenian Ministry of Defence has signed defence cooperation agreements with Bulgaria, the Czech Republic, Cyprus, Germany, Greece, and Italy.

In the case of Greece, certain aspects of defence cooperation take place within a trilateral framework that includes Greece, Cyprus, and Armenia. Key areas of collaboration with Greece include military training across various branches of the armed forces, military education, joint drills and exercises, knowledge exchange, and advisory support. This partnership reinforces Armenia's strategic ties within the Eastern Mediterranean region.

Armenia's defence cooperation with the US has also advanced, particularly in military education, advisory assistance, and joint military exercises involving the Armenian peacekeeping brigade. Armenia and the US conducted the Eagle Partner 2024 drills from 15-24 July 2024, which focused on preparing Armenian forces for participation in international peacekeeping missions. High-level meetings and negotiations on defence issues between Armenia and the United States are ongoing. However, there is no confirmed information regarding US arms supplies to Armenia, aside from a statement by US Ambassador to Armenia, Kristina Kvien, who mentioned the potential delivery of military medical armoured vehicles.

▶ **US and Armenian soldiers participate in a patrol lane during exercise Eagle Partner 24 at Zar, Armenia, 23 July 2024. [US Army/Spc Alexcia Rupert]**

Armenia's arsenal and diversification challenges

In late June 2024, Armen Grigoryan, the Secretary of Armenia's Security Council announced that Russia's share in Armenia's arms procurement has dropped dramatically, from over 96% before 2022 to just 10%. This sharp decline underscores Armenia's success in securing alternative suppliers to rearm its military and strengthen its defence capabilities. The remaining 10% from Russia likely consists of previously paid but undelivered weaponry from 2021 contracts, indicating that Armenia has not placed new orders with Russia since then.

However, this shift does not mean Armenia has entirely phased out its legacy Soviet and Russian military equipment. The Armenian army remains largely equipped with Soviet-era and Russian-made weaponry, necessitating continued reliance on Russian-standard ammunition, spare parts, and maintenance for the foreseeable future. A shortage of critical components could critically impact Armenia's defence readiness. Reducing this dependence further will require substantial time, financial investment, and the strategic selection of alternative partners. By diversifying defence cooperation and expanding supply sources while gradually reducing reliance on Russian arms, Armenia gains both operational flexibility and strategic autonomy.

Radka Konderlová, Director General of the Czech Ministry of Defence's Industrial Cooperation Agency, led a delegation to Armenia for talks on defence collaboration, joined by Czech military-industrial representatives. [Armenian MoD]

Nonetheless, this transition comes with considerable challenges. Integrating new weaponry with different standards and calibres while maintaining existing stockpiles demands extensive retraining of personnel and fundamental military reforms. Adjusting to non-Russian systems will require a more strategic personnel policy, including the recruitment and training of specialists capable of managing the country's evolving military landscape.

A notable complication in this transition is the issue of military uniformity. As Armenia acquires Western-standard weaponry and calibres alongside its existing Soviet/Russian systems, it faces the challenge of operating a mixed arsenal. This is particularly evident in Armenia's procurement of modern artillery, marking a shift from the Warsaw Pact standard 152 mm calibre – used for over three decades – over to the widely-adopted NATO standard 155 mm calibre. This change necessitates adaptation to new, more sophisticated equipment, alongside training and logistical adjustments.

Previously, the maintenance and operational support of Armenia's Russian-made weapons relied heavily on Russian enterprises. In this regard, partnerships with India and, to a lesser extent, the Czech Republic, play an increasingly vital role. These countries offer alternative solutions for spare parts, upgrades, and logistical support, helping Armenia reduce its dependence on Russian defence infrastructure while modernising its military capabilities.

Both India and the Czech Republic have significant potential to supply Armenia with high-quality domestic weaponry and equipment, while also helping to service and modernise Soviet/Russian-made armaments.
India, the world's largest operator of Russian military equipment after Russia itself, utilises a wide range of systems – from Su-30 fighter jets and armoured vehicles to air defence systems, ATGMs, and small arms. These systems are manufactured in Indian facilities and serviced by Indian specialists. For Armenia, this positions India as an effective alternative to Russia. India can manufacture spare parts and has experience in repairing and upgrading Soviet/Russian military equipment used by its armed forces.

Likewise, the Czech Republic brings significant expertise, infrastructure, and highly qualified specialists to the repair and modernisation of Soviet/Russian military equipment. The defence cooperation agreement signed in Yerevan in 2024 between Armenia and the Czech Republic, with the participation of representatives from the Czech defence industry, likely reflects an understanding of the need to mitigate risks associated with dependence on Russian supplies. The Armenian Ministry of Defence stated that the meeting with the Czech delegation resulted in a number of agreements, though specific details regarding their nature and scope have not yet been disclosed.

Alongside efforts to procure weaponry from new defence partners, resolving logistical challenges remains a priority. Armenia is a landlocked country, making it entirely dependent on transit routes through neighbouring states. Armenia must therefore engage in significant diplomatic efforts to

ensure stable transit. Azerbaijan and Türkiye completely block Armenian communication routes, preventing transit through their territories, leaving Georgia and Iran as the only viable transportation corridors for military shipments.

Closing thoughts

In the coming years, Armenia will face the complex task of modernising its armed forces and diversifying its arms supplies. This is a difficult and costly process that will require substantial financial resources and considerable governmental effort. However, Armenia has few alternatives.

It is essential for Armenia to modernise its existing military arsenal and foster the development of its domestic defence industry, which will help reduce dependence on external sources in certain areas. In recent years, local defence industry enterprises have received a record allocation of AMD 122 billion (USD 310 million) from the State budget for military procurement. According to Armenia's Minister of Industry and High Technologies, this amount was expected to exceed AMD 190 billion (USD 500 million) by the end of 2024.

Overall, Armenia's military industry has limited capabilities and occupies a niche role in supplying the Armenian army with military equipment. Several Armenian enterprises and companies have experience and sufficient capacity in producing mortars, small arms, and ammunition, as well as developing innovative solutions in surveillance and reconnaissance systems, unmanned aerial vehicles (UAVs), and robotics. As such the aforementioned substantial increase in financial support will enable local enterprises to expand defence production. Some companies and start-ups may be able to transition from laboratory-scale to industrial-scale manufacturing, reaching mass production capabilities.

It is also crucial to strengthen international cooperation by expanding the network of defence partners who can provide technical and financial assistance, while supporting the acquisition of modern weaponry and technologies.

Finally, Armenia must prioritise enhanced training for its military personnel to effectively use new weapons and apply modern tactical approaches on the battlefield. The quality of military education and retraining of active-duty personnel are essential for improving combat readiness and learning from armies with sophisticated military capabilities.

Strengthening the offensive potential of the Armenian Army's infantry requires improvements in tactics, equipment, and combat training. Through a comprehensive approach and well-structured training programmes, Armenian infantry can develop a more agile and dynamic combat style suited to modern warfare. With proper management and a sustained financial commitment, significant improvements to the country's military capabilities are achievable within a few years.

Russia's defence industry: What to expect after a ceasefire?

Maxim Starchak

Despite the fact that many experts remain unsure whether or not Russia is interested in a ceasefire in Ukraine, Russian officials are preparing for the post-war situation and believe that the Russian defence industry should maintain high production even after a ceasefire. The defence industry became a driver of the Russian economy during the war years, however, the future development of the industry will face numerous problems, some of which can only be solved with government support.

The current state of Russia's economy

Russia's GDP grew by 4.1% in 2024. GDP growth was driven by industries related to the defence industry: manufacturing, mechanical engineering, IT, and chemicals. However, the federal budget deficit in 2024 amounted to RUB 3.485 trillion, or 1.7% of GDP, which was covered by the National Welfare Fund. During the three years of conflict, it has decreased by two-thirds. The inflation rate was 9.5% at the end of the year. As a result, 2024 became the year of exhaustion of the existing growth model based on budgetary increases in the face of sanctions.

As a result, according to the government's Centre for Macroeconomic Analysis and Short-Term Forecasting, the Russian economy has moved into stagnation. The Russian economy is constrained by the fact that capacity utilisation in Russia has reached an extremely high 80%. There is a severe shortage of personnel and lack of access to modern global technologies. This imposes restrictions on the increase in labour productivity. Furthermore, tight monetary policy has slowed down investments. However, according to analysts, this will have little effect on the development of the Russian defence industry.

AUTHOR

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Meeting of the Bureau of the Union of Machine Builders of Russia and the Defense Enterprises Assistance League on 7 February 2025. [Union of Machine-Builders of Russia]

Budget expenditures

Russia's total defence spending in 2024 increased by 42% to RUB 13.1 trillion, reaching 6.3% of GDP and 32.5% of the federal budget. It was assumed that the record increase in defence spending to RUB 10.8 trillion in 2024 would be a one-time increase, and then, according to the budget plan for the next two years, they would decrease to RUB 8.5 trillion in 2025 and RUB 7.4 trillion in 2026. However, in reality, in 2025, military spending should amount to about RUB 13.5 trillion in 2025 (which is 4.2 times more than in 2021), then expected to decrease slightly to RUB 12.8 trillion in 2026, and rising slightly to RUB 13 trillion in 2027. Russia has not spent so much since Soviet times. The government's plans to live within its means are not justified by Putin's interest in betting on war and the formation of a military economy.

After the ceasefire, according to Pavel Luzin, a military expert from the Center for European Policy Analysis, *"there will be some reduction due to lower production rates and, consequently, working hours. Overworking will stop and the schedule will return to the standard 8-hour day on 5/2 [five weekdays worked, two weekend days off]. There is also an opportunity for relatively painless optimisation by sending retirees to retirement."*

In addition, *"the Kremlin will be able to reduce the costs that are spent on direct support of the military operation in Ukraine, that is, about 2.5 trillion roubles, and partially military benefits, by stopping payments to the families of the victims, payments for participation in military operations, which may amount to about 1.5 trillion roubles out of the 3 trillion currently paid,"* said economist Vyacheslav Inozemtsev.

This means that defence spending will decrease, but will remain high, while maintaining its leading values over other industries. After the ceasefire, defence industry enterprises will lobby in every possible way to maintain high costs by the need to replenish the depleted reserves of the Ministry of Defence (MoD) and export orders. Spending on national defence may remain at the level of RUB 10 trillion per year.

Defence exports

The Stockholm International Peace Research Institute (SIPRI) estimated that Russian arms exports halved between 2019 and 2023 compared with the previous five-year period. In 2019, Russia sold weapons to 31 countries – in 2023, that number dropped to 12, SIRPI found. Russian officials confirmed at the St Petersburg Economic Forum in 2024 that military exports are facing the negative impact of sanctions and a number of other foreign policy factors.

As a result of this, the maintenance of Russian weapons has become increasingly difficult for buyers. "Therefore, in order to protect themselves from uncertain service, countries are looking for more sellers that are reliable. In addition, the dependence of Russian companies on imported electronics and machine tools at the production stage also hinders exports," says Pavel Luzin.

▲ **The Pantsir-M naval short-range air defence system on display at a High Precision Systems exhibition stand. [Rostec]**

Russian officials believe that after the ceasefire, the pressure on Russian exports will disappear, resources for export production will be freed up, and the defence industry will be able to return to the foreign market. According to Rostec CEO Sergey Chemezov, his "company has an export portfolio of almost USD 60 billion. First of all, these are the countries of the Asia-Pacific region, the Middle East, Africa and Latin America." However, according to Pavel Luzin, "data on a portfolio of export orders of [USD] 50 billion has been available for many years, probably counting the weapons that were not delivered in 2022-24, they collected [USD] 60 billion."

Luzin added, *"of course, countries such as Iran, Myanmar, and others may want to buy Russian weapons, but Russia's return to the global arms market, even in a limited form, will be difficult. Preferential loans, subsidies, discounts, etc. will be needed again. In other words, exports will ultimately be carried out largely at the expense of the Russian budget. Given its deficit and the occupation of the market by other players, Russia may not be able to regain its position in the foreign market".*

Reserve replacement

"Russia would be interested to continue exporting arms to reduce unit costs and bring home hard currency, but this is probably in conflict with the ambition to regain its own lost military capability as soon as possible," says Tomas Malmlöf, Research Analyst at Swedish Defence Research Agency. Indeed, according to First Deputy Prime Minister Denis Manturov, "priority will be given to replenishing the reserves of the Ministry of Defence." This replenishment is unlikely to be completed soon – according to Sergey Chemezov, it will take ten years to replenish the warehouses of the Ministry of Defence.

Taking into account personnel and sanctions restrictions, production will decrease, but it will remain disproportionately high relative to other industries. That is, after a ceasefire, Russia will not accelerate production and produce weapons at the same high rate as during the war. The production of 9M723 Iskander-M short-range ballistic missiles (SRBMs) is estimated to decrease to 150 per year; K4-47M2 Kinzhal aeroballistic missiles to 40; Kh-101 air-launched cruise missiles to 300; and Kalibr family cruise missiles to 170. Russia uses a stockpile of R95-300 engines to produce long-range cruise missiles, "however, the stockpile is not infinite, the production of TRDD-50 engine in different versions until 2022 was measured in the range of 100 per year, and it is hardly possible to increase it by 4-5 times, unless one or two more engine plants are reoriented to its production, which is not happening," explained Pavel Luzin.

▼ **A K-4386 Typhoon-VDV with 32V01 remote turret, on display at the Armiya 2023 exhibition. [RecoMonkey]**

However, it is not clear what priorities Russia will have in replenishing its weapons stocks. "Russia's future military equipment portfolio will be younger than the pre-war one, as so much heavy equipment has been destroyed in Ukraine, and the storage bases for tanks and armoured vehicles have been emptied of vehicles suitable for refurbishment or modernisation. As so much of the equipment of the ground forces will have to be built from scratch, it will at least push the time scale to the right," said Tomas Malmlöf.

Russian officials say that the defence industry has gained new competencies in the production of unmanned systems of various classes and produces tens of thousands of drones per year. However, they are only in such high demand during wartime; after the ceasefire, production is expected to collapse significantly. Many private civilian companies were involved in this production, and after the war, the shrinking military budget will no longer be shared with them. In addition, the drones were assembled at the expense using of Iranian and Chinese components. As such, their cost will be higher, and Russian drones are unlikely to win in the foreign market over China's drones, to which Russia is already losing the market for inexpensive weapons.

According to military expert Dmitry Smirnov, *"the restoration of the Ministry of Defence's reserves is a good way for companies and factories to secure contracts. Enterprises are interested in the longest possible inventory recovery process. They will justify the high costs of the defence industry, not only by replenishing reserves, but also by the need to maintain high salaries, social infrastructure, pensions and loans to hundreds of thousands of workers in this field, import substitution of equipment and components, as well as geopolitical challenges in the world".*

Civilian production within the defence industry

Back in 2017, President Putin set a goal to achieve 30% of civilian production within the defence industry by 2025 and 50% by 2030, and did not cancel it. According to First Deputy Prime Minister Denis Manturov, "Russia wants to preserve the defence industry as a driver of economic growth even after the end of military action; therefore, the defence industry will gradually release capacity for the production of civilian products."

To meet the needs of the defence industry, Russia is aiming to increase its production of microelectronics, high-precision machining tools and robotics, aerospace technology, drones, medicines, telecommunications equipment and software, optics and electronics. To this end, RUB 3.6 billion will be allocated to create various parts for these industries by 2026. The government has also selected 160 projects from these industries with a total value of over RUB 210 billion, of which 10% will be funded through federal grants. The remaining expenses will be covered by defence industry investments.

However, according to Pavel Samuta, an engineer and former employee of an industry, "defence industry enterprises are not interested in civilian production, and will do everything possible to develop defence production, because only in this sector there are large incomes, and guaranteed buyers. Only 10-15% of enterprises will be able to produce dual-use products," Samuta said. Defence industry enterprises and their managers do not know the civilian market well and do not know how to work with it. Defence industry enterprises do not need to look for sources of financing. Tactical and technical characteristics are more important than timing and price. The situation in the civilian market is fundamentally different. Here, the defence industry, with its non-military products, faces a large number of competitors, including foreign ones, even in the domestic market. Therefore, the issue of the effectiveness of civilian production at defence industry enterprises is reduced to the task of obtaining contracts for the purchase of their products by government agencies, institutions or companies. Without this, their products are not in demand. For example, the Almaz-Antey Concern developed the E-Neva electric car project, but the project was stopped it because it did not receive state financing. There was little funding available for this, and few incentives to dedicate further funding to a project uncertain to see sufficient market demand.

An RLM-ME radar from the 55ZhMME multi-band radar system, on display at the Armiya 2023 exhibition. [RecoMonkey]

Common industry problems

"Without discretionary income or leveraged financing, the defence industry will not be able to produce civilian products," said Professor Anna Bakulina. Some defence industry enterprises take preferential loans from the Industrial Development Fund, in which case the government subsidises the bank rate. However, resources are limited, so most businesses have to obtain loans on general terms at current bank rates of 18-20%. At the same time, profitability in state defence orders does not exceed 3-5%. Accordingly, if an enterprise receives a long-term loan at a high rate, then, even after the final payment from the customer, it will still end up in the red.

Consequently, as Denis Manturov admitted, *"there is almost no money for research and development work, and without this, it will not be possible to develop our own production of components and civilian production. There will also be no money for salary increases, which have grown not from income, but from loading enterprises with state defence orders."* With a reduction in state orders, salaries will decrease or stagnate; for example, Sevmash, a submarine manufacturing plant, is already cutting salaries, and elsewhere, the plants of the United Engine Corporation are laying off workers.

"After the ceasefire, this trend may become more pronounced. Older workers will return to retirement because enterprises will no longer have the funds to pay for their work," said Luzin. Furthermore, salaries will be equalised with the civilian sector, which means that the shortage of low-cost personnel is set to continue. According to the government, by 2026, the shortage in the industry will amount to 240 thousand specialists, of which 1/3 are engineers and designers, 2/3 are workers. To address the personnel issue, various career guidance programs have been developed in the system of additional, general education, specialised secondary and higher education. Defence industry companies finance the education of the required number of students in the necessary programmes and participate in the education process. However, such programmes will not have an immediate effect, and so the development of the defence industry will be hindered by circumstance.

Dependence on foreign components remains high, it is not easy to find them, and all this affects the price of the final product. In other words, it will be impossible to compete with China. Therefore, several years ago, Alexey Belyaev, General Director of the Sarapul Electric Generating Plant, suggested that "the government take some protective measures against foreign competitors. [Otherwise], civilian production is not profitable for defence industry enterprises."

Reflecting on the situation, Tomas Malmlöf noted, "However difficult it may be, the defence industry, according to Russian officials, has become the driver of the Russian economy. Therefore, the Russian regime will take great care not to end up in the same situation as in 1991, when the defence industry more or less collapsed and entered into a period of 20 years of depression due to weak demand and overcapacity".

Vladimir Gutenev, State Duma deputy, and President of the League for Assistance to Defence Enterprises noted, "The efficiency of defence industry enterprises could be solved by reducing costs. However, it is not profitable. If the company reduces costs, then it gets the task planned from what it has achieved". Consequently, the government is developing mechanisms to change cost calculations of products so that factories can make more profit.

In sum, a potential ceasefire will reduce the Russian budget for conducting military operations and save the industry from the costs associated with accelerating arms production.

A scale model of an Su-57 on display at Rostec's stand at the Dubai Airshow. [Rostec]

However, the Russian defence industry is unable to generate sufficient income on state orders to make investment loans worthwhile, and similarly, civilian production is not profitable for the defence industry. As such, Russian defence enterprises will look to preserve military production in every possible way. Since arms exports may not recover, the only thing left for the defence industry is to replenish the reserves of the Ministry of Defence. In turn, since the defence industry looks set to remain low-profit but is strategically important, the Russian government will aim to everything possible to support it with state funding; the dependence of the Russian economy on the defence industry has made this cycle inevitable.

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ESD is happy to announce the magazine secured two awards at the 2024 Defence Media Awards (DMAs) along a with a further win at the 2024 European Military Press Association (EMPA) awards.

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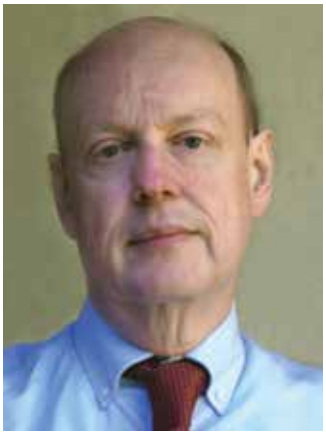

It is inevitable that any editorial discussing current naval developments will be influenced by recent political events in the United States. The arrival of the second Trump presidency is already challenging the international network of alliances that has been broadly successful in maintaining global stability since the end of the Second World War. Instead, the United States' longstanding defence partners are now seemingly its new economic enemies. Similarly, the system of global free trade that has driven prosperity during this era also looks set to be consigned to history in favour of new tariff regimes that are likely to generate few winners. Both developments will have longstanding effects on maritime trade and, also, on the navies that are the guardians of its security.

Amongst all the disruption generated by the Trump administration, it is easy to overlook the fundamental challenges to the dominance of American naval power that has been one of the primary enablers of the United States' global influence. Accordingly, our leading article examines the major issues – strategic, structural and financial – that the second Trump presidency will need to address to face these challenges, as well as the approaches it might chose to take. In particular, the need to revitalise America's naval shipbuilding sector, as well as to improve execution of shipbuilding projects, are longstanding imperatives for which there are unlikely to be any quick or easy answers. It is uncertain whether a fast-expanding People's Liberation Army Navy (PLAN) will give its US Navy rival sufficient time to implement a solution.

One potential way forward is to accelerate reliance on emerging technologies. A significant area where the United States has apparently achieved a material advantage is in the area of uncrewed vehicles of all shapes and sizes. Development of uncrewed systems has, perhaps, reached greatest maturity in the air. However, various steps have been underway for some time to expand the operational relevance uncrewed and autonomous vessels beyond their existing dominance in the field of mine countermeasures to realise a broader potential that has already been demonstrated in the war in Ukraine. Our article on the US Navy's uncrewed future explores how the transition to utilising this technology across the maritime domain might develop over coming decades.

Other articles in the edition assess changing trends in crewed warship design, progress across a number of items of naval equipment, and current warship procurement and construction across a number of European countries. One programme that will have particular relevance to many *Maritime Defence Monitor* readers is that pertaining to the German Navy's planned F127 class air and missile defence frigates. In a significant move, Germany has taken the decision to eschew previous longstanding collaboration with the Netherlands to adapt a combat management solution based around the US Aegis system for the new warships. The wisdom of maintaining this reliance on American technology in the light of the recent political developments already referenced above is certainly open to question given the ready availability of European alternatives.

In concluding, it seems to the editor that the political changes that have been unleashed by the second Trump presidency will produce security and industrial changes to an extent that have not been seen for decades. Whilst it is far too early to predict what the ultimate results might be, the United States' decision to upturn a system of international defence and trade partnerships which have acted to its overwhelming benefit across multiple decades is unlikely to withstand the judgement of history. *MDM's* editorial team hope that you, the reader, will continue to find our analysis of value in our shared voyage through ever-changing seas.

Conrad Waters

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MARITIME Defence Monitor
From the Sea and Beyond

Maritime Defence Monitor
MDM · Special Issue,
May 2025
ISSN 1617-7983

Published by
Mittler Report Verlag GmbH
A company of the TAMM Media Group

Contact Details
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Production: Lehmann Offsetdruck und Verlag GmbH,
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Cover Photo: The Royal Navy Type 45 destroyer HMS Dragon (D35) fires its 4.5 inch (114 mm) gun as part of exercise Formidable Shield 2021, on 28 May 2021. [Crown Copyright 2021]

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Europe

United Kingdom: Keel laying ceremony for the first new strategic submarine

A ceremony was held at BAE Systems' Barrow-in-Furness shipyard in north-west England on 20 March 2025 to mark the formal keel laying of HMS *Dreadnought*, the first of four strategic submarines designed to carry the Trident ballistic missiles that comprise the United Kingdom's nuclear deterrent. The importance of the ceremony was reflected by a distinguished guest list headed by British Prime Minister Sir Keir Starmer and Defence Secretary John Healey, who attended alongside a host of other senior political, naval and defence sector leaders. Displacing in excess of 17,000 tonnes and with a length of 13.6 metres, *Dreadnought* is equipped with launch tubes for up to twelve Trident II D5 missiles. She is expected to enter service in the first half of the 2030s and, together with her three sisters, will replace the existing *Vanguard* class boats.

▲ Guests assembled in the Devonshire Dock Hall at BAE Systems' Barrow-in Furness shipyard to attend the keel laying ceremony for the new British strategic submarine, HMS *Dreadnought*. [BAE Systems]

MDM editorial commentary: The keel laying carried out in March 2025 was essentially a ceremonial event, with the first steel for *Dreadnought* being cut as long ago as October 2016. Subsequent construction has focused on the fabrication of 16 separate sub-units, which have then been assembled into three 'mega units' prior to final integration in the shipyard's huge Devonshire Dock Hall. The first of these mega units arrived in the ship hall in the autumn of 2023 and the arrival of the third and final unit is said to be imminent. Whilst BAE Systems' press release highlighted the progress that has been made with building the submarine to date, much remains to be done to achieve what is generally regarded as a challenging delivery schedule.

BAE Systems were also keen to use the event to showcase the *Dreadnought* programme's industrial significance. After suffering significant decline in the post-Cold War era, employment in the Barrow shipyard has experienced substantial growth as part of an investment programme valued in excess of GBP 1 billion. The group's press release issued to mark the keel laying stated that the submarines workforce, centred in Barrow, had grown by more than 3,000 to 14,700 in the short period since 2023. Moreover, this growth is expected to continue as the existing *Dreadnought* class programme is supplemented by construction of the new SSN-AUKUS class of conventionally-armed attack submarines.

Portugal: Turkish industry selected to build new logistic support ships

Portugal became the latest country to boost Türkiye's growing naval export sector in December 2024 with the announcement that project management and systems engineering group STM had been selected to supply two logistics support ships to the Portuguese Navy. The two vessels – officially referred to as 'auxiliary oiler replenisher and logistics ships' – in STM's press release are claimed to be the first naval vessels STM has exported to either a European Union or NATO country. The contractual agreement envisaged STM acting as prime contractor for the overall programme, which will be subject to detailed design and construction in a private Turkish shipyard. Fabrication is due to commence in 2025.

Details released at the time of the award state that the two logistic support ships will be 137 metres in length and displace approximately 11,000 tonnes. They will have capacity for 4,000 m^3 of F-76 diesel fuel, 350 m^3 of F-44 aviation fuel and 650 m^3 of potable water in addition to provision for

▲ A graphic of the two logistic support ships ordered by Portugal from Türkiye's STM. [STM]

general cargo and six TEU containers. There will also be space to carry up to 20 light armoured vehicles and 100 personnel in addition to the ships' core crews. Graphics suggest two main replenishment stations (one to port and one to starboard) together with the possibility of vertical replenishment by means of a helicopter flight deck. Range will be as much as 14,000 nautical miles at 14 knots and the vessels will be able to remain at sea for up to 90 days. Whilst

primarily designed for at sea-replenishment, the conduct of command and control, amphibious and humanitarian operations all fall within their extensive list of capabilities.

Sweden: Submarine mid-life upgrade programme draws to a close

Sweden's mid-life modernisation of its three A19 Gotland class submarines has progressed towards a successful conclusion with the return to the water of HSwMS *Halland* at Saab's Karlskrona shipyard on 13 February 2025. The work is being undertaken in accordance with a SEK 1.1 billion contract between the Swedish defence conglomerate and Sweden's FMV Defence Materiel Organisation that was announced in March 2022. *Halland* is the final member of the class to go through the upgrade process, with her sister boats *Gotland* and *Uppland* having been previously re-launched in 2018 and 2019 respectively.

The *Gotland* class mid-life upgrades encompass the insertion of a 2 metre hull plug, an upgraded air independent propulsion (AIP) installation, and various combat management system, sensor and communications enhancements. Many new technologies incorporated in the modernisation will also be used in the two new A26 *Blekinge* class boats that Saab is currently building. Accordingly, the A19 upgrade programme is playing an important role in smoothing the way for this next generation of submarines to enter service during the second half of the decade.

▲ HSwMS *Halland*, the third and final *Gotland* class submarine to undergo mid-life modernisation, has been re-launched from Saab's Karlskrona shipyard. [Saab]

The Netherlands: Combat support ship HNLMS Den Helder christened

The Royal Netherlands Navy's new combat support ship HNLMS *Den Helder* was christened by Catharina-Amalia, Princess of Orange at a ceremony held at the Damen Naval shipyard in Vlissingen on 22 February 2025. The vessel had previously arrived in the Netherlands for the first time on 13 December 2024 after undertaking her maiden voyage and initial sea trials from Damen's facility in Galati, Romania. The ship was subsequently handed over to the Dutch Ministry of Defence's Materiel and IT Command on 24 March and is due to complete final outfitting before entering operational service with the Royal Netherlands Navy in the course of 2026.

▲ The new Dutch logistic support ship HNLMS *Den Helder* pictured at the time of her arrival in the Netherlands in December 2024. [Damen]

HNLMS *Den Helder* is the first Dutch warship to be christened since the multi-role support ship HMNLS *Karel Doorman* in 2014. However, with orders for ASWF frigates and *Orka* class submarines placed over recent years, the new combat support ship is likely to be only the first of many new warships handed over to the Royal Netherlands Navy in the course of the coming decade.

The Americas

United States: Hypersonic missile defence testing progresses

The US Missile Defence Agency (MDA) claimed to have taken a significant step towards countering the threat posed by hypersonic missiles after the successful conclusion of a simulated engagement against a hypersonic target vehicle on 24 March 2025. The simulation was carried out by the destroyer USS *Pinckney* (DDG-91) in the course of a trial designated as Flight Test Other-40 (FTX-40), also known as Stellar Banshee.

▼ The destroyer USS *Pinckney* (DDG-91) has carried out a simulated engagement against a hypersonic target as part of the US Missile Defence Agency's efforts to counter the hypersonic missile threat. [US Navy]

Canada: Contract for first 'River' class destroyers awarded

On 3 March 2025, the Canadian government announced the award of an implementation contract to Irving Shipbuilding Inc. (ISI) for the construction of an initial batch of three' River' class destroyers. The contract follows on from an August 2023 commitment of significant government investment in ISI's Halifax shipyard to prepare the facility for destroyer construction and the subsequent commencement of fabrication of a production test module at the Halifax facility in June 2024. Current plans envisage the lead ship of the class, HMCS *Fraser*, being delivered in the early 2030s. An eventual total of 15 'River' class destroyers is projected.

A graphic of the Royal Canadian Navy's 'River' class destroyer, which is derived from the British Type 26 frigate. Contracts for the first three of a total projected class of 15 ships have recently been signed. [BAE Systems]

Despite its destroyer nomenclature, the 'River' class is a derivative of the British Type 26 frigate built by BAE Systems, which became the preferred design for what was then known as the Canadian Surface Combatant (CSC) programme as long ago as October 2018. Like the Type 26, anti-submarine warfare (ASW) is a primary design focus and the two variants share an acoustically stealthy CODLOG propulsion system and hull-mounted Ultra Electronics Type 2150 bow sonar. However, the basic Type 26 design has been heavily modified by a team headed by Lockheed Martin Canada to meet specific Canadian requirements, incorporating the company's CMS-330 combat management system that has already retrofitted to the existing *Halifax* class. This is being used in conjunction with the US Lockheed Martin's parent's International Aegis Fire Control Loop and AN/SPY-7 multifunction radar in the new 'River' class destroyers to provide the ships with a powerful air defence capability.

MDM editorial commentary: The implementation contract awarded to ISI has a reported initial value of CAD 8 billion and is intended to support delivery of the leading three ships of the class during their first six years of construction, as well as the development and delivery of associated training, spares and maintenance. This is only a fraction of the estimated total cost – including equipment, systems and ammunition – of CAD 22.2 billion (the equivalent of USD 16 billion) – that Canada believes will eventually need to be spent to bring the first three ships into service. This cost is significantly higher than that for the British Type 26 frigates and other comparable warship designs. Whilst part of the difference can be explained by the high level specification of the River class destroyers ' outfit of weapons and sensors – reflecting their importance as Canada's only major surface combatants – it also demonstrates the heavy burden on defence spending arising from the re-establishment of an indigenous warship construction capacity under the country's National Shipbuilding sector.

More positively, the award of the construction contract marks a major step forward in the long-delayed modernisation of the Royal Canadian Navy's surface fleet, which has seen a number of warships retired decades before the likely arrival of their ultimate replacements. It also means that firm orders for the Type 26 class and its derivatives have now been placed by three countries, with Canada's commitment following on from Australia's signature of the purchase agreement for its own initial trio of *Hunter* class frigates in June 2024. The Type 26 is also on the shortlist for the Royal Norwegian Navy's frigate programme (see separate article later in this edition), pointing to the success of the British Royal Navy's and BAE System's design approach.

Details of the trial released by the MDA stated that its objective was to demonstrate the ability of the Sea Based Terminal (SBT) Increment 3 capability embedded in the latest Aegis software baseline to detect, track and perform a simulated engagement against an advanced, manoeuvring hypersonic target. The live target was an air-launched medium range ballistic missile incorporating a hypersonic target vehicle front end whilst the simulated interceptor was a Standard SM-6 Block IAU. FTX-40 also trialled the use of a Hypersonic and Ballistic Tracking Space Sensor (HBTSS) demonstration satellite to pass data to the destroyer's combat system.

FTX-40 served as a key risk reduction flight for the new MDA developed test target and a data collection opportunity for the current Aegis baseline against a representative hypersonic target. This exercise was regarded as a building block towards a live intercept of a target using the upgraded SM-6 missile. This planned test has been designated as Flight Test Aegis Weapon System-43 (FTM-43).

Asia-Pacific

Indonesia: PPA type frigates renamed at Fincantieri

On 29 January 2025, Fincantieri hosted a renaming ceremony at its Muggiano shipyard for the two PPA type multipurpose combat ships – frigates in all but name – that had previously been sold to Indonesia under a EUR 1.2bn contract signed in 2024. The two vessels were originally built as *Marcantonio Colonna* and *Ruggiero di Lauria* for the Italian Navy but were transferred to Indonesia in order to expedite delivery. They have been allocated the new names KRI *Brawijaya* and KRI *Prabu SIliwangi* and are expected to be handed over to the Indonesian Navy before the end of 2025.

The innovative multirole PPA design has been constructed with various equipment outfits – referred to as 'Light', 'Light Plus' or 'Full' configurations – of various levels of sophistica-

▲ The Indonesian Navy's PPA type multipurpose combat ship KRI *Brawijaya* was previously destined for Italian Navy service as *Marcantonio Colonna*. [Fincantieri]

tion. The two Indonesian ships were originally ordered to the intermediate 'Light Plus' standard, incorporating the Leonardo Kronos C-band radar system and two octuple Sylver A50 vertical launch systems for the MBDA Aster family of surface-to-air missiles. This will include the future Aster 30 Block 1 NT variant, opening up the possibility of the Indonesian Navy acquiring the ability to intercept short and medium-range tactical ballistic missiles at some stage in the future.

The Indian Ocean & Middle East

Israel: Launch of INS *Drakon*

A rare glimmer of light was shed on Israel's secretive submarine programmes when INS *Drakon*, the third and final Israeli *Dolphin* II class AIP-equipped submarine, was the subject of a ceremonial launching event at tkMS's shipyard in Kiel on 11 November 2024. Open source reports have long speculated that Israel's submarine flotilla has been equipped with nuclear-armed weapons to provide the country with a so-called 'second strike' capability, with *Drakon* herself rumoured to be equipped with a vertical launch system (VLS) capacity within an enlarged fin (sail). An IDF press release at the time of the launch lent credibility to these rumours, stating that the submarine is "...equipped with unique systems, including ground-breaking technologies that expand the range of the IDF's capabilities across various arenas". The submarine will be delivered to the Israeli Navy before the end of 2025.

Drakon's launching ceremony was combined with the start of production of the lead boat of a new series of Israeli submarines that are to be known as the *Dakar* class. The three-strong class was contracted with tkMS in 2022. The total programme cost has been reported to amount to EUR 3 billion, part of which will be

The Philippines: Naval modernisation picks up pace

The Philippine Navy marked a major step forward in its accelerating programme of fleet renewal through a ceremony to mark the arrival of the future BRP *Miguel Malvar* (FFG-06) at the Naval Operating Base Subic, Zambales on 8 April 2025. Headed by Philippine Secretary of National Defense Gilberto C Teodoro Junior and attended by numerous other dignitaries, the ceremony was used to highlight the steady progress being achieved in implementing the ongoing Armed Forces of the Philippines (AFP) Modernisation Programme and the important role being played by the Republic of Korea in developing the nation's defence capabilities.

Ordered from South Korea's Hyundai Heavy Industries (HHI) in December 2021, *Miguel Malvar* is the lead vessel of a class of two 'corvettes' ordered under the so-called 'Horizon 2' phase of the AFP's three phase modernisation. The two ships are based on the HHI HDC-3100 design and, with a displacement of around 3,100 tonnes and a length of 118 metres, are actually somewhat larger and better equipped than the preceding Jose *Rizal* (FF-150) class frigates that were also built by HHI and delivered in 2020-2021. Notably, they include a vertical launch system for MBDA VL-MICA short range surface-to-air missiles, significantly upgrading the navy's limited air defence capacity. Construction of *Miguel Malvar* commenced in May 2023 prior to an official launch ceremony on 18 June 2024. Her sister, the future BRP *Diego Silang* (FFG-07), was officially launched in March 2025 and is also due for delivery before the year's end.

MDM editorial commentary: The Philippine Navy has been a significant source of export business for HHI's warship business in recent years. In addition to the previous pair of *Jose Rizal* class frigates and the two *Miguel Malvar* class vessels that are now in the course of delivery, the South Korean shipbuilder has also been allocated the construction of six offshore patrol vessels under a contract awarded in June 2022. These will be built to the company's HDP-2200 design and are expected to be entirely gun-armed. Nevertheless, they are still likely to share much equipment with the Philippine Navy's other HHI-built ships, providing a welcome degree of homogeneity.

Meanwhile, the AFP has now moved into the 'Horizon 3' phase of its modernisation programme, holding out the prospect of further naval procurement. Open source information suggests that further acquisitions of surface vessels, along with equipment upgrades to existing ships, are likely to be immediate priorities but the navy still holds out the hope of being able to acquire submarines in the foreseeable future. These could be a significant asymmetrical counter to Chinese naval influence in the region but would be a costly and ambitious purchase. Naval Group's 'Scorpène', Navantia's S-80, a variant of the South Korean KSS-III submarine and Fincantieri's Type 212 NFS (proposed in partnership with tkMS) are all regarded as potential contenders for any contract that does emerge.

◀ The Philippine Navy had taken delivery of the future BRP *Miguel Malvar* (FFG-06) from South Korea's Hyundai Heavy Industries. [Philippine Department of National Defense]

contributed by the German government. These new submarines will eventually replace the three original *Dolphin* I class boats that were commissioned between 1999 and 2000.

The end of 2024 was a busy one for tkMS' submarine business. On 19 December, the shipbuilder confirmed receipt of a German government order for a further four Type 212CD submarines, taking the total number of German boats of the type to six. The Norwegian Navy is also expected to increase its initial order for four members of the class in the near term. Yet further good news for the submarine business was subsequently received in March 2025 when Singapore announced that it intended to acquire two additional submarines to add to its four existing Type 218SG *Invincible* class boats. All-in-all, it would seem that recent announcements will ensure continuity of submarine production at Kiel well into the future.

The Israeli submarine INS *Drakon* was ceremonially launched at Kiel on 12 November 2024. [tkMS]

India: Simultaneous delivery of major combatants

The Indian Navy's ongoing modernisation efforts received a significant boost on 15 January 2025 when Prime Minister Narendra Modi presided over a commissioning ceremony in Mumbai to mark the simultaneous entry of three major combatants into naval service. The three vessels involved were the Project 75 'Scorpène' type submarine INS *Vaghsheer*, the Project 15B destroyer INS *Surat* and Project 17A frigate INS *Nilgiri*. All three units had been completed by local shipyard Mazagon Dock Limited (MDL).

The commissioning of the destroyer and submarine effectively marked the conclusion of two longstanding construction programmes. INS *Surat* is the final member of four Project 15B *Visakhapatnam* class destroyers ordered in 2011 and completed from 2021 onwards. The quartet is closely related to three earlier Project 15A *Kolkata* class destroyers commissioned between 2014 and 2016, which were themselves broadly derived from the previous Project 15B *Delhi* class. *Surat's* delivery seemingly represents the end of this design line, with future destroyer production likely to transition to a larger Project 18 type 'Next Generation Destroyer' that is likely to enter construction later in the decade. Meanwhile, the submarine *Vaghsheer* represents the sixth and, to date, final member of the Project 75 *Kalvari* class, which were contracted with what is now Naval Group under a transfer of technology arrangement as long ago as 2005. In this case, however, it seems that a second batch of three additional derivatives of the type may soon be contracted to bridge the gap until a long-awaited decision on the follow-on Project 75I submarine is finally taken.

In contrast with the other two units, INS *Nilgiri* represents something of a new beginning, being the first of seven Project 17A frigates ordered in February 2015 as a follow-on to the previous Project 17 *Shivalik* class design. Four of the frigates are being built by MDL and three by Garden Reach Shipbuilders & Engineers (GRSE) in Kolkata. Displacing approximately 7,000 tonnes in full load condition, the vessels incorporate the Israeli EL/M-2248 MF-STAR multifunction radar and Barak 8 surface-to-air missiles also found aboard the Project 15A and 15B *Kolkata/Visakhapatnam* class destroyers, as well as the new aircraft carrier INS *Vikrant*. As such, they represent both an upward step compared with previous Indian Navy frigates and an important move towards providing the fleet with a state-of-the-art and relatively homogenous air defence capability.

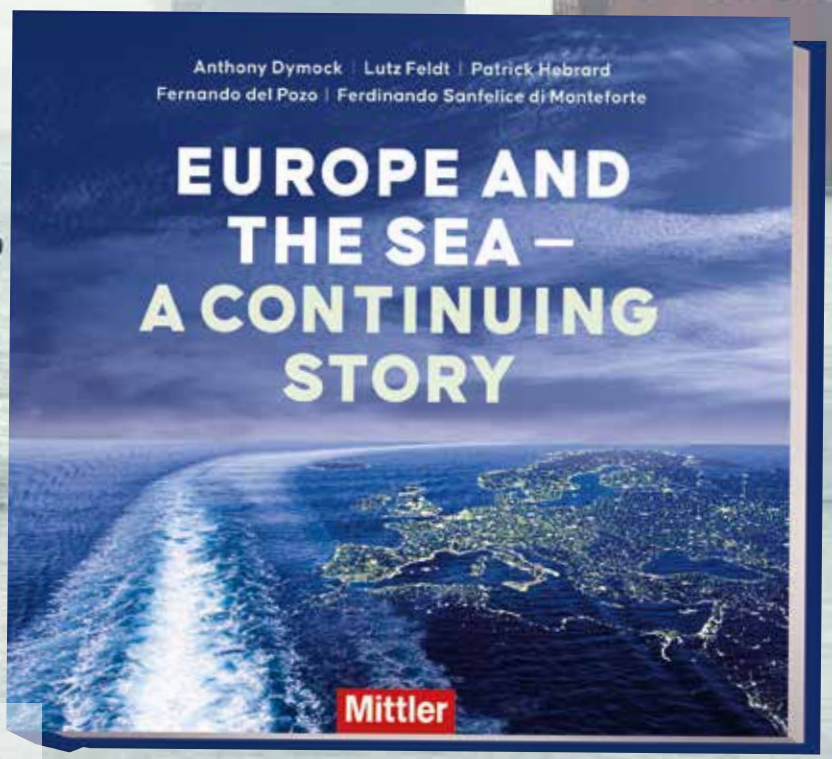
MDM editorial commentary: The multiple commissioning ceremonies held at Mumbai were indicative of the progress that the Indian shipbuilding sector is slowly achieving with respect to improvements in warship building times; a necessary prerequisite for the fleet to achieve targeted growth given the Modi regime's focus on indigenous construction in accordance with the tenets of 'Atmanirbhar Bharat' (a self-reliant India). For example, *Surat's* completion time of around 78 months compares favourably with the nearly 11 years from keel laying to commissioning experienced by INS *Kolkata*, the first ship of the Project 15A and 15B series to be delivered. Similarly, *Nilgiri* was commissioned a little over seven years from being laid down; a notable improvement compared with previous lead ships in spite of taking somewhat longer than initially anticipated.

It will be interesting to observe whether MDL's recent achievements will be replicated by the performance of GRSE, arguably India's other premier state-owned warship builder and the shipyard with which construction of the Project 17A design is being shared. Positively, GRSE's first Project 17A frigate – the future INS *Himgiri* (yard number 3022) – reportedly completed contractor sea trials on 3 March 2025, which suggests that her delivery is likely to be imminent.

A ceremony presided over by Indian Prime Minister Narendra Modi on 15 January 2025 saw three major warships – the destroyer INS *Surat* (foreground), the frigate INS *Nilgiri* (rear), and the submarine INS *Vaghsheer* (left) commissioned into Indian Navy service. [Indian Ministry of Defence]

EUROPE AND THE SEA

A CONTINUING STORY



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Race against time: The naval policy of the second Trump administration

Sidney E Dean

Objectively speaking, the US Navy remains the world's most powerful maritime force. However, it faces a determined challenge from a fast-growing Chinese fleet. The Trump administration has promised early steps to address the shortfall in American shipbuilding capacity. Adjustments to naval force structure are also expected, although these plans are still being developed.

Background

Donald Trump returned to office in January 2025 promising to strengthen America's military through "record funding" and to make the US armed forces "the most powerful military of the future." A brief look at defence and naval policy during President Trump's first term in office (2017–2021) can provide some perspectives for these more recent statements. In fiscal terms, the first Trump administration had a good record on defence spending compared with that of the previous Obama regime despite the impact of Congressional restraints relating to budgetary control during the later years of his presidency. The budget for the Department of the Navy – which includes funding for the US Marine Corps (USMC) – saw growth that was broadly in line with the overall increase achieved in defence spending.

First-term President Trump visits the then pre-commissioning unit *Gerald R. Ford* (CVN-78) in Newport News, Virginia, on 2 March, 2017. During his address he promised to expand the fleet and increase the defence budget. [US Navy]

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Regarding US Navy structure, President Trump had campaigned in 2016 on the goal of achieving a 350 ship fleet. He subsequently adopted the navy's goal of increasing the fleet to 355 vessels. By July 2020 the fleet had actually grown to 301 ships. Whilst this was up from 274 four years earlier, much of this procurement had been initiated before Trump took office. In October 2020, then US Defense Secretary Mark Esper presented the Battle Force 2045 concept. This foresaw a fleet of approximately 500 vessels, including between 140 and 240 unmanned units, by 2045 in order to maintain global obligations and provide the capacity to fight a major war. This construct remains the template for the navy's current fleet planning, although target figures are periodically adjusted.

Despite the long-term focus on growth, which was maintained under the Biden administration, short term force structure has stagnated since 2020. In March 2025, the US Navy fielded a battle force of just 295 deployable ships. The Congressional Budget Office (CBO) analysis of the navy's FY2025 shipbuilding plan predicts that a combination of increased retirements and delayed construction will see the battle force bottom out at 283 units in 2027 before real fleet growth resumes.

Overall strategy: Focus on China

The Pentagon has considered China as the United States' number one 'pacing challenge' since the early days of the Biden administration, reinforcing a longer-term 'pivot to the Pacific'. This stance was formally articulated in the 2022 National Defense Strategy, which prioritised addressing China's growing influence and assertiveness. The Trump administration is taking this approach one step further. On 29 March 2025 an internal planning memo from the desk of US Defense Secretary Pete Hegseth was leaked. This Interim National Defense Strategic Guidance document cites the United States' strategic priorities as deterring a Chinese

invasion of Taiwan, and defence of the US homeland. "China is the Department's sole pacing threat, and denial of a Chinese fait accompli seizure of Taiwan – while simultaneously defending the US homeland is the Department's sole pacing scenario," Hegseth wrote.

▲ **Trump's Defense Secretary Pete Hegseth (seen here touring Guam) continues to affirm the US commitment to the security of Indo-Pacific allies, a commitment which disproportionally relies on maritime forces. [US Navy]**

Regarding force planning, the guidance states that the services should exclusively consider conflict with Beijing when planning contingencies for a major power war. While this does not equate to abandonment of other geographic regions, the document states that the US is now willing to "assume risk" in other parts of the world. This includes increased pressure on European, Middle Eastern and East Asian allies to take much greater (if not sole) responsibility for deterring Russia, Iran and North Korea. The guidance also implies that the US will devote fewer resources to constraining militants in the Middle East and Africa who are regionally destabilising but lack the ambition to launch international attacks.

Fleet expansion and maintenance

Any conflict in the Indo-Pacific region will disproportionally involve the United States' maritime forces, including the US Navy and USMC. Given this, President Trump's statements early in his second term have highlighted the need to improve naval readiness and force posture. During a 6 January 2025 television interview given shortly before his inauguration, he declared that the US has been "sitting back watching" and "suffering tremendously" while China's fleet grows. He declared his intent to initiate a significant fleet expansion quickly, and implied he was open to contracting with allies in order to increase procurement rates. The latter approach had already been advocated by President Biden's Navy Secretary, Carlos del Toro, in 2024 after touring shipyards in Japan and South Korea.

During his Senate confirmation hearing on 14 January 2025 then designate Defense Secretary, Pete Hegseth, stated that shipbuilding would be a top priority of the administration. "We need to reinvigorate our defense industrial base in this country to include our shipbuilding capacity," Hegseth said. "Shipbuilding is an urgent national security priority. If confirmed, I will immediately direct the Secretary of the Navy and the Under Secretary of Defense for Acquisition and Sustainment to create a shipbuilding roadmap to increase our capacity." Subsequently, on 4 March, President Trump announced his intention to establish the Office of Shipbuilding within the White House. While the office will pursue revitalisation of both the commercial and military shipbuilding sectors, the president emphasised the impact on the defence industrial base and the need to speed up and expand naval shipbuilding. "To boost our defense industrial base, we are going to resurrect the American shipbuilding industry, including commercial shipbuilding and military shipbuilding...It will have a huge impact to further enhance our national security," Trump said during an address to Congress. Further details about the new office's authority and likely approach are, however, still awaited.

Strengthening the Navy's industrial base was also a focus during Navy Secretary John Phelan's confirmation hearings in February 2025. Speeding construction of new vessels while reigning in cost overruns is only part of this equation, with Phelan citing the need to replenish stockpiles of munitions and to overcome the fleet's significant maintenance backlog as important objectives. Phelan, a financier with no prior government or military experience, was specifically chosen in order to replace the status quo within the department. "The U.S. Navy is at crossroads, with extended deployments, inadequate maintenance, huge cost overruns, delayed shipbuilding, failed audits, subpar housing, and, sadly, record-high suicide rates," Phelan stated during his confirmation hearing. "These are systemic failures that have gone unaddressed for far too long. Frankly, this is unacceptable...My role is to...step outside the status quo and take decisive action with a results-oriented approach."

▶ **John Phelan was sworn in as Navy Secretary on 25 March, 2025. [US Navy]**

Details of how the new secretary plans to alleviate the shortfalls within the shipbuilding industry – shortfalls that have multiple causes including insufficient and outdated infrastructure as well as a lack of skilled labour – are yet to emerge. In general terms Phelan has spoken of incentivising industry while holding contractors responsible for cost overruns and delays. Increasing competition with regard to the supply of components is also regarded as a potential solution. However, the new secretary has cited the need to conduct a "root cause analysis" before proposing concrete solutions to the shipbuilding crisis.

Budgetary priorities

Finding ways to finance increased naval procurement is a fundamental consideration. Shortly before leaving office in January 2025, President Biden's defense secretary, Lloyd Austin,

had proposed an increase in defence spending of approximately USD 50 billion per annum over previous projections beginning with the FY2026 budget in order to support a much needed growth in defence acquisitions, as well as operations and training. The recommendation would have raised defence spending to more than USD 1 trillion by 2028. While the new administration seems to agree on the amount of additional funding needed, it is taking a different approach to that suggested by Austin.

For the moment, Donald Trump has backed away from his campaign's stated goal of major defence budget increases; instead the administration's current fiscal focus is on the annual reallocation of around USD 50 billion in planned defence spending away from lower priority programmes – including those associated with climate change and diversity programmes – to key procurement accounts. The White House also wants to make drastic cuts to the civilian staff of the US Department of Defense (DoD) on the assumption that federal government bureaucracies are oversized and inefficient.

The implications of the administration's plans are uncertain. If internal DoD savings of USD 50 billion can, indeed, be realised, this could put numerous programmes across all the services on a much more solid footing. For example, the CBO's January 2025 Analysis of the US Navy's 2025 Shipbuilding Plan finds that the required procurement budget over that timeframe will average USD 40 billion per annum. This is 17% more than the navy's estimate of USD 33.2 billion. The CBO concluded that "including the costs of operating and maintaining those ships, buying new aircraft and weapons, and funding the Marine Corps, the Navy's total budget would need to increase from USD 255 billion today to USD 340 billion (in 2024 dollars) in 2054 to implement the 2025 plan." This funding shortfall is expected to cause delays or lead to programme cancellations. The hardest hit by these shortfalls are capital-intensive and long-term projects, including shipbuilding, aircraft and missile systems. Clearly, this problem could be significantly reduced by the allocation of billions of dollars from lower priority objectives

However, most analysts agree that savings of this magnitude cannot be achieved without cutting into training, maintenance and personnel accounts, risking operational readiness. Currently discussed plans to cut 50,000-60,000 DoD civilian positions are also expected by many to impact readiness and, ironically, oversight of military research, development and acquisition programmes. It remains to be seen whether the administration can overcome these concerns.

Force structure options

The stated goal of fleet expansion will not preclude cancelling acquisition programmes which are perceived as troubled or which do not align with the administration's strategic priorities. The *Columbia* (SSBN-826) class strategic submarine programme is suffering delays, but is considered safe because it is integral to revitalising the nation's strategic arsenal. Likewise, the *Virginia* (SSN-774) class unclear-powered attack submarines remain a priority. The Trump administration has expressed strong support for unmanned systems and other advanced technologies, and is expected to approve development and production of the 6th generation manned carrier-based strike fighter, the F/A-XX.

However, some acquisition projects which were until recently considered high priority may face cancellation over technology issues and doubts over performance. One possible candidate for the red pen is the *Constellation* (FFG-62) class frigate, which is now three years behind schedule and USD 200 million per ship over budget. John Phelan has labelled the ship a "mess." Both he and President Trump have blamed US Navy leadership for demanding belated and counterproductive changes to the frigate's design, which have led to unplanned weight increase and threaten to reduce manoeuvrability. Given the comparatively early state of the class's construction programme and the outlook for high-performance large unmanned vessels – which could assume some of the roles assigned to the class – it is not inconceivable that the programme could be cancelled or reduced in order to free resources for other projects.

Medium and large-sized unmanned surface vessels such as the 55 metre, 240 tonne NOMARS (No Manning Required Ship) *Defiant* (USX-1) are likely to make up a major portion of the future US Navy fleet. [DARPA]

▲ The keel laying ceremony for the first *Columbia* class ballistic missile submarine, USS *District of Columbia* (SSBN-826), in June 2022. Given the Trump administration's support for strengthening nuclear deterrence, the *Columbia* class strategic submarine programme is expected to continue with no cuts or delays. [US Navy]

▲ The FA/XX 6th generation carrier based fighter aircraft will enhance US Navy fleet lethality and survivability, and is expected to survive any force structure adjustments. Contenders as of March 2025 were Boeing and Northrop Grumman. [Boeing]

A work in progress

It is only four months into the new administration; early days by any measure. The immediate focus on addressing the catastrophic shortfall in shipbuilding and maintenance infrastructure are promising. The big question is how quickly existing shipyards can be reformed, modernised and expanded? South Korean and Japanese industry are likely to offer lessons which can, at least in part, be applied in the United States as well, although the process of revising procedures, retraining personnel, and installing new technology will take time. Building new shipyards, component factories, and maintenance facilities, or reactivating closed installations, will take even longer. Nonetheless, a start has been made, and needs to be carried through with resolve; even partial progress will be an improvement.

In the interim, procurement of foreign built (rather than simply foreign designed) platforms would provide a time-sensitive boost to the fleet. President Trump has repeatedly praised the Italian FREMM on which the *Constellation* class was originally based, and has spoken of an option to procure vessels in allied nations if domestic reforms are inadequate. Whether this remains a serious option given the preference for boosting domestic industry displayed by the levying of tariffs on imports from these same nations, as well as likely Congressional opposition to shifting critical defence work overseas, remains to be seen.

The decision to focus exclusively on the Indo-Pacific region and homeland defence, as outlined in Secretary Hegseth's interim guidance document, is also problematic. While Washington may expect allies to assume a greater share of the burden of securing regional seaways, the US Navy's assets would be sorely missed in the North Atlantic or other strategically vital regions. The joint US Navy/US Air Force bombing campaign against the Houthi militia in March 2025 seems to reflect recognition of this fact. Even though US commercial shipping interests may be less reliant on Red Sea transit than European, Middle Eastern or Asian commerce, the waterway is of strategic importance to the United States, including as a key transit route for military ships and logistics vessels. The unavoidable truth is, global superpower status and global presence go hand in hand. For Washington, the US Navy and USMC are fundamental to this global presence.

▼ The *Constellation* (FFG-62) class frigate programme is suffering multi-year delays, uncertainty over cost, and warnings that unplanned weight growth could limit service life. Given the early stage of the procurement programme, there is speculation that the class might be cancelled or curtailed to free up funds for other acquisition projects. [Fincantieri]

Romanian naval modernisation: Status report

Conrad Waters

The Romanian Navy has seen only limited investment since the Cold War's end. Accordingly, the deteriorating security situation and increasing defence expenditure has driven plans for wholesale modernisation. However, prioritisation given to other branches of the Romanian Armed Forces and, notably, difficulties in concluding acquisition contracts have meant that, to date, only limited progress has been achieved. This article examines the challenges that Romanian naval modernisation has faced over recent years and assesses its likely future direction.

Current fleet structure

Some 25 years after the end of the Cold War, the Romanian Naval Forces still retain much of their Warsaw Pact era equipment. The core of the surface fleet comprises the frigate NMS *Mărășești* and a quartet of 'Tetal I' and 'Tetal II' class corvettes. These ships were all first completed in Romania during the 1980s. They are supplemented by numbers of fast attack craft, minehunters and riverine patrol vessels built locally or in the Soviet Union during a similar timeframe.

The most significant naval investment during the post-Cold War era was the acquisition of two former British Royal Navy Type 22 frigates, which was announced in January 2003. Their purchase was intended to enhance interoperability with Romania's new NATO partners. The ships were commissioned as NMS *Regele Ferdinand* (ex HMS *Coventry*) and NMS *Regina Maria* (ex HMS *London*) in, respectively, September 2004 and April 2005. Their acquisition included a limited, GBP 116 million (EUR 138 million), refurbishment and modernisation. This encompassed combat management system upgrades and installation of a 76 mm gun. Although stripped of their missile armament, they are arguably the Romanian Navy's most effective assets. However, the two vessels were first completed in the late 1980s, meaning that they are roughly contemporary with the remainder of Romania's fast-aging fleet.

The initial Type 22 frigate refurbishment was originally intended to be the first phase of a more extensive modernisation project that would ultimately provide these ships with a much wider range of capabilities. Limited defence funding during this phase of the post-Cold War era and priority accorded to the air force and army meant that this ambition was deferred. However, Russia's annexation of the Crimea meant that the need to undertake a more through programme of naval modernisation was increasingly recognised. Accordingly, in November 2016, the Romanian government announced that Damen's 'Sigma' 10514 light frigate design had been selected to meet a requirement for four new corvettes in a deal variously reported to be worth between EUR 1.1 billion and EUR 1.6 billion. Construction was to be carried out at Damen's Romanian Galati shipyard and include the long delayed Type 22 frigate upgrades. This decision proved to be short-lived, as a change of government resulted in the project being cancelled.

▲ The Romanian Navy continues to be composed largely of Warsaw Pact era ships. This is the frigate NMS *Mărășești* seen during operations with the US Navy in 2021. [US Navy]

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▲ **Two former British Royal Navy Type 22 frigates arguably form Romania's most effective assets but their modernisation has been long-delayed. This is NMS *Regina Maria* operating with other NATO warships in 2020. [US Navy]**

Abortive collaboration with Naval Group

Despite this setback, the acquisition of new surface combatants and modernisation of the Type 22 frigates remained a priority. It formed part of a wider framework of eight major equipment programmes approved in 2017 under the Romanian Armed Forces Acquisition Plan 2017-2026. This led to the opening of a competitive tender process the following year that initially attracted proposals from five European shipbuilding groups. Subsequently, in July 2019, the Romanian government announced the selection of France's Naval Group, acting in partnership with local company Santierul Naval Constanta (SNC), to undertake the naval modernisation programme. Reportedly valued at EUR 1.2 billion, this encompassed the construction of four new 'Gowind' type corvettes and implementation of the long-delayed Type 22 upgrades. The creation of associated maintenance and training facilities was also included. Contemporary news reports suggested that the first of the newly-built 'Gowind' corvettes would be delivered in the course of 2022.

Despite this positive development, tangible progress remained elusive. Part of this was seemingly due to continued prioritisation of army and air force programmes, such as US 'Patriot' surface-to-air missiles and 'Piranha' armoured personnel carriers. This, alongside legal challenges to the preferred bid, resulted in delays to contract discussions. However, it seems that a more significant problem related to reported tensions in the Naval Group-SNC alliance over the contractual details of how the programme was to be implemented. Although hopes were raised as to a final conclusion of the deal after signature of a letter of intent between France and Romania in June 2022 to enhance naval collaboration, signature of a final agreement continued to be postponed. In August 2023, the Romanian government finally lost patience and cancelled the agreement, throwing the navy's most important procurement programme into disarray.

Incremental successes

In spite of the considerable problems faced by the 'flagship' corvette acquisition, more success has been achieved with other Romanian naval projects. The most significant of these relates to the procurement of mobile anti-ship missile launchers. This was another of the major schemes contained within the 2017-2026 acquisition plan. After several false starts, Raytheon was awarded a USD 209 million (EUR 192 million) contract for the Naval Strike Missile (NSM) Coastal Defence System under the US Foreign Military Sales (FMS) process in December 2022. The contract followed receipt of US State Department approval for the sale in 2020. Its value could be increased to USD 217 million (EUR 200 million) if all options are exercised. The majority of the work will be carried out by Kongsberg in Norway and is expected to be finished by September 2028. Each NSM Coastal Defence System encompasses a fire distribution (command and control) centre, mobile launch and transportation vehicles, and – optionally – a suitable surveillance and tracking radar.

Another significant purchase has been the acquisition of two former British Royal Navy *Sandown* class minehunters under a government-to-government transfer agreement approved by the Romanian parliament in May 2023. Their purchase was probably influenced by the increased risk to Black Sea shipping posed by stray sea mines after the outbreak of the current Russo-Ukrainian War. This had seen one of Romania's existing minesweepers, NMS Lt. *Dimitrie Nicolescu*, damaged in September 2022 whilst attempting to neutralise one of these hazards. NMS *Sublocotenent Ion Ghiculescu* (formerly HMS *Blyth*) was formally handed over in September 2023 after refurbishment by Babcock International at Rosyth. She arrived at Constanta towards the end of the year. Her arrival was heralded as Romania's first significant naval acquisition in nearly two decades. Preparations for the delivery of her sister, *Căpitan Constantin Dumitrescu* (ex HMS *Pembroke*) were well advanced as of the end of 2024. However, her arrival in Romanian waters has yet to be reported.

▲ **A major Romanian naval modernisation programme that included the acquisition of four 'Gowind' corvettes from a partnership of France's Naval Group and local shipyard Santierul Naval Constanta was never finalised. [Naval Group]**

At the start of 2024, it was also confirmed that the navy would acquire two Airbus H215M helicopters equipped for anti-surface warfare under a transaction valued at approximately EUR 165 million. According to local reports, the two rotorcraft will be manufactured by Airbus in France. However, final integration is to be carried out in Romania by prime contractor IAR Brașov. It is anticipated that the lead helicopter will be delivered in 2026, with both rotorcraft likely to be assigned to the Type 22 frigates. The helicopters are to be equipped with the MBDA Marte ER (extended range) anti-ship missile, which the manufacturer claims has an effective engagement envelope of over 100 kilometres.

▲ **Two Airbus H215M helicopters equipped for anti-surface warfare have been ordered for the Romanian Navy. This image shows two H215Ms in Chilean Army colours. [Airbus]**

A potential way ahead

Although these programmes offer the likelihood of incremental improvements in Romanian naval capabilities towards the end of the current decade, it is clear that a broader programme of naval modernisation is becoming increasingly pressing. It seems that the Romanian government never considered an alternative 'Plan B' to the abortive Naval Group alliance. This produced a vacuum when contractual negotiations stalled. The fact that the long-delayed Type 22 frigate modernisation was structured as an integral part of the contract has exacerbated the navy's problems. In essence, it means that the failure to obtain new surface combatants will be accompanied by the increased obsolescence of the fleet's most effective warships.

At the time of writing, some 18 months after the collapse of the Naval Group deal, the means by which the Romanian government intends to address the navy's needs is only slowly emerging. Positively, Romania's defence spending has expanded rapidly in recent years as it responds to the deteriorating strategic situation, surging to around USD 8.6 billion (2.3% of GDP) in 2024. Moreover, surface combatant acquisition remains an important element of the government's updated procurement plans. There is, however, a danger that the priority accorded to naval requirements will, again, suffer in comparison with army and air force needs given the influence of the largely land-based Russo-Ukrainian war. This is likely to be a particular danger if an alternative naval acquisition strategy is not quickly implemented. Certainly, Romania's agreement to acquire 32 F-35A Lightning II strike fighters under a deal reportedly valued at USD 7.2 billion (EUR 6.6 billion) that was announced in November 2024 is evidence that future demands on defence spending will remain heavy in spite of the expanded financial framework.

Reports emerging in local Romanian news sources in mid-2024 suggest that a phased naval modernisation programme might now be envisaged. The first element of this plan would be the acquisition of two new offshore patrol vessels, which would be procured by means of a competitive procurement process. A project budget of some EUR 300 million has been mentioned. In due course this would likely be followed by construction of more sophisticated ships under the European Patrol Corvette (EPC) programme. In mid-2023, it emerged that Romania had joined Greece, Italy, France and Spain in the EU Permanent Structured Cooperation (PESCO) sponsored project, which is intended to produce a common hull for a modular, "second line" warship. This participation might eventually allow Romania to obtain its planned corvettes during the early part of the 2030s; a decade or so later than initially envisaged.

It is possible to speculate that a significant driver of this potential approach might be a realistic appraisal of the current capabilities of Romania's indigenous shipbuilding sector and the best means by which these might be further developed. Notably, Damen's Galati shipyard has already delivered fully-outfitted OPVs of the *Yarmook* (OPV 1900) and *Hunain* (OPV 2600) types to the Pakistan Navy, adding a further level of complexity to the naval hulls that the facility has delivered for a number of other Damen projects. It is not difficult to see the proposed Romanian OPV project as an attempt to build on this success as part of an endeavour to recreate a sovereign naval construction capacity.

▼ **A Brazilian Navy 'Scorpène' type submarine. There has been little recent news about Romanian plans to purchase two of the type. [Naval Group]**

A Romanian submarine flotilla

One other, much discussed development is the potential reconstitution of a Romanian submarine flotilla. The Romanian Naval Forces still retain the 'Kilo' class boat *Delfinul* as a harbour-based training asset after she ended her operational service in the mid-1990s. However, the potential acquisition of a more

Building on the construction of offshore patrol vessels – this is PNS Hunain – for the Pakistan Navy at Damen's Galati shipyard would be one way for Romania to kick start a major programme of naval modernisation. [Pakistan Navy]

active underwater capacity emerged in 2023 with reports that parliamentary authorisation had been received for the acquisition of two new vessels.

The submarine programme appears to have been envisaged in the previously-referenced Franco-Romanian collaboration agreement signed in June 2022. It would likely involve the purchase of French-built 'Scorpène' type units. If a contract is concluded, it would make Romania only the third submarine operator (Russia and Turkey are the two others) in the Black Sea. However, there has subsequently been little tangible news on the programme, which might potentially have fallen victim to the subsequent collapse of the 'Gowind' corvette acquisition. The realisation of such a programme would, in any event, inevitably be a costly and lengthy venture given the three decade long hiatus since Romania has last operated an active submarine.

Concluding words

The Romanian Naval Forces have suffered from a significant lack of investment in recent decades, steadily eroding their operational capability. Although this problem has long been recognised by several Romanian governments, the implementation of major modernisation has failed to gain traction in spite of several false dawns. Recently, the implementation of a number of smaller procurement projects holds out the prospect of more modest, but still valuable, incremental improvements pending the reformulation of a more comprehensive modernisation scheme. The outline of this programme is now seemingly starting to take shape, holding out the prospect of significant operational and industrial benefits. However, its ultimate achievement will remain subject to the competing demands of other elements of the Romanian Armed Forces, as well as the vagaries of an uncertain political backdrop.

Turkish naval programmes: Status report

Devrim Yaylali

Türkiye's ambition to modernise its armed forces and achieve greater self-sufficiency in defence products is most clearly evident in its naval shipbuilding industry. In January 2025, the Turkish Ministry of Defence announced that 31 warships were in various stages of construction for the Turkish Naval Forces, spanning nine different projects. These projects cover a broad range of vessels, from complex and large platforms like the National Aircraft Carrier (MUGEM) and the National Submarine (MİLDEN) to simpler designs such as fast landing craft tanks (LCTs).

▲ The corvette TCG *Heybeliada* was the first ship delivered under Türkiye's transformational MİLGEM National Ship programme. [Devrim Yaylali]

Three key factors drive these naval projects. The first is the ageing fleet of the Turkish Naval Forces. On average, the 16 frigates currently in service have already exceeded their operational lifespans. Moreover, similar concerns relating to ageing apply to submarines and fast attack craft, necessitating a programme of fleet renewal.

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The second factor is the aim to become more self-reliant by developing and procuring domestic weapons, sensors, and other sub-systems to keep warships operational and habitable.

The third factor is Türkiye's strategic vision, which recognises that its future lies in the seas. A strong naval force supported by a robust shipbuilding industry is regarded as being essential for national security and economic prosperity. Exporting warships further strengthens Türkiye's financial standing, influence, and reputation. The Turkish naval shipbuilding industry has already exported warships to Egypt, Georgia, Malaysia, Nigeria, Pakistan, Portugal, Qatar, Romania, Turkmenistan, Ukraine, and the United Arab Emirates.

The MİLGEM renaissance

The renaissance of the Turkish naval shipbuilding industry began with the National Ship (MİLGEM) project. This initiative has led to the development of 'Ada' class corvettes, 'İstif' class frigates, 'Hisar 'class offshore patrol vessels and 'Ufuk' class intelligence ships, as well as various corvette-sized warships sold to Pakistan, Ukraine, and Malaysia.

The origins of many of Türkiye's current shipbuilding projects can be traced back to the MİLGEM project. In 1996, the Turkish Navy sought to procure eight corvettes to replace older coastal patrol and anti-submarine warfare (ASW) vessels. This project set the groundwork for future Turkish Navy warship development by emphasising indigenous design and control over the programme. The first corvette, TCG *Heybeliada* (F-111), served as a prototype. Initially, the next three corvettes were to be built by private shipyards. However, political considerations ultimately led to all four ships being constructed at the Istanbul Naval Shipyard. Collectively, these ships are known as the 'Ada' class in Turkish service.

This model was successfully applied to the 'İstif' class frigate programme. The first ship, TCG *Istanbul*, was built at Istanbul Naval Shipyard, while seven more are being constructed at Anadolu Shipyard (three units), Sefine Ship-

yard (two units), and Sedef Shipyard (two units). While their details have not been disclosed yet it seems likely that the final four planned 'İstif' class frigates will be optimised for ASW roles, as they will be fitted with the DÜFAS low frequency towed sonar system developed by Turkish defence conglomerate Aselsan.

TCG *Istanbul* (F-515) is 113.2 metres long, 14.4 metres in breadth and has a 4.1 metre draft. Her displacement is approximately 3,000 tonnes. The frigate is essentially an enlarged version of the 'Ada' class corvettes, incorporating enhanced multi-threat engagement capabilities and more advanced weapon and sensor systems. Her main gun is a 76mm/62 calibre mounting and her primary offensive weapon 16 Roketsan Atmaca anti-ship missiles. She is also equipped with Roketsan Hisar-D RF anti-air missiles, launched from the domestically developed MIDLAS vertical launch system (VLS). Originally, the ships were to be fitted with the US made Mk 41 VLS, but delays in US approval forced Türkiye to develop its own launcher, impacting the project timeline. Close-range weapons also reflect the importance of indigenous industry, comprising two Aselsan 25mm STOP remotely controlled weapon systems and the company's Gökdeniz 35mm close-in weapon system (CIWS). This utilises dual 35mm barrels capable of firing at high rates and has its own search and fire-control radar, as well as electro-optic sensors.

▲ **The 'İstif' class frigate programme currently involves the construction of eight frigates. The lead ship, TCG *Istanbul*, was delivered in January 2024. [Devrim Yaylali]**

Aselsan is also responsible for much of TCG *Istanbul's* electronics' outfit. The main surveillance radar is the company's Cenk 400-N active array, which is complemented by Aselsan-produced surface search and fire control radars and by its ARES-2N electronic countermeasures (ECM) and AREAS-2 electronic support measures (ESM) systems. Additional onboard systems produced by Aselsan include the Piri infrared search and track (IRST) system, Denizgözü Ahtapot forward looking infrared (FLIR) and Fersah hull-mounted sonar. The combat management system is Havelsan's Advent.

TCG *Istanbul* was delivered in January 2024 and good progress is being made with building the series-production ships. The most advanced of these, *İzmir* (F-516) and *İzmit* (F-517), were both launched in January 2025.

The TF-2000 air defence destroyer

The Turkish Navy's next major surface combatant programme is for the TF-2000 air defence warship. Designed by the Turkish Navy, the lead ship is being constructed at Istanbul Naval Shipyard, where the first steel was cut for the prototype vessel in January 2025. The TF-2000 is a next-generation air defence warship designed to detect and neutralise guided and ballistic missile threats while offering robust, all-round naval combat capabilities. Work on this project began in earnest in 2017 after previous false starts, and the design has evolved through several iterations. The current configuration is for a ship measuring 149 metres in length, 21.3 metres in breadth, and with a draft of 5.8 metres. Displacement will be 8,300 tonnes.

The TF-2000 will be powered by a combined diesel or gas (CODOG) propulsion system, which will allow it to achieve speeds in excess of 26 knots. It is to be armed with a 127mm main gun, two 25mm remote-controlled weapon stations, and a 35mm Gökdeniz close-in weapon system. The ship's air defence capabilities will comprise a 32-cell VLS at the bow and a 64-cell VLS amidships, both domestically produced as part of the MIDLAS project. The vertical launchers will be able to deploy a range of air defence missiles, as well as the Gezgin cruise missile. As external launchers for the Atmaca anti-ship missile have been omitted from the latest graphics of the design, it seems likely that they will be launched from the VLS as well.

A fundamental enabler of the TF-2000 destroyer's capabilities will be Aselsan's Çafrad active multi-function phased array radar. Graphics suggest its fixed arrays will be split between the forward and aft masts and superstructure in the TF-2000 to facilitate unrestricted 360° scanning, target detection and tracking without ant visual obstruction. It comprises both

◀ **A model of the TF-2000 air defence destroyer. She carries a total of 96 VLS cells located forward and amidships. Her multifunction radar arrays are split between the forward and aft superstructure/masts. [Devrim Yaylali]**

S-Band arrays for long range volume search in excess of 450 km and X-Band arrays to perform shorter range search, tracking and target illumination functions. It incorporates non rotating IFF. The CMS will again form part of Havelsan's Advent series.

The 'Reis' and MİLDEN submarine projects

The most strategically significant project amongst the Turkish Navy's current acquisitions is arguably the MİLDEN submarine programme. Construction will begin once the ongoing 'Reis' class submarine project at Gölcük Naval Shipyard is completed.

Türkiye's National Submarine (MİLDEN) project is expected to leverage lessons learned from the preceding 'Reis' class submarine programme for six improved Type 214 boats. This is the lead member of the 'Reis' class, TCG *Pirireis*. [Devrim Yaylali]

The six 'Reis' class boats are an improved version of the Type 214 air independent propulsion (AIP) equipped submarine. An agreement for their construction was signed with thyssenkrupp Marine Systems (tkMS) in July 2009, entering into effect in June 2011. The first submarine, TCG *Pirireis* (S-330), began construction in October 2015 and was finally commissioned in August 2024. Delays arose due to Turkish Navy-driven modifications to the design, which included increases to length and displacement, as well as a result of the COVID pandemic.

'Reis' class submarines are 68.4 metres long and 6.3 meters wide, making them 3.4 meters longer and 125 tonnes heavier than standard Type 214 submarines. They are powered by two MTU diesel engines and one Siemens Permasyn electric motor with a 3,900 kW output. Their AIP system consists of two BZM 120 PEM fuel cells, each generating 120 kW. The submarines have eight 533 mm torpedo tubes and are armed with Mk 48 Mod 6AT torpedoes and UGM-84A Harpoon anti-ship missiles. Indigenous Akya heavyweight torpedoes and Atmaca anti-ship missiles will be integrated in due course. TCG *Pirireis* and her sister vessels also incorporate an unprecedented level of participation from indigenous defence companies compared with previous Turkish submarines.

The National Submarine (MİLDEN) project is expected to leverage lessons learned from the 'Reis' class submarine programme while incorporating further domestic capabilities. Following the now-proven formula for the MİLGEM project, the Turkish Navy established a MİLDEN Design Office in 2019. This was tasked with developing the future submarine. Subsequently, the first weld for the lead MİLDEN type boat was completed at Gölcük Naval Shipyard in January 2025.

Due to the general secrecy that typically surrounds submarine operations, the Turkish Navy has shared only limited details about the project. Publicly released information suggests that the MİLDEN design is about 80 metres in length and has a surfaced displacement in the region of 2,700 tonnes. The submarine will be equipped with eight 533mm torpedo tubes, capable of launching indigenous weapons such as the Akya heavyweight torpedo, Atmaca anti-ship missile, and Gezgin cruise missile. In addition to these armaments, MİLDEN will utilise a domestically developed navigation radar, as well as a sonar suite that integrates low-frequency flank arrays, bow arrays, and towed arrays to provide comprehensive situational awareness.

The MİLDEN submarine will feature a hull constructed from locally produced HY-100 steels coated with anechoic material, minimising acoustic wave reflection and enhancing stealth in sonar-dense environments. Equipped with diesel-electric propulsion, MİLDEN will incorporate an undisclosed type of AIP system. The submarine is expected to operate at greater depths, carry a heavier weapons load, and remain submerged longer than previous Turkish boats.

A set of Turkish navy graphics of the new National Aircraft Carrier (MUGEN). [Turkish Navy]

The National Aircraft Carrier

The first weld for the National Aircraft Carrier (MUGEN) was also performed in January 2025. According to information shared by the Turkish Navy, the ship will be 285 metres long and 75 metres wide, with a draft of 10 metres and a projected displacement of 60,000 tonnes. This will make it more than twice the displacement of the current largest warship in the Turkish Navy, the amphibious assault ship TCG *Anadolu*. The dimensions are very similar to those of the British Royal Navy's *Queen Elizabeth* class aircraft carriers.

The MUGEN will be constructed to a short take-off and barrier arrested recovery (STOBAR) configuration, utilising a ski jump of approximately 12-14°. This configuration is a pragmatic design choice given that it is unlikely that the United States would be willing to provide catapult technology to Türkiye. Furthermore, it will ease the work of Turkish aircraft designers and engineers, as they will not have to reconfigure their planes and landing gears for catapult launching.

Design illustrations show a single island on the starboard side. One elevator is located ahead of the island and a second one aft. The preliminary design shows three possibly take off positions. The shortest one, located in line with the bridge on the centreline is for the TB-3 unmanned combat air vehicle (UCAV). The second runs diagonally across the ship from her port side abaft the island to the centreline and is for the Hürjet manned aircraft. An extension to a third take off position on the port quarter is for the Kızılelma unmanned jet aircraft. To land the aircraft there are three arresting wires and an angled deck.

The ship will have a combined gas and gas (COGAG) configuration with four gas turbines. These will probably be GE's LM2500, as this type of turbines is already used by various other warships in the Turkish Navy. Estimated speed is 25 knots. Since the new design does not show any provision for amphibious operations such as a well deck or ramps for loading and unloading of vehicles, it can be assumed that the Turkish Navy wishes to have a purely dedicated aircraft carrier without any additional amphibious capabilities.

Other programmes

Other significant ongoing projects include those for the 'Hisar' class offshore patrol ships (OPVs), new fast attack craft and new mine countermeasures vessels. Of these three projects, the production of the 'Hisar' class OPVs is the most advanced, with first two vessels TCG *Akhisar* (P-1220) and TCG *Koçhisar* (P-1221) launched from the Istanbul Naval Shipyard in September 2023. The OPVs are based on the proven MİLGEM design but carry less sophisticated electronics and pack a more modest punch. They are armed with one 76mm main gun, and two 12,7mm RCWS. They are, however, also fitted 'for but not with' Atmaca anti-ship missiles. The other two projects are still in their earlier stages. The new fast attack craft are worthy of particular mention as being the first combatant project where the Turkish Navy did not lead the project with its own design. Instead, the whole preliminary and detailed design of the vessels was performed by STM, making this project unique.

Conclusion

Türkiye sees its future and its fortunes in the seas, as demonstrated by the emphasis given to its 'Blue Homeland' doctrine. [1] To secure these interests, the Turkish Navy aims to achieve a high-tech and modern force structure within the 2035-40 timeframe. This vision for the Turkish Naval forces encompasses not only a defensive role but also the creation of a force structure capable of power projection overseas.

The commencement of construction of vessels under the MUGEM, MİLDEN and TF-2000 projects is in line with this objective. These projects are notable in being technologically challenging and politically ambitious. However, the Turkish naval shipbuilding industry created as a result of the original MILGEM project should now have achieved sufficient maturity to be able to support the navy's needs by delivering these challenging projects. If successful, delivery of these programmes will ensure that the Turkish Navy becomes both a regional power and an effective global naval force, whilst reinforcing the independence of the nation's defence industry and thus helping to secure Türkiye's future.

▲ **The 'Hisar' class OPVs TCG *Akhisar* and TCG *Koçhisar* are currently under construction at Istanbul Naval Shipyard. [ASFAT]**

Editor's Note

1. The 'Blue Homeland' doctrine was introduced in 2019, signalling a shift in emphasis from Türkiye as a land power towards a greater focus on protecting the country's maritime zones and interests. The doctrine also has a political aspect in connection with the various maritime disputes in the Eastern Mediterranean.

Recent trends in surface warship design

Conrad Waters

Procurement of major warships is experiencing a notable resurgence against a backdrop of increased global tensions. Some fleets are embarking on their first purchases of new-build surface combatants in recent years, whilst many others are expanding acquisition programmes to encompass several warship classes. This upturn in activity is often being accompanied by an assessment of how operational capacity can be best enhanced through the incorporation of the many technological developments of the post-Cold War era into these new ships. This article aims to examine the resultant changes in warship design that are now underway and what trends are likely to emerge in the future.

A slow evolution

The end of the Cold War brought significant changes to the world's leading navies. For many, there was a substantial reorientation away from previous missions – for example, anti-submarine warfare for the British Royal Navy or littoral defence for the Baltic fleets – towards expeditionary and stabilisation roles. This shift was accompanied by an almost universal desire to reduce defence spending (the so-called 'peace dividend') that inevitably produced a dramatic slowdown in naval procurement. In addition to wholesale fleet reductions, many existing programmes were reduced in scope and new projects shelved. Whilst the major fleets did manage to maintain some new surface warship construction, acquisitions were reduced in number and typically took longer to complete than was previously the case.

This marked slowdown in construction was not fully replicated in a similar reduction in technological progress. Cold War research and development (R&D) programmes had achieved considerable momentum, allowing important development work to continue in its aftermath. Moreover, rapid evolution in civilian R&D, perhaps most notably in the field of computing, had important consequences for the defence and naval sectors. An often-cited example in the underwater field was the US Navy's Acoustic Rapid COTS Insertion (ARCI) programme. This improved the performance of the existing sonar systems installed in submarines by periodically upgrading them with refreshed computer hardware of commercial origin that was, in turn, able to benefit from the latest software enhancements. A similar approach was subsequently taken with respect to the combat management systems used in surface warships. Clearly, this strategy was particularly attractive in a budget-conscious era by maximising the capacity of existing sensors at minimal cost.

▲ **The restricted extent of naval construction in the post-Cold War era meant that the full impact of technological change was only slowly evidenced in modern warship design. Moreover some innovative projects, such as the US Navy's *Zumwalt* (DDG-1000) class pictured here, ultimately proved to be dead ends. [General Dynamics/Bath Iron Works]**

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Financial considerations drove other developments. Notably, limited budgets saw the control of operating and sustainment expense attract increasing attention, perhaps most evidently in ongoing efforts to reduce crew sizes. Another important aspect of the financial backdrop was a continued emphasis on late Cold War concepts focused on modularity. In addition to having the potential of reducing construction and upgrade costs, these held out the prospect of being able to adapt one hull to carry out several different missions. The US Navy's littoral combat ships are a good example of this philosophy.

Although many of these approaches were adopted in the new warships of the post-Cold War era, the limited number and extent of active construction programmes meant that the full impact of technological change has only been slowly seen in modern warship design. Moreover, troubled implementation of some new projects – the US Navy's *Zumwalt* (DDG-1000) class being the most obvious example – has resulted in legacy designs such as the *Arleigh Burke* (DDG-51) class remain in production with only limited adaptation. However, the increasingly pressing need to replace remaining Cold War period vessels and the additional impetus provided by renewed East-West tensions are now accelerating new construction. The result is the arrival of a new generation of warship designs that incorporate significant enhancements over their predecessors.

New naval behemoths

Perhaps the most evident design feature of the new generation of surface warships is their increase in size. Concept designs for the new German Navy F127 frigates (please see article in this edition for further information) suggest they will be naval behemoths of some 10,000 tonnes full load displacement; nearly double the weight of the F124 *Sachsen* class frigates that they are intended to replace. Whilst this is, perhaps, an extreme example, most current surface combatant construction programmes encompass ships that are significantly larger than their predecessors.

Several factors have driven this growth in warship dimensions, all of which are themselves indicative of other recent trends impacting warship design. Amongst the more important are:

- **Enhanced user requirements:** In simple terms, the overall reduction seen in the number of warships in service has meant that each individual hull is expected to do more. Whilst ships may still be optimised to prioritise a particular role, such as air defence or anti-submarine warfare (ASW), the single-role warship of the Cold War era is largely a thing of the past. Most major surface combatant classes are now expected to be able to perform effectively across a broad spectrum of missions. For example, the aforementioned F127 design is not only required to provide hypersonic and ballistic missile defence in addition to its predecessors' more limited air defence role but also has to be capable of long-range land attack, as well as to lead joint military operations. The space required for the resultant weapons and sensors inevitably requires a larger ship.
- **Equipment volume:** Developments in the field of technology are another factor exerting upward pressure on ship dimensions. One example is the almost universal adoption of vertical launch system (VLS) equipment, which has a marked influence on ship beam and depth in the area of installation. Similarly, increased use of relatively heavy and power-intensive multifunction radars have had implications with respect to necessary stability and power generation margins.
- **Modern construction and design practices:** The previously referenced adoption of modular design practices heralded by the Cold War-era German MEKO and Danish StanFlex systems has also tended to increase volume requirements. The relevant modules tend to demand more space for installation; a demand that has been further driven by the increased trend for maintenance by replacement (due, for example, to the space required for access and transportation routes). The German Navy's recent F125 *Baden-Württemberg* class stabilisation frigates have taken this trend further, duplicating key systems to ensure resilience and maintained operational effectiveness on lengthy overseas deployments. The modern emphasis on visual stealth has also had implications. Notably, the angular structures typically adopted to reduce radar cross section (RCS) are not always the most efficient in maximising internal volume.
- **Supporting modular equipment:** Modularity is also making itself felt in terms of the need to ship and support the increasing volumes of modular, often containerised equipment that are an increasingly common element of naval operations. Most recent warship designs incorporate spacious mission bays to stow this equipment, along with cranes and other handling equipment to facilitate its rapid deployment. A good example is provided by the Italian Navy's PPA *Paolo Thaon di Revel* class multi-role combat

Recent surface warships have grown markedly in size. The current German F126 and F127 frigate programmes – the former is illustrated here – both envisage vessels of more than 10,000 tonnes full load displacement. [Damen]

ships. These incorporate a central modular area located amidships that is sized to host up to eight ISO 1C (20 ft) containers in addition to a stern mission zone under the helicopter deck that is capable of housing a further five containers (or other equipment such as autonomous vehicles). All this inevitably makes for larger ships than those they replaced.

- **Improved habitability:** Although crew sizes have been reducing dramatically, particularly in European fleets, this has not been reflected in the space required for accommodation and other crew facilities. Today's crew is typically better educated and professional than the often conscripted complements of Cold War era warships. As demonstrated by widespread recruitment and retention difficulties, such crews have much greater expectations than those of the past. This has driven demand for improved accommodation evidenced by the shift from communal to cabin berthing, often with private washrooms attached, and enhanced provision of recreational facilities. The widespread adoption of 'mixed' crewing has inevitably only created additional demands.

Powering the fleet

A defining feature of warship design during the Cold War era was a shift away from steam turbine propulsion in all but nuclear-powered vessels. The replacement prime movers were gas turbines and large diesels, often used in 'and/or' combinations. In essence, gas turbines offered high power in a compact format but were particularly inefficient at lower outputs, whilst diesels offered relatively good efficiency across a range of outputs at the expense of both size and noise/vibration. Both options offered savings in terms of manpower and maintenance compared with their steam-powered predecessors.

Improvements in diesel technology have meant that direct-drive diesel propulsion has remained a credible propulsion option in the current day. China's extended series of Type 054A frigates and the recent British Type 31 and French FDI designs are all examples of this approach. However, there has been a notable trend towards the adoption of electrical warships, utilising either hybrid electro-mechanical or full electric propulsion. The British Royal Navy has been in the forefront of both approaches.

Hybrid electro-mechanical propulsion typically combines the use of electric motors for low speed operation, with direct mechanical drive (whether by gas turbine or diesel) being clutched in when higher speeds are required. The British Royal Navy's Type 23 ASW frigates, which started to enter service just as the Cold War was coming to an end, were important influences in driving the popularity of this

▲ The mission bay aboard a British Type 26 frigate. The need to support modular mission equipment has been one factor pushing up warship size. [BAE Systems]

▶ The British Royal Navy Type 23 frigate HMS *Kent* leads the Type 45 destroyer HMS *Dauntless* into Portsmouth Harbour. The frigate uses hybrid CODLOG propulsion whilst the larger destroyer incorporates full integrated electric propulsion (IEP). The photograph also demonstrates the evolving approach to RCS evidenced by comparing the older Kent with the more recent *Dauntless*. [Conrad Waters]

arrangement. In the Type 23s, the use of acoustically stealthy, raft-mounted diesel generators in combination with electrical motors wrapped around the ships' shafts allowed for silent anti-submarine operation at lower speeds. These could be supplemented by gearing in two Rolls-Royce Spey gas turbines to, for example, sprint to the scene of a contact. This combined diesel electric and gas (CODLAG) arrangement – as well as the similar combined diesel electric or gas (CODLOG) system – is being widely adopted for ships where achievement of a low acoustic signature is a primary objective.

A more radical approach has been the use of fully integrated electric propulsion (IEP). Here there is no direct connection between the prime movers and the shaft lines and all propulsion is provided by means of electrical motors supplied through a ship's electrical distribution network. This arrangement allows power generation to be located anywhere in the ship, potentially enhancing flexibility and redundancy. IEP has been successfully installed in a number of large surface warships, such as amphibious assault ships and the British *Queen Elizabeth* class aircraft carriers. The main examples of its use in major frontline surface combatants are the British Type 45 *Daring* class air defence destroyers and the US Navy's *Zumwalt* (DDG-1000) class. The former have suffered propulsion reliability issues arising from a lack of balance between their diesel and gas turbine generating capacity that has necessitated implementation of an expensive power improvement project (PIP). Despite these teething troubles, IEP looks likely to have an increasing influence in future surface combatants, as it offers the prospect of providing the large amount of electrical power required by the new generation of directed energy weapons such as lasers that are now under development.

A prototype Laser Weapon System (LaWS) demonstrator installed aboard the DDG-51 type destroyer USS *Dewey* (DDG-105). The move towards operational directed energy weapons could increase the popularity of IEP due to its ability to provide the large amount of electrical power required by these weapons. [US Navy]

Changes in propulsion technology have been accompanied by the widespread introduction of integrated platform management systems (IPMS) to simplify machinery control and automate damage response.

An integrated response

Turning to combat management and weapon systems, a fundamental but less visually apparent development has been the progress achieved in effectively integrating the tactical picture provided by surface warships' combat management systems (CMS) with the appropriate fire control response. This was heralded by the introduction of the US Navy's automated Aegis weapon system in USS *Ticonderoga* (CG-47) as long ago as 1983. However, Aegis' capacity has only been fully replicated across the major fleets in recent years. The expansion of CMS capability has been aided by the rapid pace of development in commercially-derived computing power over recent decades, as already previously referenced. This change has been accompanied by a switch from centralised computing networks – in which consoles, sensors and weapon systems

The former US Navy Aegis-equipped, *Ticonderoga* class cruiser Vincennes (CG-49). Whilst Aegis was first introduced into operational service in 1983, it is only in recent years that the system's capacity to integrate sensors and weapons has been widely replicated across other fleets. [US Navy]

are connected to one or more centralised computers in a star architecture – to distributed architectures that disperse computing power around a local area network (LAN). Such distributed systems avoid the single point of vulnerability inherent in using a centralised computer and are typically considerably easier to upgrade.

A more obvious warship design change associated with combat systems relates to the configuration of operations rooms (combat management centres). These have steadily evolved from cramped compartments sometimes located deep in the bowels of the ship to more spacious layouts somewhat reminiscent of a commercial office or computer centre. Ongoing efforts to reduce crewing requirements are evident in attempts to merge some combat management, platform management and bridge duties when operating in lower threat environments. An example of this trend is the so-called 'naval cockpit' introduced in Fincantieri's PPA design and which is now being extended to other Italian warships. Located in the foremost part of the bridge, this provides a position from which two operators can access an integrated console linked to a PPA's separate platform management and CMS networks. The Italian Navy argues that the cockpit minimises the level of crewing required to conduct normal navigation functions whilst facilitating a rapid switch to control from the traditional combat management centre (located behind the bridge) if an unexpected threat emerges.

The way that information in combat management centres is displayed is also evolving. Whilst CMS consoles are now an almost ubiquitous feature of all operations rooms, much effort is being expended on improving their utility. For example, some manufacturers have supported a shift from multiple screen displays to a single, reconfigurable large screen on the basis that operator experience suggests that this is more user-friendly. There is also increasing use of electronic tactical display tables to assist the command team's situational awareness. In the new Japanese ***Mogami*** (FFM-1) class frigates, this effort has extended to the use of a 360° wrap-round panoramic display screen that can be used to display a wide range of information.

Looking at changes to weapons and sensors, the widespread use of vertical missile launchers and of multifunction arrays has already been mentioned. The latter has been associated with the widespread replacement of traditional rotating radars with fixed, electronically-directed arrays. It has sometimes been difficult to find suitable locations to ensure the requisite 360° coverage and the appearance of many surface warships has been significantly altered as a result of their introduction. More positively, the switch to fixed arrays has assisted implementation of the focus on RCS stealth that has also been previously referenced.

An autonomous future

Future developments in surface warship weaponry will likely be driven by the need to counter the sheer volume of threats faced by vessels operating in combat zones. These include the proliferation of anti-ship cruise and ballistic missiles (including hypersonic weapons), as well as the growth in aerial and surface drones. Countering the missile threat is driving a trend to increasing VLS capacity, as evidenced by the 112 cell installations in China's Type 055 'Renhai' class destroyers and similar increases in the latest European designs. This will inevitably place further upward pressure on warship dimensions in the absence of mitigating measures, such as the use of quad-packed cells in Mk 41 launch systems equipped with the American Evolved Sea Sparrow Missile (ESSM). Missile and gun defences will also be increasingly supplemented by directed energy weapons, which may well become the weapon of choice to defeat less sophisticated drones. The British Royal Navy, for example, recently announced plans to accelerate the introduction of 'DragonFire' laser weapons aboard its surface warships, with four vessels scheduled to be equipped with the system as early as 2027.

Upgrades in weapon capacity will also be accompanied by similar enhancements to sensors and combat management systems. Cooperative engagement capability – which integrates weapons and sensors across

The so-called 'naval cockpit' aboard the Italian multi-role combat ship ITS *Paolo Thaon di Revel*. It provides a position from which two operators can access an integrated console linked to the ship's platform management and CMS networks. [Italian Navy]

It is possible to imagine future surface combatants becoming primarily focused on operating warfighting drones in similar fashion to the way the Belgo-Dutch rMCM 'City class' will act as motherships for mine clearance vehicles. [Naval Group]

ships and aircraft to provide a single, distributed air defence capacity – is already well established in the US Navy and is steadily being introduced in other fleets. Whilst subject to a degree of secrecy, it also seems inevitable that combat management will benefit from steadily increasing use of artificial intelligence (AI). The ever-increasing pace of naval warfare, such as the advent of hypersonic weaponry, coupled with the sheer volume of data now available, is already stretching the ability of personnel to react in a timely and effective fashion. The use of AI to enhance the interface between operators and systems is the obvious way to resolve this problem. Many leading navies already have active development programmes in this area.

Wider-ranging naval autonomy – in the form of unmanned systems of various kinds – is already well-established. The configuration of the mission bays being installed in many new surface combatants is being increasingly influenced by the need to support these systems; a trend which is only likely to expand in the years ahead. It is not inconceivable to imagine future surface combatants being designed primarily as motherships for a wide range of warfighting drones in similar fashion to the mine countermeasures mothership approach that lies at the heart of the Belgo-Dutch 'City' class rMCM programme. Even if this concept does not emerge, it seems likely that future crewed surface warships will play an important role as command and control centres for large and medium sized uncrewed vessels deploying distributed weapons and sensors in line with concepts such as the US Navy's crewed/uncrewed teaming project. Whilst some commentators see the establishment of fully uncrewed warship fleets as the ultimate direction of travel, many hurdles would still need to be overcome to achieve such a speculative vision.

‘Firsts’ class: RN’s new autonomous experimentation vessel brings new achievements in uncrewed concepts and capabilities

Dr Lee Willett

For a navy investing in platforms like aircraft carriers, nuclear-powered submarines, and anti-submarine warfare frigates, one of the UK Royal Navy’s (RN’s) most interesting, and important, recent platform investments is not a frontline warship. Such higher-end platforms play a crucial role for the RN in providing capability to deter and defend against threats across the spectrum of operations, across all domains, and across the Euro-Atlantic theatre at a time of real risk of escalation at sea. However, another platform is playing a crucial role in preparing RN concepts, capabilities, and personnel to meet the requirements of the evolving naval operational environment. That platform is its autonomy testbed ship, the experimental vessel (XV) Patrick Blackett.

In the Russo-Ukraine war, as demonstrated at sea as well as in the air and on land, the use of autonomous concepts and autonomous capabilities is having a significant impact on the conflict’s daily development. In the maritime domain, perhaps most notable is the Ukrainian armed forces’ use of uncrewed surface vessels (USVs), integrated with ‘first-person view’ autonomous command-and-control (C2) capability, to target Russian naval and commercial ships at sea and in port in the Black Sea with such regularity and effectiveness that Russia has been forced to restrict its Black Sea Fleet operations to eastern coastal waters. This example illustrates how autonomy can be harnessed to give an armed force with (in this instance) only minimal naval assets and no established C2 at sea the capacity to generate sea denial, something having significant strategic effect in the conflict’s wider context.

The UK Royal Navy’s (RN’s) experimental vessel (XV) *Patrick Blackett* is pictured conducting trials with an ‘APAC24’ uncrewed seaboat off Portsmouth, UK in November 2024. *Patrick Blackett* is the RN’s testbed vessel for accelerating delivery of autonomous concepts and capabilities to frontline operators. [Crown copyright 2024]

For the RN, *Patrick Blackett* is the centrepiece of its efforts to accelerate the delivery of autonomy and enhanced lethality to the navy through building understanding of and

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capability for using autonomous platforms and autonomous systems in contemporary naval operations.

The vessel supports extensive trials and testing work in UK waters, but also participates in high-end operational experimentation (OPEX) activities including with international partners. For example, it is a regular presence at the Portuguese Navy/NATO co-hosted 'Robotic Experimentation and Prototyping with Maritime Unmanned Systems' ('REPMUS') OPEX exercise, an annual activity held each September off Tróia, southern Portugal, where multi-domain serials are conducted to develop autonomous concepts and capabilities towards readiness for use with operational units.

Thus, Patrick Blackett is a busy ship, testing – amongst other things – new autonomous concepts, new autonomous kit, and new autonomy-shaped crewing models.

▲ **Blending crewed and uncrewed capabilities into a mutually enabling and supportive operational construct is the core RN principle in harnessing autonomous capability. [Crown copyright 2024]**

Achieving firsts

Being both a relatively new ship and a new type of ship concept for the RN, the nature of its job means *Patrick Blackett* is often achieving 'firsts' for and with the navy.

For example, in November 2024 the ship was used as the 'host' platform for a trial with a USV, in which the USV was remote controlled by *Patrick Blackett*. In the trials – which took place off Portsmouth, UK where busy waterways are criss-crossed by naval vessels plus ferries and other commercial traffic – *Patrick Blackett* supported both remote and autonomous piloting of the Autonomous Pacific 24 ('APAC24') rigid-hull inflatable craft, the RN said in a statement. The 'APAC24' seaboat is used by the RN to conduct tasks like maritime interdiction, search and rescue, and ship-to-shore transfers.

In the remote testing, an operator onboard *Patrick Blackett* controlled the USV via a console; the autonomous tests saw the USV follow a pre-programmed route and conduct pre-programmed manoeuvres. The RN noted this was the first time such tests had been conducted in UK waters, with the 'APAC24' seaboat having been tested autonomously previously at 'REPMUS' in 2024. Off Portsmouth, with a range of trials conducted by NavyX – the RN team responsible for driving innovation and experimentation to quickly deliver enhanced and novel capability to the frontline – cameras and other sensors onboard the 'APAC24' USV were used to gather data, including live video footage, which was fed back to *Patrick Blackett* for analysis.

In the RN statement, Commander Michael Hutchinson – *Patrick Blackett*'s commanding officer, and NavyX experimentation team leader – said "Integrating crewed and uncrewed systems

▼ ***Patrick Blackett* is pictured with 'APAC24' off Tróia, southern Portugal for the 'REPMUS 24' operational experimentation activity. The ship supported the USV in conducting a remote ISR mission. [Crown copyright/UK MoD, 2024]**

and operating them at the same time is a huge step forward for the RN .... The trials and experiments we do will develop the standard operating procedures (SOPs) for 'APAC' and how to use uncrewed systems effectively for warfighting." Such work, he added, "forms the backbone for further integration that future ships will have with autonomous technology".
For example, the RN statement noted, adding an uncrewed aerial vehicle (UAV) to deploy from *Patrick Blackett* would enable the ship to extend the range at which it could control the USV.

"[*Patrick Blackett*] is a trials and evaluation ship that can develop operating manuals for technology and see what works, what doesn't, and how we get it ready for further use by the fleet," Cdr Hutchinson added. Such further use also relates to improving wider understanding of the fact that the RN is now operating such uncrewed capabilities. Cdr Hutchinson explained that operating uncrewed systems more regularly around the UK will help show that such systems are being operated, and safely.

Patrick Blackett is helping the RN understand autonomous system use from several perspectives. First, how to operate uncrewed systems safely in a modern, congested maritime environment. Second, how to operate them in an integrated manner with crewed platforms. Third, how to understand and enhance their contribution to naval operations including combat-related activities. *Patrick Blackett*'s testing work is allowing the RN to understand, develop, and operationalise the tactics, techniques, and procedures (TTPs) designed to enable autonomous systems to contribute most effectively in these contexts. These three points all come together to illustrate how the RN, as with many navies, sees uncrewed platforms currently as working in an enabling, supporting capacity for crewed platforms, for example to allow the crewed platforms to focus on the tasks where an operator-in-the-loop is needed; and/or to enhance the output of those crewed platforms by providing supporting capability through 'dull' tasks such as sustained sensing input, as well as more 'dirty' and 'dangerous' activities.

Unveiling new capability

The RN formally unveiled *Patrick Blackett* in July 2022.
A Damen 4008 Fast Crew Supply commercial vessel acquired and adapted over the previous 12 months, the 42 m, 270 tonne vessel – given the RN designator X01 – was procured to provide a dedicated and available trials and experimentation platform for developing autonomy and autonomous systems for RN operations. According to the RN, *Patrick Blackett* is designed to be an autonomy, lethality, and innovation accelerator for the navy. The ship brings greater flexibility in experimentation capability for new technologies, and capacity to generate accelerated delivery of new concepts, technologies, and capabilities to the frontline through enhanced and dedicated testing. The ship is also intended to show how autonomy and autonomous capabilities can shape the RN's 'navy after next' thinking, which is looking ahead to how maritime uncrewed systems (MUS) can support the navy's current generation of crewed platforms out to 2050 (even integrating within set-ups like an RN carrier strike group), and then perhaps to provide alternative platform options beyond 2050. Underlining the perhaps unconventional role the ship plays for the navy, its crucial capabilities are perhaps not so much its systems as its open nature, in terms of both space and architecture. Its 140 m2 working deck, located aft, can accommodate four standard 20 ft ISO shipping containers, embarked using a two-tonne crane. This capacity underlines how the platform can support testing of modular capabilities, utilising for example the navy's Persistent Operational Deployment containers (PODs), which are used to carry a range of autonomous and supporting capabilities and can be integrated with the ship using a 'plug-and-play' approach. With the vessel's flexible design, physical space, and adaptable C2 architecture allowing both hardware and software to be onboarded as required, this set up enables the conduct of testing both in the ship and from the ship.

The platform is also used for testing of more conventional capability. For example, as announced in May 2023, Saab's Sea Giraffe 1X surveillance radar – 11 of which have been procured by the UK Ministry of Defence, according to Navy Lookout – was embarked for trials.

REPMUS reputation

Patrick Blackett deployed outside UK waters for the first time in September 2023, to participate in 'REMPUS'. It has participated in the exercise in both 2023 and 2024.

Over these two 'REPMUS' exercises, the ship has established a reputation as playing an integral role in testing and capability development in what is one of NATO's primary MUS OPEX activities. This is underlined by the fact that, for the 2024 iteration of 'REPMUS', the ship was forward deployed to Tróia in advance to support exercise planning and serial development to help optimise the outcome of the MUS testing and the ship's role therein. *Patrick Blackett*'s design flexibility, open-architecture C2, and working deck capacity allows it to contribute to MUS testing in all domains – UAVs, USVs, and UUVs (uncrewed underwater vehicles).

For the RN, *Patrick Blackett*'s work at 'REPMUS' plays a key role in building the navy's understanding of the contribution of MUS to frontline operations. At the OPEX activity, the ship and NavyX personnel work very closely with the Portuguese Navy's two primary MUS technology innovation, capability, and operational development cells, both of which are based in Tróia: the Centre for Naval Operational Experimentation (Centro de Experimentação Operacional da Marinha: CEOM); and the Operational Experimentation Cell for Uncrewed Vehicles (Célula de Experimentação Operacional de Veículos Não Tripulados: CEOV).

In 'REPMUS 23', the ship integrated into live operations using various autonomous systems, including tasking different MUS to investigate, identify, and track threats, especially in the underwater domain. In this latter context, it supported ASW work and participated in critical undersea infrastructure (CUI) security serials (working with a USV to deploy UUVs to search the seabed for CUI interference). Illustrating its adaptability for C2 integration, the ship embarked mesh

networks and SATCOM systems, and plugged into the navy's Naval Strike Network (NSN) C2 architecture.

'REPMUS 24' demonstrated *Patrick Blackett*'s wider-still development and integration of its capabilities. With the OPEX activities focused in particular on above water warfare, especially anti-air and anti-surface warfare (AAW, ASuW) serials, the ship worked with several different UAVs and USVs, and was used as a launching platform for different MUS systems.

As regards working with UAVs, it operated with a Schiebel S-100 Camcopter, and was used as a target for a simulated aerial attacks by a Rotron Talon DT-300 drone.

As regards USV serials, *Patrick Blackett* operated the 'APAC24' remotely in an 'end-to-end' mission, with the USV deploying in 'remote' mode from harbour to conduct an intelligence, surveillance, and reconnaissance (ISR) task before returning 'remotely'.

Lean machine

Patrick Blackett's role in helping the RN bridge any gap, or build any links, between crewed and uncrewed platforms by developing concepts of operations (CONOPS) for integrating autonomy and autonomous platforms is underlined by the fact that the ship has a core crew numbering just five personnel (all drawn from the NaxyX team). There are spare bunks onboard for an additional seven people.

As well as operating with a lean crew, *Patrick Blackett* also supports testing of lean crewing concepts. The RN has been looking at several different models for lean crewing, one reason for which is to provide crew constructs that can underpin platforms that are moving to greater degrees of autonomy onboard and will use more autonomous systems offboard to generate effects (thus in principle needing less people).

▲ **Off Tróia at 'REPMUS 24', *Patrick Blackett* works with uncrewed surface vessels. The ship's capacity to work with various capabilities is enabled by its spacious aft working deck. [Crown copyright 2024]**

'REPMUS 24' demonstrated another 'first', with the RN's StrikeNet (formerly NSN) C2 network installed onboard *Patrick Blackett* for the first time, with the ship providing an open architecture operating construct and an open computing environment (OCE) – which enables 'plug-and-play' shared infrastructure hosting – in which the StrikeNet architecture could be trialled and tested. Regular software updates for the system were uploaded, and regular communication was maintained with the RN StrikeNet team via SATCOM connectivity.

RN activities at 'REPMUS 24' also included working with MUS systems in other contexts. For example, under the Australia/UK/US (AUKUS) strategic partnership construct's 'Maritime Big Play' MUS programme, personnel from all three navies were deployed to a command node in Tróia to operate MUS systems in waters close-in to Tróia itself and at distance off Australia.

Underlining the ship's role in developing autonomous platforms for safe routine, daily function at sea, Patrick Blackett has supported various RN future navigation system and capability trials. For example, in May 2023, the ship embarked for trials a quantum sensing system – a technology that can support development of improved inertial navigation, through bringing improved accuracy over a longer time period.

For a ship that is testing autonomous platform and capability concepts, harnessing data from the platform and its systems is very important for feeding back information to the RN. To support this requirement, the ship is fitted with a remote monitoring and data collection system; in parallel, NavyX can draw on a 'digital twin' shore-based electronic model of *Patrick Blackett* that provides a predictive data analytical tool.

Forging tomorrow's soft-kill shield

Richard Scott

Electronic countermeasures (ECM) to defend warships against guided weapon attacks are not a new development. Rudimentary jamming devices were fitted to Royal Navy and US Navy ships as far back as 1943 to disrupt the communications link used in German Hs 293 and Fritz-X radio-controlled bombs. Subsequently, off-board expendable decoys, typified by radio frequency (RF) chaff, have been widely fitted since the 1960s to confuse targeting, distract active radar seekers in the search phase, and seduce seekers in the terminal homing stage.

▲ A Mk 245 IR seduction round being fired from a RN Type 23 frigate. The Mk 245 deploys a series of sub-munitions in a 'walk-off' pattern. [Crown Copyright]

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However, there is a recognition that the anti-surface threat has evolved substantially in recent decades. Anti-ship guided weapon systems have become more diverse, more adaptable and more intelligent in their use of the electromagnetic spectrum to find, fix, track, target and engage. Warning times have been slashed as missiles have become either faster or more stealthy. And adversaries have become more adept in their planning and tactics; for example, combining and coordinating different weapon types to generate complex multi-threat, multi-axis attacks.

Moreover, characterisation of the threat increasingly blurs the boundaries of 'conventional,' 'hybrid' and 'asymmetric'. Proliferation of anti-ship cruise missiles and anti-ship ballistic missiles to proxies and non-state actors has become a reality, latterly evidenced by the Houthi attacks on shipping transiting through the Red Sea. Cheap and abundant one-way attack drones may further complicate the threat calculous.

Assuring an acceptable level of maritime platform survivability in the face of this increasingly stressing threat presents new challenges for ship defences. Inherent constraints within a platform – such as the replenishment limitation of hard-kill anti-air missiles and numbers of vertical launch silos – quickly compromise a maritime platform's ability to function in a contested environment. This situation has forced operational practitioners, the defence scientific community and industry alike, to think afresh about the contribution that soft-kill devices – and specifically off-board countermeasures – can make as part of a balanced ship self-protection suite. In particular, there is an understanding that soft-kill has a vital role in redressing the unfavourable cost exchange advantage currently enjoyed by adversaries, and adding 'magazine depth' both to augment and complement hard-kill effectors.

This renewed interest in soft-kill anti-ship missile defence (ASMD) is reflected in a number of identifiable strands of science, research and technology development: the development of advanced countermeasure payloads to overcome increasingly

▲ The Mk 234 Nulka is a joint Australian/US development combining a hovering rocket flight vehicle (produced by BAE Systems Australia) and a US-manufactured EW payload. [US Navy]

sophisticated counter-countermeasure techniques; the proliferation of a new generation of trainable decoy launcher systems able to place countermeasures payloads with improved accuracy in time and space; moves to field a new generation of persistent countermeasures hosted on long endurance carrier vehicles; and the development of advanced software-driven electronic warfare command and control (EWC2) functionality to plan and coordinate the soft-kill response, and synchronise with other defensive responses.

Payload evolution

Chaff has been the mainstay of soft-kill ASMD over half a century, reflecting the preponderance of RF-guided anti-ship threats deployed worldwide. Effectiveness has been enhanced over time thanks to engineering improvements such as variable range and height of burst, optimised payload placement patterns, and faster bloom time. Infrared (IR) decoys designed to seduce IR threat seekers are also a standard feature of most soft-kill decoy systems. Modern naval IR decoys typically deploy a series of individual payloads/or sub-munitions at variable ranges to 'walk off' the seeker of the threat missile. Dual-mode RF/IR seduction countermeasures are designed to present a combined a multispectral response. These rounds – dispensing co-located chaff and IR payloads – address the need to provide signature-matched protection for low-radar cross section (RCS) ships, and offer a capability to counter dual-mode seeker threats.

From a payload perspective, the biggest change in the market is a recognition that the efficacy of chaff is being eroded by the proliferation of missiles using advanced active radar seekers embodying sophisticated electronic counter-countermeasures (ECCM) techniques. There are also threats emerging in portions of the electromagnetic spectrum outside of the conventional chaff bands, most notably millimetric wave (mmW) radar seekers operating in the 35 GHz region (Ka-Band).

Given these concerns, interest has grown in the use of corner reflector payloads as an alternative to chaff. The employment of this technology is by no means new; floating corner reflectors have been used by the British Royal Navy (RN) and a handful of other navies since the 1980s. However, recent years have seen a number of decoy manufacturers package smaller, slow-descent airborne corner reflectors into standard countermeasure cartridges. Advocates of this technology argue that corner reflectors afford several advantages over chaff including: a consistent response irrespective of the threat bearing or azimuth; no need for prior threat knowledge; insensitivity to the polarisation of the RF seeker; a radar return that is more representative of a ship target in terms of scintillation, glint, polarisation, spectral density fluctuations, and range/azimuth error signals; resistance to the chaff discrimination logic employed by modern RF seekers; and multi-band performance extending into the Ka-Band.

▼ Lacroix Defense of France has developed a pyrotechnically-activated a 'pop-up' corner reflector structure that expands instantaneously so as to minimise the time between the firing command and the delivery of a high RCS decoy effect. [Lacroix Defense]

One example is the WIZARD countermeasure developed by Israel's Rafael Advanced Defense Systems. This deploys a broadband payload comprising a pair of fast-inflating corner reflectors. Lacroix Defense in France has also embraced corner reflectors, albeit taking a different technical approach. Rather than an inflatable decoy, Lacroix's SEALEM round deploys a pyrotechnically-activated 'pop-up' structure that expands instantaneously so as to minimise the time between the firing command and the delivery of a high RCS decoy effect. According to the company, the use of a pop-up mechanism provides for a very stiff and stable structure with a very precise geometry, thus creating a more credible RF return.

Another approach, more complex in its execution and effect, is to deploy an active off-board decoy – a mini-jammer – to achieve angular seduction. This type of countermeasure, which marries an electronic warfare payload from a cartridge or using a carrier vehicle, seeks to 'capture' the threat missile seeker and then generate a jamming waveform to pull it off the intended target. Active off-board decoys are, round-for-round, far more expensive than chaff or corner reflectors. However, they bring a number of advantages: only one decoy expended per engagement; no requirement for evasive manoeuvres; and a capability to defeat the most sophisticated ECCM logic.

▲ Rafael's C-GEM decoy being fired from a Saar 6 corvette during trials. [Rafael]

The best known example of an active off-board decoy is the Mk 234 Nulka round. A joint Australian/US development, Nulka combines a hovering rocket flight vehicle (produced by BAE Systems Australia) with a US-manufactured EW payload. The original Nulka electronic decoy cartridge mounted a broadband RF repeater payload produced by Lockheed Martin. To counter more advanced threat seekers, a so-called Advanced Decoy Architecture Program (ADAP) has been pursued as a rapid development effort to meet both US Navy and Royal Australian Navy needs. L3Harris is responsible for delivering ADAP payloads – using an advanced transmitter and improved signal processing – to target specific threats outside the performance scope of the existing Nulka payload.

Rafael Advanced Defense Systems has taken a different route with its C-GEM active off-board decoy. Packaged in a 115 mm cartridge, the rocket-powered C-GEM is fired to its intended range/bearing before deploying a Digital Radio Frequency Memory (DRFM) EW payload beneath a parawing. C-GEM has recently entered Israeli Navy service on the new Saar 6 corvettes.

Trainable launch

It goes without saying that any decoy must replicate the signature characteristics of the actual target so as to present a credible alternative to the threat seeker. However, the efficacy of any soft-kill response also depends on the deployment of the decoy(s) to the right position in time and space such that it is located inside the seeker range and angle 'gates'. Any target – or decoy – outside of this volume will be ignored or rejected. This is particularly important for countermeasures being deployed for distraction (when the seeker is in the search phase) or seduction (when the seeker will have framed its tracking gates around the target).

Many legacy decoy systems have used fixed launchers with barrel sets angled at pre-set bearings and elevations. While fixed launchers are simple, reliable, easy to maintain, and occupy a small deck footprint, they suffer from a number of limitations.

- First, they are inherently constrained in terms of the accuracy of decoy placement because they lack any form of stabilisation or positional capability.
- Second, they demand careful selection of the launcher 'barrel of choice'.
- Third they cannot fully exploit the performance of more advanced multi-part decoy rounds.
- Fourth, they require the defended ship to perform carefully coordinated manoeuvres as part of the countermeasure ploy.

Accordingly, more and more navies are investing in fully stabilised and trainable decoy launch systems. While these equipments are larger, heavier and more complex than fixed launch systems, their ability to traverse and elevate with precision affords far greater accuracy in the delivery of decoy payloads/patterns, enables the optimised deployment of advanced RF and IR countermeasures programmable in height and range, and minimises/obviates the need for ship manoeuvre.

Elbit Systems in Israel was amongst the first companies to introduce a trainable decoy launcher in the shape of its Deseaver system. Originally designed in the early 1990s to meet the needs of the Israeli Navy, variants of Deseaver are currently fitted to the Israel Navy's Saar 4.5 strike craft, Saar 5 corvettes and, in the case of the latest Deseaver Mk 4, the new Saar 6 corvettes. All variants in Israeli service are engineered to fire standard 115 mm decoy rockets supplied by Rafael.

Rheinmetall's Multi-Ammunition Softkill System (MASS) is another example. Conceived in the early 1990s, MASS uses a

▲ SEA's Ancilia trainable decoy launcher has been selected to meet the RN's EWCM Increment 1a requirement. [SEA]

lightweight trainable launcher to fire 81mm OmniTrap multispectral decoys so as to provide a capability to counter RF, IR and electro-optical seekers. MASS has established itself as a market leader, with over 240 launchers sold to 16 customers, Each MASS launcher can host up to 32 OmniTrap munitions: the system solution offers 'five degrees of freedom' with regard to bearing, range, altitude, number of decoys, and firing interval between decoys.

French company Safran is another exponent of trainable launchers. Its NGDS (New Generation Dagaie System) – developed as the successor to the widely sold Dagaie and Dagaie Mk 2 decoy systems – uses a twin-axis launcher trainable in elevation and azimuth to enable accurate decoy placement to counter specific threat types. To meet the specific needs of the French Navy, countermeasures supplier Lacroix Defense developed a new generation of NGDS-compatible SEALEM and SEALIR 150 mm decoy rockets (respectively deploying advanced RF and IR payloads). NGDS has been installed on the French Navy's 'Horizon' anti-air warfare frigates and *Aquitaine* class multi-mission frigates. It has been exported to the navies of Morocco, Egypt and Singapore.

The major change impacting the trainable decoy launcher market in recent years is the introduction of systems compatible with NATO standard 130mm rounds. Prior to this, users of 130 mm decoy cartridges were restricted to using fixed barrel launchers such as the US Navy's Mk 137 (part of the Mk 36 Decoy Launch System). Both Safran (NGDS Configuration D) and Elbit (Deseaver Mk 4) have now introduced variants of their existing launchers adapted for 130 mm decoys.

Meanwhile, United Kingdom company SEA has introduced a brand new 12-round launcher system, known as Ancilia, to the market. Procured to meet the RN's Electronic Warfare Countermeasures Increment 1a requirement, the Ancilia system combines a trainable launcher (using twin six-barrel 'cassettes' mounted on a training/elevating platform developed by Chess Dynamics) with inboard launch control electronics developed by SEA as part of a technology refresh for the RN's legacy Outfit DLH fixed launcher. SEA has recently teamed with Denmark's Terma to integrate Ancilia as part of an improved Mk II variant of Terma's widely sold C-Guard 130 mm soft-kill countermeasures system.

Persistent effects

As the ASMD threat evolves – with warning times reduced and an increased threat from multi-axis salvo attacks – navies are becoming acutely aware of two major drawbacks associated with 'traditional' shipborne decoy systems. One is that they are reactive in operation, which means that there is an inevitable delay between receipt of warning, system initiation and payload deployment/effect. The other is that expendable decoys have a short duration of effect; from several tens of seconds to a few minutes.

In response to this changing threat dynamic, several naval forces have funded science, technology and experimentation activity to explore the technical feasibility and operational practicality of persistent off-board soft-kill marrying an EW payload with a long-endurance carrier vehicle. While one solution is to use a crewed helicopter as the host for an active ECM payload, the greatest potential over the longer term is by means of autonomous uncrewed systems either flying or sailing in consort with a ship or task group.

The US Naval Research Laboratory (NRL), under the sponsorship of the Office of Naval Research (ONR), has been pursuing technology demonstration for several years. One example is the Netted Off-board Miniature Active Decoy (NOMAD) low-cost rotary-wing mini-UAV developed by the NRL as a part of ONR's NEMESIS (Netted Emulation of Multi-Element Signatures Against Integrated Sensors) Innovative Naval Prototype programme. Capable of deployment as either as a single unit,

▼ NRL's NOMAD rotary-wing mini-UAV, developed as part of ONR's NEMESIS Innovative Naval Prototype programme, was successfully tested at sea in 2017. [US Navy]

or in a coordinated 'nest' of multiple decoys, the 'soft-launch' NOMAD vehicle is effected from a tube launcher and then deploys flip-out counter-rotating coaxial rotors located at either end of a longitudinally-extending body.

US Navy ambitions in this area are currently being taken forward under the Long Endurance Electronic Decoy (LEED) programme, which is itself drawing on technologies developed and matured under the ONR's Long Endurance Airborne Platform project. Integrating with the shipboard AN/SLQ-32(V)6 and V(7) systems, LEED is intended to provide the fleet with enhanced EW coordination and capability, including the ability to stretch engagement timelines and counter heterogeneous missile attacks. Lockheed Martin is prime contractor for the LEED development effort. Production representative units are planned to complete at-sea capability assessments towards the end of the decade.

▲ **Rafael Advanced Defense Systems has advertised development of an EW variant of its Protector USV system. [Rafael]**

Unmanned surface vehicles (USVs) are also being evaluated as potential EW payload carriers. Canada's Naval Electronic Attack Recapitalization-Unmanned (NEAR-U) project, being led by Rheinmetall Canada, has pursued the implementation and test of a Naval Off-Board anti-Missile Active Decoy that integrated an Elbit DRFM-based EW payload with a QinetiQ Humpback USV. The latter is a variant of QinetiQ's existing Hammerhead unmanned surface target vehicle modified for specific payload applications. Meanwhile, Rafael Advanced Defense Systems has advertised development of a dedicated EW variant of its Protector USV system able to contribute to both ASMD and area defence. The payload for this solution would exploit technology from the company's C-Pearl-DV digital electronic support measures and Digital Shark EA systems to create a lightweight, compact EW module suitable for unmanned operation.

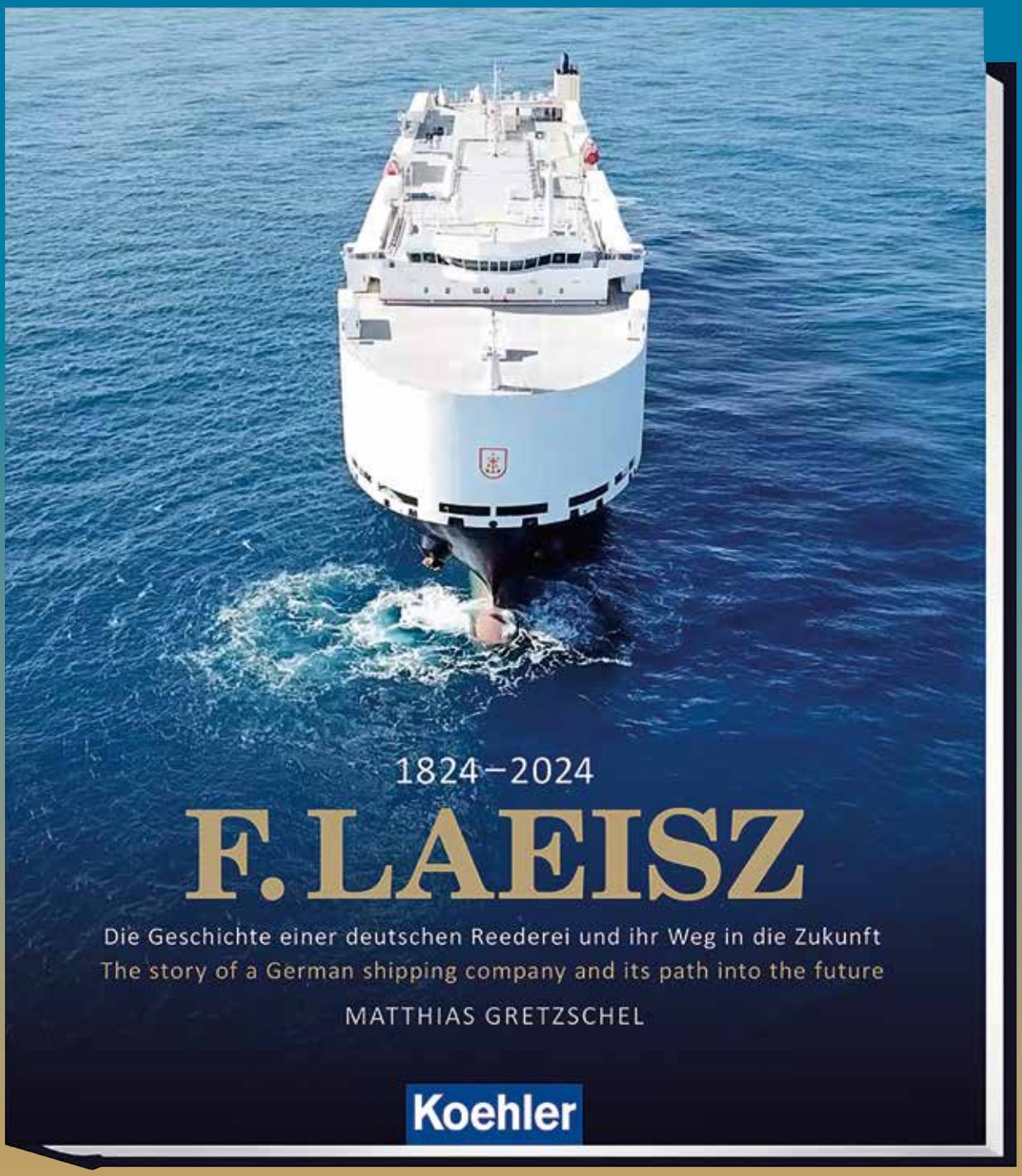
Electronic warfare command and control

The final piece of the soft-kill jigsaw – and arguably the most important – is electronic warfare command and control (EWC2). EWC2 encompasses the planning, management and employment of EW resources – including de-conflicting or synergising hard-kill and soft-kill responses – to maximise ship or force survivability. Historically a so-called 'mandraulic' activity reliant on well-drilled responses from EW operators and the wider command team, the pace of the modern warfare environment increasingly demands that EWC2 is automated, with tactics and doctrine encoded in software to improve response time, alleviate operator cognitive load, and optimise the use of resources.

At the single ship level, EWC2 can function in a manner akin to the threat evaluation and weapon allocation (TEWA) functionality resident in hard-kill systems. This TEWA process will then drive a recommended decoy firing solution/countermeasure type based on the multiple variables pertaining to a specific threat scenario (including, but are not limited to, threat angle of approach, threat speed, threat seeker parameters/characteristics, own ship course and speed, and wind speed and direction). Force level EWC2 looks at the survivability of the broader task group, recognising that not all units will be fitted with decoys or even sensors. This may require a ship to deploy a decoy to protect a ship in consort.

One example of EWC2 is the Soft Kill Coordination System (SKCS) being introduced to US Navy DDG-51 guided missile destroyers as part of the SEWIP Block 2 upgrade. Designed to improve decoy effector coordination and enhanced situational awareness in support of soft-kill engagement decisions, the SKCS is an 'in-house' navy development involving the Naval Surface Warfare Center Dahlgren Division and Johns Hopkins University Applied Physics Laboratory.

Meanwhile, an EWC2 function is a key part of the Maritime Electronic Warfare Systems Integrated Capability (MEWSIC) Increment 1 system being delivered to the RN by a team of Babcock International and Elbit Systems UK. The ship-level EWC2 functionality in MEWSIC Increment 1 will automate EW engagement planning with users 'on the loop', embed tactics for multi-threat engagements, and include the ability to take indicators and warnings from any organic or non-organic source. Its open architecture has been designed to accommodate expansion through-life, including future force-level EWC2.



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Credible capability: Spain's future frigate delivers multi-domain, multi-mission deterrence and defence

Dr Lee Willett

In December 2024, a first live tracking of an airborne object was achieved for Lockheed Martin's AN/SPY-7(V)2 solid-state, fixed-face, S-band (NATO E/F-band) radar, being developed as part of the Spanish Navy's F-110 frigate programme. The testing – conducted at the US company's Moorestown, New Jersey facility – used a single-face variant, instantiated in an engineering development model (EDM) of the system. SPY-7 is a core capability for the navy's future frigate, which is in turn central to Spain's future naval force structure. The F-110 will bring multi-role capabilities to bolster deterrence and defence against the multitude of threats NATO navies face today, with Russian activity across the Euro-Atlantic theatre demonstrating the requirement in response for significant multi-domain anti-air (AAW), anti-submarine (ASW), and anti-surface warfare (ASuW) capabilities.

In a January 2025 statement, Lockheed Martin and Spanish national shipbuilder Navantia said the successful December test marked a milestone in the radar's software and hardware development and in the ship's capability progression. The statement added that Lockheed Martin's formal delivery of the radar to Navantia and to the first ship is scheduled for 2026, as a key step in the frigate programme's combat system 'light off'.

In April 2019, Spain's Ministry of Defence (MoD) awarded Navantia a EUR 4.32 billion (USD 4.69 billion) contract to build five *Bonifaz* class F-110 frigates, under the PROTEC 110 (Programas Tecnologicos F-110) programme. Replacing the in-service F-80 *Santa María* class frigates, operating alongside the F-100 *Álvaro de Bazán* class frigates, and providing integrated support for the navy's wider surface fleet, the F-110s will provide multi-mission capability supporting multi-domain operations.

▲ A single-face EDM variant of Lockheed Martin's AN/SPY-7(V)2 four fixed-face, S-band radar was used for a first live tracking of an airborne object by the system, in a December 2024 test at Lockheed Martin's ASIC facility (Moorestown, New Jersey). The radar is a core F-110 capability. [Lockheed Martin]

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The Aegis-integrated radar will provide state-of-the-art AAW capability, a requirement underscored by the impact of 'precise mass' in conventional strike operations conducted in the Russo-Ukraine war. Increasing Russian underwater activity across the maritime domain and across the spectrum of operations (from nuclear-powered submarine deployments to possible campaigns against seabed critical underwater infrastructure [CUI]) underscores the requirement for high-end ASW capability. Fitting the frigates with the anti-ship/land-attack capable Kongsberg Naval Strike Missile (NSM) meets the contemporary naval operational requirement for projecting power at and from the sea.

If push comes to shove

In the context of Russia's strategic push into Ukraine, in the maritime domain NATO's destroyer and frigate force has been required to provide visible, credible presence and defence capability theatre-wide, to deter any risk of strategic push coming to operational shove up against NATO countries and forces in conflict spillover into other regions.

A high-end, multi-purpose, multi-domain frigate like the F-110 is the perfect fit for providing such deterrence and defence output.

Even before the Russo-Ukraine war, Spain's national security thinking had been underlining core security requirements relevant to the navy's escort ships. The 2021 National Security Strategy stressed that protecting the high seas and maritime routes was integral to European security; that melting Arctic ice would open new, strategically important trans-Polar maritime routes that would need to be secured; that maritime disputes in various places around the world would threaten regional security; and that maintaining maritime security was essential to Spain as a maritime country.

These challenges have been underscored since the war broke out. For example, as shown by the threat to commercial and naval shipping from drifting mines or maritime uncrewed systems in the Black Sea, and by CUI attacks in the Baltic, sea lines of communication (SLOCs) are now contested. The Northern Sea Route connecting East and West across the Arctic could be a new 'strategic' SLOC; used mostly by Russia and China, its emergence still mandates increased NATO naval presence in High North waters. SLOCs are also impacted in places like the Eastern Mediterranean, where NATO and Russian ships and submarines now gather in numbers to maintain presence and influence in the wider region following Türkiye's closing of the Bosporus/Dardanelles straits to non-Black Sea resident naval ships.

Other impacts from the war illustrate the importance of the F-110's capabilities. For example, the 'precise mass' employed offensively by both protagonists – with traditional conventional combat focus on using weapons in large numbers now enhanced with high-end precision strike technology – demonstrates that, in areas like AAW or ASuW, defensive mass in platforms and missiles is required. This may explain why Spain is considering adding two more ships – both set to be specialist AAW platforms – to its F-110 inventory.

Indeed, perhaps given the 'precise mass' of conventional weaponry being used in the war (including ballistic and cruise missiles, hypersonic weapons, and air-based uncrewed systems), NATO has called for member states to generate increased AAW quantity and quality.

▲ **An artist's rendering of the Spanish Navy's new F-110 frigate. Two ships are in build of a currently planned five-ship class that could number up to seven vessels. [Navantia]**

▶ **The Spanish Navy F-100 frigate ESPS *Almirante Juan De Borbon* is pictured sailing from Norway while leading a NATO SNMG1 deployment in 2024. Spain's high-end, multi-purpose, multi-domain frigate family, including the F-100 and F-110, provide essential deterrence and defence output at sea for NATO. [Dr Lee Willett]**

Despite the F-110's original conception primarily as an ASW platform, the AAW capability onboard, the prospective addition of further AAW-focused hulls, and the ASuW presence delivered by NSM indicate that – perhaps reflecting the broadening nature of the Russian threat since 2022 – the ships will bring a balanced, multi-mission, full-spectrum, and multi-domain operational approach to countering the challenges in the evolving naval warfare environment.

The Spanish Navy's current contribution to NATO operations underlines the full-spectrum and multi-domain role of its surface fleet, to be continued with the F-110. For example, between January and July 2024, the navy commanded Standing NATO Maritime Group 1 (SNMG1) – NATO Allied Maritime Command's North Atlantic-focused, destroyer/frigate-based, standing naval force – with the F-100 frigate ESPS ***Almirante Juan De Borbon*** as flagship. SNMG1 roamed widely from the Eastern Atlantic to the Arctic, and into the North and Baltic seas, with tasking including AAW and ASW. During that same period, the navy sent its own flagship, the amphibious assault ship ESPS ***Juan Carlos I***, to the Striking and Support Forces NATO (SFN) integrated multi-carrier operational activity 'Neptune Strike'. Deploying a large 'flat top' on operations in regions like the Eastern Mediterranean – where 'Neptune Strike' activities often occur – mandates high-end AAW, ASW, and ASuW task group support to counter the Russian presence.

Building capability

"The F-110 frigate is designed to operate in high-, medium-, and low-intensity scenarios, with significant combat capability in all major warfare areas. The required capabilities include addressing an increasingly complex conventional and asymmetric threat," Rafael Seijo, Navantia's F-110 programme manager, told MDM in a late March written interview.

According to Navantia, "The F-110 frigates ... are multi-purpose escort ships, with anti-aircraft, anti-surface, and anti-submarine capabilities to perform force protection and naval power projection duties. They will operate in combination with other units .... They are versatile platforms that can also perform functions related to maritime security and support to civilian authorities."

Moreover, the programme is adding capability for Spain in industry, technology, sovereignty, and economy terms. "The F-110 will represent a qualitative leap from the point of view of the navy's capabilities and the industrial and technological potential of Navantia and its collaborating industry," the company said. "It thus contributes to Spain's strategic autonomy and cutting-edge industrial and technological base, while at the same time opening new export opportunities."

The process of delivering Spain's new frigate is well underway, with two F-110s in build, work on the third set to start in 2025, and the procurement and build programme being on schedule.

"The F-110 programme is progressing without any slips in the scheduled dates," said Seijo. "The programme has successfully achieved all key engineering milestones."

The schedule is one ship a year launched, and one ship a year commissioned. Construction of first-in-class ship Bonifaz has been underway at Navantia's Ferrol shipyard, northern Spain since April 2022, with keel laying occurring in August 2023. Seijo confirmed the ship is set to be launched in 2025 and delivered in 2028; in between, platform trials are set for 2026, and sea trials and combat system 'light off' for 2027.

"The corresponding milestones of each of the remaining vessels ... is approximately one year later than those of each previous unit," said Siejo.

To help accelerate the programme, Navantia has opened a second slipway at Ferrol to enable simultaneous build of two ships.

Lead F-110 frigate *Bonifaz* is pictured in build on Ferrol's slipway, in early 2025. Navantia has added a second slipway at the yard to support simultaneous build of two ships. [Navantia]

Alongside construction, system integration testing has been accelerating. Several developments are worth highlighting.

First, in January 2023, combat management system (CMS) integration began with the first test of Navantia's SCOMBA (Sistema de Combate de los Buques de la Armada) CMS system with Lockheed Martin's International Aegis Fire Control Loop (IAFCL) construct. This testing set-up was established at Lockheed Martin's Aegis/SCOMBA Integration Center (ASIC) facility at Moorestown. By June 2023, a common operating picture was being shared between the two systems. While the Spanish Navy is a long-established Aegis operator, the F-110 programme represents the first time the navy has integrated Aegis with its indigenous SCOMBA CMS.

Second, several steps have been taken in developing the SPY-7(V)2 radar as the ship's primary AAW sensor. In May 2024, the critical design review (CDR) was completed. CDR work included full assessment of the design, integration and testing processes, and system readiness for production. CDR completion enabled the system to move into full-rate production, along with development of the land-based SPY-7 radar test site (again, using a single-face version) at the navy's Centro de Integracion de Sistemas en Tierra (CIST) facility, Rota Naval Base, Cadiz, southern Spain. Next came the successful December tracking test. This testing was enabled by installing the SPY-7 EDM version at the Moorestown ASIC facility; this facility supports land-based testing of the CMS and wider combat system end-to-end capability, including demonstrating missile track engagement and exchange.

In a combined Lockheed Martin/Navantia media briefing in January, held following the SPY-7 test, Mike Koch – Lockheed Martin's European mission systems programme manager – said that alongside the EDM integration work to achieve the first track, Navantia Sistemas and Lockheed Martin engineers were working on SCOMBA integration into the IAFCL testing structure at Moorestown as the first steps in preparing to demonstrate full, end-to-end combat system and radar integration that will see live SPY-7 tracks displayed on SCOMBA screens. The aim is to complete this integration in mid-2025; Koch told MDM that "significant progress" is being made and that "We remain on schedule to complete the integration over the coming months."

Cristina Abad – Director of Navantia Sistemas – told the briefing: "Later in 2026, once a single face of the SPY-7 radar has been completely installed at CIST, both teams will have the opportunity to perform integration and testing for the radar in a coastal maritime environment, which will allow for a solid and consistent integration of the Aegis and SCOMBA systems before moving on to the ship."

Integration of a full, four-face SPY-7(V)2 radar into Bonifaz is scheduled for 2027.

The SPY-7 capability is crucial for both air and missile defence, said Seijo. Integrated air and missile defence (IAMD) capability, like that provided by the radar, an integrated mast, and the combined Aegis/SCOMBA CMS, will be crucial in the ship's capability for dealing with ballistic and cruise missile and uncrewed air system threats. These threats are proving to be a dominant factor in the Russo-Ukraine war.

In the F-110 programme's next phase, with ships heading to sea for testing and with others in build in parallel, Seijo said that one of the challenges the programme is tackling is recruiting and maintaining suitably qualified and experienced shipbuilding personnel.

Kit and capability

Seijo described the F-110 programme as an opportunity to introduce new technologies as a driver of transformation and technological innovation within Spanish defence industry. Here, he highlighted several significant technological advances in the frigate's design, like the integrated mast, a multi-mission bay, and the more efficient and quieter hybrid propulsion system.

The F-110 frigates are multi-purpose, multi-domain platforms designed for high-end force protection and power projection roles, plus constabulary duties like maritime security patrol. F-100 frigate *Almirante Juan De Borbon* is pictured here sailing past critical infrastructure off Stavanger, Norway in 2024. [Dr Lee Willett]

The F-110's multi-role, multi-domain concept is illustrated across the ships' capability fit.

The multi-role output is enabled by the space and weight provision in the 6,300-tonne, 145 m design. Such dimensions offer flexibility for the current planned capability, plus future capability growth margin.

In general maritime operational terms, F-110 range is 4,100 n miles at 15 kt; top speed is 26 kt. Propulsion is generated by a combined diesel-electric/gas (CODLAG) power infrastructure, built around four Navantia/MTU 20V 4000 M35B diesel engines and one GE LM2500 gas turbine. According to Navantia, the CODLAG arrangement – when operated in electric mode – reduces the ship's radiated noise profile, enhancing ASW capability.

In one of the latest testing and integration developments, in February 2025 Navantia announced completion (in November 2024) of barge shock qualification for the frigate's electrical and propulsion equipment. This process encompassed various onboard equipment including the diesel generator, electric propulsion motor, and main switchboard.

In specific naval operational terms, the frigate's sensor and weapons fit-outs are extensive.

Central to the sensing capability is, of course, SPY-7. The F-110s will be the first ships, globally, to carry the SPY-7(V)2 radar. As a multi-function radar, SPY-7 mirrors the ship's multi-function operational concept. According to Lockheed Martin, SPY-7 is the maritime version of the long-range discrimination radar (LRDR) technology underpinning the company's radar concepts.

Seijo said the Aegis/SPY-7 integration had been the major technical challenge in the programme to date, alongside the extensive shock qualification plan.

Surface search radar capability is provided by the Indra Prisma 25X fixed-face I/J-band radar.

sensing is based around two sonars. Mounted under the bow is a Thales BlueMaster/UMS 4110 low-frequency active/passive system. A Thales CAPTAS 4 Compact low-frequency active/passive variable-depth sonar (VDS) system provides the ships' 'tail'. Acoustic processing is conducted by the Thales BlueScan system.

The ship's radar and electronic warfare capabilities are fitted within the integrated sensor mast (Mastil Integrado). F-110 will be the first Spanish Navy ship type carrying an integrated mast. A full-scale mast prototype has been set up at CIST. Along with the radar, also incorporated into the mast are various other sensors, using flat-array technology and high digitisation to meet the demands of a technologically advanced vessel and to reduce the mast's radar cross-section, Seijo explained. These sensors include the electronic warfare suite, an Identification Friend or Foe (IFF) system, and the Indra/Tecnobit IRST i110 electro-optical/infra-red (EO/IR) detection and tracking system.

Other IR capabilities include the Navantia DORNA RE-O radar/TV/IR tracking system.

The F-110's enhanced sensor suite contributes significantly to different warfare areas by improving situational awareness, said Seijo.

Sensing capability is integrated into both the Aegis (Baseline 9C.2) and SCOMBA CMS systems. Navantia Sistemas is the CMS design agent.

Fire control capability is provided by a Navantia DORNA RE-O K-band system for the main gun, and a pair of Raytheon SPG-62 Mk 99 I/J-band illuminators for the other armaments.
The impact of these integrated capabilities is collective. "The combat system is highly capable of operating under saturation conditions in AAW, with multiple attacks and reduced reaction times," said Seijo.

With most combat system components defined and procured, only minor communications system elements remain. Seijo said there is provision for these in the ship's hardware and software design, but selection has been deferred to a later stage to minimise obsolescence.

Amongst ship effectors, perhaps most striking are eight, quad-packed NSM Block 1A missiles. NSM brings anti-ship and land-attack capability, with the 1A variant understood to add range.

Naval fires are also provided by a Leonardo 127 mm/LW64 Vulcano medium-calibre main gun. Additional surface fires are provided by two Escribano Sentinel 30 30 mm guns and four Escribano Sentinel 2.0 remote weapons stations (RWSs) carrying 12.7 mm machine guns. Seijo said the RWS set-up is designed to tackle asymmetric threats, including through incorporating significant tracking and precision improvements and harnessing the ship's EO search capability.

Air-defence effectors come in two different capabilities for two different contexts. Area including task group air defence is provided by the Raytheon Standard Missile-2 (SM-2) Block IIIA/B. Ship and local self-defence is provided by quad-packed Raytheon RIM-162 Evolved SeaSparrow Missiles (ESSMs). These surface-to-air missile (SAM) capabilities will be fitted in the ships' 16-cell (2 x 8) Lockheed Martin Mk41 vertical launching system (VLS).

Sub-surface defence, against both surface and underwater platforms, is provided by the Raytheon Mk54 torpedo, fired out of four (two pairs) of 324 mm launchers.

Anti-submarine sensing and prosecuting capability is provided by a medium helicopter, like the MH-60R Seahawk.

The ship's flexible spaces include a flight deck, hangar, and multi-mission bay. The 170 m2 mission bay can accommodate air, surface, and sub-surface uncrewed assets, up to four 20 ft ISO containers, rigid-hull inflatable boats, and task-specific mission modules. It can also act as a second hangar space.

"The multi-mission bay allows the ships to adopt a series of different profiles depending on the assigned mission," Seijo explained. "This space is where remotely piloted systems – whether aerial, surface, or underwater – can be embarked, providing the ship with significant improvement in ability to perform its assigned missions." It is a space, he continued, which "expands the ship's capabilities in all warfare segments".

Digitisation transformation

Central to the effective delivery of credible capability with F-110 is the integration of a digital approach to ship design and operation, within a wider transformation of Navantia's and the navy's overall digital approach to shipbuilding. "The integration of digital technology in F-110 represents a substantial advancement in the navy's capabilities, and showcases the industrial and technological potential of Navantia and its collaborating industry," said Seijo.

▲ **Blocks for F-110 ships are pictured being fitted out. Each ship consists of 33 blocks. Digital modelling is used both of individual blocks and the whole ship to improve understanding of build, assembly, and maintenance. [Navantia]**

Navantia has attributed the build work being ahead of schedule largely to design and engineering work maturity, the integrated relationship between industry and the navy, and using a 3-D digital model including of the final design for each of the 33 blocks used per ship.

The importance of digital modelling in the programme is also reflected in support for the ships' operational use and upkeep. A 'digital twin' – developed by Navantia Sistemas, in collaboration with the navy and the Spanish MoD's Directorate General of Armament and Material – will provide a shore-based "virtual replica of the ship that continuously receives data from a network of sensors distributed throughout the vessel," said Seijo. Drawing out and integrating such data will inform and prepare ship maintenance and spares plans. "This technology significantly enhances maintenance and operational efficiency," Seijo added, noting that the 'digital twin' is one of the innovative elements of the ship's concept. The navy's use of a 'digital twin' is another example of F-110 'firsts'. According to Navantia, the 'digital twin' approach presents a 'cyber-physical system' that, through integrating behavioural models and technologies including cloud computing, machine learning, and the 'Internet of Things', enables delivery of maintenance and operational support even when the ships are at sea.

Another 'at sea' example of the navy's digital transformation will be the fitting onboard of 3-D printers, allowing manufacture of spare parts during deployments.

Ashore, Navantia's wider digital transformation includes establishing a 'digital twin' 'centre of excellence' at Ferrol. Also at Ferrol is a 'digital block factory' – a fully digitised, automated, and robotised facility focused on using advanced technology machinery to improve block build processes to enhance product quality and shorten delivery times. For example, Navantia said, it is looking at technologies like hybrid lasers to improve welding performance including minimising distortions. The company aims to start using the factory for ship three's blocks.

Beyond these facilities, Navantia's digitisation transformation includes focus on incorporating technologies like artificial intelligence (AI), 'Big Data', cyber security (reflecting the navy's desire to develop fleet capacity for integrated cyber security), and augmented and virtual reality.

Elements like using AI, 'Big Data', 'digital twins', and the 'Internet of Things' all highlight the F-110 programme's role for the navy as a transformation driver towards a logistics support model that allows for increased efficiency in resource management, said Seijo.

Runners and riders: Norway assesses options for its future fleet 'workhorse'

Dr Lee Willett

In November 2024, Norway announced that four countries – France, Germany, the United Kingdom, and the United States – had been short-listed as potential government-to-government partners in delivering Norway's future frigate. Norway is progressing with a procurement plan to replace the Royal Norwegian Navy's (RNoN's) in-service *Fridtjof Nansen* class frigates; the process is aiming to down-select a final government partner in 2025, in order to support delivery of the first new frigate in 2029 and enable introduction of the new ships into RNoN service from 2030.

▲ The Royal Norwegian Navy (RNoN) frigate HNoMS *Fridtjof Nansen* is pictured in the Norwegian fjords during Exercise Joint Viking in 2024. Norway is in the process of securing a strategic partner to deliver the RNoN's future frigate. [Norwegian Armed Forces]

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Crucial in this partnering approach is joining forces with another country that has a frigate programme already underway. The respective programmes for the four short-listed partners are: France's *Amiral Ronarc'h* class frégate de défense et d'intervention (FDI) frigates, the first of which is on sea trials ahead of scheduled commissioning in 2025; Germany's F-126 *Niedersachsen* class frigate, the lead ship for which was launched in 2024, and is due for commissioning in 2028 (Germany's future F-127 frigate is another possible option); the UK's Type 26 City-class frigate, of which two have been launched with the first scheduled for commissioning in 2028; and the United States' FFG-62 *Constellation* class vessel, the first of which was laid down in April 2024.

The fact that Norway's procurement programme is framed in the context of a government-to-government partnership underlines that this is more than just a future frigate acquisition. First, it is about building a capability partnership – particularly in anti-submarine warfare (ASW). Indeed, in announcing the short list, the Norwegian Ministry of Defence (MoD) underlined that developing a strategic partnership would be as much about industrial co-operation, research and development (R&D), and collaboration in ship operation, support, maintenance, and capability evolution as it is about the nuts and bolts of a frigate acquisition.

Second, given the importance of ASW capability for NATO in the context of deterring the current Russian underwater threat – especially Northern Fleet boats coming out of the Barents Sea and bringing with them the capability to strike Northern European NATO targets with long-range sea-launched cruise missiles (SLCMs) – Norway's geostrategic position makes this one of NATO's most important future frigate, and wider ASW, programmes.

▲ The French Navy's lead FDI frigate, *Amiral Ronarc'h,* is set for commissioning in 2025. The ship is pictured off Brest, western France in September 2024, crossing paths with a French Navy nuclear-powered submarine. [Marine Nationale]

Third, in naval operational terms, a new frigate acquisition is critical both for the RNoN and for the NATO navies and commands it operates and integrates with. Given the need for NATO navies to be deployed across the Euro-Atlantic theatre with visible presence and credible capability to deter what seems likely for the foreseeable future to be sustained Russian activity, Norway's future frigates will be particularly busy, not least as frigates are often referred to as the 'workhorses' of the fleet. In terms of the Euro-Atlantic ASW threat – not to mention the wider, multi-domain operational challenges today's multi-mission frigate must deter and defend against – Norway's future frigates will be very busy ships.

Strategic interest

Norway needs robust naval capability to defend its coastline (including deep-water fjords), to operate across the North Atlantic (especially the Norwegian and Barents seas) and up into the High North, and to work with NATO Allies. In these geographic contexts, the RNoN needs to generate presence, patrol, and sea control capability, including to secure Norway's economic interests, sea lines of communication (SLOCs), and critical infrastructure. Today, it must do so against increasingly capable Russian Northern Fleet submarines and surface ships in an increasingly unstable operational and geostrategic environment. As a routine and regular contributor to NATO Allied Maritime Command's (MARCOM's) standing naval force activities, the RNoN's frigate force has a key role to play in supporting NATO requirements to push Russian submarines back into the Barents Sea to take their missiles out of range of Northern European targets; and to support NATO presence in the High North, especially with the Northern Sea Route now opening up and with some North Atlantic NATO navies now having to focus more on the Baltic Sea.

Central for Norway in its future frigate and wider strategic partnership programme is working with a partner sharing and demonstrating common strategic interests like these.
In June 2023, the Norwegian MoD's *The Military Advice of the Chief of Defence for 2023* – written by Chief of Defence General Eirik Kristoffersen – set out the case for maintaining and enhancing Norway's frigate fleet, including to add impact and output with partners.

"The armed forces must maintain their ability to inflict losses on an adversary, both on their own and alongside allies," the report said, adding that "To ensure sufficient firepower and mobility, the armed forces must retain a core set of capabilities." It noted that such capabilities include, for the RNoN, submarines and frigates. For the frigates, the report recommended a force level of between four and six new ASW-focused ships, which should also bring multi-mission

▼ The UK Royal Navy's second-in-class Type 26 ASW frigate the future HMS *Cardiff* is pictured under tow in September 2024, during its outfitting process. [Crown copyright 2024]

capability for anti-air and anti-surface warfare (AAW, ASuW) tasks: a force of six frigates, it noted, would enhance operational availability significantly, allowing different tasks to be tackled simultaneously.

Kristofferson's frigate recommendations were taken forward into Norway's long-term defence plan for the 2025–2036 period, which was published in April 2024 and adopted by the country's Parliament in June 2024. The plan called for five frigates to be funded, with an option for a sixth ship.
When revealing the future fleet plans in April 2024, within the long-term defence planning announcement, the MoD noted that co-operating with a strategic partner of choice could reduce the risks inherent in being the sole operator of an advanced, high-technology, platform.

▲ **An artist's rendering, published in 2023, of a US Navy FFG-62 *Constellation* class frigate. These future frigates bring an ASW suite integrated around and into the Navy's Aegis combat system. [US Navy]**

In announcing the short list in November and setting out the strategic and operational context around it, the MoD noted that the four candidate countries have long-term geostrategic interests overlapping with Norway's, an overlap that would help provide a solid and predictable security and defence policy co-operation foundation to the partnership, and would underpin the acquisition itself. The MoD added that further, intensified dialogue was underway with all four, alongside the formal activation of the frigate procurement programme.

In tandem, the RNoN has been continuing to review the conceptual and operational requirements for the new frigates. In the fleet plan announcement, the MoD underlined that sea control in the country's local areas is perhaps Norway's most important task in the NATO context. For Norway itself, the ships must be able to operate continuously across all of Norway's areas of interest. Both contexts require the durability of a large platform designed for open-ocean operations and able to carry out the full range of naval operational missions. Crucially, both contexts also require the availability of high-end ASW capability.

Horses for courses

Norway's wider naval needs, in support of NATO and its own national interests, are based around such high-end ASW capability. The country's geostrategic position puts it at the centre of the current underwater 'battle' between NATO and Russia, both in terms of traditional ASW requirements and the emerging need to deter and defend against threats generated by Russian sub-surface capabilities to critical undersea infrastructure (CUI).

Northern Norway hosts the southern point of a line running from Norway's Svalbard Island, south past Bear Island, down to the North Cape. This line represents what is known as the Bear Island Gap, the dividing line between the Barents Sea (where Russia's submarines can seek sanctuary in bastions) and the deeper waters of the Norwegian Sea (from where those same boats could strike at Northern European NATO targets at sea and ashore). Today, with the increased distance at which Russian submarines can strike such targets using long-range SLCMs, the Bear Island Gap has become as strategically significant as the more recognised Greenland-Iceland-UK (GIUK) Gap. From Russia's perspective, the GIUK Gap has likely transformed from an access point into the North Atlantic to more of a barrier, helping keep US 'heavy metal' out of the Norwegian Sea. Meanwhile, from NATO's perspective, the Bear Island Gap has become not only a barrier behind which to keep Russian boats bottled up in the Barents Sea, but a barrier through which it must deploy in times of crisis to push those boats even further away from the Northern European targets.

The Bear Island Gap example also illustrates the fact that ASW is now a type of warfare that has relevance across the operational spectrum. At the higher end of the operational spectrum is this requirement to push Russian boats back through the Gap and up into the north-eastern reaches of the Barents Sea, out of range of Northern European NATO targets. At the lower end of this spectrum, two CUI incidents – in November 2021 when an underwater environmental sensing network in shallow water off Norway's Lofoten peninsula was disrupted, and in November 2022 when communications cables laying in deep water off Svalbard and connecting the island to the Norwegian mainland were cut – underlined how CUI security is central to ASW operations today.

Meeting the requirement

The four candidate platforms are each fitted with state-of-the-art ASW suites that can provide sensing and effect across this full range of operations.

The French *Amiral Ronarc'h* ships carry a Thales sensing capability, consisting of the Kingclip Mk II medium-frequency active/passive hull-mounted sonar and the CAPTAS 4 Compact combined low-frequency active variable-depth (VDS)/low-frequency passive towed array sonar package as its tail. An NH90 Caiman helicopter will provide the rotary-wing ASW sensing presence, with its Thales FLASH active dipping sonar, and UMS 2000-TSM 8203 sonobuoy processing system. Sensor integration to generate targets for effectors is conducted through the Naval Group SETIS-derived combat management system (CMS). Effectors come in the form of Eurotorp MU90 active/passive homing torpedoes, launched from the ship (via two twin-packed 324 mm torpedo tubes) and from the helicopters.

Germany's potential platform in any partnership with Norway would be based around either the F126 frigate (Damen's design shown above). [Damen] ; Or the F127 frigate design, shown on the right in scale model form at UDT 2025. [Hans Uwe Mergener]

The UK Royal Navy (RN) has always defined its Type 26 ASW frigate as being designed from the keel up using submarine technology to be acoustically quiet. The ASW sensing capability spread includes an Ultra Electronics Type 2150 medium-frequency active/passive hull-mounted sonar at the bow, to a Thales Sonar 2087 combined low-frequency active VDS/passive towed array sonar at the stern. An evolution of BAE Systems' Insyte's DNA(2) CMS provides sensor data integration as the CMS. The option to embark a Merlin HM2 helicopter will provide dipping sonar capability, with its FLASH/Sonar 2189 system.

The RN and RNoN have a demonstrably close operational relationship. For example, the RNoN is set to send a frigate and the auxiliary ship HNoMS *Maud* with the RN's CSG25 deployment this year, within the HMS *Prince of Wales* carrier strike group (CSG).

The US Navy's combat suite brings a different, but similarly capable, set of ASW capabilities. The Aegis-integrated SQQ-89(V)16 software suite integrates the active/passive SQS-53B/C/D hull-mounted sonar, the CAPTAS 4 Compact low-frequency active VDS, and the TB-37 low-frequency passive multifunction towed array (MFTA) sonar. Rotary-wing ASW capability is provided by the MH60R Seahawk. The combat system is, of course, Aegis (Baseline 10).

The German bid appears to be based around either the F-126 or F-127 options. The ASW fit for the F-126/*Niedersachsen* ships comprises an Atlas Elektronik mission module incorporating a low-frequency active VDS plus a passive towed array. The NH90 Sea Tiger helicopter provides the onboard rotary-wing capability, bringing the Thales FLASH Sonics active dipping sonar acoustic suite to the fight. The Thales TACTICOS Baseline 2.0 is the CMS. The F-127 ships – intended to provide AAW capability as their primary mission – are set to arrive from the 2030s, and to be based around the MEKO A-400 AMD design. Thyssenkrupp Marine Systems (tkMS) refers to the A-400 as a "multipurpose frigate – a flexible, modular platform that can be tailored for a variety of missions, particularly ASW and air/missile defence [AMD]." Germany and Norway already have a strategic partnership in place for naval systems, encompassing the combined-build Type 212CD diesel-electric submarine and Norway's Kongsberg Naval Strike Missile.

Looking across these capability suites, Norway's tight timeframe requirements and the off-the-shelf acquisition will mandate commonality in requirement and capability – but also perhaps some compromise. While this may present a requirements challenge for the RNoN in something as significant as ASW, it also presents other opportunities. Working with a strategic partner deploying a common platform increases opportunities for mutual support – and, thus, improved availability. Availability of such high-end ASW capability across Norway's areas of interest and operational requirements will be crucial.

Germany's F127 frigate programme: Important decisions ahead

Conrad Waters

Intended to replace and expand the capacity provided by the German Navy's existing F124 *Sachsen* class air defence frigates, the F127 frigate programme will deliver up to six new major surface combatants from the mid-2030s onwards. The project has been gathering momentum over recent months and important decisions on its future direction are imminent. This article looks at the progress that the programme has achieved to date and explores its importance for Germany's naval industry.

Programme requirement

The German Navy's current air defence capabilities primarily reside in its F124 Sachsen class frigates. These ships were developed in collaboration with the Netherlands and Spain following the collapse of the NFR-90 NATO Frigate Replacement programme. They were completed with the Thales APAR multifunction and SMART-L surveillance radars also found in the contemporary Dutch LCF *(De Zeven Provinciën)* class. Three ships of the F124 type were ordered from the ARGE F124 consortium in June 1996, entering service between 2003 and 2006. An option for a fourth vessel was never exercised.

Current defence planning envisages the *Sachsen* class being decommissioned in the course of the 2030s. Given the long timeframes involved in warship design and construction, studies for their replacement have already been underway for several years. In contrast with previous naval programmes, development of the initial capability profile for these replacement vessels was led by the German Federal Ministry of Defence rather than the navy. This may have influenced the formulation of a much broader range of requirements than provided by the *Sachsen* class.

In addition to replacing the maritime and theatre air defence capacity offered by the existing air defence frigates, the F127 class are expected to make a broader contribution by providing a sea-based capability to defend against hypersonic and ballistic missile threats in the lower interception layer. This will, in turn, give them a significant role in, notably, homeland defence, as well as forming part of a NATO ballistic missile shield. This decision has had important consequences with respect to equipment selection. The F127s are also specifically intended to provide a long-range precision strike capability against hardened targets, as well as being able to contribute towards a broader range of maritime functions.

▲ The German Navy's F127 class frigates are intended to replace the existing three F124 *Sachsen* class vessels, as illustrated here by FGS *Hamburg*. [Conrad Waters]

The current official requirement is for five F127 frigates to replace the three members of the F124 *Sachsen* class, presumably reflecting the more extensive range of missions that they are expected to perform. However, the German Navy's 'Vision 2035+' fleet structure plan envisages the eventual acquisition of six F127 frigates. This is in line with its consistent applica-

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▲ **A graphic of the tkMS MEKO A-400 AMD frigate concept. Air and missile defence, including interception of hypersonic and ballistic missile threats, are at the heart of the F127 frigates' mission requirements. [tkMS]**

tion of a 1:3 ratio under which each deployable vessel needs to be supplemented by two more to provide for maintenance and training.

Progress to date

The F127 project is currently in the final stage of what is known in Germany as the analysis phase, part 2. This process is being conducted by the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw) with the support of the independent MTG Marinetechnik GmbH naval consultancy. It encompasses a range of system architecture, requirements and life cycle cost analyses, as well a market survey of suitable national ship designs. This process will lead to a selection decision, which is expected to be taken imminently. This in turn, should pave the way for the conclusion of negotiations with a preferred commercial partner prior to the receipt of parliamentary approval for contract signature. This is likely to be received in the course of 2026.

One important decision that has already been taken was the 2023 selection of Lockheed Martin's Aegis combat system to form a core element of the new frigates' combat management equipment. This reflects Germany's desire to use a proven system to provide the new class's broader range of air and missile defence capabilities, with Aegis being the natural choice in this regard. The use of Aegis also essentially determines the selection of US Navy Standard missiles and Mk 41 vertical launch systems (VLS) for the frigates' primary armament. Aegis will be linked to a broader combat management system in similar fashion to the use of the International Aegis Fire Control Loop (IAFCL) in conjunction with the Spanish Navy's SCOMBA combat management system in their F110 *Bonifaz* class frigates. The new Canadian 'River' class destroyers will also integrate the IAFCL with the Lockheed Martin Canada developed CMS-330 combat management system. There has been widespread media speculation that this combination may be used in the German ship.

In December 2024, the German parliament's Defence and Budget Committees approved funding of EUR 44.5 million for preparatory studies relating to the integration of Aegis within the preferred F127 class design. It has been reported that his work will be allocated to Lockheed Martin through the US Foreign Military Sales (FMS) process and that it will assist completion of contractual discussions with the preferred builder scheduled for later this year.

Industrial considerations

The selection of Aegis has had significant implications for the broader industrial strategy underpinning the F127 frigate programme. It was initially envisaged that the successful collaboration between Germany and Netherlands that produced the existing F124 Sachsen and LCF *De Zeven Provinciën* classes would be continued into their next generation of air defence warships. To this end, a letter of intent relating to the joint development of these new ships and their main systems was signed between the two countries in December 2020. However, Germany's subsequent choice of US technology for key elements of their ships' combat systems seems to have put paid to this cooperation. This is largely because Thales' Dutch operations have effectively been denied the opportunity to supply their equipment to the F127 programme.

It seems likely that this loosening of naval industrial ties between Germany and Netherlands will also extend to the programme's shipbuilding strategy. Germany's current,

▼ **Oliver Burkhard, CEO of thyssenkrupp Marine Systems, and Friedrich Lürssen of the NVL Group pictured at the time of signing of an agreement between the two companies to collaborate on the F127 frigate project. The model is of the tkMS MEKO A-400 AMD frigate concept. [tkMS]**

six-strong F126 class shipbuilding programme is being led by Dutch Damen in partnership with NVL. This involves an industrial framework under which much design and systems engineering work is taking place in the Netherlands but with actual construction being located in Germany. However, it seems that realisation of the F127 frigates will return to being an all-German model following the announcement of a partnership between thyssenkrupp Marine Systems (tkMS) and NVL to bid for the programme in September 2024.

The cooperation agreement, signed at the SMM 2024 maritime trade fair, envisages tkMS being the lead shareholder in the new consortium and, thus, taking the primary role in the F127 design's development and production. Current thinking involves construction taking place at the recently-acquired tkMS shipyard at Wismar (previously MV Werften Wismar), as well as at the NVL facilities in Hamburg and Wolgast. The use of the Wismar shipyard for F127 construction will likely ease pressure on other German naval shipyards, which will be heavily utilised completing the current F126 *Niedersachsen* class well into the 2030s. Whether Germany's other major naval shipbuilder, German Naval Yards Kiel, will be assigned a role in the project is yet to be clarified.

The tkMS-NVL consortium's position as lead contractor for the F127 project will not become official until contracts are finalised. However, it is difficult to see a competitor for the role emerging given the likely inability of any other German shipbuilder able to implement such a complex programme. Nevertheless, the likely re-emergence of tkMS to lead the project is a remarkable turnaround from its much-criticised delivery of the F125 *Baden-Württemberg* class stabilisation frigates and subsequent exclusion from the final round of bids for the F126 *Niedersachsen* class. It remains to be seen whether it can put these past difficulties behind it in implementing the new project.

MEKO A-400 AMD design

The reality that tkMS has achieved pole position to secure the F127 contract makes it increasingly likely that its MEKO A-400 AMD (air and missile defence) concept will form the basis for the new frigate's design. Details of the concept first emerged in mid-2024 but should be regarded as only suggestive of the F127's likely configuration pending a formal announcement of the preferred bidder.

The information provided by tkMS suggests a vessel with a length of 160 metres and a full load ("deployed") displacement of approximately 10,000 tonnes. These figures are broadly similar to the key metrics of the F126 class frigates that are now under construction but significantly greater than the 143 metre length and 5,800 tonne displacement of the *Sachsen* class ships they will replace. A maximum speed of 32 knots and endurance of approximately 4,000 nautical miles is suggested, with a combined diesel electric or gas (CODLOG) system the default propulsion option. The MEKO A-400 AMD will be able to remain at sea in excess of 30 days without replenishment. The design's key specifications are summarised in Table 1.

TABLE 1

MEKO A-400 AMD Concept – Principal Particulars

Deployed displacement:	10,000 tonnes
Dimensions::	160 m (165 m overall) × 21 m × 5.5 m
Propulsion:	CODLOG. Maximum speed of 32 kt
Endurance:	Approximately 4,000 NM. Over 30 days at sea without replenishment.
Possible armament:	Defensive missiles to combat air threats, long-range missiles to combat targets at sea and on land, tube-launched weapons.

▾ The tkMS MEKO A-400 AMD frigate concept forms the company's baseline proposal to meet the German Navy's F127 frigate requirement. The concept has a length of 160 metres and a full load displacement of around 10,000 tonnes. [tkMS]

▲ **The tkMS proposal for the F127 frigate project appears to be influenced by the previous F125 *Baden-Württemberg* class design. [German Armed Forces]**

Graphic released by tkMS suggest an evolution of previous MEKO designs, including the 'twin citadel' forward and aft superstructure arrangement first introduced in the *Baden-Württemberg* class. This facilitates an element of redundancy in key equipment. Space has been found for a total of 64 vertical launch system (VLS) cells split equally forward and amidships; twice the number found in the Sachsen class but arguably still on the low side given both current trends and the hull's overall size. Up to two helicopters can be embarked and sustained, whilst there is provision for modular systems. Much equipment is already within the German Navy's current inventory. This in line with company claims that, "The use of proven concepts (for example, propulsion system, electrical power supply, on-board helicopter integration, accommodation standards, and well-known weapon system components) minimises construction risk". The design's primary arrays could be either Raytheon's AN/SPY-6 radar or Lockheed Martin's competing AN/SPY-7 system, with the final selection still being subject to German confirmation.

The international dimension

Whilst a formal German design selection is still awaited, tkMS is already promoting the MEKO A-400 AMD concept for the Norwegian Navy's requirement for new frigates. Norway's quadrennial Long-term Defence Plan for the period through to 2036, approved by the Norwegian parliament in June 2024, stated that a minimum of five frigates equipped with anti-submarine helicopters were needed to replace its remaining four Navantia-built *Fridtjof Nansen* class vessels. Subsequently, in November 2024, the country

announced that France, Germany, the United Kingdom and the United States had been invited to discuss meeting the requirement as part of a strategic partnership. Given its established relationship with Norway through the joint Type 212CD submarine acquisition, tkMS presumably believes it is in a strong position to gain the lucrative contract.

n March 2025, during the Undersea Defence Technology (UDT) exhibition in Oslo, tkMS signed a letter of intent with Norwegian shipbuilder Ulstein Verft to collaborate on supplying the Norwegian frigates. Full details of the agreement – that pledges, "a significant portion of the value creation will take place in Norway" – have not been revealed. However, Ulstein will undertake outfitting of the ships at its shipyard in Ultseinvik if tkMS is awarded the contract.

Although tkMS' sales campaign has much in its favour, it will face stiff competition. Positively, in addition to Germany's existing links with the Norwegian defence sector through the Type 212CD programme, the offer of an Aegis-equipped vessel might also prove attractive given the Royal Norwegian Navy's previous preference for the system in the *Fridtjof Nansen* class. However, the Norwegian requirement seemingly emphasises a strong anti-submarine warfare (ASW) capacity, which is not one of the F127 class programme's primary design requirements. Norway also wants to achieve deliveries of the new ships at an early date. However, the F127 programme is at a much more immature stage in its development than its competitors. At the time of writing, the Norwegian government is scheduled to make a decision as to which country to partner before the end of 2025.

A model of the MEKO A-400 AMD concept on display at the UDT exhibition. The imminent selection of a design for the F127 programme, followed by the planned conclusion of Norway's deliberations about a selection of strategic partner for its own frigate requirement, will have important implications for the German shipbuilding sector. [Hans Uwe Mergener]

Joachim Wacker, Head of Product Sales & Product Strategy at thyssenkrupp Marine Systems (right) and Lars Lühr Olsen, Managing Director at Ulstein Verft (left) signed a letter of intent to collaborate on Norway's future frigate programme at the UDT exhibition in March 2025. [tkMS]

Important decisions ahead

With a total programme cost currently estimated at around EUR 15 billion, the F127 frigate programme represents the German Navy's most significant acquisition of recent years. From a purely operational perspective, it provides the navy with a very significant uplift in its overall capabilities, notably extending its role beyond the seas to form an important component of homeland air defence. However, the programme's significance is, perhaps, most notable in the industrial sphere. Here, the formation of the tkMS-NVL consortium to realise the programme will likely lead to the former's return to its former leadership in German naval construction and, potentially, even give rise to the long-debated consolidation of the German naval shipbuilding sector. With the Norwegian government's decision on which country to partner to realise its own frigate requirement in the months ahead, 2025 looks set to be a significant year for German naval shipbuilding.

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Interview with Commander Riccardo Chericoni, Commanding Officer of *Thaon di Revel*

Guy Toremans

Commander Riccardo Chericoni, Commanding Officer of *Thaon di Revel*. [Guy Toremans]

Thaon di Revel is an Offshore Patrol Vessel of the Italian Navy. Within the Marina Militare, she is classified as a multipurpose Offshore Patrol Vessel or Pattugliatore Polivalente d'Altura, PPA.

CDR Chericoni, you must be proud to be in command of ITS *Thaon di Revel*. Equipped with the latest generation of modular and scalable combat systems, she represents a huge leap in technology.

Indeed, it is a great honour to command of the *Thaon di Revel*. The *Thaon di Revel* is a radical new approach to multi-mission warfare. A highly versatile combat ship, she blends cutting-edge digital technologies with advanced combat capabilities.

MDM: What would you say is particularly distinctive?
Chericoni: The innovations cover almost every aspect of the ship; amongst these are the wave-piercing 'axe bow' designed hull, the integration of advanced IT systems and the stern area under the flight deck housing two multifunction mission bays, with the forward zone equipped for embarking up to five mission specific containers and the aft zone featuring a slipway with a launch and recovery system for rigid-hulled inflatable boats (RHIBs). But the standout feature is without doubt the "naval cockpit", centred on a twin-seat station on the navigation bridge, manned by the navigating officer and the bridge watch officer - our 'pilots'. Drawing inspiration from aviation technology, it is a major leap forward in vessel management, merging sensors, weapon systems, communication technologies and combat functions into a streamlined interface that dynamically adjusts to different mission requirements, prioritising critical information and automatic routine tasks. This allows for rapid and coordinated responses

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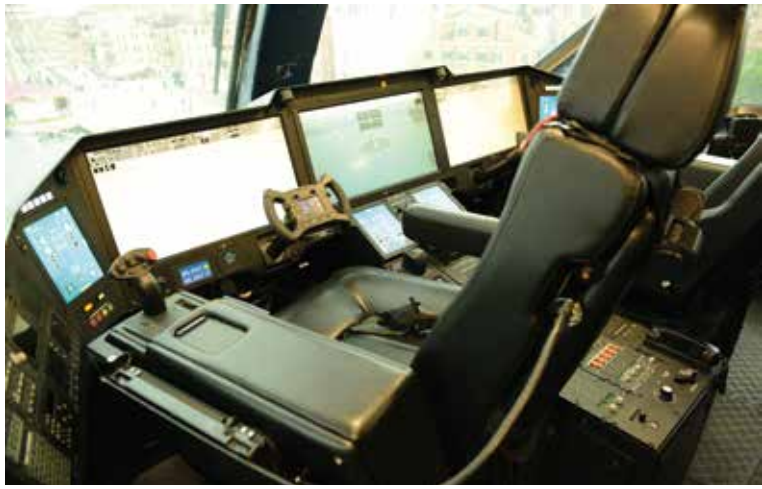

The innovative twin-station 'cockpit' navigation bridge. The central console features three large multifunction colour displays at either side of the cockpit and a large number of switches, lights and knobs, very similar to that of an aircraft or helicopter. [Guy Toremans]

Behind the twin-station 'cockpit' is the 'Captain's chair' from where the commanding officer can oversee the tactical operations in real time which offers better reaction times than a traditional navigation bridge. [Marina Militare]

to any situation. To drive the ship, the 'pilots' use joysticks and 'hands-on-throttle-and-stick' (HOTAS) controls to handle the ship's navigation, platform systems, and combat functions and they can view, via advanced digital consoles, the information of the propulsion, power generation, and platform security control and monitoring subsystems on three large multifunction touch-screen displays.

Another state-of-the-art feature is the Seastema's SeasNavy Integrated Comprehensive Ship Management Station (Postazione Integrata di Controllo Nave – PICN), jointly developed by Selex ES and Fincantieri. This PICN ensures a permanent surveillance, identification and control of all technical components, interfaces with all platform systems, integrates seamlessly with the Combat Management System (CMS) and the ship's maintenance systems. Particular attention has also been paid to cyber defence and secure networks, with protection assured by both onboard and shore-based security operations centres. Without doubt, the Italian Navy's PPAs are setting a new standard for modern naval vessels.

MDM: Obviously, damage control is an imperative on board warships. What are your ship's survival capabilities?

Chericoni: The hull has 14 water- and gas-tight bulkheads, while the ship itself is divided into two self-contained damage control zones, each divided in six subzones that operate independently for the generation and distribution of electrical power and detection of flooding, fires, smoke and toxic hazards. The indigenously developed integrated battle damage control system – the so-called Stabilisation and Safety Informatic Supervisor (Supervisore Informatizzato Sicurezza e stabilità - SISS) controls and activates all firefighting equipment. The critical areas and compartments are remotely monitored by numerous CCTV cameras and 900 smoke and temperature detectors strategically placed throughout the ship. Our extensive array of firefighting equipment includes. multiple fire suppression systems, high-capacity bilge pumps, a NOVEC fixed and semifixed systems, portable fire extinguisher low expansion foam systems, high-pressure demineralised water nebulization system, high pressure water sprinklers, CO_2fire-fighting systems in the enclosed engine rooms. The hangar and the flight deck are equipped with F500 hoses and an AFFF water hose. And for NBC protection, the PPAs are fitted with a detection system, filters and dampers for air conditioning, an overpressure citadel, a pre-washing system and a decontamination station.

MDM: Given the density of the sensors on the topside structure, what about the electromagnetic compatibility to manage the interference risks associated with radar, communication, and electronic warfare systems?

Chericoni: Significant effort has been devoted to testing electromagnetic compatibility to manage the interference risks associated with radar, communication, and electronic warfare (EW) systems. This work has been supported by Ingegneria Dei Sistemi (IDS), Fincantieri's Cetena Research and Development Centre, and our Navy's Experimental and Support Centre (CSSN). We have incorporated cutting-edge design solutions to mitigate interference, including specialised shielding and frequency management protocols. Additionally, our systems are tested extensively to ensure they can operate simultaneously without causing disruption. Regular maintenance and updates ensure this integration remains effective.

MDM: Which tasks and missions are usually assigned to your ship?

Chericoni: ITS *Thaon di Revel* and her sisterships are designed for global deployment and have the capacity to conduct complex symmetric and asymmetric warfare missions in both blue waters as well as littoral areas. Being one of the two 'light' variants, our primary missions include patrolling Italy's territorial and EEZ waters, conduct surveillance and maritime security tasks such as anti-piracy and combating illegal trafficking, as well as contributing to international missions with NATO and other Allied nations. Thanks to our modularity and adaptability the ship can seamlessly transition from military operations to provide support and assistance during to humanitarian assistance and disaster

With an overall length of 143 m, a beam of 17.5 m, a 5 m draught, the ITS *Thaon di Revel* has a displacement of some 7,150 tonnes. [Guy Toremans]

In November 2015, the Italian Navy signed a contract with Italian shipyard Fincantieri for the construction of seven multi-purpose offshore patrol vessels - also known as the 'Pattugliatore Polivalente d'Altura' (PPA) - to replace four Soldati and eight Minerva class corvettes. This new class - the *Thaon di Revel* class - comes in three configurations: two 'Light' variants, three 'Light Plus' variants and two 'Full Combat' versions. The two units, the initial fifth and sixth of the seven PPAs - *Marcantonio Colonna* and *Ruggiero di Lauria* have been transferred to the Indonesian Navy and renamed respectively KRI *Brawijaya* (new pennant number 320), and KRI *Prabu Siliwangi* (new pennant number 321).

As replacement for these two Light Plus variants, the Italian Navy will acquire a new pair of PPAs, likely the PPA EVO design which was unveiled by Fincantieri at Euronaval 2024. This new version offers improvements in terms of modularity and increased capacity. These units will be equipped with a 64-cell Sylver A50 and A70 vertical launch system, capable of launching cruise missile, and the new version's management capability for unmanned vehicles is also enhanced.

The ITS *Thaon di Revel* (P 430), laid down on 9 May 2017 and launched on 15 June 2019, was officially delivered to the Italian Navy on 18 March 2022. On 12 August 2022, the PPA departed from La Spezia for a five-month maiden operational deployment in the Mediterranean, the Red Sea, and the Indian Ocean. Throughout this deployment, ITS *Thaon di Revel* provided support to the multinational Combined Maritime Force's Combined Task Force 153 (CTF 153) in the Red Sea and participated in the European-led Operation Atalanta and the European Maritime Awareness in the Strait of Hormuz (EMASoH) mission Operation Agenor. After her arrival back home on 27 January 2023 and was declared fully operational capable (FOC).

TABLE 1

Thaon di Revel class summary

Name	Variant	Laid Down	Launched	In service
ITS *Thaon di Revel* (P 430)	Light	9 May 2017	15 June 2019	18 March 2022
ITS *Fransesco Morosini* (P 431)	Light	16 Feb 2018	22 May 2020	22 Oct 2022
ITS *Raimondo Montecuccoli* (P432)	Light +	8 Nov 2018	13 Mar 2021	27 Sept 2023
ITS *Giovanni Bande Nere* (P434)	Full	28 Aug 2019	12 Feb 2022	2 Oct 2024
ITS *Marcantonio Colonna* (P 433)	Light +	3 Sept 2020	26 Nov 2022	to Indonesia renamed KRI *Brawijaya*
ITS *Ruggiero di Lauria* (P435)	Light +	20 Oct 2021	10 Oct 2023	to Indonesia, renamed KRI *Prabu Siliwangi*
ITS *Domenico Millelire* (P436)	Full	17 May 2022	13 July 2024	2026

relief (HA/DR) operations and peace support missions. If necessary, we can even embark specific modules that may also involve a strong cooperation with civilian emergency organisations, such as the Red Cross.

MDM: ITS *Thaon di Revel* can also serve as a command platform. In August 2022, staff members of Operation AGENOR embarked on board. What facilities are provided for an embarked staff?

Chericoni: The ship is equipped with latest generation of communication and coordination facilities. There are dedicated spaces for an embarked staff of up to 30 crew, who have at their disposal a briefing and planning room, secure communication systems, and several workstations. The ship's network is designed to support real-time data sharing and command coordination across multiple units and allied forces, making it an ideal platform for managing operations at sea and even ashore. If needed, we can also embark specific containerised command and control modules.

MDM: Between 20 November and 18 December 2022 your ship also played a key role in establishing a security framework during the FIFA Football World Cup in Qatar. What was learned from this mission?

Chericoni: From Operation AGENOR, we learned the importance of how to integrate multinational staff quickly and effectively into the ship's operations. We enhanced our ability to work collaboratively in a high-stakes maritime security environment. As for the FIFA World Cup in Qatar, the mission required close coordination with local and international partners to ensure maritime security during a major global event. We learned valuable lessons about conducting security operations in a highly visible, politically sensitive environment while maintaining a high readiness for any potential threats

MDM: Your ship also has the capability to support humanitarian aid/disaster relief operations?
What facilities and equipment are installed, or can be embarked on board?

Chericoni: We can embark medical modules and shelters, different types of vehicles, specific hospital and medical equipment, as well as ample storage space for medical supplies and emergency provisions. which makes the ship an excellent platform for providing emergency aid and supporting in crisis situations. The ship features a NATO Role 1 medical facility including a medical treatment room, a sickbay, a dental cabin and a small laboratory. These facilities can be expanded to a

Role 2 by embarking medical modules in the reconfigurable mission bay and the area between the superstructure blocks. The PPAs are the first ships in the Italian Navy to feature a 690V/60Hz electrical system with the capacity to provide 2 MW of power ashore, our diesel generators capable to generate sufficient energy and water, we can support small communities of about 6,000 people with power and drinking water. This capability is critical in situations where local power grids are compromised, and ensures that we can contribute to stabilisation efforts in affected regions.

MDM: Being a very innovative unit, how are the crew members prepared prior coming on board?

Chericoni: Given the advanced technology, we place a strong emphasis on familiarising (new) crewmembers with our modular combat system, advanced radar, and communications infrastructure from day one. The crew members undergo specialised training, including both theoretical tuition on the ship's systems and tailored naval drills. They follow a two-week course at the Navy Programming Centre, followed by another two weeks for the Platform System instruction and another week for the Combat System training. Piloting the 'naval cockpit' in particular requires specific training. The instruction takes place on the simulators in our Navy's training centres, as well as at the Leonardo, Fincantieri NexTech and Seastema companies. And it goes without saying, the "on-the-job" training continues when we are at sea.

MDM: With a core crew of 137 do you think this number is sufficient when you have to operate in a high-intensity operation, while simultaneously having to cope with the high risk of DC/FF?

Chericoni: Thanks to the automation and advanced systems onboard a crew of 137 is sufficient for most standard missions. However, when we simulated 'worst case' scenarios in 6-on/6-off watch routines during which 'action stations' were called and the crew had to face warlike situations or were engaged in high-intensity operations and with a lot of complicated DC/FF situations thrown-in simultaneously, we saw that a crew of 137 was not sufficient to continue responding effectively during extended periods of time. Consequently, we are considering to augment the core crew of the PPAs.

MDM: As you mentioned previously, both your ship and ITS

Chericoni: Francesco Morosini - the second of the class -are 'Light' variant PPAs. But the Italian Navy plans to upgrade both PPAs. What will this include and what is the anticipated timeframe to carry out this upgrade?

Indeed, we are to be upgraded to the 'full combat' configuration. This will include the installation of a complete anti-air warfare, anti-surface warfare and anti-submarine warfare suite made up of the Leonardo's Kronos Quad C StarFire X-band AESA radars, two eight-cell DCNS Sylver A50 launchers for MBDA Aster 15/30 air-defence missiles (as is the 'Light Plus' version). It will also be fitted for the Mk 2/E extended-range version of MBDA Otomat/Teseo anti-ship missile, the DSS-IRST system, the OLDS decoy launchers, as well as the launch and recovery system (LARS) for the ATAS towed sonar. But is not decided yet when this upgrade will be implemented. However, following the lessons-learned of our first three years of service, we are already in the process to enhance both ships' radar systems, and communication equipment and studying how to operate unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs), which will significantly enhance our surveillance and reconnaissance capabilities. In due course these systems' effectiveness are going to be tested in a variety of operational scenarios.

▲ **The modular, reconfigurable, multi-sensor mast integrating the majority of the main sensor systems: the Leonardo Kronos AESA dual-band radar; on top of the mast the so-called ESM/ECM system. Underneath the radomes with SATCOM and MilSATCOM systems systems. [Guy Toremans]**

MDM: What is the toughest challenge being the Commanding Officer?

Chericoni: Commanding a ship like the *Thaon di Revel* requires a blend of technical expertise, strategic thinking, and strong leadership skills. The journey to this position has been both challenging and rewarding

Commanding a highly versatile ship like *Thaon di Revel* requires constant attention to mission accomplishment while ensuring that the crew remains motivated, trained, and well-supported. The toughest challenge is balancing the operational demands of the ship with the welfare and training of my crew. Maintaining this balance, especially during long deployments or high-stress situations, is both challenging and rewarding

CDR CHERICONI, grazie mille for granting this interview and for the possibility to visit on board.

The US Navy's uncrewed future

Dr. Scott Savitz

The US Navy faces several fundamental, interrelated challenges as it tries to shape the fleet it will have in the mid-21st century and beyond. [1] These issues are not unique to the United States, but are common to many democratic nations across Europe and East Asia. The US Navy's ability to acquire new ships is hampered both by their prohibitive cost and by the limited scale of the US defence industrial base, since the US Congress precludes the navy from buying warships from allied nations. Even if this could be overcome, the US Navy's long-term ability to adequately crew ships will gradually be diminished by declining cohorts of young people and the unwillingness or inability of many of them to serve.

The result is that the US Navy's ships are individually valuable to the point of being almost irreplaceable. When this point is combined with the fact that its largest ships contain thousands of personnel, naval commanders are almost compelled to be risk-averse, causing some even to challenge the value of aircraft carriers. A potentially hostile China, whose fleet now outnumbers that of the United States, may perceive that it can keep the US Navy at bay during any future conflict in East Asia by demonstrating the ability to impose intolerable risks. Other powers may also believe that the US Navy will be incapable of challenging them without undertaking politically and militarily unacceptable risks, regardless of the inclinations of the American government.

The emergence of increasingly capable uncrewed technologies may help the US Navy, and other navies facing similar issues,

▲ *Jack H. Lucas* (DDG-125), the lead Flight III variant of the US Navy's *Arleigh Burke* destroyer class, pictured departing the busy Ingalls Shipbuilding yard at Pascagoula, Mississippi in September 2023. The high cost of new warships and a finite industrial base is hampering the US Navy's ability to expand its fleet. [Huntington Ingalls Industries]

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to overcome some of these challenges. This also aligns with the US Navy's 2024 ***Navigation Plan,*** in which then Chief of Naval Operations, Admiral Lisa Franchetti, made the case for increasing operational integration of robotic and autonomous systems. In this article, we explore how this can be done to help make the navies of the mid-21st century more effective and risk-tolerant, enabling them to secure the peace for decades to come.

Identifying future missions to shape long-term fleet design
The development of a fleet is inherently a long-term process. The ships that the US Navy designs and starts to build in the 2020s will be commissioned in the 2030s, and most of those will still be in the fleet in the 2070s, or even 2080s. [2] A key challenge is that future geopolitical circumstances, and how these will translate into operational needs, are unpredictable at such a distance. Any extrapolations from the present are likely to be as wrong as Cold War assumptions from 1975 or 1985 would have been regarding present-day naval needs.

▲ **This photograph of the US Navy carrier USS *Enterprise* (CVN-65) was taken in September 2012 towards the end of her 50 year long career. The development of a fleet structure is an inherently long-term process; ships under construction today could still be in service in the 2080s. [US Navy]**

While we do not know what the future fleet may actually be required to do, we can amalgamate the insights of an array of great naval thinkers from the past century and a half: Bernard Brodie, Raoul Castex, Julian Corbett, Wayne Hughes, James R Holmes, Alfred Thayer Mahan, and William S Sims. Although it would be impossible to comprehensively describe their collective work in a short article, we can integrate and summarise some of their ideas about what naval forces do, categorising them as belonging to three broad purposes.

- The first purpose is to secure military and civilian use of the sea and its airspace, while preventing adversaries from using it. Navies need to protect the ability of their nations' military forces, across all services, to move across and within the sea. They also need to secure civilian maritime shipping and resource extraction, while thwarting the other side's military and civilian movements at sea. A few relevant missions include anti-submarine warfare, naval mine warfare, surface warfare, anti-air warfare, missile defence, and blockade. These may be supported by intelligence collection, electronic warfare, and other missions.

- The second purpose is to conduct operations against land and the airspace above it, while countering adversaries' ability to do so. A naval maxim, sometimes attributed to Vice Admiral Horatio Nelson, is that that "the seat of power is on the land." Key missions relating to this purpose include striking land targets from the sea, landing forces ashore, and operating on inland waterways, as well as forestalling adversaries' attempts to do any of these.

- The third purpose is to deter hostile actions by demonstrating the ability and will to perform the first two items. This can be achieved using some combination of presence, international engagement, demonstrative exercises, and either public or private communication.

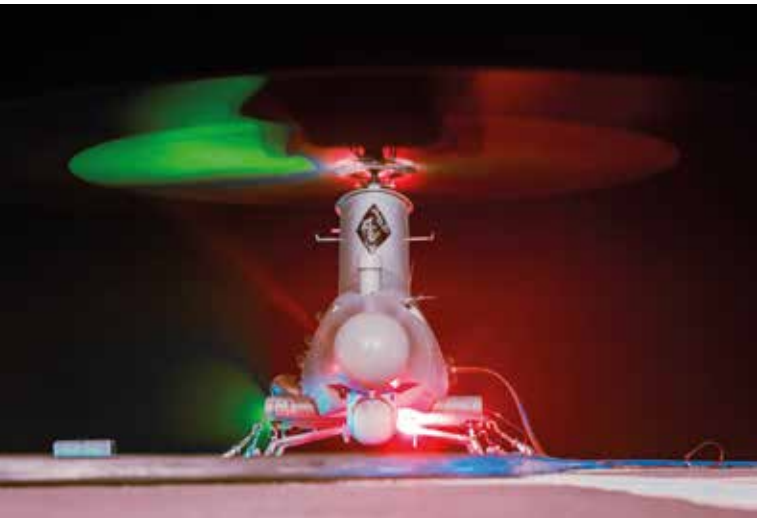
Given this framework, we can anticipate that, regardless of the geo-political specifics, the US Navy of the 2070s and the navies of its allies need to be able to conduct a wide array of possible missions. Even if they do not actually conduct specific missions, that may be – paradoxically – because their ability to do so has deterred an adversary from taking actions that require them. In this context, we can also assume that some types of capabilities will still be required. Ships will continue to launch aircraft for intelligence, surveillance, reconnaissance, logistics, electronic warfare, missile defence, and long-range strike. There will also be a need for ships that can accommodate substantial payloads. Even if some sensors can be distributed to small off-board platforms, large numbers of missiles, torpedoes, and other weapons still need to be launched in bulk.

Using uncrewed vehicles for distributed lethality and increased capacity

There are several advantages associated with the increasing use of uncrewed vehicles across multiple domains in naval operations. Eliminating personnel from a vehicle can free up extensive space and resources for payloads or fuel storage; alternatively, the vehicle itself can shrink in size and cost. The absence of personnel can also reduce design constraints. For example, as Vice Admiral Joseph Metcalf noted in a January 1988 US Naval Institute ***Proceedings*** article, 'Revolution at Sea' regarding crewed warship redesign, if a ship is no longer controlled by people requiring direct views of the outside world, control functions can be embedded deeply within the vessel, where they may be less vulnerable to superficial damage. Similarly, uncrewed aircraft can be redesigned to be capable of manoeuvres whose extreme accelerations would kill or incapacitate a pilot. This can also enable them to use shorter runways for take-off and landing. The endurance of the aircraft is no longer constrained by that of a human pilot: with periodic air-to-air refuelling and high-reliability design, on-station time can be greatly increased.

▲ The US Navy's unmanned surface vessels Mariner and Ranger pictured during exercises in the Pacific in September 2023. The increasing use of uncrewed vessels offers potential advantages in terms both of capacity and distributed lethality. [US Navy]

duced, that can enable the US Navy to attain a long-pursued goal: more 'distributed lethality', that is the dispersion of combat power onto more platforms, diminishing the risks associated with losing any one of them. While there will still be an interest in preventing the loss of key assets, their growing numbers and the absence of personnel aboard means that they can undertake greater dangers than would be possible in a navy composed of almost irreplaceable assets. This is also a way out of the "protection spiral" in which assets are given multiple layers of protection and resilience, making them more valuable, which in turn demands more layers of protection and resilience, inevitably culminating in a navy composed of a few, prohibitively expensive platforms.



▲ A MQ-8B Fire Scout unmanned aerial vehicle (UAV) seen operating from the littoral combat ship USS *Billings* (LCS-15) in January 2022. UAVs are already relatively technologically mature but further developments could increase their scope of operation and utility.[US Navy]

The proliferation of platforms also enables them to be in more places at once. This effective growth in capacity can be valuable in the event of near-simultaneous crises in different parts of the world, or if there is a need to sustain presence as a deterrent in one area while conducting combat operations in another. Ultimately, the most important advantage of distributed naval lethality may be strategic: an adversary hoping to destroy that navy's power with a quick, decisive strike – as Japan sought to do at Pearl Harbor in 1941 – would recognise that to be an impossible aspiration.

The future aircraft carrier: crewed, with only uncrewed aircraft

In the remainder of this article, we explore two ways in which uncrewed vehicles could reshape navies over time. The first is by having crewed aircraft carriers that only launch uncrewed aerial vehicles (UAVs), and the second is by having full-fledged ships without personnel aboard.

As was noted above, a suitably designed UAV can be subjected to more intense acceleration than a piloted aircraft. If newly emerging, stronger materials were to be used for launch and recovery mechanisms, the runway length could be appreciably shortened,

In some cases, acquisition and operational costs for uncrewed vehicles have been lower than those for crewed vehicles performing the same missions, though there have also been cases where uncrewed vehicle costs were comparable or higher. To the extent that costs can be re-

▶ The Portuguese Navy's innovative multifunctional naval platform *NRP D. João* II, currently under construction by Damen, is one of the world's first purpose-designed drone carriers. It is conceivable to imagine a fully-fledged aircraft carrier dedicated to UAV operation. [Damen]

and so could the aircraft carrier. Further size reductions might be attainable using other emerging technologies. For example, UAV parts and even the structures if additional UAVs could be generated on demand from compact powders using 3D printing (a key constraint being that 3D printing would need to be improved so as to withstand a ship's movements, vibrations, and dust). Both UAVs and parts of the ship's own machinery could be coated with corrosion-resistant materials, reducing maintenance requirements and the numbers of maintenance personnel needed.

Using advanced algorithms to automate some aspects of watch-standing, while providing better human-machine interfaces to enhance situational awareness, might also reduce watch-stander numbers. Using non-nuclear reactors could further limit both space and personnel requirements. Crew-size requirements that stem from damage control could potentially be diminished through the use of small crawling and swimming robots to investigate and respond, as well as more automated damage-control systems. Moreover, for every hundred operators whose roles were eliminated, dozens more support personnel could also be subtracted from the crew. The net result would be a smaller, less populated ship than today's aircraft carriers, and one that would be potentially less expensive to build or operate. More of them could therefore be built, enabling greater dispersion of combat power.

Future uncrewed ships

Uncrewed surface vehicles (USVs) are less technologically mature than UAVs. Nonetheless, they are emerging and becoming increasingly capable. Even as USVs extending tens of metres in length are being developed, commercial cargo ships are reducing crew sizes to almost vestigial levels. This is partly due to improvements in both information technology and mechanical reliability.

Some of the advantages of ship-sized USVs have previously been suggested. All of the resources and spaces that would otherwise be required to accommodate humans can be eliminated. Removing some corrosive oxygen from the ship's atmosphere can also increase system reliability and reduce the need for in-port maintenance. These USVs can have several types of payloads: radars and other sensors, weapons, or fuel. For example, corvette-sized, sensor-studded USVs could operate in an outer circle around a carrier strike group to detect air, surface, or undersea threats. These USVs might even launch small, expendable UAVs to gain further situational awareness. An inner ring of frigate-sized or larger USVs could launch missiles or torpedoes in response to human command. The crewed ships, including one or more UAV carriers, would be at the centre. Several refuelling USVs could operate in their vicinity, with one of their number always going to or from port to refill its tanks. Treating refuelling USVs as external storage tanks could also free up space in crewed ships or enable them to shrink. Communications among various ships would be reliable and secure due to a benign electromagnetic environment: any intruder emitting enough to disrupt communications or perceptions would be easily targeted.

A protracted but steady timeline

The types of changes outlined above will take decades to implement, in part because most of the ships in the US Navy of 2045 are already in the fleet. However, a gradual transition can enable experimentation and learning over time, as was the case for some of the successful naval transformations of the last two centuries. The protracted emergence of all-UAV carriers and ship-sized USVs can avoid the pitfalls of programmes like the US Navy's Littoral Combat Ship, in which too many untested technologies were combined in an effort to rapidly supplant existing systems. One approach might be to use existing ships as test platforms: for example, an amphibious ship could be repurposed as an all-UAV carrier on a trial basis. Lessons from that experience could inform the development of purpose-designed all-UAV carriers that would accompany existing carrier strike groups to boost capacity and develop concepts of operations. In time, all-UAV carriers could eventually operate without traditional carriers in some contexts, and then gradually become the nuclei of future carrier strike groups.

▲ **The US Navy's unmanned surface vessels Mariner and Ranger alongside the Japanese Mogami class frigate Kumano (FFM-2). USVs capable of performing roles now allocated to major surface combatants could emerge over time through experimentation on scaling up corvette-sized USVs to frigate-sized ones and beyond. [US Navy]**

Similarly, ship-sized USVs could emerge over time, with experimentation on scaling up corvette-sized USVs to frigate-sized ones and beyond. After ample experience of having those USVs complement existing ships, they can eventually be substituted for some of them in ways that increase the capacity and capabilities of a navy that can go into harm's way.

Notes

1. This article draws on analysis presented in Savitz, Scott and Amanda Perez, *Could the U.S. Navy Fleet of the Mid-21st Century Include Large Uncrewed Vehicles?* RAND Corporation, PE-A2854-1, January 2025. As of April 2025 this can be found at: https://www.rand.org/pubs/perspectives/PEA2854-1.html

2. The battleship USS *Missouri* (BB-63), which fought in the Second World War and was famously the site of Japan's surrender ceremony, also participated in Operation Desert Storm half a century later. Similarly, the aircraft carrier USS *Enterprise* (CVN-65) was involved in the 1962 Cuban Missile Crisis and retired in 2012.

Ripple effects: Cyber vulnerability at sea

Dr Alix Valenti

In May 2023, Microsoft detected a Chinese malware attack (Volt Typhoon) on US critical infrastructure on the Guam base – a crucial node in US operations in the Pacific. The attack relied on simple techniques and, if undetected, could have resulted in hackers successfully modifying tools and commands. In early 2024, the US successfully carried out a cyberattack on an Iranian (alleged) spy ship, M/V *Beshad*. Although open-source information on the attack itself is limited, the aim of the attack was clear: to prevent intelligence sharing with Houthi rebels. A source also told the author that a recent analysis of a major navy's critical ship's cyber defences revealed that it could paralyse the ship by merely attacking its water supply logistic chain.

These are but three examples of the myriad ways in which cyberattacks can affect a navy. They reveal that adversaries can target any system or platform and, with limited efforts and means, inflict significant damage beyond the hacked system.

As such, addressing a threat with multiple – and potentially unknown – ripple effects requires mobilising several resources. From supply chain and industry leaders to navy strategic thinkers and system operators, "cybersecurity is not just a matter for experts; it's everyone's responsibility", as Patrick Radja, Vice President of Cybersecurity Director at Naval Group, told *MDM*.

The digital century

Naval platforms and systems have become significantly digitalised and interconnected over the last ten years. Captain Thomas, Deputy to the Authority responsible for coordinating cybersecurity within the French Navy, explained in an interview with *MDM* that their goal was to use advancements in new technologies, especially those involving data, to enhance reaction times, facilitate data sharing, and improve maritime situational awareness through sensor data pooling. These sensors can collect data on a ship's systems for predictive maintenance and asset management as well as gather, analyse, and share information related to situational awareness during missions, including collaborative combat.

However, this increase in digitalisation has also widened the door for potential attacks for adversaries. This issue affects both older platforms that were not designed with cybersecu-

In May 2023, Microsoft detected a Chinese malware attack (Volt Typhoon) on US critical infrastructure on the Guam. The attack relied on simple techniques and, if undetected, could have resulted in hackers successfully modifying tools and commands. [USN]

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rity in mind and newer, highly digitalised platforms such as the French FDI frigate (Frégate de Défense et d'Intervention). The challenge also extends to the growing use of unmanned aerial, surface, and underwater systems, each having unique constraints. The consequences of a cyberattack disrupting communication links or allowing an adversary to gain control for reverse engineering or data theft are serious.

▲ **Naval Group's FDI frigates are highly digitalised, offering tactical advantages but also expanding the attack surface. [Naval Group]**

"These concerns are critical not just for naval operations but also for interoperability with other military branches," said Captain Thomas. A cyberattack on a ship can damage the quality of data transferred to other services or spread malware to other platforms through interconnected systems. Cybersecurity issues similarly affect interoperability with allies, especially NATO, but also other task forces involving NATO partners. Eric Lambert, Head of Strategic Partnerships and Government Relations - France at Renaissance Strategic Advisors, during discussions with *MDM*, noted that an adversary could exploit a vulnerability in a Link 16 connection within one allied platform to target other naval forces.

Several interviewees mentioned that cyber vulnerabilities are not new. "Certain systems inherently have vulnerabilities throughout their lifecycle," Captain Thomas added. However, the conflict in Ukraine has highlighted the importance of cybersecurity as an established combat domain. Radja stressed

▼ **HMS *Prince of Wales*, and the embarked Air Wing, is leading NATO's maritime forces as part of Joint Warrior 24-1. Operating as part of a task force with different levels of cybersecurity on board ships can create new vulnerabilities. [Crown Copyright]**

that it's crucial to be aware of the cyber weapon's ability to neutralise, disrupt, or impair adversary operations or extract classified information directly from weapon systems or supply chains. Therefore, cybersecurity—considering possible vulnerabilities and solutions—must become a fundamental part of operational practices.

Industry cybersecurity gaps

Cybersecurity is often thought to begin with the conception of the platform or system—at least today, given interconnectedness. But in practice, it starts much earlier, with the supply chain.

Alain Deturche, Cybersecurity Authority for Thales Defence Mission Systems, explained to MDM that "Primes such as Thales have been working for several years to secure internal production processes," making it more difficult to hack companies like Thales. He noted, "For hackers, the easiest way to attack a system is to hack a subcontractor." Several subcontractors are typically involved in developing a system or platform, and not all will have the same levels of cyber maturity and protection. Consequently, an attacker could hack one of the subcontractors, inserting malicious code into the part of the system they are delivering—whether a radar, a communication system, or a SCADA (Supervisory Control and Data Acquisition) system—that has been programmed for activation with specific commands.

Axel Durbec, Technical Project Manager at Exail, reported cases where systems were physically hacked on the production site, with attackers introducing malware that provides remote access to the system once it is operational with the acquiring navy.

Beyond the physical supply chain, prime contractors working with subcontractors also need to monitor potential software supply chain hacks. Systems developed by companies like Thales, Naval Group, L3Harris, or BAE Systems include multiple external software components, requiring complete visibility over the software supply chain. Radja emphasised the need for full traceability and an adequate selection and monitoring process to trust and integrate any software component into their system. This is particularly important for unmanned and autonomous systems. As Durbec noted, installing malware on these systems could affect their capabilities or result in espionage by intercepting valuable, sensitive information.

Ultimately, Mark Keyworth, Cybersecurity Consultant at BMT, told *MDM*, "It is not just about who these companies are dealing with from a supply company basis; it is also about being able to track the supply chain provenance as far back as where they are getting their supplies from, such as the motherboard, chip, or piece of equipment."

Vulnerability at sea

"When trying to understand cyber vulnerabilities for naval platforms, whether manned or unmanned, one key element to bear in mind is that these platforms combine very different types of technologies [e.g., SCADA systems, operational

technologies, information technology, combat management system, sensors, etc.] and, as such, the result is a very complex architecture," Deturche explained. Each of these systems will have its own lifecycles and undergo various system updates and upgrades, making it particularly difficult to maintain an up-to-date mapping of all systems and – inevitably – vulnerabilities.

Nevertheless, all interviewees agreed that Operational Technologies (OT) are one of the most significant vulnerabilities on board a naval platform. "Before the digitalisation of the past decade, cybersecurity of OT systems was not a priority because those systems, such as propulsion and turbines, were not connected," Keyworth said. Yet because many OTs are now connected to onboard platform management systems, sharing information with other systems, it has become critical to understand how the convergence of ITs and OTs creates a gap for cyber attackers to exploit. For instance, by exploiting a vulnerability in a communication network, a hacker could gain access to the propulsion systems and render a ship completely inoperable. Without having to deploy kinetics effects, the ship has been neutralised in its mission.

Another significant surface of attack that has emerged over the past few years, especially since the war in Ukraine, is within the electronic warfare (EW) domain. There have been several reports of GPS jamming in the Black Sea, Baltic Sea and Persian Gulf regions, which can create significant disruption. GPS spoofing is also a substantial threat to navy ships. Such attacks can generally be managed in a manned vessel, where the crew can use other systems (such as gyro compass and inertial navigation) to navigate. "Crew onboard may also have emergency response plans to restore a ship's functions if there are no irreversible impacts on the system, but for unmanned (i.e., human-in-the-loop) and (fully) autonomous systems, which rely on communication systems for several critical functions, restoring functionality after an attack may require recovering the asset," Durbec explained.

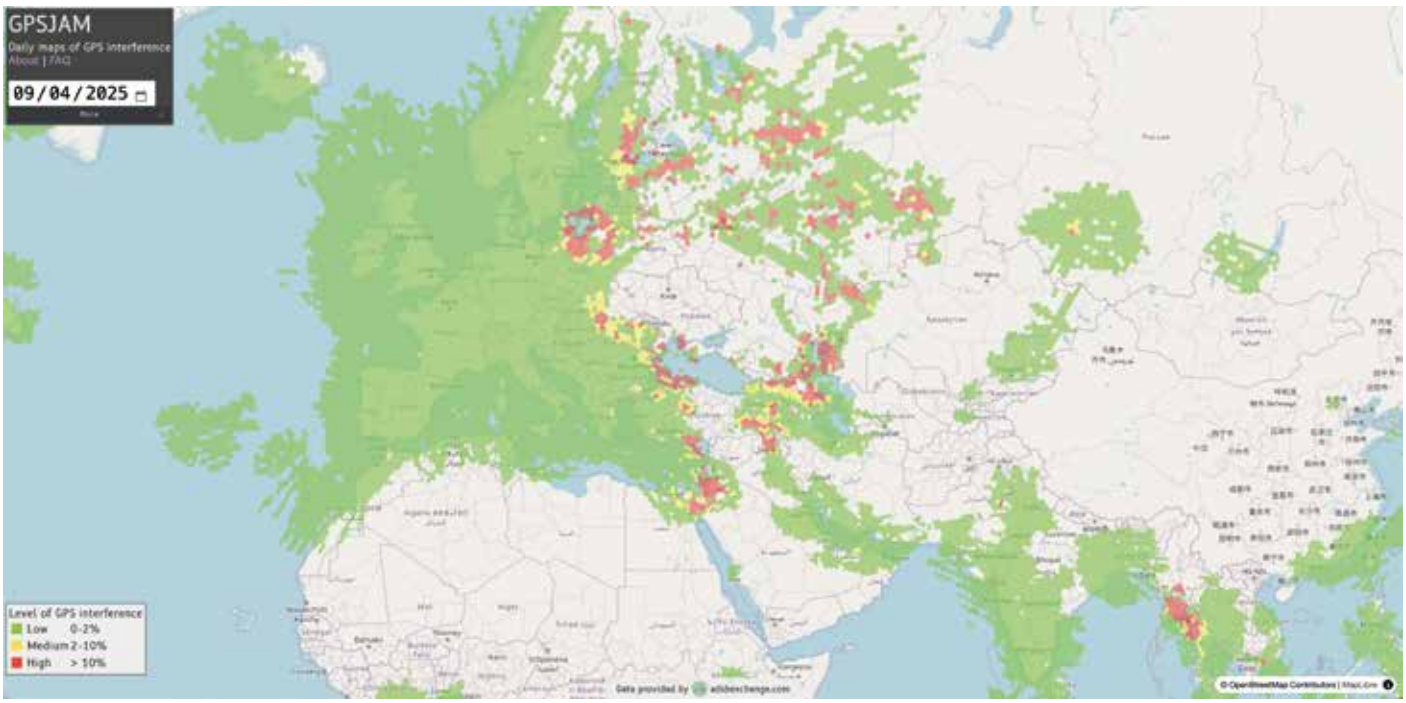
In fact, unmanned and autonomous systems present an extended potential surface of attack compared to manned ships. In addition to the vulnerabilities presented above, cyber attackers can remotely hack into a system via its communication links or through the Programmable Logic Controllers (PLC) if the latter are not cybersecure by design or have not been updated and/or patched. As a result, the hacker could gain remote access to the system and either direct it to its location - possibly to access valuable information and/or retro-engineer it – or, as Lambert explained, even use it to cause physical damage to its mothership.

Finally, and as important as any of the physical and software vulnerabilities outlined above, there is the human factor. "There are three main categories of cybersecurity vulnerabilities for a navy," Captain Thomas explained, "and those are technological, humans operating systems onboard, and humans using other communication systems for recreational purposes." Most reports published on cyberattacks highlight that in 90% of the cases these attacks were successful due to human error.

High-Level solutions

"Over the past few years, regulations concerning cybersecurity have evolved to meet some of the main challenges the naval industry faces at all levels," Radja noted. Legislative frameworks like the European NIS-2 directive and IACS Unified Requirements have increased awareness among stakeholders. The French Navy's cybersecurity strategy, Navy Cyber Ambition 2030, outlines three strategic objectives: digital security, innovative cyber defence, and cyber intelligence.

There have been several reports of GPS jamming in the Black Sea, Baltic Sea and Persian Gulf regions, which can create significant disruption – especially for unmanned systems. [gpsjam.org]



"We see a positive impact on client awareness and demand for cyber resilience," Radja explained, "fostering collective action." Captain Thomas added that the new framework helps armed forces manage cyber threats and maintain operational freedom.

As is often the case, regulatory progress remains slow, which subsequently can also slow down, or even hinder, innovation. Take USVs (unmanned surface vehicles) as an example. As they can potentially navigate in busy waters, they are subject to COLREG (Collision Regulations) to ensure safety of navigation. This delays certification processes. "Where industry will work to ensure cybersecurity maintenance, making regular real-time adjustments to meet emerging threats, the complex safety certification process prevents easy and regular updates," Deturche explained.

▲ **USVs are subject to COLREGs and other regulations, slowing their updates. Thales' MMCM system for the UK Royal Navy. [Thales]**

Durbec mentioned that lengthy legislative processes can create cybersecurity gaps on naval platforms. As cyber threats become more sophisticated, the challenge is how to evolve regulations without stifling innovation or disrupting military operations.

Industry solutions

"Every cybersecurity study begins with a risk assessment," Durbec explained, "and this risk estimation drives the measures put in place to mitigate them." This sentiment was echoed by all interviewees for this article.

Risk analysis entails understanding not only the system itself – its surface of attack and potential security gaps - but also the context in which it will operate, the types of missions it will carry out (will it be used to monitor critical infrastructure or on intelligence, surveillance and reconnaissance (ISR) missions off a potential adversaries' coast), and which potential adversary it will encounter. This analysis will subsequently inform the intrinsic cybersecurity quality of the system that will be delivered to the customer, but it is not enough. It needs to be complemented with extensive exchanges with customers to understand the right balance between the level of acceptance for certain risks versus mission criticality. "We often support customers balance strict cyber strategies with operators' evolving mission needs," added Durbec.

▲ **Cybersecurity begins with a risk assessment, which informs systems' design to make sure that they are cybersecure by design. Pictured here, Exail's DriX. [Exail]**

Consequently, companies such as Exail, Thales and Naval Group offer custom levels of cybersecurity-by-design for military customers. Both Thales and Naval Group actively collaborate with their customers to identify cybersecurity requirements, often through wargaming exercises. The most comprehensive exercise in France is DEFNET, conducted annually by the Ministry of Defence *(Ministère des Armées),* involving all branches of the armed forces. Radja noted, "DEFNET allows us to work closely with our customer to define our strengths and work collectively to address our weaknesses – from weapon system up to our suppliers and our industrial means."

In addition to collaborating on risk analyses that guide the development of cybersecure platforms and systems, some companies maintain their own CERT (Computer Emergency Response Team), such as Naval Group, or equivalent industry actors. Similar to the DEFNET wargaming event, the CERT conducts scenario planning to assess potential risks and devise effective solutions. Ultimately, as Deturche explained, "It is all about having the relevant expertise to be able to have the right risk analysis and the right solution for each specific need and constraint."

These exercises extend to cyber-risk analysis and security within the supply chain. "Continuous web teaming, cyber wargaming and simulating defensive cyber-operations are critical to introducing resilience in the supply chain but also to ensuring that there is rapid incident response," Keyworth noted. It is about training people and ensuring they understand the stakes rather than merely seeking to comply with cybersecurity rules. "Successful training leads to people operating and maintaining their equipment in a cyber secure manner," Radja commented, "whereas mere compliance is inefficient." To this end, large companies such as Naval Group and Thales will also work closely with their subcontractors and suppliers to train their employees.

Cybersecurity at Sea

Captain Thomas told *MDM* that the French Navy addressed technology-related cybersecurity issues in four ways.
The first approach is cybersecurity by design. As emphasised by industry leaders interviewed for this article, this is a critical step, with the French Navy adhering to its own cybersecurity requirements in addition to European and IACS standards. Captain Thomas elaborated: "For certain types of ships, such as submarines and surface ships, there are specific documents issued by the DGA *(Direction Générale de l'Armement)* which outline cybersecurity requirements tailored to the operational contexts of these vessels."

The second approach involves cybersecurity maintenance *(Maintient en Conditions de Sécurité* - MCS). Analogous to In-Service support, MCS focuses on the continuous management of identified vulnerabilities within a contractual framework. Captain Thomas further clarified, "It also encompasses all the skills necessary for the crew to effectively address a cyber incident."

The third approach is cyber surveillance, which entails the ongoing monitoring of all systems to identify potential cybersecurity incidents and attacks. This function is performed by the Security Operations Centre and relies on detection rules that enable operators to recognise anomalies in system operations and determine whether they signify a cyberattack or a false positive.

The fourth approach, consistent with industry practices, is the accreditation of an information system. This process aims to deliver a formal decision on the system's authorisation to operate based on the desired security level and acceptable residual risks. In the military context, this command-level decision is informed by system use descriptions, threat assessments, risk analyses, technical studies, and penetration testing. Captain Thomas noted, "On this basis, we define the level of risk we are prepared to accept for our systems."

At the organisational level, the French Navy incorporates information system security specialists, operational cybersecurity specialists, and cybersecurity experts across all commands. Additionally, the Cyber Defence Support Centre undertakes three specific missions: training crews to respond to cyber incidents (including through DEFNET and E=MC2 wargaming exercises),

Several navies, including the French Navy with DEFNET and E=MC2 (pictured here), conduct wargaming exercises to identify potential cybersecurity vulnerabilities and ensure preparedness. [Ministère des Armées]

The Royal Navy regularly carries out wargaming exercises, including the Cyber Sentinel with the Five Eyes nations. These exercises will be crucial to prepare for the challenge of zero trust architecture required by the USN. [Crown Copyright]

constant network monitoring to detect incidents and attacks, and intervention in the event of a cyberattack.

Although it was not possible to consult an expert from the Royal Navy (RN) for this article, the British forces also engage in numerous exercises to maintain the highest level of cybersecurity readiness. These include Exercise Cyber Sentinel, conducted as a Five Eyes nations exercise, and Defence Cyber Marvel, a large-scale exercise involving multiple nations, including Ukraine in 2023 and Japan in 2024. The RN also has dedicated wargaming facilities, such as the UK Strategic Command Defence Experimentation and Wargaming Hub in Southwick, to support cybersecurity decision-making and enhance operational effectiveness across the UK armed forces.

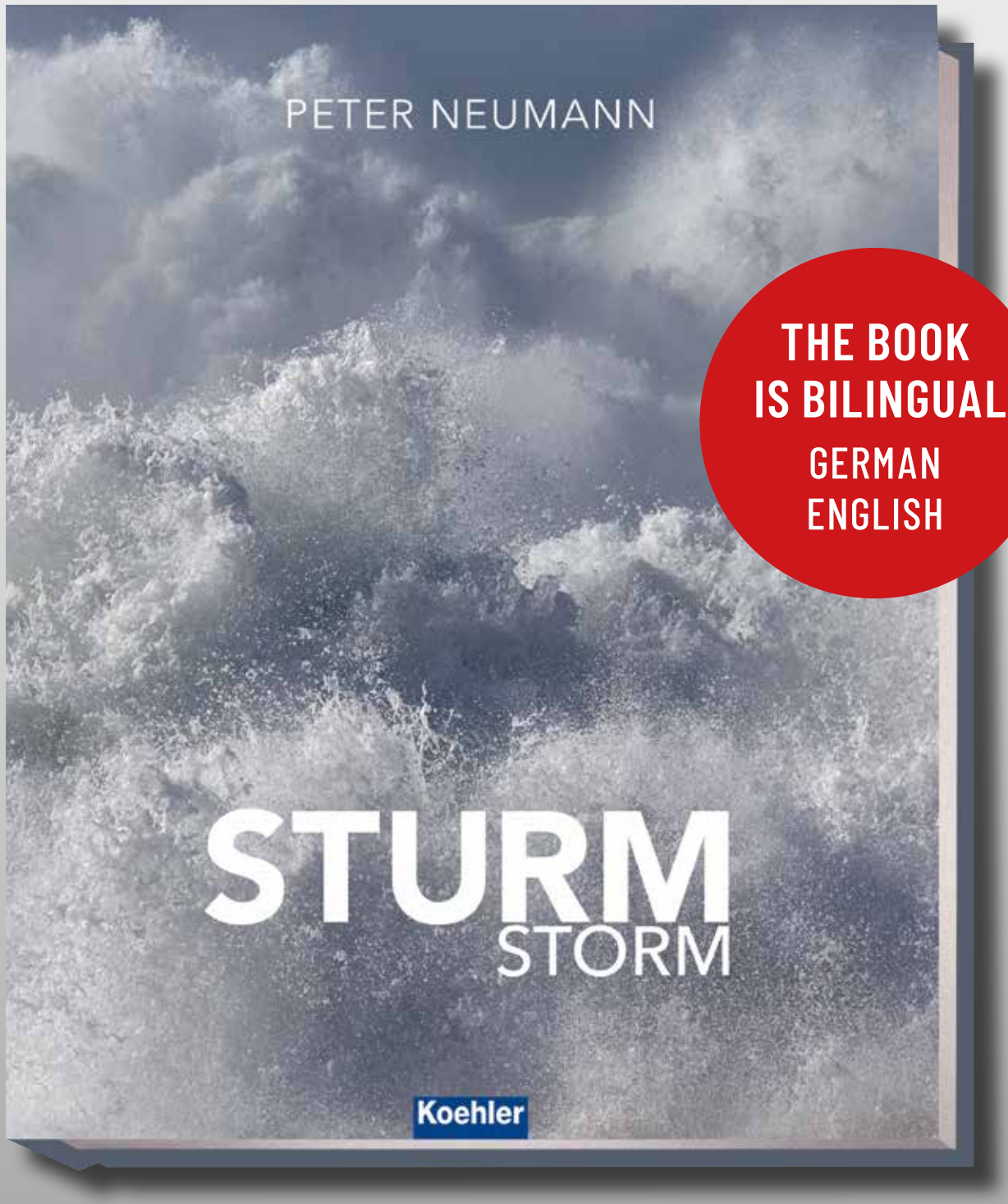
The autonomy cyber conundrum

The increasing integration of artificial intelligence (AI) in navy systems to support decision-making and enable autonomous systems will bring new cybersecurity challenges in the near future.

One key challenge will be ensuring the integrity of the data used to train AI algorithms, noted Lambert. Data poisoning, which involves injecting incorrect information into the training algorithm, could impair a system's capabilities, such as causing a radar to fail to recognise certain targets, or provide inaccurate decision-making scenarios to an autonomous system.

To mitigate such risks, it will be important to ensure data integrity and develop explainable AI models, according to Captain Thomas. Thales has initiated cortAIx, an AI accelerator aimed at enhancing the integration of AI technology across all sectors of the company, including defence. Deturche highlighted that despite these efforts, some AI models may still be susceptible to attacks or data poisoning, making behavioural analysis crucial for detecting cyberattacks against AI-enabled systems. Behavioural analysis involves comparing an AI system's actions with its expected behaviour to identify inconsistencies.

In the long term, several navies may adopt 'zero trust' architecture for their OT, IT, and C4ISR systems, as indicated by Lambert. This approach is primarily driven by the US Navy and NATO. "This is the ultimate in-depth defence concept, and navies will have to integrate it into their thinking because it will be critical for interoperability," Captain Thomas concluded.



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An active detection regime: ASW on the noisy future battlefield

Dr Sidharth Kaushal

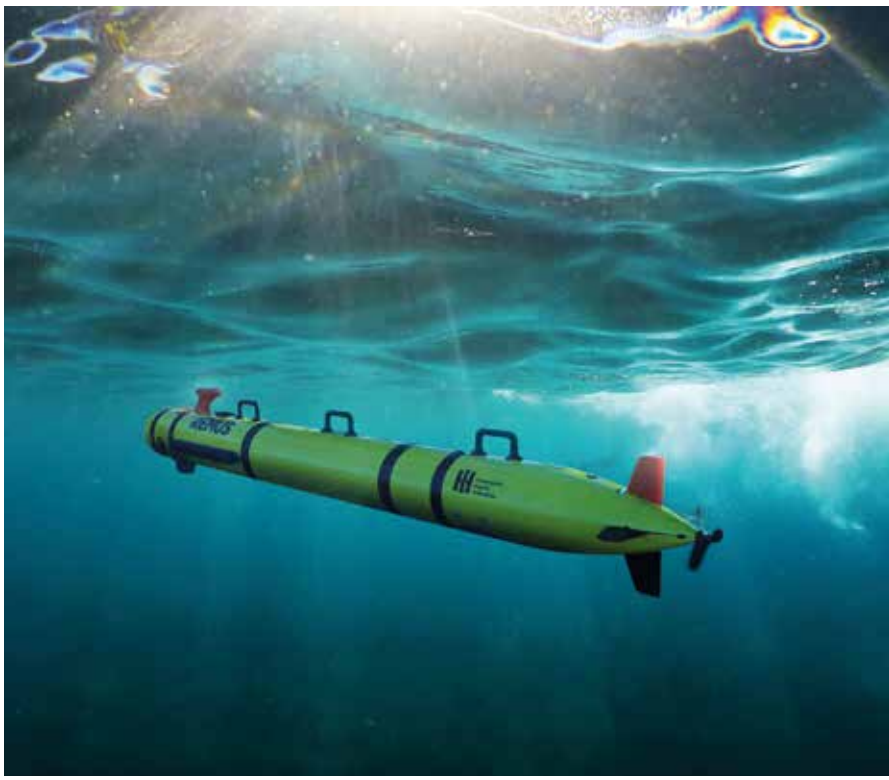
The ability to remain quiet has been a cardinal virtue for both submariners and anti-submarine warfare (ASW) operators for most of history. This has stemmed from the fact that active detection poses a considerable risk of counter detection and, thus, destruction by an opponent. Consequently, for most of the Cold War, competitors raced both to quieten their nuclear attack submarines and also to field increasingly quiet anti-submarine warfare frigates. However, in the contemporary operating environment, the focus may be changing.

The emergence of long-endurance uncrewed underwater vehicles (UUVs) has fundamentally changed the dynamics of undersea water as they relate to emissions control. A number of UUVs now have the endurance to operate at sea for extended periods of time. The CETUS UUV being trialled for the Royal Navy, for example, is meant to have an endurance of five days while the Solus-LR has an advertised range of 2,000 km. These platforms have the range and, potentially, the payload to accompany and support submarines, but they are very noisy. UUVs like the US Navy's Remus 300 typically use brushless motors which likely result in noise levels of around 120 dB. These noise levels would be high, verging on unacceptable, for a modern nuclear-powered attack submarine (SSN).

However, if UUVs are paired with submarines, the multiplication of the number of contacts could pose a challenge for ASW operators. Whilst they might be able to detect contacts more easily, they might find it harder to classify them using passive sensors. If there are multiple contacts, some faint and others loud, this challenge is simplified. However, if contacts are comparably loud, the challenge is complicated considerably. An implication of this would be that submariners have an incentive to become louder to hide within the noise. In effect, the emergence of UUVs on the modern battlefield might mean that older and louder SSNs could receive a lease of life. This would be of particular importance in the Pacific, where Chinese SSNs such as the Type 093 still lag western and Russian counterparts by a significant margin.

Equally, increasing quietness poses a diametrically opposite problem with convergent ramifications for passive sonar. The increasing quietness of modern SSNs means that they will be increasingly difficult to detect and classify through passive means alone (except at exceedingly short distances, where in all likelihood the pursuing frigate may be at greater risk than its quarry). This is especially true of modern Russian submarine classes such as the Project 885 'Yasen' series.

In effect, submariners have two options. Operators of louder submarines, such as a Chinese Type 093, might well opt to employ larger volumes of clutter to mask their signatures, thereby making submarines which might have previously been deemed subpar more usable. Quieter submarines such as a 'Yasen' or *Virginia* (SSN-774) class boat might, by contrast, continue to be employed in ways optimised to evade passive detection. For ASW operators, the challenge of detection is thus compounded with one of classification.



▲ A CG render of a Remus family UUV. [HII]

AUTHOR

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The *Virginia* class attack submarine pre-commissioning unit *Missouri* (SSN-780) pulls into Naval Submarine Base New London on 22 July 2010. [US Navy/John Narewski]

On the other side of the ledger, the trend towards expanding use of uncrewed vehicles cuts both ways. One of the primary reasons that ASW operators avoid the regular use of active sonar is the risk of counter-detection by submarines, which in many cases outrange ASW frigates. In effect, active sonar might simplify the tasks of both detection and classification, but it can only be used intermittently. However, uncrewed systems can act as towed array passive receivers for vessels emitting active sonar (extending an emitting vessel's range by reducing transmission distances) or as sources of noise that might be used to mask vessel signatures.

Uncrewed vehicles might also be used to carry non-acoustic sensors such as light emitting diodes, which might usefully be paired with sonar in an increasingly cluttered operating environment. Additionally, machine learning could significantly reduce the impact of false positives on active sonar returns, which have been a particular challenge for the employment of low frequency active sonar as an enabler of detection over long ranges. Frigates, too, could thus have an incentive to get noisier.

In a context where the competition between submarines and ASW assets becomes more noisy, a number of principles regarding vessel design and employment might change. In particular, a greater focus on mass and the ability to saturate an area with active sensors, rather than to employ smaller numbers of passive systems, might become an increasingly important feature of ASW.

Case study: Evolving competitor approaches to ASW

The approaches taken by competitors such as China and Russia, whose ASW operators have always been somewhat disadvantaged in a passive detection regime, might provide a glimpse of what future antisubmarine warfare might look like when all parties have to shift partially from passive detection.

China: Over the past two decades, China's People's Liberation Army Navy (PLAN) has dedicated substantial resources toward building a maritime force capable of challenging US and allied naval supremacy across the western Pacific. While progress in many domains has been swift, the undersea domain has remained a comparative weak point. However, that gap is beginning to narrow. Though PLAN submariners and ASW operators still lack the operational experience and finesse of their Western counterparts, the broader force has begun assembling a layered system of ASW tools that might, over time, mitigate this deficiency.

This emerging approach does not depend solely on refined tactics or elite operator skill. Instead, the PLAN is embracing a strategy rooted in sensor saturation and rapid response, particularly within the boundaries of the first island chain. While this evolving system may still struggle with expeditionary operations or to withstand the challenge of stealthy US attack submarines far from China's coastline, its growing density and reach pose an increasingly formidable obstacle to adversarial sub-surface activity.

The PLAN's central method for countering the acoustic stealth of adversary submarines relies on widespread use of active sonar systems. Contrary to Western doctrine – where passive listening remains the norm due to concerns about reveal-

The Type 056A corvette *Huangshi* seen during a maritime training exercise in mid-August, 2024. [China Military/Wang Guangjie]

ing one's position – the PLAN prioritises active emissions, especially in the constrained environments of the East and South China Seas. By prioritising simplicity and coverage over subtlety, China aims to negate the acoustic advantages held by quieter foreign submarines.

Key to this strategy is the widespread deployment of the Type 056A corvette — an ASW-optimised vessel equipped with variable depth sonar (VDS). With approximately 50 vessels in service, this class forms the bedrock of China's coastal ASW operations. Unlike Western operators, who might use VDS cautiously, PLAN doctrine encourages aggressive active search, with authors in Chinese defence publications such as Modern Ships explicitly stating the belief that such an approach can deny submarines any real chance of concealment. Complementing the Type 056A's sonar capabilities is its integration with the Z-9 helicopter, which – despite its limited payload – provides an aerial vector for sonobuoy deployment and threat detection. Where the Z-9 falls short in payload, the Yu-8 missile (a vertically launched rocket-assisted torpedo) extends the corvette's reach, enabling standoff engagement of contacts without requiring the helicopter to carry its own torpedoes.

In addition to conventional surface combatants, the PLAN is turning to both manned and unmanned undersea vehicles to broaden its sensor web. While older platforms like the Type 035G submarine contribute little in high-intensity conflict, it has been suggested that they may serve as active emitters employed either for detection or forcing engagements that expose enemy submarine positions. Unmanned underwater vehicles (UUVs) such as the HSU001, which boasts long endurance and modular sensor payloads, are being developed for this purpose.

A screenshot of a Chinese HSU001 UUV seen during the 1 October 2019 military parade to mark the 70th anniversary of the founding of the PRC. [CCTV]

Russia: Another example of the shift to a likely active detection regime is Russia's Harmony network, an analogue to the United States' SOSUS and IUSS. While the details of Harmony are not publicly known, the network is understood to be partially powered by undersea nuclear reactors. There are several rationales for such an approach but one potential explanation is that Russia has opted to rely more heavily on low frequency active sensors for detection, which would align with stated Russian concerns regarding its ability to detect quiet SSN. A shift to an active detection regime would necessarily be power consuming, which might explain the employment of ATGU atomic generators.

In effect Harmony would represent a variant of the reliable acoustic path systems which employ a large number of distributed sensors (as contrasted with the large, highly sensitive fixed arrays of western networks such as SOSUS). The advantage of these systems has been a lower requirement for high sensor fidelity but they have been challenged by their relatively limited range. This can be resolved with low frequency active sonar but given the power consumption of sonar (detection of a submarine type target at 10 km absorbs half a million watts) this has historically been challenging. However fixed arrays powered by underwater power stations largely circumvent this challenge and may become an increasingly prominent feature of maritime combat.

While both of these Russian and Chinese solutions are primarily related to the issue of quietness rather than a noisy battlefield – both competitors faced challenges in their ability to track western submarines – the set of solutions arrived at may provide a glimpse of what future competition below the ocean surface might look like.

Conclusion

The observations made in this article are not a suggestion that quietness and stealth will lose their value on future battlefields. Rather, the argument is that – in much the same way as combat in the air domain may increasingly come to be conducted by 'high/low mixes' of capability – the inclusion of large numbers of relatively noisy UUVs in the future operating environment may have the effect of reviving the fortunes of older and nosier classes of submarine. This in turn will result in a growing premium being placed on the ability to saturate an area with active sensors, as well as non-acoustic methods of detection. This will impact both how ASW assets are designed and how they are employed.

Much as the emergence of low cost strike munitions like the HESA Shahed has not removed the threat of capabilities such as cruise missiles, new undersea platforms and increasingly usable older submarines may not end the role of the quiet SSN. However, they will make it one part of a more complex battlefield.

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