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An uncertain new year beckons

As 2025 draws to a close, it is worth examining the recent operational picture in Ukraine, and some of the key dynamics expected in the year ahead.

The last few months have been somewhat of a mixed bag for Ukraine. While Russian forces managed to attain a very strong position in both Kupiansk and Pokrovsk in late-November 2025, by the time of writing in mid-December, Ukraine managed to effectively break Russia's stranglehold over Kupiansk, and effectively stalled Russia's offensive efforts toward Kostiantinivka and Lyman. Of these, contesting Kupiansk is particularly significant, as it prevents Russia from cementing its control over a large section of the East bank of the Oskil river. Although this move buys Ukraine valuable time and breathing room, keeping the city will be difficult to sustain over the longer term, particularly given Russia was reported to have signed up 403,000 new recruits in 2025.

Despite losing their grip on Kupiansk, Russia's armed forces have made notable gains in a number of areas, having captured most of Siversk, consolidated their position in Pokrovsk and mostly surrounded Myrnohrad, along with launching a major push into Huliaipole. A pattern worth highlighting is that since October, Russian forces have managed to advance significantly faster in the South than the North. As such, it would seem that Ukraine has committed more of its defensive capacity to defending key towns along the northern portion of the front.

Zooming out to look at operational dynamics shaping the battlefield, Ukraine's aerial strike campaign has achieved highly-publicised successes in striking Russia's oil and gas infrastructure since September. However, it would seem that sustaining these successes will be challenging, as highlighted in a December 2025 Royal United Services Institute (RUSI) report, titled 'Disrupting Russian Air Defence Production: Reclaiming the Sky':

"The regular images of fires in Russia have caused a perception that Russian air defences are failing to protect the territory. The reality is more complex. There are a lot of targets in Russia, and they are geographically dispersed, meaning that they cannot all be defended. Ukraine has, over time, become quite adept at attacking targets that lack air defence and has prioritised targets where flammable or sensitive materials will allow small numbers of munitions with limited payloads to cause cascading damage to a facility. This leaves large numbers of targets that the Russians have decided to defend, and that, consequently, Ukraine has struggled to hit."

Consequently, Ukraine's success rate against protected targets has been relatively low, as the report explained:

"When Ukraine has attacked more protected targets, the results have been consistent. Out of a salvo of 100–150 UAVs, costing between [USD]20,000 and [USD]80,000 each, around 10 will get to their target, where their small payload often causes negligible damage that can quickly be repaired. The overall success rate of Ukrainian strikes has been that less than 10% of munitions have reached a target, and fewer still have delivered an effect. Successful strikes on hardened targets have often required Ukraine to fire over 100 UAVs on one attack vector to exhaust the air defences in a sector, and only then fire cruise missiles or larger UAVs to deliver damage. Even where Storm Shadow or other prestige weapons are used by Ukraine, the improvements in Russian munitions matching have meant that they often intercept over 50% of these munitions, even when they are part of a complex salvo."

Russia's air defence forces have also shown a fairly noteworthy ability to adapt to threats, as noted by the RUSI report:

"Guided multiple launch rocket systems (GMLRS), and later, army tactical missile systems (ATACMS), inflicted substantial losses on the Russians when first employed. Nevertheless, over time, Russian air defences learned how to track and engage these munitions effectively and the rate of successful hits dropped from close to 70% with GMLRS in 2022, to around 30% in 2023 and 2024, and often close to 8% in 2025. For attacks on components of the air defence system, it has been found that up to 10 ATACMS must be committed to destroy one radar."

As such, despite Ukraine's advances in developing domestic long-range one-way attack (OWA) drones and cruise missiles, a sizeable portion of Russian critical infrastructure will likely remain a tough nut to crack.

On the Russian side, aerial strikes against Ukraine's energy infrastructure have continued, and escalated, with a reported 5,000 drones and missiles launched in November alone, pushing Ukraine's power grid to the brink of collapse. A concerning recent trend has been the increasing quantity of Russian OWA drones such as Molniya-2 equipped with Starlink terminals, enabling their operators to retain a control link at distances beyond those of typical line-of-sight radio datalinks. This in turn expands the range of targets which can be engaged by these drones, complicating the task for Ukraine's air defenders.

Zooming out further, political developments have largely overshadowed battlefield developments, and remain the most likely factor to significantly disrupt the status quo. The Trump administration's continued pressure on Ukraine in peace negotiations and adversarial posture toward Europe, as outlined within the recently published US National Security Strategy, have both caused alarm among European leaders. While US 'Article 5-like' security guarantees have been offered as an incentive for Ukraine, it remains to be seen if these will be a valid substitute for the real thing. Ukraine finds itself in a difficult position. US pressure is mounting, and increasingly, the signals from White House indicate that unless Ukraine makes significant concessions in the name of a peace deal, it will be left to face Russia without US assistance. Should this come to pass, the consequences would be dire for Ukraine, and would leave Europe in a deeply unenviable position.

Mark Cazalet

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ESD [European Security & Defence]
Issue 12/2025 – 01/2026, December 2025, January 2026
ISSN 1617-7983
www.euro-sd.com

Published by
Mittler Report Verlag GmbH
A TAMM Media Group company

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Cover Photo: US Soldiers with 3rd Brigade, 10th Mountain Division conducted driver training with the New Generation Tactical Vehicle-Hybrid (NGTV-H) troop transport during exercise Combined Resolve 25-1 at the Hohenfels Training Area, Germany, on 14 January 2025. [US Army/Sgt Chandler Coats]

Annual subscription rate: €129.00 incl. postage Reduced annual subscription rate for distribution in Germany: €108.00 incl. postage

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FOC declared for UK Carrier Strike Group as it is put under NATO command

(pf) HMS *Prince of Wales* and its associated UK Carrier Strike Group has reached full operating capability (FOC) and has been placed under the command of NATO, UK Defence Secretary John Healey declared on 17 November 2025.

The move means that for the first time NATO will have a carrier strike group under its command with advanced fifth-generation F-35B Joint Strike Fighters and conforms with the UK's NATO-first approach, as set out in the Strategic Defence Review published in June 2025.

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The announcement came as Healey and UK Foreign Secretary Yvette Cooper hosted their Italian counterparts on 17 November aboard HMS *Prince of Wales*, off the coast of Naples, during a visit to the historic city. Meeting with Italian Defence Minister Guido Crosetto and Foreign Minister Antonio Tajani, they discussed deepening defence and security co-operation, including joint efforts to counter hybrid warfare threats and bolster European security in the face of Russia's illegal invasion of Ukraine.

"This is a proud moment for Britain," Healey stated. "The UK is stepping up for European security and delivering on our NATO-first plan. I am deeply grateful for the professionalism and dedication of all those who've worked to reach this significant moment.

"We are in a new era of threat that demands a new era for defence," Healey added. "Our strength comes from hard power and strong alliances, so it is fitting to mark this moment alongside one of our closest NATO allies in Italy. Their F-35s have been operating from the carrier to demonstrate the deep partnership between our militaries."

Ships and aircraft from the UK's Carrier Strike Group – the largest international carrier strike group the UK has ever assembled – proceeded work with allies for the major NATO Exercise 'Neptune Strike' in the Mediterranean, testing NATO's ability to strike targets at sea, conduct carrier-based air missions and amphibious landings, and carry out anti-submarine drills.

The UK Carrier Strike Group's return to the Mediterranean follows five months of operations, engagements and defence diplomacy in the Indo-Pacific.

In the approach to FOC being declared for the Carrier Strike Group, on 6 November 2025 the Royal Navy reported that HMS *Prince of Wales* had embarked 24 British F-35Bs for the first time: the highest number of F-35Bs ever assembled on either of the Royal Navy's Queen Elizabeth-class aircraft carriers.

Noise and vibration issues again bring Ajax armoured vehicles to a halt

(pf) The British Army has again halted all use of its Ajax tracked armoured vehicles as noise and vibration issues continue to affect the health of vehicle crews.

The halt comes despite the UK Ministry of Defence (MoD) declaring an initial operating capability (IOC) with the Ajax family on 6 November 2025, with Defence Readiness & Industry Minister Luke Pollard insisting that the noise and vibration issues with the vehicle had been fixed and that the MoD would not be giving IOC status to "any platform that we did not think was safe for the men and women of our forces to use".

Meanwhile, at an event in London on 4 November that will now be seen with some irony, the Ajax programme won Megaproject of the Year at the Global Project Controls Expo Awards.

At that point around 165 Ajax vehicles had been delivered.

However, *BFBS Forces News* reported on 20 November that three members of the Household Cavalry Regiment were facing medical discharge due to injuries sustained since the introduction of Ajax to their unit.

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The UK MoD has since confirmed that 31 personnel showed noise and vibration symptoms following Exercise 'Titan Storm' which took place on Salisbury Plain from the beginning of November and involved both the Household Cavalry and the Royal Lancers.

The obvious question therefore – for the British Army, as well as the UK MoD and its Defence Equipment & Support organisation – is how is it possible that IOC was declared for a vehicle that continued to pose health risks for the service personnel using it? On 26 November a written statement made by Pollard to the

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House of Commons read as follows: "As safety is my top priority, prior to IOC I asked for and was given assurances in writing by senior Ministry of Defence (MoD) personnel that the system was safe. On 22 November 2025 around 30 service personnel operating Ajax reported noise and vibration symptoms during a training exercise. The exercise was stopped immediately in line with our safety protocols and those affected received full medical care and attention, and continue to be monitored. There have not been any hospitalisations and none of the symptoms are life threatening.

"The safety of our service personnel remains a top priority for the MoD. As such, and out of an abundance of caution, I have directed a pause on use of Ajax for training and exercising, while a safety investigation is carried out."

The Ajax family of tracked armoured vehicles is produced by General Dynamics UK (GDUK) and based on a developed version of GD's ASCOD tracked platform. Ajax was initially selected in 2010, with the UK MoD then ordering 589 vehicles from GDUK in September 2014 under a fixed-price GBP 5.522 billion (EUR 6.28 billion) contract. That order for 589 vehicles breaks down into seven variants: 245 turreted reconnaissance, surveillance and joint fire control vehicles (with these three types known as Ajax variants); 93 Ares armoured personnel carrier variants; 112 Athena command-and-control variants; 34 Ares formation reconnaissance overwatch variants; 51 Argus engineer reconnaissance variants; 38 Atlas armoured recovery vehicles; and 50 Apollo repair vehicles.

However, in June 2021 it emerged that issues with excessive vibration and noise had led to trials of Ajax variants being halted from November 2020 to March 2021. On 3 June 2022 a report published by the UK House of Commons Public Accounts Committee said the Ajax programme had "gone badly wrong, with no deployable vehicle delivered to date".

ESD has been told by a highly placed source with intimate knowledge of the Ajax programme that there were three main issues that caused problems with the vehicles' development. Firstly, a significant resulted from the quality of ASCOD-based platforms being delivered from General Dynamics European Land Systems' manufacturing site in Spain, which gave the engineers at GDUK's facilities in Merthyr Tydfil in Wales a number of engineering issues.

Secondly, there was excessive tinkering with the vehicles' requirements as the project was passed from one desk to another within the British Army/MoD, leading to additional and often unnecessary engineering issues to meet the resulting design revisions.

Lastly, there was an unhelpful reticence from the overarching GD management to concede there were issues to be addressed and to grasp the nettle of addressing them.

By early 2023, however, GDUK appeared to have finally got to grips with the programme. When on 22 February 2023 then UK Defence Secretary Ben Wallace visited the British Army's Bovington Camp in Dorset, where the Ajax vehicles were being trialled, he declared, "We think the remedies are in place, we are now going through the normal trials. ... I am confident we have turned the corner on this troubled programme."

NATO AWACS partners cancel plans to buy the E-7 Wedgetail

(pf) The Netherlands and several NATO European partners have decided to cancel the alliance's programme to acquire six Boeing E-7 Wedgetail airborne early warning and control (AEW&C) aircraft, the Dutch Ministry of Defence (MoD) announced on 13 November 2025.

[Dutch MoD]

The aircraft would have replaced NATO's fleet of Boeing E-3A Sentry Airborne Warning and Control System (AWACS) aircraft, of which 14 remain of an original fleet of 18 that began operations from 1982.

"These will reach the end of their service life in 2035 and are causing noise pollution," the Dutch MoD said of the NATO E-3As.

The NATO AWACS fleet operates out of NATO Air Base Geilenkirchen, which is in the German state of North Rhine-Westphalia but literally on Germany's border with the Netherlands.

At the end of June 2025 the US Department of Defense (DoD) announced plans to cancel its own Wedgetail programme, citing soaring costs and survivability concerns, although two aircraft are still being acquired for rapid prototyping purposes. In the interim the US DoD said it would purchase more E-2D Advanced Hawkeye AEW&C platforms while redirecting its focus toward space-based surveillance solutions.

"Due to the US withdrawal last July, the replacement programme is now undergoing significant changes," the Dutch MoD stated. "Under the previous programme, both the strategic and financial foundations were lost. Therefore, the remaining countries, united in the Support Partnership Committee, halted the acquisition of the E-7. The members are now exploring alternatives for fleet replacement and seeking new partners."

Dutch State Secretary for Defence Gijs Tuinman stated, "The goal remains to have other, quieter aircraft operational by 2035. The US withdrawal also demonstrates the importance of investing as much as possible in European industry."

The demise of the NATO Wedgetail programme thus leaves the field wide open for Saab's GlobalEye AEW&C platform, which in November 2023 lost out to the E-7 Wedgetail in a procurement decision made by the NATO Support and Procurement Agency (NSPA).

While the E-7 Wedgetail is based on the Boeing 737 Next Generation commercial airliner, which has a wingspan of 35.8 m, and features a dorsally mounted Northrop Grumman Multi-role Electronically Scanned Array (MESA) radar, the GlobalEye is based on the smaller Bombardier Global 6000/6500 business jet range, which has a wingspan of 28.7 m and carries Saab's own Erieye Extended Range radar, also dorsally mounted. The smaller size of the GlobalEye increases the number of airports from which it can be deployed.

The E-7 has a range of 6,500 km, while its MESA radar has a maximum detection range of over 600 km in 'look-up' mode, when it is scanning upwards towards the horizon, or over 370 km in 'look-down' mode when looking for fighter-sized targets.

A base Bombardier Global 6500 has a range of 12, 223 km, although a GlobalEye platform would have a range a little less than this. Meanwhile, Saab states that a GlobalEye operating at 35 000 ft can detect low-level threats (at 200 ft) at distances exceeding 458 km.

The current customers of the E-7 Wedgetail platform are Australia, Turkey (E-7 Peace Eagle aircraft), South Korea and the United Kingdom.

So far the GlobalEye platform is in service with the United Arab Emirates Air Force and on order for the Swedish Air Force.

UK DragonFire DEW contract points to new way of warfare for Royal Navy

(lw) The UK Ministry of Defence (MoD) has contracted MBDA UK to fit its DragonFire laser-based directed energy weapon (DEW) onto two Royal Navy (RN) Type 45 air-defence destroyers, in a capability development offering the navy a new deterrence and defence option against a new threat in the modern battlespace.

The GBP 316 million (EUR 360 million) contract – announced on 20 November 2025 at MBDA's Stevenage site by UK Minister for Defence Readiness and Industry Luke Pollard – will deliver integration of the first ship fit by the end of 2027. In a media briefing Pollard confirmed commitment to four Type 45 ship fits in total.

Delivery of the first by 2027 is five years ahead of the programme's original planned timeframe.

In revealing the contract Pollard said DragonFire's development "is an opportunity to have a mix of capabilities to protect our warships in more dangerous times", adding, "DragonFire doesn't replace missiles: it's complementary to missiles; it provides a low-cost ability to defeat threats to those ships."

DragonFire is being delivered by a consortium of MBDA UK, Leonardo and QinetiQ. BAE Systems is supporting the programme by delivering shipborne integration.

[Crown Copyright]

The contract follows the successful completion in October 2025 of the latest testing. Conducted on the UK's Hebrides range, this involved DragonFire tracking large uncrewed aerial vehicles (UAVs), including some able to travel at speeds of up to 650 km/h, and then targeting and shooting down the UAVs, including (for the first time) in an above-the-horizon engagement process.

The contract also follows the UK Strategic Defence Review (SDR), published in June 2025, calling for delivery of DEW capabilities like DragonFire to create low-cost, sustainable alternatives to missiles.

It also follows lessons learned from recent operations – not just uncrewed systems emerging as a new threat in the modern battlespace in the Russo-Ukraine war (including in operations in the Black Sea), but Yemen-based Houthi rebels' use in the Red Sea of UAVs, uncrewed surface vessels, and ballistic and cruise missiles to target commercial and naval vessels transiting the region.

These emerging operational requirements have underlined the need for navies to increase their lethality and how that is generated, Pollard explained to media. This need, he continued, is illustrated in the DragonFire programme, including with its accelerated procurement.

"The speed and pace of implementation is what's significantly changed here," said Pollard. "That reflects the more dangerous times we're in – but also a changing approach from the government … to move funding into those cutting-edge technologies that give us the edge. That's what SDR set out very clearly, and that's what we intend to do here."

Bayraktar Kizilelma UCAV destroys jet-powered air target using Gökdoğan BVRAAM

(pf) Turkish unmanned aerial vehicle (UAV) specialist Bayraktar achieved a significant first on 29 November 2025 in the Sinop Firing Area off Türkiye's Black Sea coast when a Bayraktar Kizilelma unmanned combat air vehicle (UCAV) successfully destroyed a jet-powered aerial target using a beyond-visual-range air-to-air missile (BVRAAM).

The Kizilelma UCAV took off for its firing test, in formation with five Turkish F-16 fighters, from the 5th Main Jet Base Command in Merzifon. It then used its Aselsan Murad active electronically scanned array (AESA) fire control radar to provide a firing solution and a wing-mounted Tubitak Sage Gökdoğan BVRAAM to destroy the target.

Bayraktar asserted that its Kizilelma UCAV "has become the first and only platform in the world to demonstrate air-to-air combat capability through its latest firing test, opening a new chapter in aviation history".

That is not strictly true, as in November 2017 the US Air Force used an MQ-9 Reaper UAV to shoot down a target drone using a heat-seeking missile (probably an AIM-9 Sidewinder) during a test out of Creech Air Force Base in Nevada. However, Bayraktar can most likely claim a first successful air-to-air engagement using a BVRAAM.

[Bayraktar]

The 14.5 m-long Kizilelma UCAV has a wingspan of 10 m and features a low radar cross-section. It is expected to operate in future from the Turkish Navy's flagship, the amphibious assault ship TCG *Anadolu*, as well as the Mugem aircraft carrier currently under construction.

The turbofan-powered UCAV has a maximum take-off weight of 8.5 tonnes and features a 1.5-tonne payload capacity, with a wide range of munition options. With a maximum speed of Mach 0.9, the Kizilelma has an endurance of more than three hours.

In previous tests the Kizilelma has achieved direct hits on ground targets using Tolun INS/GPS-guided glide munitions and bombs featuring the Teber-82 guidance kit.

Zelenskyy and Macron sign major defence deal that will see Ukraine receive 100 Rafales

(pf) Ukrainian President Volodymyr Zelenskyy and French President Emmanuel Macron signed a major defence agreement at Vélizy-Villacoublay Air Base near Paris on 17 November 2025 under which Ukraine will acquire 100 Dassault Rafale fighters over the next 10 years.

The deal also includes eight MBDA SAMP/T air defence systems, each with six launch units, and hundreds of Safran Armement Air-

[V Zelenskyy X account]

Sol Modulaire (AASM) Hammer stand-off, precision-guided bombs, which have a range that can exceed 70 km and are already used by the Ukrainian Air Force, as well as air-to-air missiles.

"Today marks a significant moment, truly historic for both our nations: France and Ukraine," Zelenskyy stated on his X social media account. "Together with Emmanuel Macron, we signed a Declaration of Intent on Cooperation in the Acquisition of Defense Equipment for Ukraine. This document enables Ukraine to procure military equipment from France's defence-industrial and technological base, including 100 Rafale F4 aircraft by 2035 for Ukraine's combat aviation, SAMP/T air-defence systems, air-defence radars, air-to-air missiles and aerial bombs. Joint projects between our defence sectors will also begin this year; we will co-produce interceptor drones and work on developing critical technologies and components that can be integrated into Ukrainian drones.

"New aircraft, new reinforcements, new steps to strengthen our army and our country. I am deeply grateful to France, President Emmanuel Macron and all the French people," Zelenskyy added.

The news that Ukraine will acquire 100 Rafales of the latest operational F4 standard is significant, coming as it does after the Swedish government outlined plans in October 2025 to export at least 100 Gripen fighters to Ukraine in support of its struggle with invading Russian forces. Signing a letter of intent with Zelenskyy in Linköping, southern Sweden, on 22 October 2025, Swedish Prime Minister Ulf Kristersson stated, "Today we have signed an important Letter of Intent, marking a step towards a massive possible export deal regarding Gripen – likely between 100 and 150 fighter jets – to build a new and very strong Ukrainian Air Force."

These European fighter fleets will exceed the numbers of second-hand F-16AM/BM fighters that have been pledged/sent to Ukraine from the Netherlands, Denmark, Norway and Belgium, which total around 85.

Ukraine has lost three of these F-16s in combat.

Colombia places order with Saab for 17 Gripen E/Fs

(pf) On 14 November 2025 the Colombian government contracted with Saab for the acquisition of 17 Gripen E/F aircraft at a signing ceremony held in the Colombian city of Cali.

The order, which covers 15 Gripen E one-seater and two Gripen F two-seater fighters as well as associated equipment and weapons, training and services, is valued at EUR 3.1 billion, according to Saab, with deliveries to take place from 2026 to 2032.

Saab and the Colombian government also signed two offset agreements outlining the framework for various military and social projects. These cover a comprehensive industrial co-operation package that will benefit Colombia in areas including aeronautics, cyber security, health, sustainable energy and water purification technology.

[Saab]

Colombia announced in April 2025 that it had selected the Gripen E/F to replace its ageing fleet of around 19 IAI Kfir fighters, which were delivered from 1989 and were due to be retired in 2023.

Colombia thus becomes the second South American country to select the Gripen E/F after Brazil, which ordered 28 Gripen Es and eight Gripen Fs in October 2014 and has an assembly line for the aircraft.

Asked by *ESD* whether the Colombian Gripens will be produced in Brazil as opposed to Sweden, a Saab spokesperson replied, "We will make available all our capacity in both locations to meet the needs and delivery times agreed with Colombia.

BAE Systems, Boeing and Saab combine to pitch T-7A as RAF's next advanced jet trainer

(pf) BAE Systems, Boeing and Saab announced on 18 November 2025 that they have signed a letter of intent to collaborate on the UK Royal Air Force (RAF) fast-jet trainer programme, leveraging the Boeing/Saab T-7A Red Hawk advanced jet trainer as the core of the training system and creating a path for the three companies to support future international pilot training opportunities.

[Saab]

The companies will collaborate on a training system, integrating live and synthetic training capability and associated mission systems and will explore further opportunities for growing the UK supply chain on the aircraft. BAE Systems will lead the activity, which will include a UK-based final assembly facility.

The requirement for a new UK advanced jet trainer to replace the RAF's fleet of 28 BAE Systems Hawk T2s was set out in the 2025 Strategic Defence Review.

The original Hawk T1, which is still flown by the RAF's Red Arrows aerobatic team, first entered RAF service in 1976, with the Hawk T2, featuring advanced avionics and a glass cockpit, was introduced in 2004.

The T-7A Red Hawk, meanwhile, was selected by the US Air Force as the centrepiece of its Advanced Pilot Training System (APTS) in 2018.

It was described in a joint Boeing/Saab/BAE Systems press release as "a leading-edge, integrated-live, virtual and constructive fourth-, fifth- and sixth-generation aircrew training system that delivers a multi-generational leap in capability. Its versatile design allows it to adapt to changing technologies and mission requirements, training new pilots to fly the most advanced multi-role fighter/fast-jet and bomber aircraft in the world."

Powered by a single General Electric F404-GE-103 afterburning turbofan delivering 49 kN of thrust dry and 77 kN with afterburner, the T-7A has a maximum speed of Mach 0.975, a maximum altitude of 45,000 ft (13,716 m), a maximum angle of attack of 30° and a maximum g limit of 8 g, according to the Boeing website.

The aircraft was designed for ease of access to maintenance panels and avionics compartments and increased reliability to reduce the impact of planned and unplanned maintenance, thus increasing pilot proficiency, safety and force readiness.

The wider APTS, Boeing states, "includes state-of-the-art ground-based training, the most advanced visual display systems ever fielded in a simulator and integrated-live, virtual and constructive (I-LVC) and embedded training".

FMS order for AH-64Es will see Poland becoming largest international Apache operator

(pf) Boeing has received a Foreign Military Sales (FMS) from the US Army for AH-64E Apache attack helicopters worth almost USD 4.7 billion (EUR 4 billion) that will see the company build 96 of the helicopters for the Polish armed forces.

The other FMS customers that will receive AH-64Es under the deal are Egypt and Kuwait, although Boeing has not directly specified how many helicopters these countries will receive. However, a Kuwaiti FMS request for eight AH-64Es was approved in December 2020, while Egypt was approved in 2018 to receive 10 new-build AH-64Es alongside the upgrading of older AH-64 variants.

The Polish order, however, represents the largest number of Apache aircraft ordered outside of the United States in the programme's history. Poland is the 19th global operator of the type.

With deliveries expected to begin in 2028, the Polish Ministry of National Defence (MND) is already training pilots and maintainers on eight AH-64Ds leased from the US Army.

Through an offset agreement announced last year between Boeing and the Polish MND, local industry will play a key role in performing maintenance and support of the Polish Apache fleet. Boeing will also establish training programmes in Poland and help develop a composite laboratory.

[Boeing]

Gen Wisbach formally installed as new US Air Force Chief of Staff

(pf) General Kenneth Wilsbach was formally installed as 24th US Air Force Chief of Staff on 18 November 2025 during a ceremony at Joint Base Andrews in Maryland presided over by Department of the Air Force Secretary Troy Meink and attended by Chairman of the Joint Chiefs General Dan Caine and various elected officials and senior military leaders.

Gen Wilsbach, who was nominated for the role by President Donald Trump in September 2025, stated during the ceremony that the US Air Force remains "the strongest, most capable, and lethal force in the world" and promised to maintain US air superiority while instilling a "fly, fix, fight" mentality across the air force.

[USAF]

Gen Wilsbach, a command pilot with more than 6,200 hours in flight, has flown aircraft ranging from the F-15C, F-16C, MC-12 and F-22A. During Operations 'Northern Watch' and 'Southern Watch', maintaining no-fly zones over Iraq from January 1997 until May 2003, and 'Enduring Freedom', encompassing the war in Afghanistan and the wider Global War on Terrorism from 2001, Gen Wilsbach flew 71 combat missions.

Gen Wilsbach recently commanded Air Combat Command and was planning to retire after nearly four decades of active-duty service, but the current USAF chief of staff, General David Allvin, unexpectedly announced in August 2025 that he would retire early. Gen Allvin was confirmed as USAF chief of staff on 2 November 2023 and sworn in on the same day, meaning that the usual four-year term for the post would have seen him serve in that capacity until 2027.

Neither Gen Allvin nor the USAF gave any specific reason for him retiring early, but the relationship between US Defense Secretary Pete Hegseth and the senior US military leadership has often been fraught. For example, General C Q Brown, who was Gen Allvin's predecessor as chief of staff and went on to become Chairman of the Joint Chiefs of Staff, was fired by Hegseth, who has waged an 'anti-woke' campaign based on 'warrior ethos' in the US military, while rebadging himself as the secretary of war and the US Department of Defense as the 'Department of War'.

Michael Coulter named as new head of Hanwha Defense USA

(pf) Hanwha has appointed Michael Coulter as the new president and CEO of Hanwha Defense USA (HDUSA), underscoring the company's strategic commitment to expanding its presence in the US market, the company announced on 3 November 2025.

[Hanwha]

Coulter previously served as president and CEO of Hanwha Aerospace and Hanwha Global Defense (HGD), where he led global business initiatives. Under his leadership, Hanwha crafted a new global strategy focused on building sovereign capabilities and strengthening international partnerships while expanding its regional presence by appointing new leaders in Europe, Australia, and the Middle East. Coulter also spearheaded the establishment of HGD, which oversees Hanwha's global defence and shipbuilding initiatives spanning Hanwha Aerospace, Hanwha Systems and Hanwha Ocean.

In his new role as president and CEO of HDUSA, Coulter will focus on strengthening Hanwha's US partnerships and driving growth in this critical market, spanning both the shipbuilding and defence sectors. Remaining a board member of Hanwha Aerospace, he will continue to support the company's global strategy and collaborate with Korean and international leadership to advance Hanwha's transformation plans.

Mike Smith, who has served as president and CEO of HDUSA, will assume the role of chief operating officer (COO) and president of Land Systems.

"These appointments come as Hanwha seeks to play a greater role in the revitalisation of the US shipbuilding industry, while also supporting the growth of the US defence-industrial base as a trusted partner," Hanwha stated in a press release.

In December 2024 Hanwha Systems and Hanwha Ocean announced the successful completion of their USD 100 million (EUR 86.9 million) acquisition of Philly Shipyard: a leading US shipbuilder for commercial and government projects.

Coulter has more than 30 years of experience in national security and defence, including senior roles in the aerospace industry following leadership roles at the US Department of Defense, Department of State and US Senate. He is also a US Navy Reserve officer with command and combat experience in the Middle East, Europe, Asia and Africa. He holds an MBA from Georgetown University and a Master's in National Security and Strategic Studies from the US Naval War College.

The NATO ammunition interchangeability challenge in the land domain

Osman Tasman

This article explores the challenges of ammunition interoperability within the land warfare domain, and was written with contributions from the chairs, experts, and staff of NATO NAAG and CASG communities.

NATO is confronted with the largest and deadliest war in Europe since World War II. As a major escalation of the relatively smaller scale conflict that was on-going in Donbass and Crimea since 2014, Russia attempted a full invasion of Ukraine on 24 February 2022 but faced the heroic resistance of the Ukrainian people and armed forces. The war continues unabated since then, testing the unity and preparedness of NATO, while also changing its strategic perspectives.

The West quickly reacted with substantive support to Ukraine spanning political, humanitarian and military aid, including weaponry and ammunition. Different nations provided different types of firing platforms, as well as ammunition systems and parts, often unfamiliar to Ukrainian soldiers. Figuring out how to operate this unknown materiel while under fire constituted an additional struggle for them. The problems encountered in the field were mostly unforeseen by the supplying nations, as their soldiers were accustomed with these systems – having been fielded after a long acquisition, testing and certification process – through extensive training and use since being fielded.

Ukraine's struggle with 155 mm artillery munitions

The difficulties that the Ukrainian soldier experienced can best be described through the example of 155 mm artillery. Ukrainian artillery largely consisted of 152 mm systems, incompatible with the NATO's 155 mm. The military aid consisted of a long menu of western systems; American M777, British AS-90, French Caesar, German PzH2000, just to name a few. On the ammunition side the picture was even more complex: different nations sent different ammunition components (projectiles, fuzes, charges, and primers), which were mixed in the Ukrainian logistics chains. Immediately after the first shipments, national and NATO headquarters started to be bombarded with messages and calls from Ukrainian gunners: '...can I fire this projectile, with that charge, that fuze etc., from this gun?... and please send the firing table...'

These messages had pictures of ammunition components, some familiar to the recipients and some not. The Ukrainian struggle immediately became a huge challenge for the supplying nations, and for NATO – the standardisation authority. In fact, the Ukrainian struggle with 155 mm munitions revealed a more global challenge that the NATO community faces with ammunition interchangeability.

NATO's challenge

In the three decades-long peace delusion following the collapse of the Warsaw Pact, NATO nations' defence budgets shrunk, NATO reduced its staff, the number of Alliance Member Nations doubled, and the entire subject of ammunition lost its appeal. But the attack on Ukraine rang wake-up bells for the Alliance to realise the impact of this 30-year period on ammunition manufacture and stockpiles and to rediscover the importance of interchangeability.

155 mm projectiles. [NATO Photo Library (iStock)]

AUTHOR

Osman Tasman is a defence procurement expert, who previously served as NATO Land Armaments Advisor, and Secretary to the NATO Army Armaments Group (NAAG).

Let's continue with 155 mm ammunition to illustrate the situation. In parallel to dwindling NATO nations' artillery forces, assets, and ammunition stocks, the development of different weapon platforms and different ammunition systems continued based on national processes. Countries individually test and certify the systems they acquire and develop firing tables for their use. Countries are also often bound with guarantee and maintenance contracts that are ingeniously written by the lawyers of their defence industries to protect their interest and competitiveness, prescribing only certain ammunition and component types and brands. In principle, this does not necessarily negate NATO standardisation, which is a voluntary process, leaving room for countries to develop their weapon systems and apply novel technologies to maintain technological superiority. Standardisation should not be at the expanse of innovation and development.

Countries only test those firing and ammunition systems combinations they acquire. This leaves a huge bunch of untested combinations. A NATO staff study looking only at five main artillery producing countries indicated that they were more than 60,000 theoretical combinations, making it manifestly impossible to test all of them. This number would grow exponentially to millions, if one considers all products of all NATO and partner countries.

On the one hand, many combinations, even though they could be put together in terms of form & fit only, are obviously not viable for the targeted effect, safety, or economical aspects (for example, one would not want to fire a projectile intended for long range from an old/basic firing system). On the other hand, many other combinations cannot be discarded at first sight, and no one knows whether they would be viable or not without testing.

The questions coming from Ukraine created a flurry of consultations among the experts of different countries, facilitated by the NATO committee structure. The responses depended on whether the combination in question was tested by a country (and reported to NATO), or whether the experts could develop at least an approximate judgement, or nothing could be said.

This also sparked intense discussions throughout NATO hierarchy, and decisions were taken to intensify efforts in ammunition interchangeability, not only for 155 mm but covering all ammunition types. Before going into what these efforts are or should be, it is important to examine interchangeability from a general perspective and in a historical context.

Why is ammunition interchangeability critical?

Ammunition interchangeability is not only a logistical convenience – which, on its own, is a very important matter; it is a force multiplier. Where allied units operate side-by-side, being able to share ammunition can mean the difference between winning and losing. Supply lines are critical, and often vulnerable, regardless of whether the operations are expeditionary or high-intensity. Ensuring that allied forces can draw from each other's stockpiles allows for flexibility, redundancy, and resilience. Furthermore, interchangeability enhances efficiency in procurement, warehousing, and training; lowering costs, simplifying maintenance, and ensuring that weapons systems behave predictably and safely across national lines.

A 155 mm shell leaving the barrel. [NATO Photo Library (iStock)]

In a NATO study conducted immediately after the deployment of enhanced Forward Presence (eFP) battle groups in the Baltics and Poland, the field commanders raised ammunition interchangeability among their top priority concerns. They drew attention on the fact that some countries with small contributions do not establish and maintain supply lines and storages and rely on the logistics structures of the larger contributors, making interchangeability a precondition.

A brief history of NATO efforts on ammunition interchangeability

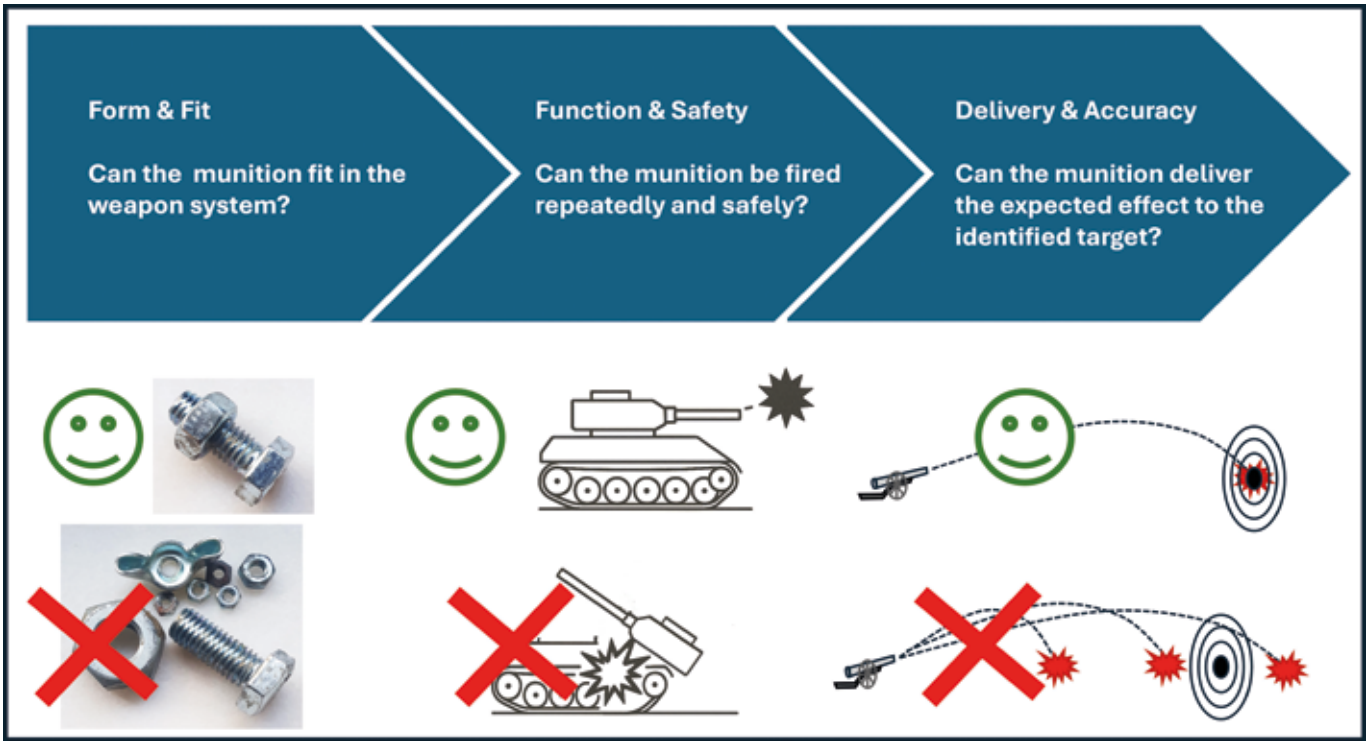
Interchangeable ammunition in NATO emerged as an imperative upon lessons from WWII. Allied forces had fought the war using incompatible weapons and ammo, which hampered common and mutual resupply, strained logistics, and increased casualties.

In the early Cold War era, facing the threat of a Warsaw Pact invasion, NATO felt the urgent necessity for common calibres. On formation of the NATO committee structure in the 1950s, the Allied Committee (AC) 116 on Small Arms Ammunition and the AC/175 on Close Support Artillery were among the first bodies to develop the necessary approaches and standards to achieve this aim in the land domain. AC/116 was the author of the 'breakthrough standard' (STANAG 2310) on 7.62 mm x 51 ammunition. Currently, more than 60 years since, NATO Qualification of 7.62 mm and 9 mm ammunition designs are processed with AC/116 NATO Design Numbers.

The NATO Army Armaments Group (NAAG, AC/225) replaced these initial structures in 1963, and still serves as NATO's technical authority for ammunition interchangeability in the land domain, alongside the Military Committee Ammunition Interoperability Working Group (I-AMMO WG) for procedural matters, and the AC/326 on ammunition safety for handling & logistics safety. In addition, NATO operates two Regional Test Centres (RTCs) in the UK (Europe) and USA (North America) for testing of small-calibre ammunition (up to 40 mm).

Current NATO approaches

NATO's founding ethos is collective defence, and the Alliance's ability to fight as one force, or interoperability, hinges not only on strategic alignment and an integrated command structure,



Three of the four key aspects of ammunition interchangeability. [Osman Tasman]

but also on logistical and technical coherence. A non-glamorous yet vital aspect of this coherence is ammunition interchangeability.

One should understand interoperability as the ability of operating together; interchangeability as exchanging similar enough systems and using them safely, with the same/similar effects; and commonality as using the same systems.
The NATO approaches to ammunition interchangeability vary according to the type and calibre of ammunition, and the corresponding need for and feasibility of standardisation and testing. Not all ammunition needs to be interchangeable. NATO efforts excludes those specific ammunition types not used by many countries, produced in small quantities, and not deemed essential for interchangeability.

To constitute the basis for ammunition interchangeability, four general aspects need to be standardised (bearing in mind that NATO uses slightly different terms for small and large calibres):

1) **Form & fit:** type, weight and geometry (the physical dimensions and shape of all applicable components). Will the round fit in the chamber?
2) **Functioning and firing safety:** Will the projectile survive the gun launch? Will the fuze properly arm? Will the propellant ignition have the correct pressure, and will the weapon system tolerate this?
3) **Delivery and accuracy:** Will the projectile fly to the intended target area? Will the ammunition hit the target with the required lethality? Noting that any variation in, for instance, chamber pressure, powder type, primer sensitivity, weight, material, centre of gravity etc. can affect performance. The tests include, *inter alia*, pressure curves, muzzle velocity, barrel wear, interior & exterior ballistics, error budgets, fragmentation patterns, and more.
4) **Handling & logistics:** Is the ammunition (and its components) compatible with the production, transportation, storage, handling, decommissioning safety procedures 'from cradle to grave'? The concerns include sensitivity against environmental factors (heat, humidity, vibration etc.), fuzing safety mechanisms, packaging, labelling, etc.

While NATO standards cover all four aspects in some munitions – like the classic 7.62 mm x 51, some munitions are only partially covered (for instance, only for form & fit) and some do not have any dedicated standard at all. Most handling & logistics standards are applicable throughout, regardless of type and size of ammunition (except for specific ammunition that requires particular handling & logistics).

However, it is important to understand that whilst NATO standards establish the foundation for interchangeability, they alone may not suffice to ensure it. Other factors beyond standardisation like the national processes and procedures that may be driven by the weapon system guarantee and maintenance contracts may pose restrictions on interchangeability. In addition, each NATO member remains sovereign regarding how and when they decide to implement the NATO standards they have ratified. Such aspects are not addressed in detail in this article.

Small arms ammunition: Infantry ammunition up to 40 mm

Over the years, NATO has very successfully established the required technical baseline for small arms calibres, including the procedures and processes for testing and NATO qualification, and the test facilities. Remaining challenges do not stem from a gap in the NATO system, but from occasional non-compliance of countries. In fact, countries may opt out of NATO qualification in cases of ammunition for which there is no need for interchangeability, like those munitions destined for purely national use, training etc.

The standardisation, as well as testing and NATO qualification of common infantry weapons ammunition (such as: 5.56 mm, 7.62 mm, 9 mm, 12.7 mm) are governed by the AC/225 (NAAG) - Land Capa-

A box of 5.56 mm × 45 NATO rounds, stamped with the NATO interchangeability symbol (AEP-97). [NATO-NAAG-LCGDSS-SG1]

The NATO Interchangeability symbol (AEP-97). [NATO]

bility Group Dismounted Soldier System (LCGDSS), Sub-Group 1 on Small Arms Ammunition Interchangeability (SG/1). The two NATO Regional Test Centres (RTC) report to SG/1 and conduct standardised tests on ammunition sent to them by countries, in accordance with AEP-97 Multi-Calibre Manual of Proof and Inspection (M-C MOPI). Such tests can also be performed in those national test facilities that are certified by SG/1 and the RTCs and monitored for continuous compliance.

Once an ammunition design passes all tests stipulated in the M-C MOPI, it is assigned a NATO Design Number (NDN, starting with AC/116 or AC/225 and then a serial) and declared interchangeable by NAAG with an official document. This ammunition is then marked with the NATO interchangeability symbol (usually on the crates).

The M-C MOPI prescribes NATO qualification and NATO production tests, the former to qualify an ammunition design, and the latter to verify the conformity of the NATO qualified design with continued manufacture through submission of a production sample annually or when production resumes. NATO Production testing is important to ensure the maintenance of production quality and to avoid deviations from the NATO qualified design, which may have severe consequences.

NATO aspires for more extensive qualification, and to that aim, the NATO Support and Procurement Agency (NSPA) Ammunition Support Partnership (ASP) limits its acquisition activities of standard small arms ammunition to NATO qualified ammunition designs only.

Indirect fire ammunition

Large calibres pose significant obstacles to the establishment of a NATO qualification system like what has been established for small arms ammunition. Obviously, cost is the primary concern, in addition to major technical problems like the replicability issues in open-air testing, and the difficulties in designating a reference weapon. As a result, rather than a NATO centralised testing and qualification process, countries conduct their individual certification activities. According to STANAG 4425 (AOP-29), countries report the results of tests and their national assessments regarding which ammunition system (projectile, fuze, charge, primer) could be safely and successfully fired from which weapon platform. AOP-29 is the compilation of these national results but does not constitute a 'NATO interchangeability certification document'. The judgement on whether this information constitutes a basis for national acquisition processes, or for interchangeability, is entirely left to countries. In addition, due to their regulations and the lack of mutual recognition, countries often conduct their own testing even for systems reported favourably in AOP-29 by another country.

AOP-29 contains information on 81 mm and 120 mm mortars, along with 105 mm and 155mm artillery. However, the information in the current document is quite old and does not contain data from systems fielded after mid-1990s. As such, the firing and ammunition systems developed over the last 30 years, and those systems in service in those Allied countries that were not NATO members at that time are not included. Based on lessons from Ukraine, the NATO expert community within the NAAG Integrated Capability Group Indirect Fire (ICGIF), Sub-Group 2 on Ballistics, Effectiveness and Fire Control Software (SG/2) intensified efforts for rapid testing of most common systems, along with collection of data from the Ukraine experience. A new digital and 'living' AOP-29 is expected to be released before end of 2025.

The main components of a 155 mm round include the projectile, fuze, charges and primer. [Osman Tasman]

Besides, the SG/2 standards portfolio covers, inter alia, test procedures and measurement methods, external ballistics (such as aerodynamics, guidance systems), internal ballistics (thermodynamics), muzzle velocity calculations, fire appreciation, error budget, firing tables, and the famous NATO SG/2 (standard) Shareable Software Suite (S4) for Fire Control. All these standards are imperative for an effective NATO Indirect Fire function, and they are employed intensively during the testing and national certification efforts. S4 even allows for virtual testing, meaning that in suitable cases, it can fill in for missing data and/or postulate test results through extrapolations from previous tests conducted with similar combinations of fire and ammunition systems.

120mm tank ammunition. [NATO Photo Library (iStock)]

Medium- and large-calibre direct fire ammunition

These types of ammunition are seldom subject to standardisation and interoperability activities in NATO. The old STANAGs on 105mm and 120mm tank guns prescribing the form & fit and basic testing parameters were cancelled more than a decade ago, due to obsolescence and for – according to the views of some countries – posing obstacles to innovation.

The situation in Ukraine prompted a reconsideration of these standards, and studies are ongoing under the NAAG Land Capability Group Land Engagement (LCGLE) for their update. In addition, there are few standards for the cannon calibres, such as 30 mm x 173 and the new 40 mm case-telescoped ammunition (typically referred to as 40 mm × 255, although the case diameter is actually 65 mm). A study is ongoing under LCGLE to identify needs for interchangeability standardisation of the most common cannon calibre ammunition, to follow with actual interchangeability work.

Obstacles to interchangeability

Despite NATO's multiplied efforts in the area of ammunition standards, there are many persistent challenges standing against this thrust. This short article will not attempt to give a comprehensive list of these challenges nor discuss each of them. Rather, it will summarise with a short list of some of the most important issues in no specific order:

- Standardisation is a long and very laborious process (but for good reasons).
- Interchangeability is expensive. Particularly the testing activities require tremendous investments and efforts.
- NATO decision making (for example, decision on what ammunition is to be standardised requires the consensus of 32 countries).
- Countries may be reluctant to share sensitive information, such as lethality data.
- Industry/country contracts may limit the use of different ammunition. Particularly in cases of large systems, which are calibrated for certain munitions; changing ammunition types would mean recalibrating fire control systems and confirming firing tables.
- Industry in many cases owns the technical data package for the munition, where it was developed to give the commercial firm a competitive advantage in the market, they would likely be reluctant to share this information with their competitors.
- National and multinational legislation (for instance, environmental laws banning some primary materials. Use of alternatives may alter ballistic properties).
- National legislation requiring national certification and varying acceptance criteria (as opposed to relying on prior tests by other countries). This is a serious issue that NATO is aiming to address through the NATO Ammunition Recognition Program (NARP).
- Batch qualification, which is hardly manageable in peacetime, may be impossible in wartime as it slows down ammunition flow and reduces flexibility.
- Potential inefficiencies in NATO committees dealing with munitions interchangeability.

How should NATO move forward?

To truly enable ammunition interchangeability, NATO must expand the focus from technical standardisation to wider operational harmonisation, and this has to be done in a holistic way. This means tackling certification, testing, and logistics integration at the Alliance level. As such, NATO should aim at a paradigm shift, with reduced and shared overall burden, minimal bureaucratic hurdles, and faster testing and certification/qualification, but without sacrificing the robustness of established methods. Rising budgets offer a unique opportunity to take such remedial actions urgently. These may include, in no specific order:

- Common certification protocols and/or systems for mutual recognition of national certificates (such as NARP).
- Use of digital technologies – including AI and block-chain – to enable faster testing and verification, marking of ammunition and data registration (for traceability to identify problem sources).
- Ensure digital information from allies can be integrated into national fire control systems across NATO to enable common fire mission data inputs.
- More multinational testing to reduce qualification/certification gaps in the most common ammunition.
- Effective exploitation of Ukraine's experience, transferring information gained in the field. Ukraine has arguably the best information on NATO ammunition interchangeability.
- Extensive use of NATO/national exercises and training events: integrating ammunition swaps into exercises to identify and address practical gaps.
- Forward deployment planning to allow for mixed stocks. This should include forward deployment of pre-certified stockpiles.
- Flexible contracts with industry, allowing for use of interchangeable ammunition.
- Standardisation of system parameters with a view to converge toward common NATO ammunition.
- Establishment of a more potent test capacity, to include large calibres. To this end, NATO is establishing a Joint Fires Centre of Excellence (JF COE) in Slovakia.
- More support of countries to conduct interchangeability work, on the fair-share principle.

In short, NATO should make the best use of increasing budgets, attention, and production capacities through a synchronised action, to include policy harmonisation, mutual trust in certification, and use of advanced technologies for ammunition production, management and practical testing, to complement the efforts being made on technical specifications.

Assessing air defence requirements for ground formations on the modern battlefield

Chris Mulvihill

Ground-based air defence (GBAD) has emerged as one of the dominant procurement priorities of the decade, with military and political leaders across Europe increasingly uneasy at the scale and variety of aerial threats revealed by the war in Ukraine. This concern reflects a hard reality: many European states lack meaningful quantities of modern air defence systems, and the deterrent value these capabilities provide has eroded as inventories have dwindled since the end of the Cold War.

To address the GBAD deficit, several nations have already begun large-scale procurement efforts to replenish or, in some cases, completely rebuild sovereign air defence capabilities. Although long-range air defence (LRAD) systems such as PATRIOT often receive the most attention, very short-range air defence (VSHORAD) and short-range air defence (SHORAD) remain the most relevant instruments for protecting ground formations. Unlike their Cold War predecessors, today's defence planners must contend with an expanded threat environment that includes not only fixed- and rotary-wing aircraft and cruise missiles, but also a diverse range of unmanned aerial vehicles (UAVs), from sub-10 kg Group 1 quadcopters to high-altitude intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) platforms and mass-produced one-way attack (OWA) munitions, to name just a few from a variety of expected threats.

Meeting this challenge will require ground formations to field far greater quantities of air defence platforms than has been typical over the past three decades. These systems must be mobile enough to accompany dispersed manoeuvre units, and critically, their engagement methods must be cost-effective against increasingly low-cost aerial threats. Achieving this balance will demand shorter procurement cycles, greater use of off-the-shelf solutions, and resistance to institutional tendencies favouring bespoke or overly complex systems.

Air defence in the Armed Forces

Air defence encompasses a range of measures designed to deter, disrupt, or destroy hostile aerial activity. The UK's Ministry of Defence (MoD) defines it as the effort "to nullify or reduce the effectiveness of enemy air and missile threats through active or passive measures", employing various assets.

Following the decommissioning of the Air Defence Anti-Tank System (ADATS) in 2011, the Canadian Army spent 13 years without any GBAD assets until receiving its first RBS 70 NG systems in 2024. While Canada is an extreme example, Ottawa was not alone in a trend that saw many downsize and even eliminate GBAD. [Canadian Army]

Ground-based assets form the backbone of many national air defence postures. Practically every military possesses a land force component, but not all have sufficient air or naval components able to shoulder any responsibility for air defence. Typically, assets like V/SHORAD systems are assigned to ground formations, whereas medium-range air defence (MRAD) and LRAD systems may sit mostly under joint or air-force control, even if ground-based.

In practice, the distribution of responsibilities varies considerably. The UK's Armed Forces, for example, rely heavily on air and naval assets for homeland air defence, with ground-based systems providing only point defence. Although the British Army fields both the Lightweight Multirole Missile (LMM) and the CAMM-based Sky Sabre surface-to-air missile (SAM) system, these assets are too few in number to guarantee coverage for deployed ground formations. In a high-intensity conflict, the Army need to rely on the Royal Air Force achieving air supremacy, or on their air assets being diverted to support ground units in the defensive counter-air role – a precarious assumption in a potential peer conflict.

The UK is far from alone. Many NATO armies face similar constraints, having reduced or disbanded air defence units during the post-Cold War peace dividend. Rebuilding organic air defence capacity has therefore become a recurring theme across Western rearmament plans.

Ensuring that air defence is not concentrated solely within air or naval components is essential. While devolving responsibility across the armed forces increases the pool of available assets, it must not encourage complacency from individual domains. Given the persistence and proliferation of low-altitude threats – particularly UAVs and loitering munitions – ground formations require organic air defence measures. This demands not only dedicated SHORAD units but also the integration of secondary air defence capabilities across a wider range of land systems, including counter-UAV (C-UAV) sensors, soft- and hard-kill systems, and distributed man-portable air defence systems (MANPADS) teams, among other measures.

Layered defence in a complex threat environment

The modern threat environment is characterised by a high density of guided munitions and uncrewed platforms, enabled by the reduction in the cost of designing and producing such aerial objects. Ground formations now face an array of threats that vary widely in size, speed, altitude, and lethality. No single system can counter the entire spectrum effectively, making a layered air defence architecture essential. This may consist of organic VSHORAD, SHORAD, and access to joint MRAD or LRAD assets.

VSHORAD

VSHORAD constitutes the final protective layer for ground forces, covering engagement ranges from a few dozen metres to over 5 kilometres, though definitions vary, with some placing it at 8 km or even as far as 10 km. Importantly, this layer does not have to rely solely on kinetic effectors. Electronic warfare (EW) systems, including static and handheld jammers, have proved effective against the proliferation of wireless micro-UAVs observed in Ukraine, namely quadcopters, disrupting their respective command links and video feeds back to their operators.

Kinetic VSHORAD options can include small arms enhanced with miniaturised fire-control systems for small arms (such as SMASH), machine gun and medium-calibre cannon-based systems, man-portable air defence system (MANPADS) and similar small-dimension missiles, along with emerging high-energy laser (HEL) and high-power microwave (HPM) effectors. The increasing availability of these systems allows non-specialist units to field credible organic VSHORAD without reliance on dedicated air defence units.

SHORAD

Dedicated SHORAD units extend engagement ranges out from approximately 8 km out to around 25 km, though again definitions vary and some place the edge of this band slightly lower than this.

Systems in this range band typically employ missiles larger than MANPADS, such as the IRIS-T-SLM, or the Tor-M2. Though having said that, there are MANPADS missiles which could be considered SHORAD class under some definitions. While MANPADS have retained broadly similar form factors, thanks to advances in rocketry, modern variants have improved range performance. Consequently, systems such as Roketsan's Sungur now offer ranges approaching 8 km, greatly expanding their coverage up from legacy designs such as Stinger whose range hovered around 5 km.

▲ **Another trend away from bespoke design is utilising air-to-air missiles shared with air forces for ground-launch use from SAM systems. NOMADS (pictured here) is stated to be able to launch both IRIS-T SLS and AIM-9X. [Kongsberg]**

▼ **MANPADS provide short-range point defence and require minimal training to use, although risks of friendly fire do necessitate command-and-control systems be in place to defog the air above combat zones. [Ukrainian MoD]**

A somewhat more typical example of a modern dedicated SHORAD vehicle would be Kongsberg Defence & Aerospace's NOMADS, which combines a self-propelled launcher armed with four missiles (notionally, these would be air-to-air-derived missiles adopted in the surface-launched role), with its own Weibel XENTA-M5 search radar. Mounted on the tracked PMMC G5 chassis from Flensburger Fahrzeugbau (FFG), the system offers the off-road mobility necessary to accompany armoured and mechanised units. NOMADS is one of several emerging Western options capable of giving ground formations an organic medium-range capability with engagement ranges of up to a claimed 15 km with the IRIS-T missile. This

is marginally further than vertical-launched implementations of the IRIS-T missile such as IRIS-T, which have previously had a claimed surface-launch range of 12 km. To account for the difference, it is thought likely that NOMADS' slanted launcher (and hence slanted launch profile) could extend range slightly by providing the missile with a more direct trajectory to target, thereby conserving some energy compared to the more arcing trajectory necessitated by vertical launch.

MRAD

MRAD and LRAD capabilities have traditionally fallen under joint or air force commands. However, several recent platforms show that medium-range systems can now deliver the mobility and independence required to operate within land formations.

The CAMM-based Mała Narew provides a quick option to procure more SHORAD systems for Poland's land forces, while the MRAD CAMM-ER-equipped Narew is expected to be delivered in the latter-half of the 2020s. [Polish MoD]

MRAD and LRAD capabilities have traditionally fallen under joint or air force command structures, and within Western forces mobile MRAD systems remain relatively scarce, in contrast to Soviet air defence developments which placed substantial emphasis on providing mobile MRAD assets to ground formations. A limited number of modern truck-mounted systems now exist that offer engagement envelopes consistent with MRAD requirements; among them is Rafael Advanced Defense Systems' Spyder All-in-One, which can employ Python-5, I-Derby SR, or I-Derby ER interceptors, achieving ranges of up to 40 km with the latter. The 'All-in-One' designation reflects the launch vehicle's integration of a telescopic mast carrying a four-sided phased-array surveillance and fire-control radar, allowing the launcher to detect, track, and engage targets independently of external sensors.

European V/SHORAD rearmament

Across Europe, many states are now procuring or reassessing their air defence requirements, but clear regional patterns remain. One of the most striking divides lies between long-standing NATO members, which often downsized ground-based air defence after the Cold War, and post-1989 joiners, many of which retained a stronger institutional memory of Soviet-style air defence integration into the land forces. Poland sits firmly in the latter category.

Poland began its air defence recapitalisation earlier than most European nations. Although it inherited a broad inventory of Warsaw Pact systems, the Polish Army maintained the Soviet-influenced principle that land forces should possess a wide mix of ground-based air defence assets. Throughout the 1990s and early-2000s, despite pressures resulting from economic reforms, Poland continued to modernise and sustain domestic industry capable of upgrading legacy systems. This effort included both the refinement of Soviet designs and their gradual adaptation to NATO standards where possible.

As a result, Poland has been able to field credible indigenous V/SHORAD systems for its land forces. The Grom and more recently the Piorun MANPADS have become central to Poland's short-range capability, with the latter having seen recent export success to the Baltics and Norway.

Alongside the CAMM-ER-based Narew programme for MRAD, the Polish Ministry of Defence is undertaking the procurement of two shorter-range systems for the V/SHORAD role. The first is Mała Narew, a CAMM-based system often classed as SHORAD (though it has a range of >25 km), intended specifically for the land force's air defence units. The second is Pilica+, which uses a combination of ZUR-23-2SP Jodek-SP self-propelled anti-aircraft gun and missile (SPAAGM) systems, armed with twin 23 mm cannons and Grom or Piorun MANPADS missiles, alongside CAMM launchers.

While the primary Narew batteries and Poland's PATRIOT units will fall under the Air Force to deliver wide area air and anti-missile defence, Mała Narew is designed explicitly, in the words of the Polish MoD, "to provide cover to troops and facilities in the area of operations". This shows intent to ensure that manoeuvre formations in the land forces receive mobile ground-based protection to complement the remaining 2K12 Kub and 9K33 Osa systems, some of which have already been transferred to Ukraine and are reaching their lifespan limits.

Germany presents a sharply contrasting example. More explicitly than even the UK, Germany dismantled its dedicated army air defence branch, the Heeresflugabwehrtruppe, in 2012. Today, the few remaining ground elements are confined to Luftwaffe anti-aircraft units equipped with Stinger MANPADS for point defence of air bases and critical infrastructure. Medium- and long-range responsibilities also lie within the Luftwaffe, which operates nine Patriot batteries – with eight more on order – and will be fielding IRIS-T SLM in the near future. As a result, the Bundeswehr currently has no meaningful organic SHORAD capability to protect its ground formations

Skyranger 30 is one of a growing trend of standalone air defence turrets that can be equipped onto a variety of wheeled and tracked platforms, with energy, size, and weight requirements being the main factors into what it can be integrated onto. [Chris Mulvihill]

and would be forced to rely on Luftwaffe assets or NATO allies during combat operations.

Berlin is attempting to rectify this through the broader rearmament initiatives launched after then Chancellor Scholz's 'Zeitenwende' (ENG: Turning point) speech in early 2022, with particular emphasis on expanding air defence capability. A key component of this effort is the acquisition of modern self-propelled anti-aircraft gun (SPAAG) systems to restore a capability comparable to the now retired Gepard. The chosen solution is the Skyranger 30 air defence turret from Rheinmetall Air Defence, with an initial batch of 19 ordered for integration onto Boxer vehicles – maintaining platform consistency with Germany's mechanised forces. In parallel, the German MoD is funding joint development with MBDA of a new VSHORAD missile designed for integration onto Skyranger turrets.

Challenges for air defence procurement

Even when defence ministries recognise the need to expand their air defence inventories, obstacles frequently arise within the procurement and industrial process itself. Many European states are now seeking to acquire identical or comparable systems at the same time and often from the same industry suppliers, resulting in growing backlogs across the sector. Production bottlenecks are particularly visible in the missile domain: Stinger output, for example, is currently limited to a reported 60 units per month, which consists of refurbished or modernised rather than new-build systems. As this production rate is shared across American, allied, and Ukrainian demands, this illustrates an increasingly bleak outlook for states that have yet to join the lengthy procurement queues forming around in-demand air defence systems.

A second structural issue lies in how procurement agencies conceive acquisition cycles. Conventional multi-year processes – drafting requirements, issuing requests for information (RFIs), conducting competitive tenders, and then running extended trials – cannot keep pace with the rapid technological turnover now occurring on the battlefield. According to an article published by David Kirichenko in the Australian Strategic Policy Institute, some battlefield technologies utilised in the Ukrainian conflict now have effective lifespans as short as four to six weeks before requiring modifications and changes to remain effective. Nowhere is this more evident than in the ongoing contest between micro-UAVs and electronic-warfare (EW) countermeasures, where each side iteratively adapts new techniques and counter-measures in a matter of days and weeks.

Against this background, the traditional model of acquiring large, bespoke systems has become increasingly misaligned with reality. The US Army's Indirect Fire Protection Capability (IFPC) programme is an example. IFPC Increment 1 began in 2004 with the goal of fielding a mobile system capable of defeating cruise missiles, UAVs, and rocket, artillery, and mortar (RAM) threats. It was intended to fill the SHORAD gap, engaging threats below the level of long-range assets such as PATRIOT and THAAD for the US Army. After more than two decades of development, several restructurings, and repeated delays, the programme's Increment 2 capability (awarded a USD 237 million prototyping contract in 2021) is not expected to enter service until 2029–30. While IFPC is perhaps atypically protracted, it is emblematic of a wider pattern in which long procurement cycles, cost overruns, and slow decision-making leave forces without timely capabilities.

Amid these challenges, some positive developments have begun to emerge, particularly from recent industry entrants. A new wave of start-ups is focusing on low-cost V/SHORAD effectors that can be produced in larger numbers and deployed in large frequency across dispersed ground formations. One such example is Frankenburg Technologies of Estonia, whose Mark 1 surface-to-air missile offers an interception range of up to 2 km and is intended to provide an affordable VSHORAD option. Given the growing use of additional weapon pods across modern armoured vehicle turrets, integrating air defence effectors of this small class could enable organic coverage within mechanised and armoured units – while simultaneously imposing greater complexity on an opponent's aerial manoeuvre planning who would have to anticipate larger quantities and widely spread SHORAD defences.

However, it remains to be seen whether or not Frankenburg's Mk 1 missile offering, with a reported cost of USD 50,000 per missile represents a sufficient price-to-performance proposition. By way of comparison, according to a December 2014 speech by IDF Brigadier-General Dr Daniel Gold, the Tamir missile used by Iron Dome had a cost of USD 50,000 per missile in 2014 (equivalent to around USD 68,425 in 2025 dollars). The Tamir missile also possesses a much greater engagement range of 10 km, compared to the Frankenburg Mk 1's 2 km. Cost per engagement represents a

Frankenburg Technologies is among several that claim to use similar design and production methods that opponents use for their novel aerial threats, relying on commercially-accessible dual-use components and promising 'good enough' specifications to provide lower costs. [Frankenburg Technologies]

critical factor in air defence planning, given the sheer scale of the modern drone threat; as seen in Ukraine, Russian aerial attacks can comprise many hundreds of Geran OWA UAVs, alongside lower numbers of cruise and ballistic missiles.

Looking ahead

Europe now faces an air threat more varied and dynamic than at any point since the Cold War. Ground formations require organic, mobile, layered air defence, and procurement cycles must accelerate accordingly to achieve this in an appropriate timeframe. The growing density and diversity of aerial threats means that air defence can no longer be confined to specific branches, nor even solely to traditional air defence units. As has been widely demonstrated in Ukraine, manoeuvre formations are persistently exposed to micro-UAVs, FPV drones and various guided munitions. No single system can provide total protection; air defence must therefore become both layered and broadly distributed across ground formations.

A central requirement is the integration of secondary air defence capabilities into non-specialist units. Infantry elements will increasingly need access to MANPADS in large quantities, optical fire-control systems on small arms, and man-portable EW devices. Armoured and mechanised formations may rely more heavily on RWSs with airburst ammunition and basic UAV detection sensors. Soft-kill options such as jammers represent an affordable addition for a wide range of platforms. With industry frequently emphasising modular and upgradeable architectures, procurement agencies should exploit the ability to retrofit in-service vehicles with additional defensive and sensor suites, ensuring ground formations can adapt as aerial threats continue to evolve.

HED on the horizon: Hybrid electric drive hovers on the cusp of adoption

Peter Felstead

Despite so much promise, hybrid electric drive technology is yet to be fully embraced by military forces, but perhaps now its time in the limelight is approaching.

French drivetrain specialist Texelis is currently working with the French MoD to deliver a HED-powered prototype of the VBMR-L Serval 4×4. [Texelis/KNDS France]

Hybrid electric drive (HED) technology, whereby powering a vehicle typically combines an internal combustion engine (normally diesel) with electrical power, is hardly new. In fact, the 81.3 tonne TOG II heavy tank, the heaviest armoured vehicle in the UK's Tank Museum, which was propelled using a Paxman-Ricardo 12-cylinder diesel-electric engine mated to two electric motor transmissions, was developed in 1940 (although this was not, of course, HED technology in the modern sense and the TOG II could not be propelled by electrical power alone).

In the 21st Century, while HED has been explored in numerous programmes by Western defence manufacturers and is widely used in civilian municipal vehicles, the technology still remains on the cusp of adoption in the military arena, even as the commercial car market increasingly adopts both HED and purely electric vehicles as Western governments chase a greener future with lower carbon emissions.

AUTHOR

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The advantages of HED

While major ground platforms propelled purely electrically are not an option for armed forces – there being no electrical hook-up points on the battlefield – HED technology, on the other hand, can take full advantage of the current military logistics train for getting diesel and petrol where it needs to be.

Moreover, the tactical advantages afforded by HED have long been recognised: silent running on electrical power alone reduces heat and noise signature; silent watch capability allows an AFV to conduct reconnaissance operations using all of its systems with minimal signature; individually driven wheels enhance tactical mobility; and the plethora of incoming power-hungry AFV systems can be accommodated. Further to this, the burgeoning use of handheld individual soldier systems – from command and control (C2)/situational awareness systems to controllers for unmanned air and ground vehicles – can be readily charged in the field by HED-powered tactical vehicles.

That said, brakes still remain on the adoption of HED. While the technology has constantly matured in the civil arena, there are still questions regarding its military adoption on a wide scale on significant battlefield land platforms. Retrofitting legacy military platforms with HED technology is liable to be expensive, meaning that only introducing whole HED-powered fleets is likely to be cost effective. There is also a training/logistics angle with the need to equip army motor pools with the training and resources required to support such new technology. Meanwhile, questions remain over whether HED technology is truly 'soldier and mud proof'. Thus far, these issues have conspired to the effect that HED technology – despite its clear advantages – has so far remained beyond the horizon for real military prime time. With incremental moves, however, that situation might finally be changing.

Early endeavours

One of the first efforts in recent decades to embrace HED technology was mounted by BAE Systems Hägglunds in Sweden. Under a contract from the Swedish Defence Materiel

An early modern foray into HED-powered armoured vehicles was BAE Systems Hägglunds' Splitterskyddad enhetsplattform (SEP) programme (8×8 variant shown). However, having accumulated no international partners for the project, the Swedish FMV cancelled it in 2008 and BAE shuttered its SEP work the following year. [BAE Systems Hägglunds]

Administration (FMV) for the Splitterskyddad enhetsplattform (SEP) programme, BAE Systems Hägglunds produced a tracked demonstrator in 2000, a 6×6 version in 2003 and an 8×8 variant in 2007.

The original motivation for adopting HED for SEP was airmobility: by using HED to move away from a traditional, linear drivetrain, the vehicle could be made shorter and consequently within the 18 tonne weight limit to be transportable in a C-130 Hercules tactical transport.

However, having accumulated no international partners for the SEP programme, the FMV cancelled it in 2008 and BAE shuttered its work on the project the following year, repurposing its HED technology for civilian projects such as a pushback tractor for the A380 airliner, a mining truck and a cargo crane.

Asked by ESD about its ongoing HED initiatives, BAE Systems Hägglunds noted on 1 December 2025 that it has continuously invested in HED technology since the SEP programme, with investments in both the commercial and military realm.

"The military customers' interest in adopting electric drive technology is definitely increasing and BAE Systems Hägglunds is ready to deliver," stated a company spokesperson. "The Sirius programme, running with Luleå Technical University, is one public example. Sirius is an annual reoccurring programme, training students in programme management, with the goal to design and test a hybrid electric drive for the Bv206 [tracked all-terrain vehicle]".

The Bradley HED programme and XM30

Meanwhile, BAE Systems in the United States won a USD32 million contract in July 2020 to integrate HED technology into two M2A2 Bradley infantry fighting vehicle (IFV) testbeds. The deal was awarded by the US Army's Rapid Capabilities and Critical Technologies Office (RCCTO), working closely with Program Executive Office Ground Combat Systems (PEO GCS) on the effort, with defence technology house QinetiQ also involved as a partner in the programme.

The first vehicle was scheduled start its initial contractor testing at the end of January 2022, with the more formal programme testing with the US Army beginning in March 2022. By June 2022, the Bradley HED vehicles were set to begin assessments at Aberdeen Proving Ground, Maryland, before moving on to Yuma Proving Ground, Arizona, for additional field assessments.

Over the last couple of years the Bradley HED programme went somewhat quiet, however, but the Bradley IFV's replacement, the XM30 Mechanized Infantry Combat Vehicle (MICV) – formerly known as the Optionally Manned Fighting Vehicle (OMFV) – is slated to have a HED system. In June 2025 the two remaining contenders for this programme – General Dynamics Land Systems (GDLS) with a clean-sheet XM30 prototype (currently lacking a publicly-available designation) and American Rheinmetall Vehicles (ARV) with a modified variant of the KF41 Lynx IFV – passed the programme's critical design review and advanced into the competition's prototyping phase.

To replace to US Army's Bradley IFVs under the XM30 Mechanized Infantry Combat Vehicle (MICV) programme, American Rheinmetall Vehicles is proposing a modified variant of the KF41 Lynx IFV featuring an Allison eGen Force HED transmission. [American Rheinmetall]

The ARV Lynx XM30 design features an Allison eGen Force HED transmission, which is scalable to 68 tonne (75 US ton) tracked vehicles, potentially making it capable of meeting future main battle tank (MBT) requirements. On 5 December 2025 a GDLS spokesperson confirmed to ESD that its XM30 prototype will feature "a parallel HED solution that meets or exceeds the XM30 requirements for mobility, silent operations and electrical power growth margins".

The prototype build and test phase for the XM30 programme began in June 2025 and runs until mid-2027. Production and fielding, beginning with down-select to a single vendor and approval of low-rate initial production (LRIP), is slated for late 2027.

A full-rate production decision is expected by FY 2030, with initial operational capability for the M30 expected in FY 2032.

Cracking a difficult nut: Heavy AFVs

In February 2022 the head of mobility for Anglo-German joint venture Rheinmetall BAE Systems Ltd (RBSL), Marcus Potter, told this author that the company had decided to grasp the nettle of providing a HED solution for MBT-sized armoured vehicles.

"The reason we went for the heaviest-weight vehicle," Potter said at the time, "was because that presented the greatest challenge. Our understanding was that if we could implement a system on that vehicle, then it made all other vehicles relatively easy in comparison."

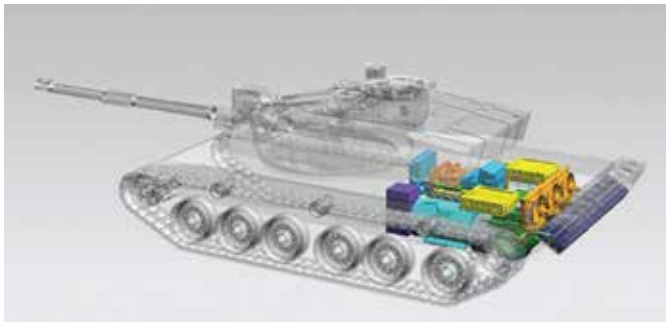
On 2 December 2025 ESD caught up with Potter to see how things had developed. "We've been investing in HED technologies for a long while now, as I'm sure a few other companies have, and we've now ramped up some of the concept work we're doing," said Potter. "We're certainly now looking a lot more serious from the studies in the past, and having discussions with suppliers at conferences, to now actually looking to get proposals from suppliers so that we can have a look at what various suppliers have to offer."

Potter noted, however, that any HED solution has to compete against traditional, mature mechanical solutions. Regarding the maturity of HED technology, Potter said, "In the commercial and automotive sectors, the TRL levels of the actual individual components are very high; we're into technology readiness levels of eight or nine; however, in a military environment they're fairly low in maturity." He added, though, *"I think a lot of the commercial hardware is very applicable to use in the defence environment; the component count is significantly reduced and the actual devices themselves are very robust. So there has been testing of certain systems that have been tested in deep wading environments and shown that they work perfectly well in those environments."*

Potter noted that HED systems in military vehicles would already be afforded a good degree of protection, while their environmental conditioning has already been tested to a high standard level in adjacent industries. Cost, however, remains a significant challenge, both in terms of the programmatic cost for introducing a HED system and the through-life costs of maintaining it.

"What we're looking at – and this has been a major focus of our investigation over the past years – is how can we get those costs where they're competitive or even lower than the current mechanical systems," said Potter. "That's what we've been heavily investing in over the past few years, so that we can aim towards getting every single advantage for the hybrid drive. Current figures are showing that that is very much a case where we can get a competitive system that is at least similar, if not lower, in total through-life cost than the current mechanical systems; that is probably our top priority."

Potter also noted that power density is an important factor in implementing HED technology: *"What we've seen, certainly over about the last 10 to 15 years, is that, where 15 years ago we were talking about power densities for the motors somewhere between one and two kW per kilogramme, nowadays the latest figure I've been looking at is something as high as 59 kW per kilogramme; we're talking about 30 times higher than it was 10 to 15 years ago. So those power densities really feed into saying, 'Well, 15 years ago it was not really feasible to power a main battle tank using the electric motors; you had to go for a fairly unique transmission layout to be able to power that.' Fortunately now, with that increase in power, that suddenly brings us into the realms of saying, 'Well, actually, we can power it just using the electric motors.' So there's certain aspects that have really changed in the EV market that, keeping a track on the advancements in that market, have allowed it now to start to feed into the military area."*



An RBSL schematic showing a HED concept for a British Challenger 2 MBT. [RBSL]

Such increases in power density have implications not just for new HED-powered military platforms but also retrofitting existing, traditionally powered fleets.

"Obviously, with a retrofit you're looking to replace the current powerpack and effectively save through-life cost to the end of the programme," Potter noted. "Now that is a very ambitious target, probably even more ambitious than a new vehicle, but that's one of the things we've been looking at," he said, stressing that HED solutions "have got to be cost competitive".

The power output of the latest HED systems is a significant plus point, especially in relation to feeding electrical power so other systems in the field. Potter noted that, while current military auxiliary power generators can deliver up to about 30 kW of power, HED systems, depending on their architecture, could deliver "something like 300 kW all the way up to well over 1500 kW of power": a capability he cited as "game changer".

While Potter conceded it remained debatable as whether such power levels would be required in the future, the advent of battlefield systems such as laser-based counter-unmanned aerial vehicle systems would suggest that they are.

Potter also emphasised that systems integration is a vital factor. "That's where the likes of RBSL come to the forefront and really enable these solutions to happen," he said, noting that how HED technology can be seamlessly integrated into an existing platform is key to making it a reality. For this, he said, you really need to build something.

"We would always start off with the CAD/CAM side of things. We'd look at the various new manufacturing technologies that that are available, so we can get the best, optimum integration of that system into the platform," said Potter, *"but nothing beats hands-on being able to see that into a vehicle, and noth-*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ing beats seeing the vehicle in operation as well. Some of the performance figures we we're talking about could blow minds. It's so special in terms of where we could be really driving the performance of these vehicles into a new regime."

Tactical military vehicles

At the easier end of the ground platform spectrum – tactical military vehicles – numerous developments from Western manufacturers have emerged in recent years, with French companies very much at the forefront of this effort.

French drivetrain specialist Texelis is currently working with the French MoD to deliver a HED-powered prototype of the VBMR-L Serval 4×4. [Texelis/KNDS France]

The first foray into HED technology by French military vehicle manufacturer Arquus was in 2016 when the company presented the VAB Electer: a HED-powered variant of the French Véhicule de l'Avant Blindé (VAB) 6×6 armoured personnel carrier (APC).

The Scarabee tactical 4×4, which was soft-launched in 2018 and officially presented in 2021, has been billed by Arquus as the "very first modern hybrid-drive armoured vehicle", but no sales of the vehicle have been secured thus far. [Arquus]

Then, after a discreet unveiling at the Eurosatory defence exhibition in June 2018, Arquus officially launched the Scarabee tactical 4×4 at the 2021 IDEX defence exhibition in Abu Dhabi. Billed by the company as the "very first modern hybrid-drive armoured vehicle", the Scarabee – a HED-powered would-be successor to previous French tactical reconnaissance vehicles such as the Panhard VBL – features a hybrid powerplant based on a V6 VMM diesel engine providing 224 kW (300 hp) coupled to a 400 V 70 kW electric motor. However, thus far no sales of the Scarabee have been secured and ESD understands that, since the sale of Arquus by the Volvo Group to Belgian defence company John Cockerill Defense was completed in July 2024, Arquus might no longer have proprietary, low-cost access to the Volvo HED technology on which the Scarabee was largely based.

Arquus has also worked on a HED-powered version of the Véhicule Blindé Multi-Rôle (VBMR) Griffon 6×6 APC developed and manufactured by KNDS France (formerly Nexter Systems): the main successor to the VAB.

A key French company in relation to the future of HED technology is powertrain specialist Texelis. Working in conjunction with Nexter/KNDS France to produce the VBMR-L Serval 4×4 that began entering service in 2022, Texelis is responsible for all of the Serval 4×4's below-the-hull automotive systems, including powertrain, driveline and the electric architecture of the mobility system. Crucially, when Texelis designed these systems, realising that the vehicle would probably be in service for the next 30 to 40 years, it ensured that the vehicle was effectively 'HED ready'. Texelis subsequently approached the French Ministry of Defence (MoD) to propose a pilot programme to implement HED technology into the Serval and this effort began in in May 2024.

Texelis opted to develop a hub drive unit (HDU)/in-wheel motor as a HED solution in partnership with QinetiQ. The HDU combines in a very compact package a 55 kW electric motor, a gearbox, a braking system and a cooling system, totalling 400 kW available energy on board, and is powered either directly by a small electric generator or via a battery. This approach frees the vehicle from the usual architecture and allows for individual piloting of each wheel.

As Lydia Zebian, deputy director of Texelis Defense and director of programmes at Texelis, explained to ESD on 5 December 2025, the initial phase of the pilot HED-powered Serval project – to determine the potential of the concept – has now been concluded. The first objective of this looked at feeding all of the potential future energy-hungry payloads, while a second objective was logistics optimisation: providing a 30% increase in range and thus reducing the logistics chain requirements of keeping tactical vehicles supplied with fuel.

"There's also less maintenance, Zebian noted, "because, for example, the braking system is fully encapsulated into the hub drive unit and so protected from the external environment. And moreover, with the regeneration of braking energy you use the brakes less, the pads have less maintenance, almost no maintenance. You have fewer mechanical parts: no transmission, no drive shafts, no prop shafts, no oil in the differential, no oil in the gearbox because there's no longer a gearbox, so then you have much less maintenance."

While Texelis started out with HED components provided by QinetiQ, the company has now developed its own. "We started

from a QinetiQ concept because they had 20 years of research behind this and different design evolutions," Zebian explained. *"However, it was not finished; a few technical problems needed to be solved and it could not be industrialised. So we started from that point, but our strength at Texelis is to improve concepts and make them possible in a production line; this is our core business. We are not only design company; we make products. So to industrialise such a good idea was our interest, and that's why the partnership with QinetiQ worked very well."*

The next phase in the Serval project is to develop a HED-powered vehicle. "The French MoD wanted to explore each benefit of the technology up to the maximum," said Zebian. He continued, *"now that the potential is known, the next phase is about limiting vehicle specification to be optimised at the correct level, so we are concentrating the need on real practical benefits, maximising only three or four criteria and not playing for 10 or 15 criteria. So that's what we're doing now, with the objective of developing and outputting a real prototype with these key specifications."*

Texelis first intends to develop a demonstrator vehicle to showcase the most critical aspects of the project. As usual with new technology, this will then be matured and tested further before a prototype is handed over to the French armed forces, which will then conduct their own testing. A prototype should be available in less than three years' time, although Texelis intends to show a lot more at the Eurosatory exhibition in Paris in June 2026.

Zebian said that the HED technology being produced for the Serval could equally be applied to numerous other vehicles, including heavy armoured vehicles, to deliver advantages such as silent drive, accommodating power-hungry payloads and to enhance the capacity for such vehicle to be subsequently robotised.
HED technology, noted Zebian, "makes the robotisation easy because you pilot everything independently. Each wheel is directly piloted by its wheel station controller and you can imagine very easily how to drive this vehicle without any driver inside. That's the next step."

Zebian added that Texelis is additionally working on a HED project related to an 8×8 armoured vehicle. "An 8×8 could be approached, say, in three years if it's a standard vehicle with drivers inside." A fully robotised vehicle with an HDU-based mobility system, she added, could be approached in seven or eight years.

A Texelis HED system hub drive unit. To the left is where the wheel would be attached; to the right is a control/energy panel that could be placed anywhere inside the vehicle. [Texelis]

Regarding battery technology, Zebian said that "it's really going very fast in this area" and that batteries in HED-powered vehicles do not have to be huge, with their size all coming down to customer requirements such as silent drive, powering onboard systems and offloading power to other platforms. "The battery technology is becoming more and more robust and used by other industries, so we're not starting from zero," said Zebian.

In a final point Zebian argued for the efficacy of serial HED systems, as used by Texelis, as opposed to parallel HED systems that retain the traditional gearbox and mechanical transmission drive of a traditionally powered vehicle in additional to an electrical powerplant.

"The parallel hybrid concept is not bringing too much added value for defence, at least compared to a serial hybrid, because you add the constraints of the conventional driving and the constraints of hybrid technology; you add mass with the parallel hybrid," Zebian explained. "The parallel hybrid for some people is just reassuring. They don't get rid of the mechanical systems so they are less afraid about the new technology, [but] when you compare with conventional mobility, if you have a problem on your traditional engine then the vehicle cannot move anymore. In the electrical propulsion concept we propose, if you have one wheel where the electrical engine has a problem, you have three other wheels, or seven other wheels, that can still move on."

In the United States, as the original provider of the Joint Light Tactical Vehicle (JLTV) to the US military and others, Oshkosh Defense unveiled the HED-powered eJLTV in January 2022. This vehicle improved the standard JLTV's fuel economy by more than 20%, provided battery capacity of 30 kWh with opportunity for growth, and eliminated the need for a towed generator by providing export power capacity of up to 115 kW.

AM General, having sourced HED technology from QinetiQ through a partnership announced in November 2021, unveiled at the Association of the US Army (AUSA) show in Washington, DC, in October 2023 the Humvee Charge hybrid electric vehicle (HEV) concept: a plug-in HEV variant of the ubiquitous Humvee tactical military vehicle. This features three drive modes – internal combustion engine (ICE) only, a hybrid ICE and electric power mode, and purely electric drive – and offers significant improvements in vehicle acceleration through the combined use of the ICE and electric motor while also offering improvements in range and fuel efficiency.

Additionally, having taken over production of the JLTV from Oshkosh Defense through a competitive contract awarded by the US Army in February 2023, AM General also showcased its JLTV A2 model at AUSA 2023 featuring an upgraded powertrain with a simplified electrical architecture designed to accommodate future hybridisation.

At the AUSA exhibition in October 2024, GM Defense unveiled its Next Generation Tactical Vehicle-Hybrid (NGTV-H) proto-

type. Based on the Chevrolet Silverado 3500HD ZR2 truck, the Next Gen combines GM's 2.8L Duramax turbo-diesel engine with a 12-module battery pack capable of storing approximately 300 kWh of power in addition to drive motors for the front and rear axles.

With its total energy output of 300 kWh, the NGTV-H can support several days of silent watch operations and between 145-209 km (90-130 miles) of silent drive, depending on road conditions (off- or on-road), weather and speed. Using both sources of power on the vehicle, GM Defense anticipates it has a range of around 483 km (300 miles), given that the diesel engine can recharge the batteries twice. The battery can go from a 20% to 80% charge in under an hour. This vehicle was tested by the US Army's 10th Mountain Division during the 'Combined Resolve' exercise in Bavaria, Germany, in early 2025.

Meanwhile, in the last quarter of 2024, GM Defense completed the first prototypes of a hybrid variant of its Infantry Squad Vehicle – Heavy (ISV-Heavy). Based on the Chevrolet Colorado mid-size pickup truck, the ISV-Heavy is a heavy-duty truck that uses the same turbo-diesel as the baseline ISV, but the hybrid variant is equipped with a 100 kWh battery bank for silent

A hybrid-powered GM Defense ISV-Heavy being trialled by the 25th Infantry Division's 3rd Mobile Brigade in Hawaii in October 2025 as part of the US Army's Transformation in Contact effort. [GM Defense]

operations and to supply electrical energy on the battlefield.

Hybrid ISV-Heavy prototypes were first evaluated by the US Army in January/February 2025 at its Joint Multinational Readiness Center in Bavaria, Germany. Then, in October 2025, GM Defense deployed two hybrid ISV-Heavy vehicles to the US Army Joint Pacific Multinational Readiness Center (JPMRC) in Hawaii. Here they were trialled by the 25th Infantry Division's 3rd Mobile Brigade as part of the US Army's Transformation in Contact effort, whereby the army seeks to operationally evaluate promising technologies and solutions for potential adoption and procurement.

The central objective of hybrid ISV-Heavy vehicles participating in the JPMRC rotation was to facilitate a crucial feedback loop, providing both the US Army and GM Defense with invaluable insights into the future of military mobility. The participation sought to test the hybrid ISV-Heavy in challenging, realistic operational environments to quickly identify areas for refinement and to ensure the platform delivers maximum warfighting capability. It also provided the 25th Infantry Division with access to next-generation commercial off-the-shelf (COTS) technology, informing how best to modernise the force.

"Participating in training exercises like the ones at JPMRC are essential to the GM Defense model, reinforcing our commitment to co-development with our military customers," a GM Defense spokesperson told ESD on 8 December 2025. "The real-time feedback gathered from soldiers using the vehicles in the field directly informs our engineering, research, and development process, ensuring our products meet the demands of the warfighter."

In Switzerland, where General Dynamics European Land Systems – Mowag (GDELS-Mowag) has been developing hybrid concepts for its Eagle 4×4 patrol vehicles in recent years, an Eagle V Hybrid technology demonstrator was presented at the company's test grounds in Bürglen in July 2025.

Just like the conventionally-powered Eagle V, this vehicle has a 210 kW six-cylinder diesel engine, but also features a 370 kW electric drive (two electric motors each developing 185 kW) and a 56 kWh battery. The vehicle thus has a peak power output of 680 kW, allowing the 8.5-tonne Eagle V Hybrid to accelerate from 0 to 50 km/h in 4.1 seconds. In 'silent drive' mode, which uses battery power alone, this vehicle has a road range of 45 km.

Further afield, in South Korea, Hanwha Aerospace has also been developing multiple HED-related technologies. In response to questions about these, Daewon Kim, senior manager of IFV business development within Hanwha Aerospace's Land Systems Business Team 2, outlined two specific projects to ESD on 4 December 2025. The first project, funded by the Korea Research Institute for Defense Technology Planning and Advancement (KRIT), relates to cross-power flow topology and control architecture and in relation to the development of HED transmission and control technology capable of propelling a 25 tonne tracked vehicle. With joint funding from Hanwha Aerospace this is to be installed on a heavy unmanned ground vehicle, with performance verification planned.

The second project is development of a HED propulsion system for Hanwha Aerospace's Tigon wheeled APC in an effort jointly funded by KRIT and Hanwha Aerospace, although Kim noted that "the e-TIGON development programme is in its early stages and detailed requirements are still being finalised".

Kim additionally noted that "a prototype capable of demonstrating a hybrid electric propulsion system for a 25 tonne tracked vehicle has been completed and we anticipate unveiling it at various exhibitions starting in 2026."

"We plan to gradually advance the development programme from a diesel-hybrid to a full-EV combat vehicle," Kim added. "This will be related to technological advancements in power sources and once technologies such as batteries and hydrogen

fuel cells mature to a level suitable for weapon systems. We will have interfaces ready for immediate application."

The UK's TD6 project

In 2018 the British Army initiated the Technology Demonstrator 6 (TD 6) project to experiment with HED technologies on three in-service platforms: a Jackal 2 4×4 high-mobility patrol vehicle, a Foxhound 4×4 protected patrol vehicle and a MAN HX60 4×4 6 tonne tactical truck.

Initially tested at UTAC's site at Millbrook, Bedfordshire, in 2022 the vehicles moved on to the British Army's Armoured Trials and Development Unit at Bovington in Dorset, where more battlefield-relevant missions were rehearsed and the vehicles' performance compared against their conventionally powered counterparts.

A HED-powered Jackal 2 4×4 high-mobility patrol vehicle and Foxhound 4×4 protected patrol vehicle on display at the DSEI defence exhibition in London in September 2021. Along with a HED-powered MAN HX60 4×4 6-tonne tactical truck, these vehicles were the focus of the British Army's TD 6 project to experiment with HED technology on in-service platforms. [P Felstead]

The TD 6 initiative has now been concluded, with a UK MoD spokesperson telling ESD on 3 December 2025, "TD 6 was an initial trial in the electrification of existing vehicles, which provided the British Army with experience and lessons which we are incorporating into the development of future capability." The MoD spokesperson added that "Extensive work is already underway across defence on incorporating innovations that can create battlefield advantage and reduce carbon emissions."

The spokesperson further noted that in 2024 the British Army "invested GBP 14 million [EUR 16 million] in battlefield electrification, with a further GBP 13 million programmed, which will inform hybrid-electric requirements for future capabilities.

"Electrification is one of five Army Futures Research and Experimentation strategies directing the technology-driven transformation of the army," the spokesperson added. "The army has conducted a number of power/energy R&D activities, including smart microgrids and advanced energy storage. These technologies are on a pathway to exploitation within the future equipment programme and advance the army's thinking around operational energy."

Immediate requirements

On 13 November 2025 GM Defense, as part of Team LionStrike (also comprising NP Aerospace and BAE Systems), demonstrated its vehicle contenders for two key procurement initiatives under the UK MoD's upcoming Land Mobility Programme (LMP) – the General Support Utility Platform (GSUP) requirement and the Light Mobility Vehicle (LMV) requirement – to replace the British Army's fleet of various Land Rover and Pinzgauer wheeled tactical vehicles. The vehicles presented were a GSUP solution based on the Chevrolet S10 Work Truck, the Silverado 1500 ZR2 and the Infantry Squad Vehicle – Utility (ISV-U).

Asked by ESD at that event if the British Army had shown an interest in including a HED capability in its future LMP fleet, JD Johnson, GM Defense's vice president for global solutions and strategy, said that, although a request for proposals was yet to emerge, the British Army had not thus far expressed any HED-related requirements.

At that event Bradley L Watters, vice president for international sales within GM Defense's Government Solutions & Strategy division, told ESD of the British Army, "They know they want the technology, but for now they need to get through replacing the Land Rovers and Pinzgauers."

On the cusp

The aforementioned projects are not a comprehensive list of HED- and hybrid-powered initiatives regarding military vehicles, but their number attests to the fact that the technology is being increasingly developed and trialled. While the advantages of HED technology have been apparent for decades, the brakes on its adoption – such as the limits of battery technology and the maturity of HED components in a military environment – are increasingly dissipating. However, it is perhaps the burgeoning number of power-requiring platform-based systems on the battlefield – such as high-power radios, IED jammers, battle management systems (BMSs), sensors, remote weapon stations (RWSs) and counter-unmanned aerial vehicle (C-UAV) systems including power-hungry high-power microwave (HPM) and high-energy laser (HEL) weapons – as well as the need to off-port energy to other soldier-based applications, such as unmanned air and ground vehicle controllers, radios and situational awareness systems, that could ultimately push HED technology over the edge into true battlefield adoption.

Amphibious armoured vehicles for marine infantry: Enhancing capabilities with next-generation technology

Sidney E. Dean

Several nations are introducing next-generation armoured amphibious vehicles, preserving the capability to conduct amphibious assault operations if required.

While the last major amphibious assault was conducted during the Korean War, the major powers maintained strong amphibious capabilities throughout the Cold War, and continue to do so today. Numerous regional powers also recognise the value of retaining this option, which offer different approaches to amphibious operations. Options include landing vehicles or dismounted personnel by landing craft or boat, or airlifting them from ship to shore via helicopter.

Amphibious armoured vehicles are designed to transit the open ocean when moving from ship to shore. Here USMC ACVs prepare to re-embark on their amphibious assault ship in the Pacific Ocean off the California coast, on 14 September 2025. [USMC/Cpl Joseph Helms]

The most demanding scenarios require launching amphibious-capable armoured vehicles from specialised warships which remain well seaward from the surf zone (open ocean deployment). Once on land, these vehicles serve as armoured transports and fighting vehicles, providing mobility and protection for the embarked marine infantry. Many armed forces currently utilise amphibious armoured vehicles which were designed decades ago. Next-generation vehicles are now entering service or being developed in several leading nations.

Amphibious Combat Vehicle (ACV)

The US Marine Corps (USMC) is replacing its 1970s-era Assault Amphibious Vehicle (AAV7A1) with the Amphibious Combat Vehicle (ACV), which self-launches from the well-deck of amphibious ships in open ocean waters. In addition to ship-to-shore operations, the ACV will conduct shore-to-shore manoeuvres. In other words, once landed the vehicle can re-enter the water and move laterally along the coast or cross bays and inlets to reach another landing point. This independence from ships for local redeployment is particularly relevant for distributed littoral operations, 'island hopping' and expeditionary advanced base operations (EABO) scenarios in the Indo-Pacific theatre. Full rate production (FRP) was authorised in December 2020. The original procurement goal of 1,122 was reduced to 632 in 2023 to align with overall force structure changes. The 300th unit was delivered to the USMC in August 2025.

The 32 tonne 8×8 ACV is designed and produced by BAE Systems in partnership with Iveco Defence Vehicles, and is derived from the Iveco SuperAV design. The blast-resistant armoured hull provides mine, IED, kinetic energy (KE), and overhead protection as well as an automatic fire suppression system. Top road speed is 105 km/h; in the water it reaches 11 km/h (6 kn). The Iveco H-Drive System delivers all-wheel trac-

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tion both on land and in the surf zone. Maximum range from ship to shore is 22.2 km (12 NM), followed by circa 400 km on land. The ship-to-shore range is less than that of the AAV7, reflecting the USMC's doctrinal shift regarding over-the-horizon launch of amphibious vehicles. Given the increasing capabilities of modern shore-based weapon systems, the Navy-Marine Corps planners concluded that they would need to maintain a 185.2 km (100 NM) range from the landing zone, which is not achievable for amphibious vehicles. The 12 NM standard was accepted as adequate for intercepting incoming anti-ship missiles while reducing the time vehicles are subject to the dangers of ocean transit.

Performance and safety

While the Corps notes that the new vehicle offers much improved performance and survivability on land, stability in the water has emerged as an issue. As a wheeled vehicle with a V-shaped hull, the ACV has less reserve buoyancy and different displacement than the tracked, flat-bottomed AAV7. The length-to-width ratio of the ACV, at circa 3:1, is also somewhat less favourable for stability than the AAV7's 2.5:1 ratio. According to BAE Systems, the ACV can operate in conditions up to Sea State 3 and through a 2.75 m (9 ft) plunging surf. However, following mishaps during training in 3.7 m plunging surf in 2022, the USMC imposed an interim limit of 1.25 m breaker height for safe operations. In September 2024, the USMC codified the new Assault Amphibian Training and Operating Procedures Standardization manual, which – until further notice – restricts operations to open ocean and to protected waters (such as harbours or basins) but prohibits transit of the more dangerous surf zone. These restrictions have been maintained during repeated overseas exercises involving the ACV since 2024. To be precise, the USMC continues to express confidence in the vehicle and its ultimate deployability. The mishaps are attributed to an early failure to recognise "significant differences between the safe operating procedures of the ACV and its predecessor", according to an April 2023 USMC statement. A dedicated transition training unit is developing new operational guidelines and procedures as well as training standards in order to ensure safe and effective handling during future real-world missions.

▾ **An ACV of the 11th Marine Expeditionary Unit launches from amphibious assault ship USS Boxer (LHD 4) in the Pacific Ocean, on 14 September 2025. [USMC/Cpl Joseph Helms]**

Mission variants

Four ACV variants are planned; most require a three-person vehicle crew consisting of commander, driver and gunner.

The personnel carrier variant (ACV-P) can carry 16 personnel (3 crew and 13 Marine dismounts) and two days of combat equipment and supplies. It mounts a remote weapon station (RWS) with either a 12.7 mm heavy machine gun (HMG) or a 40 mm automatic grenade launcher (AGL), and is designed to accommodate additional direct and indirect fire weapons in the future. Initial operational capability (IOC) of the ACV-P variant was declared in November 2020.

The command-and-control Variant/C2 (ACV-C) accommodates seven battle staff personnel. Mission systems include a modular digital network vetronics system, a battle management system, and a digital Satcom HF/VHF communications suite. The vehicle integrates the Target Handoff System Version 2.0 (THSv2), a tablet-based fire support/targeting solution which plugs into the vehicle's C2/communications system to digitally transmit target data to artillery, mortars, naval gunfire, and close air support platforms. The THSv2 can also integrate with the Army/USMC AFATDS (Advanced Field Artillery Tactical Data System) to coordinate fire support operations. A 7.62 mm MG is mounted for self-defence. IOC was declared in October 2024.

The ACV-30 fire support variant is equipped with a 30 mm Mk44 Bushmaster II chain gun mounted in a stabilised Kongsberg RT-20 remote controlled turret; the main gun is augmented by a coaxial M240 machine gun (7.62 mm). In addition to infantry targets, it can defeat unmanned aerial vehicles (UAVs) with airburst munitions and can fire armour-piercing rounds to engage light to medium armoured vehicles including some infantry fighting vehicles (IFVs). There is planned growth potential for active and passive protective systems as well as missile and rocket integration. The ACV-30 accommodates 11 personnel (3 crew and 8 dismounts). The first FRP order for the ACV-30 was placed in April 2025. IOC is anticipated in the 3rd Quarter of FY2026.

The recovery variant (ACV-R) will provide battlefield maintenance and recovery capabilities to the assault amphibious battalions. It will be equipped with an extensible rotating crane, a heavy-duty winch, a battlefield welding and cutting kit and a 7.62 mm MG. The ACV-R will have two vehicle crew plus two maintenance personnel. Three production representative test units are expected to be delivered in FY2026, with planned IOC in early FY2028.

Zaha Marine Assault Vehicle (MAV)

Türkiye is acquiring the Zaha marine assault vehicle (MAV) for the Amphibious Marine Brigade. Produced by FNSS Savunma Sistemleri, the 30 tonne tracked vehicle is designed to launch from amphibious assault ships during the beach-landing phase of amphibious operations, transporting marine infantry to shore under armour protection at circa 13 km/h (7 kn) speeds via twin waterjet propulsion. The manufacturer states that the vehicle offers seaborne, land-to-sea and shore-to-shore capabilities, and can

The Zaha MAV in sea trials. [FNSS]

handle Sea State 4. The Zaha's specific range from ship to shore is classified and has not been made public. As explained by an FNSS spokesperson, the vehicles are qualified based on a combination of sea and land performance; the overall operational range officially recorded for ZAHA is 700 km. FNSS emphasises the stability of the completely sealed, flat-bottomed vehicle hull during the waterborne phase, including the capability to self-right in case of capsizing during harsh sea conditions. Once on land, the Zaha can reach road speeds of 70 km/h and has a range of 500 km. It is intended to operate in conjunction with main battle tanks (MBTs) and other mechanised combat vehicles.

The MAV is currently deployed on the Turkish Navy's Landing Helicopter Dock (LHD) TCG Anadolu. The first public imagery of the Zaha in action was filmed by the MoD during a national-level naval training exercise in June 2023 when the MAVs self-deployed from the Anadolu's well deck and manoeuvred to the beach, where they provided over for additional forces arriving in landing craft and by helicopter. The first multinational MAV deployment took place during NATO exercise Sea Wolf in January 2024.

Configuration

The on-board offensive weapon system consists of a stabilised remote controlled ÇAKA turret (which FNSS first developed specifically for the Zaha) mounting a 12.7 mm HMG and 40 mm AGL as well as two banks of smoke grenade launchers. The turret features 360° seamless traverse and includes thermal sights for day and night operations. The aluminium hull's baseline defensive suite consists of passive ballistic and mine protection in line with STANAG 4569 standards (the precise level is classified), and includes automated fire suppression and CBRN suppression. Applique armour can be added to meet higher threat levels. The personnel carrier variant (APC) which forms the core of the MAV family of vehicles has a three-person crew plus room for 18 combat-equipped marine dismounts who egress via a rear-mounted hydraulic ramp. A manual door is embedded into the rear hatch to permit egress in case of a hydraulic failure.

A total of 27 MAV units were delivered to the Turkish armed forces by the end of April 2023. This represents the entire first tranche, consisting of 23 units of the armoured personnel carrier variant and two each of the C2 and recovery vehicle variants. FNSS states that the base vehicle can also be configured for additional variants including combat engineering and battlefield support, although to date there have been no orders for these specialised units. A fourth variant, optimised for mine breaching, has also been developed under the scope of the MAV Programme.

The firm is also offering upgraded combat capability for the amphibious armoured vehicle. FNSS presented two up-armed MAVs at the IDEF 2025 exhibition in Istanbul. Each featured a different modified variant of the ÇAKA turret. Both new configurations enhance the vehicle's anti-armour capabilities up to and including defeat of MBTs.

The Çaka 30/AT-O turret is equipped with a low-recoil 30 mm Venom LR automatic cannon produced by Samsun Yurt Savunma, plus two Roketsan OMTAS long-range anti-tank guided missiles (ATGMs). The Venom LR is chambered in the 30 mm × 113 cartridge, has an effective range of 2,000 m and can fire armour-piercing and high-explosive munitions. The OMTAS can defeat armoured targets at ranges up to 4,000 m.

Top-down view of the Zaha MAV. [FNSS]

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The lighter weight ÇAKA-AT-K turret mounts a 12.7 mm machine gun plus two Roketsan Karaok fire-and-forget ATGMs with 2,500 m range. FNSS states that both new turret variants are at Technology Readiness Level 7 (TRL 7).

Future sales

The Turkish armed forces are in the process of expanding their Marine Corps from its current strength (roughly equivalent to a reinforced brigade) to an end strength of three brigades. While the MoD has not publicly confirmed plans to purchase a second tranche of MAVs, additional orders are widely expected in order to support the expanding force structure; the Turkish press is describing such an order as pending. In that context, there is speculation that a second order might include additional variants such as a mine-clearing system or the anti-armour fire-support vehicles. Additionally, FNSS is actively marketing the Zaha MAV for the export market. The firm has cited interest from potential buyers in the Middle East and in the archipelago-rich Southeast Asia region, with Qatar and Indonesia being mentioned by name.

Korean Amphibious Armoured Vehicle (KAAV)

The Republic of Korea Marine Corps (ROKMC) currently operates the KAAV71A, also known as the Korean Amphibious Armoured Vehicle I (KAAV I) which is based on the American AAV7. The vehicle was built under licence by Hanwha Defense and delivered in the 1990s to early 2000s. Since 2015, Hanwha has been pursuing a purely domestic research and development programme to develop a successor, to be designated the KAAV II. The Korean Agency for Defence Development (ADD) awarded the firm a development contract in November 2018. ADD describes the KAAV II as being "capable of high-speed maritime operations that allow marine forces to be quickly moved from landing ships to inland target areas. KAAV2 enables marine forces to carry out cooperative operations with mechanised forces during land operations by providing mobility, firepower and armour." The Defense Acquisition Program Administration (DAPA) formally approved acquisition of the KAAV II in September 2021.

Hanwha presented a scale model at the 2019 Aerospace and Defence Exposition ADEX in Seoul. According to statements made by Hanwha to Shepard Media during ADEX 2019, the tracked vehicle will measure circa 9 m long and fall in the 35-tonne weight class. It will have a crew of three and accommodate 18 dismounts (other sources including Korean graphics available online cite 20 or 21 dismounts). An unmanned turret will mount a 40 mm S&T Dynamics cannon capable of firing case-telescoped ammunition including armour-piercing fin-stabilised discarding sabot (APFSDS) rounds. The cannon will be supplemented by a 12.7 mm HMG.

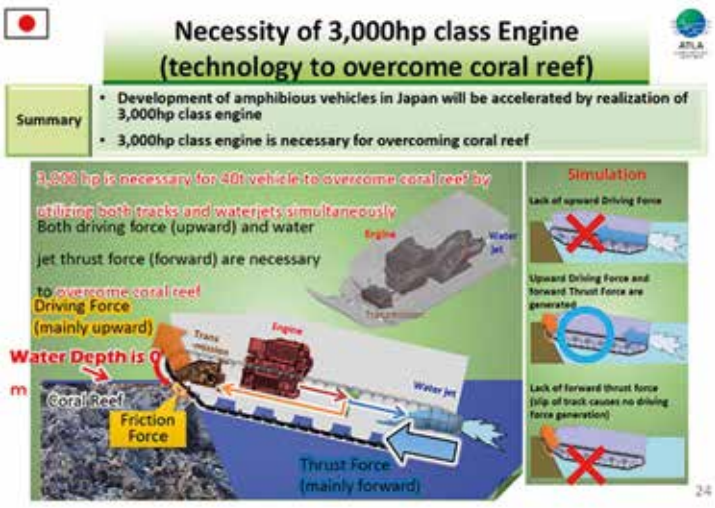
Improvements over the currently deployed KAAV I will include lighter-weight but superior-performance composite armour, modern digital systems, and improved water mobility. Hanwha partnered with Soucy Defense to develop new composite rubber tracks (CRTs) which will propel the vehicle at 70 km/h on land, and which will rotate in shallow water to assist the large-diameter twin rear-mounted waterjets. During open ocean operations, three-stage trim vanes at the front and rear improve buoyancy and reduce resistance. Additionally, side-flaps descend to cover the underside of the tracks during open ocean operations to provide a smoother surface. During ADEX 2019, Hanwha's KAAV II Program Group team leader cited an anticipated top speed approaching 13.5 kt or 24 km/h, roughly double that of the KAAV I. These statements were refined in a Hanwha press release at the June 2023 MADEX Maritime and Defence Exposition in Busan, which cited an objective speed of circa 20 km/h in the water.

At the time of the MADEX 2023 event, the KAAV II had completed the exploratory development phase (2018–2022) and entered the system development phase, which was slated to run 2023–2028. The firm projected that mass production would begin in 2029, implying a likely IOC in the early 2030s. However, the programme suffered a fatal prototype accident in September 2023 when two Hanwha Aerospace employees died when the prototype sank during testing off the coast of Pohang. At the time, South Korean media speculated that the incident investigation could delay development and entry into service. Neither the Korean government nor Hanwha have provided an updated timeline for development and serial production.

Future Amphibious Technology – Research (FAT-R)

While Japan does not maintain a marine corps, it did establish the Amphibious Rapid Deployment Brigade (ARDB) as a formation of the Japanese Ground Self-Defense Force (JGSDF). The ARDB was created in 2018 in response to the Chinese wartime threat to what is collectively known as the Ryukyu Islands, (also known as the Nansei Islands), a chain of some 200 islands stretching south-westerly from Kyushu towards Taiwan. The unit is tasked with conducting full-scale amphibious warfare, coastal defence, and rapid response operations to retake islands which have been occupied by an enemy. It was established with advice and support of the USMC, with which it trains on a regular basis. To enable amphibious landing operations, the brigade acquired refurbished and upgraded AAV7 vehicles from the USMC. For amphibious assault or landing operations the AAV7s are launched from the well deck of Osumi class tank landing ships (LST), which are frequently compared functionally to dock landing ships (LSD).

▼ **Detail of a concept model of the developmental KAAV II. [Hanwha Aerospace]**



A slide from an ATLA presentation demonstrating the necessity of combined water jet and track propulsion for FAT-R to overcome coral reefs. (ATLA)

Given the AAV7's age and limitations, these vehicles were always considered an interim solution. Japan's Acquisition, Technology & Logistics Agency (ATLA) initiated the Future Amphibious Technology Research (FAT-R) programme in 2017 to prepare for a 'next generation' successor to the AAV7. Mitsubishi Heavy Industries (MHI) was selected as industry leader to design and develop a prototype manned vehicle. Few details have been publicly revealed to date. The objective amphibious vehicle will definitely need to exceed the AAV7's 13 km/h (7 kn) water speed to minimise exposure during the water phase of operations. Another major concern specifically for Japan is the ability to overcome the coral reefs which form a barrier to many of the Nansei islands. A combination of twin 1,118.5 kW (1,500 hp) water jet propulsion assisted by rubber tracks, both driven by a very powerful 2,237 kW (3,000 hp) MHI V12 engine has been described as the optimal solution to the coral reef issue, according to a briefing on Japanese military modernisation presented during the January 2024 International Armwoured Vehicles Conference in Twickenham, London. During an April 2025 interview with Naval News, Lieutenant Colonel Seiichirō Satō, commander of the ARDB's Combat Landing Battalion, added a third priority. Describing the AAV7's 40 mm AGL as inadequate for combatting light armoured vehicles, he expressed hope for "a minimum" of a 30 mm autocannon on the new vehicle.

ATLA has not declared a firm timetable for the programme. MHI's vehicle programme is currently in the prototyping phase. If technical and operational testing take place during the late 2020s, the new amphibious armoured vehicle could enter service in the early 2030s.

Loyal amphibious wingman?

To augment the manned successor to the AAV7, Japan is also developing an unmanned amphibious vehicle. Japanese MoD documents cite two primary missions for the unmanned vehicles: acting as an advance force for manned amphibious armoured vehicles during assaults against defended beaches; and subsequently conducting supply runs from offshore ships to ground units operating on islands. As with the manned vehicle being developed, the autonomous system will be optimised for crossing the coral reef line. Once on the beach it will switch from water to land mode in order to seek out friendly units located inland. The MoD's "Defense of Japan 2025" white paper confirmed that development had begun in FY2024. Previous MoD documents have presented a precise schedule for the programme, with development in FY2024–2026, testing in FY2026–2027, and initial fielding as of FY2028.

Japan is not the only nation considering an unmanned 'wingman' for manned amphibious armoured vehicles. Rheinmetall's Mission Master unmanned ground vehicle (UGV) has repeatedly demonstrated amphibious capabilities over the course of 2025, most recently at NATO's REPMUS (Robotic Experimentation and Prototyping using Maritime Uncrewed Systems) exercise in Portugal during September. A Mission Master 2.0 modified for this purpose by Rheinmetall Canada was lowered by crane from a warship off the Portuguese coast and autonomously traversed the ocean and surf zone to land safely on the beach. Earlier in the year, Mike Brooks, director of Business Development for American Rheinmetall Vehicles, discussed the USMC's testing of the Mission Master's suitability for amphibious operations on the coast. Brooks emphasised the retractable propeller and two fold-down sponsons on either side which enable the amphibious capability. The robotic vehicle can be deployed for logistics, reconnaissance, medevac and weapons-platform missions, a versatility well suited to marine infantry operations.

The fact that Japan and various NATO members are independently pursuing this capability is a strong indicator that in the future, advanced manned amphibious armoured vehicles will be supported by capable unmanned systems, improving both lethality and survivability for marine infantry forces.

A Mission Master UGV configured for amphibious operations lands on the Portuguese coast during OPEX REPMUS/NATO DYMS in September 2025. [Rheinmetall]

Crewed or uncrewed? Assessing the current direction of travel in turret design

Chris Mulvihill

Improved sensors and electronics have forced a major rethink in turret design for armoured fighting vehicles (AFVs). The traditional crewed turret is no longer the default, with uncrewed alternatives rapidly gaining ground. This shift over the last decade is reshaping how armies are balancing protection, situational awareness and firepower.

The concept of a fully-rotating turret that houses a main armament such as a machine gun or cannon that can elevate and depress was not novel, but its application onto the Renault FT would prove to be the most optimal design going forward. [Daniel Stockman, via Wikimedia Commons; CC-BY-SA 2.0]

Turret designs for AFVs have seen a sustained evolution over the past decade as systems related to situational awareness have improved, in part due to better electronic designs and ever improving sensors. With this evolution has come a long-awaited rethink concerning the necessity of having crewmen within the turret itself, a precedent that was set and long adhered to with few exceptions since the birth of Louis Renault's FT back in 1917. While the rotating turret was not a completely new idea at the time, having been tested on the British prototype tank known as Little Willie, the FT would be the first mass-produced tank to utilise such a turret design. After over a century, the basic concept of a fully-rotating turret centred around a main armament is still an effective means of integrating an armament system onto a large variety of AFVs.

Returning to contemporary times, turrets themselves now come in all types of different configurations. One of the more interesting industrial trends since the turn of the millennium has been the divergence of responsibility for platform and turret design. While certain states have at times chosen their platform and turret individually, this has gradually become the standard procedure for vehicles such as armoured personnel carriers (APCs) and infantry fighting vehicles (IFVs). This in turn has seen the emergence of a dozen or so companies who focus on standalone turret designs that are advertised to fit onto a wide variety of platforms, so long as the latter can sustain the necessary size and weight requirements.

With the large variety of standalone turrets available on the market today, a key trend in contemporary turret design is the capability for some turrets to be operated remotely, otherwise known as uncrewed or unmanned turrets. These are turrets that can be integrated with the same sensor or weapon suites as a crewed turret, but do not require crewmembers to be seated within the bounds of the turret – instead allowing them to be stationed elsewhere on a vehicle or even stationed externally from the entire platform itself as is the case for unmanned ground vehicles (UGVs).

This article will examine turrets and weapon stations divided by their primary armament class, taking a sample from each class, and comparing their advantages and disadvantages in relations to their crewed or uncrewed capability when present.

Small-calibre weapon stations

For turrets that are designed to house armaments that typically vary from small-arms calibres (5.56 mm and 7.62 mm) up to 14.5 mm heavy machine guns (HMGs) or 40 mm automatic grenade launchers (AGLs), a long-range engagement against an armoured target is not going to be task expected of such armament. Consequently, for vehicles that are not expected to be front-line combat vehicles, it may be financially prudent to equip such vehicles with either crewed weapon stations or remote weapon stations (RWSs). Though not turrets, weapon stations have taken over roles formally given to small turrets that housed relatively small and light armaments.

OCWS on the M1286 mission command vehicle of the AMPV family. [US Army/Mark Schauer]

At its most fundamental, the protected weapon station can offer an affordable platform to house a single weapon and provide unrestricted situational awareness reliant on the human senses. A recent example of such a turret is the Objective Commander's Weapon Station (OCWS) that is to be equipped onto all five variants of the US Army's Armored Multi-Purpose Vehicle (AMPV) family. The protected open-top design sees the combination of opaque armoured material as well as protected glass. This allows the operator to peer above the protected sides of the turret when safe, and when in combat, operate the armament and retain some situational awareness by using the direct vision ports placed on all faces of the turret. While a simple design in concept, advances can be made by focusing on the materials used in the protection of such turrets. Despite not being stated for the OCWS, it would be reasonable to assume such a turret would be able to defeat small arms fire up to around 7.62 mm, allowing such a turret to operate in areas where the enemy is not expected to possess heavy weaponry.

The inherent weakness of such a design is its protection – the operator will be exposed to varying degrees, when using the weapon station. Whilst simultaneously a weakness, the ability for an operator to get a true view of their surroundings is also an advantage that is nearly impossible to fully replicate on uncrewed stations. The simplicity of such a crewed station due to the lack of any optoelectronic suite would also make it a cheaper product to equip a vehicle with, though importantly not necessarily lighter, which would depend on the weight of the ballistic protection used.

One argument in favour for utilising an RWS in place of something such as the OCWS would be for increased operator protection, the inclusion of more than one armament system, and possibly greater accuracy through automation of the target engagement process. A comparable uncrewed product to the OCWS could be Kongsberg's Protector RS4.

The Kongsberg Protector RS4 is a good representative example of a 'typical' RWS, being one of the most popular choices on the market. It typically houses a 12.7 mm M2 Browing, though it can also house a 7.62 mm machine gun or even a 40 mm AGL. For the M2, the RWS can fit one standard box of 12.7 mm ammunition, consisting of 100 rounds. The RWS can rotate 360° in azimuth at a rotational speed of 90°/s, while its elevation range is between -20° and +60°, with an elevation speed of 70°/s. The RS4's most valuable component is the optoelectronic suite, with both day and night (typically thermal) channels, and a laser range finder. Additionally, an anti-tank guided missile (ATGM) can be fitted as an option for longer-range engagements against armoured targets.

When compared to something like the OCWS, the RS4 would present greater lethality, with more flexibility in the armament fitted during the procurement stage, with the option to change the latter in the future. The main advantage would be for the operator to be located within the protected confines of the host platform,

The Protector RS4 on the M1126 infantry carrier vehicle, with the former designated by the US Army as the Common Remotely Operated Weapons Station – Javelin (CROWS-J). It can be equipped with either an M2 machine gun or the Mk 19 automatic grenade launcher (AGL), as well as a single Javelin anti-tank guided missile (ATGM). [Chris Mulvihill]

so as to not risk external exposure during combat. The optoelectronic suite also allows for operations at night, whereas an operator of a crewed weapon station would require infantry night vision equipment and tracer ammunition.

An RWS is highly automated, with the optoelectronic suite feeding into a fire-control system (FCS) that may use image recognition algorithms to recognise potential targets while a laser range finder can range targets near-instantaneously and automatically adjust the point of aim via a ballistic computer. Naturally, this level of automation comes with a much higher unit cost per system. Additionally, a survivability drawback is the necessity of reloading the armament system externally, which would need an operator to leave the armoured protection of the platform. This is particularly pressing when larger armaments can have quite limited rounds per munitions box.

Medium-calibre turrets

The market for medium-calibre turrets has moved at pace towards uncrewed designs. It is unclear if this is an industrial trend or rather something emanating from customer demands. Yet, differences still linger in procurement with some opting for uncrewed designs, while others may choose to remain with crewed designs.

One such option for a crewed medium-calibre turret design would be Elbit Systems' MT30 turret, the crewed sibling to the uncrewed UT30 Mk2. As is now the standard for modern turret design, the turret hosts a plethora of sensors and subsystems. The turret is usually marketed with and is so far sold with the 30×173 mm Mk44 Bushmaster II cannon, although with competition in the turret market being fierce, most manufacturers would be open to hosting a variety of cannon types. The MT30 can host both fundamental survivability assets such as smoke grenade dischargers and can also integrate laser warning receivers (LWRs) such as Elbit's ELAWS. The FCS and associated optical suite are also produced in-house. One of the MT30 key marketing points is the ability to host an active protection system, such as Iron Fist or Trophy.

The MT30 turret has seen success over 2025, being utilised on a General Dynamics European Land Systems-Santa Bárbara Sistemas' ASCOD 2 platform, which won a contract in Latvia for the delivery of an initial batch of 42 platforms. Elbit has since announced a USD 100 million contract to supply the UT30 Mk2 to an unknown NATO user of the ASCOD, with the primary culprit being Latvia, though this would suggest the Latvians have decided to use the uncrewed UT30 Mk2 variant rather than the crewed MT30 variant of the turret, which was used during trials. Another suspicion is whether Latvia will also opt into Elbit's Iron Fist APS, with such an idea coming from a post shared in January 2025 on X by Latvian Defence Minister Andris Spruds. The post showed a scale model of an ASCOD 2 with the crewed MT30 turret (hinted through the presence of a commander's hatch – a feature necessary for a crewed turret) with Iron Fist launchers. It remains to be seen if the option of a turret-integrated APS is chosen by the Latvians.

ASCOD 2 during trials for the Latvian replacement programme for the Combat Vehicle Reconnaissance (Tracked). Notice the presence of a commander's hatch and cupola, indicating a crewed turret. [Latvian MoD]

The Guardian 30 is an uncrewed turret with no platform intrusion, with ammunition stored in the turret and consequently has to be externally resupplied. [EM&E]

The UT30 Mk2 design was also evaluated for Spain's Dragón 8×8 programme, alongside Leonardo's HITFIST turret. However, Spain ended up opting for Escribano Mechanical & Engineering Group's (EM&E's) Guardian 30 turret. This is set to arm the most common variant of the Spanish VCR Dragón family, the VCI, with the wheeled platform based on the GDELS-MOWAG Piranha V design. The VCI's Guardian 30 is armed with a 30×173 mm Mk44 Stretch Bushmaster II and a pair of Spike LR2 ATGMs housed in a retractable pod. The turret's Apolo optoelectronic sights are developed by Escribano, while the FCS also has additional sensors including acoustic and meteorological sensors. It also comes with some passive protection systems, including LWRs and up to 12 smoke grenade dischargers. The turret, being uncrewed and also located on the roof of a platform (with no intrusion into the platform) means that the commander and gunner are placed within armoured protection. As such, a platform with such a turret could take advantage of hull-down positions, where the hull is obscured from enemy view and only the turret is exposed for reconnaissance and target engagement, to avoid placing the crew in direct danger. EM&E have also offered the turret to customers in 30×165 mm for customers accustomed to Soviet-era standard ammunition, with the turret having been trialled on the Arslon 8×8 APC being developed in Uzbekistan.

The aforementioned turret designs are marketed for the same market segment – use on wheeled and tracked infantry fighting vehicles (IFVs). When comparing both solutions, parallels can be drawn with the aforementioned crewed weapon stations and RWSs. The uncrewed Guardian 30 allows the crew to operate from under armour in the platform, but with the drawback that the main armament is understood to require external reloading (though it should be noted that some modern turrets do allow for reloading under armour). While such an issue is lacking for the crewed MT30, in comparison to the Guardian 30 it has a greater visual cross section from all arcs

in the exterior, despite being armed with the same types and quantity of armament. This is a consequence of needing sufficient internal volume within the MT30 to house a crew of two.

In terms of design, and consequently cost, uncrewed turrets possess a distinct advantage: they do not require as much internal volume in the form of a turret basket within which crew would typically sit. Removing the need to accommodate humans eliminates the substantial ergonomic constraints that shape crewed turret designs. This reduction in required internal volume has substantial benefits. A turret of smaller volume can achieve a given ballistic protection level with less armour mass, whereas a crewed turret protected to the same standard must inevitably be heavier simply because there is a larger surface area to protect. This also means that for a fixed weight allocation, an uncrewed turret may actually be protected to a higher standard, as armour can be concentrated around a smaller, more compact structure. This represents a weight saving which, if required, could be put toward greater armouring of the hull, where the crew (the single the most valuable part of any platform) are concentrated. The question of vulnerability and the ease of scoring a mission kill on

▲ A 3105 mobile gun system on the Boxer, equipped with Safran PASEO gunner and commander sights. [John Cockerill Defense]

less-protected unmanned turrets remains legitimate, but it should not be assumed that crewed turrets on APCs and IFVs are uniformly better protected; in practice, they often are not. Instead, the central trade-off concerns volume, armour distribution and weight efficiency, all of which broadly favour uncrewed designs.

Having said that, doctrinal and operational preferences of users still play a decisive role in the choice between crewed or uncrewed turrets. For roles such as peacekeeping or low-intensity conflicts, a crewed turret may be preferred, for instance, for scenarios where a crew may be required to interact with a civilian population fairly regularly, or where reliable and flexible close-in situational awareness is needed, such as when looking for hidden improvised explosive devices (IEDs). Crewed turrets can also be more useful when manoeuvring through complex terrain such as forests, as the commander can more easily observe clearances between the vehicle and various terrain obstacles. Indeed, when the crew are not 'buttoned up', peering out above a hatch is often much faster and more convenient than flicking between several cameras on a screen. However, an uncrewed turret would typically provide greater crew protection at a given weight, and often presents a smaller profile.

Future outlook: Large-calibre turrets

While the choice for standalone product offerings for medium-calibre turrets are exhaustive, large-calibre turrets as standalone products are relatively rare. In Europe, the two main products that exist in this segment are the John Cockerill 3105 and the Leonardo HITFACT II – both of which are crewed only. One particular reason for this is the relative difficulty of isolating a roof-mounted turret while accommodating a large-calibre gun that requires ample room for elevation and recoil.

The John Cockerill 3105 is a crewed two-man turret built around an in-house 105 mm rifled gun. It uses an autoloader that stores between 12 to 16 rounds. The 3105 to date has only seen commercial success through the Harimau fire support vehicle for Indonesia and the LAV 700 assault gun variant for Saudi Arabia. There are signs it may see some success in the near future, with work to integrate the 3105 onto the Leopard 1A5BE having continued since the initial unveiling at Eurosatory 2022, with recent photographs from testing in August 2025 showcasing the 3105 sitting lower onto the hull with the exposed turret ring being less pronounced than previous iterations. It has also been integrated into India's ongoing Zorawar medium tank project.

Offering a large-calibre gun in an uncrewed turret presents a major engineering challenge. This is because the gun's breech, recoil assembly and autoloader each require substantial internal volume that cannot be eliminated simply by removing the crewmen. A 105 mm gun has a long recoil stroke and a large breech that must move freely during elevation and firing. These components are physically too large to be contained entirely above the hull roof without creating a turret that is excessively tall, so engineers typically need to extend parts of the mechanism down into the platform through the turret ring, which would prevent the physical separation between operators in the hull and the turret, which is in itself the fundamental advantage with uncrewed turrets.

One example of solving this issue was demonstrated by KNDS with the Leopard 2A-RC 3.0 at Eurosatory 2024, where the company managed to integrate a 120 mm smoothbore gun into an uncrewed turret without requiring a turret basket to intrude into the hull. This enables the crew to sit in a protected side-by-side configuration within the hull, isolated from the turret. The solution uses a double-trunnion system: while conventional crewed turrets rely on a single trunnion as the gun's point of rotation, the double trunnion raises this rotation point, allowing the gun to elevate and depress without the breech

▲ Leopard 2 A-RC 3.0 with an uncrewed and isolated turret housing a 120 mm smoothbore gun. [RecoMonkey]

dropping into the platform's interior. Engineering challenges like these remain one of the limiting factors behind why large-calibre uncrewed turrets are still largely at the developmental stage, but as KNDS have shown, solutions will prevail to improve the prospects of such turrets in the near future.

While many comparisons between crewed and uncrewed turrets apply equally to large-calibre systems, one notable advantage of an uncrewed turret in this context is the ability to shift much of the turret's mass – particularly the crew and their protective armour – down into the hull, significantly lowering the platform's overall centre of mass. This can translate into improved mobility, especially for wheeled vehicles, as a lower centre of mass reduces the risk of rollover and enhances stability when firing at high angles or when engaging targets perpendicular to the platform's forward axis.

Closing thoughts

Uncrewed turrets appear set to become the default in the long term, driven by advances in situational awareness, increasing automation, and a steadily more lethal low-altitude threat environment – as seen with the rise of first-person view (FPV) drones in Ukraine. Crewed turrets, however, will retain a place in the market, offering lower-cost solutions with reduced automation and supporting doctrines that continue to value hatch access and unmediated situational awareness for vehicle commanders. Looking ahead, uncrewed turrets are likely to serve as stepping stones towards more sophisticated uncrewed platforms, even as operational autonomy remains technologically limited and autonomous armed engagement continues to raise ethical and policy concerns.

Is the future of engineering vehicles unmanned?

Alexey Tarasov

Military engineering has been a crucial element of land warfare for hundreds of years, providing essential capabilities that support operations at the tactical, operational, and even strategic levels. Ever since warfare evolved into combined-arms operations heavily dependent on mechanised ground forces, engineering vehicles have appeared on the battlefield and quickly become indispensable in a wide range of roles. Today, as ground warfare continues to evolve, engineering vehicles have once again demonstrated their importance – but they also face a number of emerging challenges. One potential path forward is the increasing automation of engineering equipment, which raises an important question: Is the future of engineering vehicles unmanned?

The US Army's Field Manual FM 3-34 states that military engineering exists to 'provide freedom of action and apply combat power to gain, retain, and exploit the initiative in order to achieve and maintain a position of relative advantage'. In turn, NATO defines military engineering in accordance with MC 560/2 Policy for Military Engineering as a 'function in support of operations to shape the physical operating environment'.

Engineer troops operate at the tactical, operational, and strategic levels, across various combat and non-combat scenarios and in diverse operational environments. These factors shape a broad spectrum of engineering tasks ranging from counter-mobility and breaching operations on or near the battlefield to demining and support to civil authorities in rear areas. These tasks are executed through three major engineering disciplines – General, Geospatial (Ancillary), and Combat Engineering, as stated in both US and European doctrines.

▲ UBIM (Universal Armoured Engineering Vehicle) is an engineering vehicle produced by Uralvagonzavod. The UBIM combines the functions of an armoured recovery vehicle (ARV), an armoured engineering vehicle (AEV), and a mine-clearing vehicle. [Alexey Tarasov]

The nature of many engineering tasks often involves labour-intensive work and requires operating close to, or in direct contact with, the enemy. Yet most of these tasks are critical to mission success.

Dull, dirty and dangerous

The major drivers behind the adoption of unmanned platforms by engineering units are generally the same as those motivating their use across the wider military. These include:

- The need to preserve increasingly limited engineering manpower following post-Cold War force reductions;
- The need to mitigate human fatigue and extend operational endurance;
- The need to reduce personnel exposure in high-risk missions.

These factors fall under the "dull, dirty, and dangerous" category defined in the Unmanned Systems Roadmap 2007–2032 released by the US Department of Defense. The document provides long-duration sorties as an example of a 'dull' mission, exposure to radioactive materials as an example of a 'dirty' mission, and explosive ordnance disposal (EOD) as the primary example of a 'dangerous' task.

As a result, engineers were among the first branches to adopt and widely introduce unmanned platforms in the 2000s. The imperative of 'keeping human personnel out of harm's way' led to a rapid increase in the number of unmanned ground vehicles (UGVs) deployed by the US Army for EOD missions in Iraq – from 162 in 2004 to more than 4,000 in 2006.

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A scale model of a Hyundai Rotem K600 CEV combat engineering vehicle. [Alexey Tarasov]

One of the first recorded deployments of autonomous systems was the use of the Uran-6 UGV in April 2022 for demining operations in the rear zone. To date, the Uran-6 remains the only member of the Uran UGV family known to have been employed in Ukraine, according to publicly available information. Ukrainian civilian and military organisations also use similar unmanned platforms, such as the Božena 5+, for demining operations in rear areas. There are claims that in 2022 Russia deployed a heavy remotely controlled Prokhod-1 system equipped with a TMT-S mine trawl in Ukraine; however, these claims remain unverified and details are scarce.

The trend toward wider adoption of autonomous platforms was reinforced by modern conflicts in the Middle East, Gaza, and Ukraine, where large-scale ground combat has returned, featuring the extensive use of mechanised formations, fortifications, minefields, counter-mobility measures, and complex terrain.

In addition, land warfare has evolved, further expanding the spectrum of 'dull, dirty, and dangerous' missions for military engineers. For example, the tasks of building fortifications or obstacle belts in the rear have become increasingly dangerous due to the extension of the combat and close-rear zones, as well as the proliferation of long-range precision weapons capable of striking to depths of 80 km or more. There are multiple instances in which engineering vehicles – excavators, loaders, and trucks – were targeted by precision-guided or loitering munitions while carrying out construction work far from the line of contact.,

An Uran-6 remotely operated mine-clearing vehicle, used to detect and neutralise explosive threats on the battlefield. [Alexey Tarasov]

In theory, the experience of ongoing conflicts should have prompted the rapid adoption of unmanned systems by engineering troops. Surprisingly, despite the proliferation of unmanned systems in other branches of the military, the broader introduction and combat employment of autonomous systems within engineering units remains limited and largely tied to specific missions.

Autonomous engineering in modern conflicts

The conflict in Ukraine has demonstrated the full spectrum of engineering operations on a scale unprecedented since the Cold War. Both sides have employed engineering units for laying massive minefields, demining, wet-gap crossings, route and area clearance, breaching during mechanised assaults, and large-scale infrastructure construction, to name a few. Yet, after three and a half years of war, the use of autonomous engineering vehicles remains limited and often confined to specific tasks.

There are documented cases in which both Russian and Ukrainian armed forces have used remotely-operated armoured vehicles, such as the MT-LB, to deliver demolition charges onto enemy strongpoints or to clear minefields. The same technique was reportedly employed by the Israeli Defense Forces (IDF) in Gaza, where remotely controlled M113 APCs were used to deliver explosive charges. However, such instances are relatively rare and, at least in the case of the Russo-Ukrainian conflict, largely disappeared following the wider introduction of glide bombs by the Russian Air Force (RuAF).

Both Russian and Ukrainian forces are using UGVs for various engineering tasks, such as delivering demolition charges, laying mines and smokescreens, and conducting engineering reconnaissance. Furthermore, Russian and Ukrainian sappers, in addition to UAV operators, frequently employ aerial drones in support of demining and route clearance operations.

Materials released by both Russian and Ukrainian sources suggest that both sides are experimenting with small and medium unmanned platforms in various auxiliary and engineering roles. Available information indicates that the range of tasks performed by UGVs is gradually expanding, and the number of deployed ground robotic systems is continuing to grow. Recent examples include a Russian UGV used for trench digging and cable laying. This is presumably the first instance of a UGV performing such a task. Significantly, in this case the UGV was operated under the surveillance of a UAV, which is standard practice for both sides in the Russo-Ukrainian conflict.

Another example is an unmanned vehicle-launched bridge, reportedly developed in Russia. According to the source, the UGV is remotely operated and carries a deployable light bridge, providing gap-crossing capability for light vehicles. However, the details and current status of the programme remain unclear.

These observations suggest that, in most cases, unmanned vehicles are deployed in controlled environments – often in the rear areas – operated by a human, and are typically small platforms with limited capabilities. Another observation from the Ukrainian conflict: the variety of UGV models suggests that field experiments are underway, while neither side has adopted any unmanned ground platform for large-scale serial production.

There are, however, no known cases of heavy or medium unmanned engineering vehicles being deployed in combat in Ukraine for standard engineering tasks such as breaching, mine clearance, or obstacle removal. In the case of the IDF, the unmanned version of the Caterpillar D9 bulldozer, dubbed 'Robdozer', has seen only limited deployment in 2025.

The constraints

What are the possible reasons for the slower adoption of heavy unmanned engineering vehicles?

First, while autonomy allows personnel to be kept away from 'dull, dirty, and dangerous' missions, it does not guarantee mission success. Unmanned engineering vehicles share the same vulnerabilities as their manned counterparts – for example, they can be immobilised by an anti-tank mine – but they also carry additional risks, such as loss of control due to enemy jamming in the case of radio-controlled systems, or loss of connection in the case of cable-controlled systems.

The second issue relates to technological limitations. The vast majority of unmanned systems currently employed in combat are remotely operated, with only a small number incorporating elements of artificial intelligence (AI) that enable limited autonomous functioning in specific scenarios. At the same time, the land domain remains the most complex environment for autonomous systems, and engineering tasks are among the most demanding within it. It is therefore reasonable to suggest that UGV technology has not yet reached full maturity, or requires additional time to adapt to the rapidly evolving conditions of contemporary land warfare.

Third, many engineering operations are highly complex and must be carried out in increasingly hostile environments, often in close coordination with other elements of combined-arms formations such as infantry and armour. These tasks demand quick judgement, adaptation, and flexibility — qualities that are difficult to automate. As a result, unmanned engineering vehicles will require a certain level of human oversight, at least at the current stage of technological development.

Finally, the wider introduction and combat deployment of heavy unmanned engineering vehicles requires developing formal procedures, doctrines, and training programmes. Although work on these is underway, armed forces need time to absorb operational experience and adapt accordingly.

There are also operational considerations. Breaching, mine-clearing, and other engineering assets are limited in most modern militaries, while the number of threats – including precision-guided weapons and tactical reconnaissance systems – has increased. As a result, a concentration of heavy engineering vehicles would likely be detected, and an adversary would almost certainly target these assets, whether they be manned or unmanned.

A Caterpillar D9 armoured bulldozer at the EDEX-2021 exhibition. An unmanned version has seen limited deployment. [Alexey Tarasov]

Complex combined-arms operations involving engineering support – such as breaching or wet-gap crossings – must be thoroughly planned, synchronised, rehearsed, and supported to succeed. However, employing unproven unmanned technology in such operations may be viewed by some military leaders as an unnecessary risk. As a result, heavy unmanned engineering vehicles so far tend to remain confined to proving grounds rather than being deployed operationally.

Concluding thoughts

So, is the future of engineering vehicles unmanned? The short answer is almost certainly yes, but with caveats.

The Husky mine detection vehicle at the 18 November 2025 military parade in Riga. [Alexey Tarasov]

vehicles. Combat engineering vehicles are expected to receive multi-layered protection similar to that of main battle tanks.

Many functions of engineering vehicles will likely be automated to reduce crew size and minimise risks to personnel. Another possible development is the emergence of multi-platform solutions similar to the MGCS, in which a manned command-and-control (C2) vehicle operates in cooperation with one or more unmanned engineering vehicles.

The general trend toward wider adoption of autonomous vehicles will continue across all branches, including military engineering. However, this shift is likely to be gradual, limited in scope, and initially focused on specific, well-controlled tasks such as construction or demining.

Optionally manned medium and heavy combat engineering vehicles will likely be introduced for testing and limited operational deployment. Nevertheless, human oversight will almost certainly remain essential for engineering vehicles, as well as for armed combat UGVs.

The protection of engineering vehicles will be significantly increased, following recent trends in protection suites already widely implemented on heavy and medium combat

The level of autonomy will increase over time. Eventually, manned and unmanned combat, engineering, and aerial vehicles may be connected within a single network, coordinating their actions as part of an integrated operational system.

In general, engineering capabilities have recently come to the forefront and received increased attention in many militaries around the world. There is a growing trend toward enhancing engineering capabilities and upgrading existing engineering vehicles, which will likely drive active procurement of a variety of engineering vehicles in the short term.

Solving the counter-mobility problem of minefields

Tim Guest

Minefields are one of the most effective battlefield obstacles, used to achieve a variety of tactical aims for those laying them, impeding an enemy's mobility and speed of manoeuvre, to name but two. Faced with such barriers, overcoming them is no easy challenge.

Minefields are a major disruptor on the battlefield, impacting mobility and manoeuvre and presenting an advancing force with the nightmare prospect of having to mount a deliberate breaching operation, likely incurring significant attritional losses in the process, with success far from guaranteed. [Dmitry Shamis, via Unsplash]

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With mobility and manoeuvre two of the most important capabilities contributing to success on today's battlefields, the counter-mobility problem caused by minefields is one that requires solutions. Deliberate breaching is a huge undertaking, typically requiring a brigade-sized unit to conduct successfully with the right equipment, in the form of latest combat engineering vehicles and systems. Experiences from Ukraine, however, in latest Russian minefield tactics, give pause for thought. Consequently, a re-think by allied forces as how best to handle these battlefield developments, may well be needed.

This article, therefore, with a brief and simplified overview of minefields, looks at what's happening in Ukraine, including recent US Army Intelligence analysis of the counter-mobility issue on the ground there, and rounds off with a brief look at some of the systems donated and supplied to the Ukrainian Armed Forces.

Setting the scene

It normally falls to military engineers to lay mines and create minefields of different kinds in line with orders from higher command and for a variety of possible tactical reasons, intentions, and hoped-for/calculated outcomes. Protective minefields, for example, might include using mines to help defend an installation of critical importance. Nuisance minefields might be laid to cause disruption, chaos, and delay. Fake or phoney minefields are a ruse most effective when encountered by an enemy already impacted and sensitised to the potential presence of mines, their fear and over-cautiousness resulting in the expending of valuable time and mine-clearing assets trying to breach and clear an area that's already free of mines. Just as with a real minefield, formations of vehicles and troops are unnecessarily delayed and diverted and become vulnerable to incoming fire from the forces who prepared the deception in the first place. The tactical minefield, however, emplaced by a defending force to hold ground and retain a positional advantage, presents the biggest challenge to the mobility and manoeuvre of an advancing formation.

Such minefields are laid, initially, with sufficient time using anti-tank (AT)/anti-vehicle (AV) and perhaps off-route mines, as opposed to potentially being hastily replenished at a later date using scatterable anti-personnel (AP) mines, while under attack. A tactical minefield's design and topography can be carefully planned, including as part of major defensive lines interlocking with other obstacle fortifications, such as dragon's teeth. In the first instance, these minefields will impact the enemy primarily through area denial and movement manipulation. Minefield depth and width will be varied by the sappers laying them, who may also create an irregular outer edge (IOE)

to the minefield, contoured to help achieve required tactical outcomes, or for other reasons such as a shortage of mines. Mines-per-square-metre density and the kinds of mines themselves, will also vary; they may be dug-in to a certain depth, and some may be laid on the surface, including by unmanned aerial vehicles (UAVs) or unmanned ground vehicles (UGVs), as used in Ukraine. While these few scene-setting lines are a vast oversimplification, it is how to deal with minefields, which is the question, as it has been since they entered warfare during WWI. Since then, a variety of different strategies, methods, tactics, and technological solutions for dealing with them have been developed, and these continue to evolve. Let's now look at the situation on the ground in Ukraine, not only to highlight fresh and concerning developments in minefield tactics and design being used by Russia, but also to highlight some of the breaching systems supplied by Ukraine's allies.

Ukraine's Dodger multifunctional unmanned ground robotic system designed by Ukrainian industry, can be used for a wide range of logistical tasks, from evacuating wounded to laying mines. Payload is 250 kg. [Ukrainian MoD]

Changing approaches: Ukraine's grim minefield challenge

On the battlefields of Ukraine, where, in some places, there are still mines left in the ground from WWII, minefields and mine warfare have been used extensively by both combatants in the current conflict. In a November 2024 report: 'Russian Minefield Tactics Pose Challenge to Mobility', by Richard Garcia and Colin Colley of the US Army Transformation and Training Command's Operational Environment and Threat Intelligence Directorate, T2COM, and worth detailed consideration in the context of this article, the authors noted that minefields being laid by Russia since the 2022 full-scale invasion have become significantly larger and more challenging than at any time since the invasion of the Donbas and Crimea annexation in 2014. The authors expand their analysis of developments on the ground and present some implications and recommendations wholly pertinent to our discussions in this feature.

In the first instance, the report sets a terrible scene, stating that the extensive use of landmines by Russian Forces, different separatist groups, and the Ukrainian Armed Forces since 2022, has resulted in Ukraine having acquired the miserable accolade of the 'most heavily mined country on Earth', surpassing previous leaders in this regard, Afghanistan and Syria. Indeed, 11 out of 27 Ukrainian regions are now said to be contaminated with landmines. Of significant changes in minefield creation, Garcia and Colley state that in the late-2022 early-2023 timeframe, the depths and widths of Russian minefields and other defensive positions along the main axis of advance of Ukrainian Forces, (who were planning a counteroffensive at the time), increased. Whereas their minefields had initially been typically 100–200 m^2 in size, minefields of at least 500 m^2 became widespread along the front, with mines, themselves, often more densely laid over these greater areas – this was, however, at a time when mines were in more plentiful supply than at time of writing. Another overarching challenge for the Ukrainians highlighted in the intelligence report is Russia's use of multiple types of domestically-made AP and AV mines, including new designs like the PTM-4M and POM-3 never previously encountered. At least 13 of each type of mine have been identified. However, the good news, in some ways, for the Ukrainians, is that domestic manufacturing capabilities have not been able to keep up with the demands of the battlefields, in turn leading the Russians to effect different approaches; one has been to create IOEs to their minefields, while others include laying mines less densely, and also mixing live AT mines with dummy mines, thereby creating 'phoney minefields'.

Early in the conflict, Ukraine had limited mine-breaching engineering capabilities, and while this has improved through the donation, by several NATO Allies over the course of the war, of various breaching systems and vehicles, some older than others, challenges remain. When faced with Russia's 500 m-deep minefields, even when using latest equipment, these present a formidable task, with the report suggesting that to breach just the mine obstacle would take around 1.5 hours. Considering the minefields are interwoven with the likes of tank ditches, dragon's teeth, and more, a breach would, however, likely be much more "challenging and time-consuming" according to Garia and Colley's report. With drones playing a huge part in this conflict, the authors also note that: "The persistent drone surveillance makes Ukrainian breaching elements vulnerable to detection and Russian artillery fire." And while Ukraine's breaching capabilities have improved since the first year of the war, the report notes that its much-heralded 2023 counteroffensive stalled, largely as a result of its forces' "inability to breach" Russian minefields effectively at that time; along their three main counteroffensive axes they advanced around only 16 km as a result.

While current mine breaching can be effective, new training regimes to go after engineer assets before they even get a chance to lay minefields must be considered. Pictured: Australian soldiers detonate a mine clearing line charge after launching it from an assault breaching vehicle on 1 August 2025, while training with soldiers from the US Army Engineer School's Combat Engineer Heavy Track Course. [US Army/Melissa Buckley]

And very much in the context of this discussion, the Garcia and Colley underline a key lesson learned by the Russians – that by using enough mines, or the threat of mines, the mobility and manoeuvre of Ukrainian Forces in assault "can be slowed or even halted by defeating their breaching operations". And this is where they suggested that in overcoming and solving this counter-mobility challenge, *"the Ukrainian Army must modify its mine-clearing and breaching solution. For example, a better counter-UAS capability could provide Ukrainian forces more time to breach by disrupting Russian surveillance drones. However, the longer it takes the Ukrainian Army to develop an effective breaching strategy, the more time it gives the Russian Army to improve its defensive positions."*

A salutary message for the Ukrainians, indeed, though in the current phases of the conflict, breaching may not be their highest tactical or strategic priority. However, in conclusion, what Garcia and Colley develop from the minefield intel gathered in Ukraine, are implications they posit for the US Army and its training regimen – and these are equally important for all NATO members, now and in the future. They stated: "As minefields and other obstacles become more advanced, US Army manoeuvre units could emphasise training on breaching deep obstacles, targeting enemy engineer assets, and the OPFOR could simulate Russian obstacle tactics."

Well, in contrast to how the US Army operates as a mobility-focused force, the Russian approach in Ukraine is one of attrition against the enemy rather than a focus on its mobility, which is where their use of minefields ends up forcing the opposition into gruelling, attritional contacts. The resulting implication and recommendation from Garcia and Colley is that US Army units may benefit from putting a "greater emphasis on training for breaching deep obstacles under constant observation and heavy indirect fire".

In addition, the option of preventing large-scale minefield emplacement in the first place, is emphasised, an approach that can be undertaken by targeting mine-laying equipment and units and disrupting their chances of laying these obstacles in the first place. Again, Garcia and Colley stress the importance of incorporating such new approaches into training, suggesting a hypothetical military exercise in which an OPFOR could adopt minelaying and obstacle tactics similar to Russia's. They could create obstacle belts, which force friendly US ground forces, whose key strength is their mobility, to overcome counter-mobility obstacles, including the kinds of deep minefields placed by the Russians, and being over-watched by persistent drone surveillance and under constant threat from artillery fire.

The report concludes by reinforcing the advantages that can be assured through the targeting of enemy engineer minelaying assets: maintaining mobility and manoeuvre, with less likelihood of having to breach deep minefields with the risks of being observed and under enemy fires during the whole breaching operation. Here, once again, Garcia and Colley emphasise the need to train in this regard, to become proficient in destroying enemy engineer minelaying assets before they deploy and reduce their overall minelaying capabilities.

Mine-breaching systems for Ukraine and beyond

Let's now take a very brief look at some of the minefield breaching equipment that has been sent to Ukraine from allied sources and has been used in battle. Systems include the likes of Pearson Engineering mine ploughs, Wescom Defence man-portable mine-breaching systems, and various vehicle-fitted mine rollers. The UK is also said to have supplied a 'manoeuvre-support package', of which minefield breaching and bridging equipment are a part, and Germany has also supplied four older Keiler mine flail vehicles in early 2023, based on the M48 Patton tank chassis. The latter is not to be confused with the recent Keiler system launched by Rheinmetall in 2024, incorporating feedback from the war, (though not deployed), and built around the Kodiak combat engineering vehicle chassis, itself based on the Leopard 2. With additional armour, the system is also equipped with 'Plofadder' mine-clearing line charges from Rheinmetall Denel Munitions, capable of clearing a 9 × 160 m path through a minefield.

Training in new approaches to mine-breaching based on experiences in Ukraine will be crucial. Pictured: Australian soldiers training at Fort Leonard Wood learn how to use mine clearing line charges, launch rockets from assault breaching vehicles on 31 July 2025. [US Army/Melissa Buckley)

Which leads on nicely to a line charge system that has been in use in Ukraine since late 2022 – the US-made M58 mine-clearing line charge (MICLIC) system. While Ukrainian forces have documented using them to breach Russian minefields, including during the 2023 counteroffensive, their success has been impacted by the evolving Russian tactics discussed earlier, even though their 100 m line charge, comprising a hose filled with 800 kg of C4 explosive, can create an 8.5 × 100 m path through a minefield. Also supplied from the US in late 2023, is the M1150 Assault Breacher Vehicle based on an M1A1 Abrams tank chassis, with its 4.5 m-wide mine-clearing plough and the same line charge as used with the M58.

While on the subject of line charges, Wescom Defence man-portable breaching systems were acquired and sent to Ukraine during 2023, including the company's H-POMBS (Heavy-Portable Obstacle and Minefield Breaching System), along with lightweight and training versions. They were to be used to clear corridors through minefields laid by the Russians around critical electricity infrastructure, in order for damaged installations could be repaired. The company initially sold the mine-clearing equipment

The H-POMBS man-portable obstacle breaching system has been used in Ukraine to clear paths through minefields to reach critical infrastructure. [Wescom Defence]

FFG's Wisent 1 mine-clearing variant with Pearson Engineering plough attachment, were delivered to the Ukrainian Forces in 2023. The ploughs have ground-engaging tines arranged across the full width of the vehicle to displace buried, pressure-fuzed mines and create a safe route through minefields. [FFG]

to Norway, but the units have since been donated to Ukraine after refurbishment by the Norwegian MoD.

While space precludes discussing many more breaching systems, a closer look at Pearson Engineering's contribution, as part of an urgent operational requirement (UOR) deal, is worthwhile. This deal was underpinned by the German Federal Government, and serviced through Pearson's German partner, Flensburger Fahrzeugbau Gesellschaft (FFG), with a contract signed in early 2023 for the delivery of an undisclosed 'large quantity' of its NATO-proven, full-width mine ploughs for integration with FFG's Wisent 1 ARV. The aim is to create the mine-clearing version of FFG's versatile vehicle. These were then delivered to the Ukrainian Forces later in 2023.

The ploughs have ground-engaging tines arranged across the full width of the vehicle, in order to displace buried, pressure-fuzed mines and create a safe route through the obstacle. This Wisent 1 mine-clearing configuration, which had already been proven at the time with various armed forces, including the Danes, is also equipped with a lane-marking system to aid the safe passage of troops following behind the vehicle. Part of Pearsons' front-end equipment (FEE) range, the mine plough is designed to integrate with a variety of AFVs and MBTs to give any of them the capability to clear paths through minefields. The ploughs are deployed and used in the US with the MICLIC and M1150 systems, mentioned earlier.

And while not in Ukraine, but in neighbouring Poland, March 2025 saw a contract award to Pearson, under which new M1A2 SEP V3 MBTs, destined for the Polish Armed Forces and part of a US Foreign Military Sales (FMS) deal, have been equipped with track-width mine ploughs, as well as combat dozer blades from Pearson. The integration has been conducted using the company's SLICE vehicle interface kit, which enables the rapid conversion of a wide range of AFVs so they can carry Pearson FEE and conduct independent battlefield engineering operations themselves, if necessary, whether minefield, or other, obstacle clearing. SLICE was actually taken into service by an unnamed first customer during 2023 to enable interoperability of FEE with MBTs and dedicated engineering vehicles. Interestingly, this was around the time the company was dealing extensively with its support for the Ukrainian Armed Forces.

As a final thought, having explored minefield breaching as part of this discussion, with all the potential horrors it might bring to those attempting it, is that for any size of force – individual soldier up to mechanised battalion – doctrine is clear: the primary course of action is to avoid minefields whenever possible. Simply put: GO AROUND!

M1A2 SEP V3 MBTs, destined for the Polish Armed Forces, have been equipped with track-width mine ploughs, as well as combat dozer blades from Pearson Engineering. [Pearson Engineering]

The Carmel programme: Recent developments

Sidney E. Dean

The IDF's Carmel programme de facto shifted from development of a new armoured fighting vehicle to become a technology integration project around 2021. This piece examines some of the highlights to have emerged from the project thus far, and provides a glimpse of what to expect going forward.

The Carmel programme was launched by the Israeli Defense Forces (IDF) in 2016 with the aim of developing a next-generation armoured fighting vehicle (AFV) concept that would be more agile and versatile than legacy systems. It would require a crew of only two (rather than the standard three or four) who would be seated in a digital cockpit. It would also rely heavily on autonomy, artificial intelligence (AI), augmented reality (AR) and sensor fusion, with the AI systems assuming the role of a 'virtual third crew member'. The enhanced situational awareness provided by the new technology would permit the crew to operate the vehicle in 'closed hatch' mode even in urban settings, thereby enhancing safety.

▲ The Carmel technology insertion programme is intended to serve a variety of current and future platforms. [IAI]

Following the initial concept phase, the Ministry of Defense (MoD) decided to change the programme's focus away from development of a single vehicle 'next generation AFV' concept; the new goal was the development of a multifaceted technology suite for integration into various AFV platforms. The firms Elbit, Rafael, and IAI submitted competing next-generation AFV demonstrator vehicles to the IDF. While all of these showcased immersive cockpits, AI-assisted crew capabilities, and autonomous navigation, each concept demonstrated different cockpit and autonomy solutions. In October 2021, Israel's MoD selected Israel Aerospace Industries (IAI) as prime contractor for Carmel, eliminating the other two contenders.

Core technologies

The solution presented by IAI, as defined by the firm, is based on automatic and autonomous systems that complement the human crew and operate the combat vehicle's central subsystems. By assuming numerous tasks, the AI component reduces the human crew's stress during intense operations, allowing the soldiers to concentrate on the most vital decision-making functions. As described by IAI in the October 2021 press release announcing the contract award, "these capabilities allow the team to define, supervise and interfere only when there is a necessity or need, and enables [them] to cover a wider area of concern while effectively meeting the challenges faced by the manoeuvring forces. The system has the ability to locate and destroy time-sensitive targets with small footprints, through quick acquisition and effective engagement of targets."

The envisioned solution is a 'system of systems'. The technologies being developed under Carmel, as defined by IAI, fall into five categories:

- **Command System** – responsible for autonomous mission planning and management;
- **Situational Awareness System** – sensor fusion and AI enhancement of radar, signals intelligence (SIGINT) and optronic sensor data to ensure 360° ground and aerial threat detection. It is intended to be capable of classifying multiple contacts in real time and differentiating friend and foe;
- **Lethality System** – prioritises targets and threats, selects the optimal weapon and munition to combat each target, and rapidly engages targets;
- **Mobility System** – for autonomous route planning and navigation, to improve manoeuvrability in urban and complex terrain;
- **Operations System** – providing the crew with multidomain battlefield data and situational awareness as well as an

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innovative user interface to enhance decision making during combat operations. It forms the vehicle's AI-enabled command-and-control framework. AI-based analysis and prioritisation of data flowing into the vehicle from the IDF's overarching networked battle management system (BMS) reduces crew stress and provides clarity for making split-second decisions in combat. This acceleration of the OODA (observe–orient–decide–act) loop is particularly critical in clutter-rich urban environments.

Under the long-term programme focus, the goal is to enable a two-person crew to operate main battle tanks (MBT) and other AFVs, with AI handling navigation, target acquisition, and decision support. AI-enabled vehicles would then be able to form a multidimensional combat team exercising operational control of unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs).

Incremental implementation

The revised Carmel Programme is not developing a single comprehensive technology insert, but a series of complementary systems to be integrated on AFVs in order to significantly enhance future capabilities. Major components and subcomponents are being developed individually by various firms and integrated onto existing AFVs as they become available. The Merkava 4 Barak MBT, which entered service in 2023, was the first platform designated to operationally integrate some of the technologies trialled during the Carmel technical demonstration phase. Alongside the Merkava IV Barak, some of the trialled technologies or their offshoots have been making their way onto the Eitan 8×8 family and the Namer heavy tracked armoured personnel carrier (APC).

Barak MBT

The Barak MBT currently features the most complete set of Carmel technologies. When the tank was officially unveiled in September 2023, the then Israeli Defence Minister Yoav Gallant declared the tank to be an "extraordinary leap forward". A joint statement by the MoD and IDF summarised the Carmel technology's role in defining the upgraded combat vehicle's capabilities: *"Sensing and front-end processing capabilities based on artificial intelligence, the ability to reveal the enemy and create targets for combat troops on the battlefield, full combat in closed ranges based on 360° peripheral observation and a 'pilot's' helmet for the commander, multi-touch screens, advanced operation controllers, adaptation to changing combat situations and improved survivability – these are just some of the capabilities of the new tank that was recently brought to service in the IDF."*

In detail, the suite on the Merkava Mk4 Barak includes:

- The full 'combat cockpit' configured with advanced crew stations featuring touchscreen displays, and sensor fusion.
- AI-driven situational awareness draws on multiple high-definition day/night external cameras and other sensors (including radars of the Trophy active protection system (APS), which is not itself Carmel-derived, along with signals intelligence sensors) distributed around the hull to jointly provide a 360° coverage of the vehicle's surroundings. Imagery is fused and transmitted in full colour to the head-up display on the commander's IronVision Augmented Reality (AR) helmet. As the tank commander turns his head, the camera facing in that direction slaves its feed to the helmet, enabling the commander to virtually 'see through' the hull to gain first-hand situational awareness while under armour. Only the vehicle commander is equipped with the AR helmet developed by Elbit Systems. However, situational data from the sensors is also displayed at the digital workstations of other crew members, primarily the driver and gunner; the data feed here is tailored to the requirements of each individual crew member.
- AI-assisted target recognition and prioritisation support is embedded on the Barak, identifying and classifying moving or static objects and persons using sophisticated algorithms and machine learning. While the AI rapidly devises a threat assessment and suggested order of engagement, the decision to engage and the act of firing primary and secondary weapons remains with the human crew. Still, the fire control system (FCS) integrates with the tank's sensors and data processing capabilities, shortening the time needed to engage targets. The gunner's workstation is equipped with a joystick used for aiming and firing the main gun, again facilitating rapid target engagement.
- The autonomous mobility systems trialled during the Carmel programme (such as automatic driving and navigation) are not yet in place.

In addition to the on-board systems, the tank is fully networked with the IDF's combat cloud and command and control (C2) systems. Data is shared in real time – in both directions – with other AFVs as well as with command nodes, dismounted infantry and UAVs. This includes sharing the threat and target mapping generated automatically by the Carmel system using the onboard sensor data.

The IronVision helmet projects imagery from the AFV's external sensors onto the crew's personal HUD. [Elbit Systems]

Eitan

The Eitan AFV will be produced in two variants. The Eitan IFV configuration (which will feature an unmanned turret mounting a 30 mm cannon) has been designated as the primary platform for evaluating Carmel technology integration on wheeled AFVs. However, the IFV variant is still in development and testing, with no official date provided for fielding.

The operational APC version has been fitted with select components similar to those trialled on Carmel, such as the touchscreen-equipped digital combat cockpit; panoramic cameras distributed around the hull to provide 360° coverage

The Eitan APC (shown here) and Merkava Barak MBT are the first AFVs to receive elements of the Carmel technology suite as they become available. [MoD Israel]

of the vehicle's surroundings; transmission of camera views to each workstation to provide real-time situational awareness; network integration and data sharing with the IDF MBSBMS).

However, the IronVision AR helmet has not been provided to the Eitan vehicle commander. Nor is the APC equipped with the full AI-guided sensor fusion suite or the advanced fire control and target prioritisation capability. As it currently stands, all indications are that the IDF will wait for the IFV variant of the Eitan before fielding such technologies on the platform. Nonetheless, the existing technologies which have been integrated optimise the APC for closed hatch urban fighting, enhancing both safety and lethality in such scenarios.

Namer

The Namer tracked heavy APC entered service in 2008 in limited numbers, with further vehicles trickling into service since. A limited number of vehicles are understood to have been equipped with Carmel-derived technologies, these thought to be the 'Namer 1500' variant, which purportedly also features a 1,119 kW (1,500 hp) engine.

Namer 1500 deliveries commenced in 2023, and operational vehicles are understood have so far received limited Carmel-derived elements including digital crew displays (but not the full combat cockpit panoply) and the panoramic external camera suite to provide a 360° overview of the vehicle's surroundings. Over time, fielding on the Namer is expected to continue to include deeper integration of multiple subsystems.

Doctrinal change

The Carmel programme is considered to be more than a standard technology upgrade. "*The Carmel solution (...) includes a combination of capabilities, systems, groundbreaking innovation and connection to the world of AI as an additional strategic capability the IDF can use in the future battlefield. Carmel will enable complex ground operations with less risk to human lives, which will transform ground combat strategy as we know it today,*" said IAI President Boaz Levy in 2021. Key shifts in operational doctrine being enabled or pushed by the new technology include:

Limited integration and evaluation of selected Carmel technologies on the Namer APC has begun. [IDF]

A see-through armour system (pictured) provides crews with 360° situational awareness, eliminating 'tunnel vision' dependence on small viewing ports. [Elbit Systems]

- **A survivability shift through closed hatch fighting:** For decades, Israeli tank doctrine relied on the commander fighting 'heads out' for situational awareness, especially in urban environments. Carmel-derived technologies allow crews to remain fully closed hatch without losing awareness. Survivability is no longer traded against visibility. Closed hatch operations have become especially crucial since the introduction of small drones on the battlefield.

- **Transformation of crew workload through AI assistance:** Carmel-derived technologies are intended to reduce the cognitive burden under fire, allowing crews to focus on command decisions rather than sensor management.

- **From platform centric to networked lethality:** Network-enabled vehicles are intended to operate as nodes in a digital battlefield rather than as standalone vehicles, significantly enhancing survivability, lethality, and speed of combat operations, especially in dense urban terrain with asymmetric threats.

Going forward

Despite the successful integration work to date, the Carmel programme is far from complete. Several core elements are still under development or being refined, including the mobility suite for AI-driven autonomous route planning. The AI-driven lethality suite for target acquisition and prioritisation system, while already integrated onto the Merkava Mk4 Barak, also continues to be refined and advanced. As the subsystems mature and are proven on one operational platform, they will be incrementally integrated onto other in-service AFVs. In August 2025, the IDF announced a USD 1.5 billion initiative (subject to Knesset approval) to increase production of Merkava Mk4 Barak MBTs as well as Namer APCs and both Eitan APCs and IFVs over the coming five years. This production surge will be accompanied by expansion of the Carmel suite of capabilities on the respective AFVs.

While the IDF has not confirmed a 'launch date' for the Eitan IFV, the new procurement plan implies confidence that it will enter service by 2030. As the designated test bed for wheeled AFVs, it is likely to have considerably deeper Carmel integration than the current Eitan APC fleet. This would presumably include the full combat cockpit, advanced fire control, networked sensor fusion for 360° situational awareness, semi-autonomous driving capability, and teaming with/control of unmanned systems.

The Israeli MoD has stated that Carmel's combat cockpit and AI systems will be gradually embedded across the IDF's armoured fleet, which could mean eventual integration of the system onto armoured engineering and support vehicles. Future AFVs are likely to integrate the full 'Carmel suite' from the beginning. For that matter, it stands to reason that the Carmel programme itself is unlikely to reach an actual end-state. Individual elements will continue to be refined, and totally new technologies may well flow into the suite over time. Deeper levels of AI support and autonomy would be consistent with technological trends in leading armed forces around the world. Introduction of an optionally unmanned capability cannot be ruled out. As the Carmel programme evolves and proves itself operationally, the conceptual 'common suite' model could become a relatively attractive option for other armed forces to consider adopting.

Tank guns: The path beyond 120 mm

David Saw

It is generally accepted that there are three key criteria in tank design, the so-called 'iron triangle' of firepower, protection and mobility. In this article our interest is firepower, the current state of tank armament and its potential future evolutionary path. Central to this purpose is understanding how we got to the current state of play as regards tank armament.

Western Cold War efforts

Both the US and the British would introduce heavy tanks with large guns in response to the threat of the IS-3 (ИС-3; ENG: Iosif Stalin 3), a late–Second World War Soviet heavy tank and its successors in the 1950s. The US commenced work on the M103 heavy tank project at the end of 1950s, with the vehicle entering service in 1957 and its most significant feature was the 120 mm M58 L/60 gun. Only 300 of these tanks were ever built, with the vast majority going to the US Marine Corps (USMC); the tank was withdrawn by 1974.

Britain decided to use the US 120 mm gun for its own heavy tank programme, producing it as the 120 mm L1 tank gun. This would become the main armament of the FV214 Conqueror tank, which entered service in 1955 with only 185 built, before the vehicle was retired in 1966. Britain also had another heavy tank programme in the works, one which was predicated on the use of an absolutely extraordinary gun system, the 183 mm L4 gun. The only ammunition nature developed was high explosive squash head (HESH), a two-piece round, with its performance objective being penetration of 152 mm of armour with a 60° slope at 1,829 m. No other gun was capable of this performance at this time and it was believed that any hit on a target tank would lead to destruction or total disablement.

The L4 gun was initially to be mounted on the FV4005 vehicle, described as a heavy self-propelled anti-tank Gun, with a limited traverse. The eventual aim was to have the gun mounted on the FV215 heavy tank though in the end it was decided to end the programme and opt for anti-tank missiles as the most effective solution for long-range target engagement.

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A Centurion Mk 12 hull mated with the FV4005 turret, sporting a 183 mm gun. [RecoMonkey]

Arguably the most significant Western tank armament development of this period was based on the British 20-pounder gun used in the Centurion Mk 3. This was the 105 mm L7 rifled gun, which would become the dominant Western tank gun of its era. The US would adopt the L7 and modify it to become the M68, further increasing its market dominance. The L7/M68 105 mm guns were effective systems, but as the Cold War drew on, it was clear that threat armour was advancing in terms of protection and firepower, and so a response was necessary.

An unconventional solution adopted by the US was the M81 152 mm rifled gun and the MGM-51 Shillelagh gun-launched anti-tank guided missile (GLATGM) installed on the M60A2 tank and also on the M551 Sheridan light tank, however results were less than satisfactory. Less adventurous solutions were being considered, including in Britain where the search for a follow-on to the L7 led to the development of the EXP-14 110 mm gun; this would have employed a semi-combustible cartridge case with a metallic stub, with an autoloader being considered as a part of the armament package. In the end, Britain decided on the 120 mm L11 rifled gun, using two-piece ammunition for its Chieftain tank. Britain would remain wedded to the 120 mm rifled gun and two-piece ammunition for decades, with the L11 of the Chieftain superseded by the 120 mm L11A5 on Challenger 1, and then later the L30A1 120 mm L55 on Challenger 2.

The 1960s and 1970s saw numerous efforts at collaborative tank programmes amongst NATO nations, though the end results were never encouraging. That being said, one thing to emerge from these collaborative efforts was a weapon

that became the de facto NATO tank armament solution, which then spread globally. This was the Rheinmetall 120 mm smoothbore gun with the original L44 variant of the gun entering service with the Leopard 2 in 1979. It was then selected as the M256 by the US for the M1A1 variant of the Abrams that was produced from 1986, with the original M1 produced from 1978 to 1985 equipped with the M68 105 mm gun. The indigenous French 120 mm CN-120-26/52 gun designed for the Leclerc main battle tank (MBT) was built around 120 × 570 mm rounds to have commonality with the German gun. The Korean K2 Black Panther tank, as used by the Republic of Korea (ROK) and Poland, mounts a CN-08 120 mm; this Korean-designed weapon was built around the standard NATO 120 × 570 mm round.

Beyond the standard 120 mm L/44 gun, Rheinmetall would go on to develop the longer L55 variant initially for the Leopard 2A6, with the latest variant being the L55A1 as used on the current Leopard 2A8 and Challenger 3.

Soviet and Russian developments

Soviet tank armament developments explored both conventional and unconventional solutions. A proposed heavy tank design that featured a 130 mm gun and an autoloader was halted, although the latter option would become a feature of next-generation Soviet tanks. Instead, in the early 1960s, the T-62 was introduced, which represented a change in tank armament direction since the vehicle featured the smoothbore 115 mm U-5TD (2A20) gun. Then came the T-64A with a 125 mm 2A26 (D-81T) smoothbore gun with a carousel autoloader. Various improvements were made to the 2A26, resulting in the 2A46 family, with the 2A46-1 introduced on the T-64B.

Among the improvements introduced by the new 2A46 series was the ability to launch the 9K112 Kobra gun-launched anti-tank guided missile (GLATGM) developed by KBP to allow accurate engagements at extended ranges. Soviet GLATGM developments would provide capability for T-72, T-80 and T-90 tanks, as well as for earlier models such as the T-55 and the T-62 with the 9K116-2 Sheksna system. In parallel, improvements were made to the 2A46 gun to extract increased performance. It should be noted that Soviet technology provided the basis for current Russian and Ukrainian GLATGM systems, as well as Chinese weapons in this category.

A T-64B, which received the 2A46-1 125 mm smoothbore gun, which was also provided with GLATGMs and APFSDS rounds among its ammunition loadout. [RecoMonkey]

At the end of the Soviet period, a number of future tank programmes featured a significant increase in firepower. The first of these was Obiekt 292 undertaken by the Kirov Plant in what was then Leningrad, and which was based on the T-80 platform. The hull was a T-80U, with the turret being a T-80BV. The vehicle was equipped with an LP-83 152 mm smoothbore gun and autoloader. Allegedly the intention had been to develop a rifled 152 mm gun, but resources were not available to pursue this approach. A single Obiekt 292 vehicle was completed in September 1990 and tested in 1991, with the LP-83 said to have delivered 50% more muzzle energy than the standard 2A46 125 mm tank gun of the era. With the collapse of the Soviet Union, the Obiekt 292 programme made no further progress.

The Nizhny Tagil tank plant, later Uralvagonzavod (UVZ), was commissioned to design a new tank for the Soviet Army at the end of the 1980s as Obiekt 195, often referred to as the T-95. It was significantly heavier than Soviet tanks of the time and was equipped with a 2A83 152 mm L55 smoothbore gun and autoloader – a different design to the Obiekt 292 gun. The collapse of the Soviet Union saw all work halted on the programme in the early 1990s, but in the early 2000s, UVZ began working on the programme once more, but official support for the project ended by the late 2000s, although UVZ did try to continue the programme as a private venture for a little while.

Another Nizhny Tagil programme was Obiekt 187, which featured improved protection and mobility compared to other Soviet tanks of the 1980s. It also featured a new gun, the 2A66 125 mm L48 smoothbore, which had more impressive performance than the standard 2A46 tank gun. In parallel with Obiekt 187, Nizhny Tagil also worked on a lower-risk tank design in the form of Obiekt 188, which would eventually go into production as the T-90. The T-90 in turn would also see the arrival of more capable GLATGMs in the form of the 9M119M Invar and 9M119M1 Invar-M.

There were a number of other Soviet-era large tank gun programmes that entered the testing phase, including the 130 mm M-65 L60 rifled gun that emerged in the 1950s. This gun system would emerge once more at the end of the 1970s in an improved version becoming part of the Obiekt 795 testing programme. This programme would also see the arrival of an early version of the 2A82 125 mm smoothbore gun.

The T-14 Armata, first shown in 2015, was fitted with the 2A82-1M 125 mm gun, operating at higher pressures and capable of firing longer munitions than the earlier 2A46 series. [RecoMonkey]

However, it was the arrival of the UVZ T-14 Armata tank prototype in 2015, previously known as Obiekt 148, which can be said to have acted as a catalyst to recent Western tank developments. Advanced in conception and equipped with a 2A82-1M 125 mm gun offering higher performance than the 2A46 family, and capable of handling longer ammunition, the Armata represented a major advance in Russian tank capability. However, actually fielding significant numbers of these tanks appears to be beyond Russian industrial capabilities at this time.

MGCS: The way ahead?

The Franco-German Main Ground Combat System (MGCS) is a collaborative defence programme intended to meet future armour needs. Inevitably, multinational collaborative programmes are complicated, highly politicised and industrially complex. This complexity is demonstrated by the fact that there are two choices for the main gun of the MGCS tank variant, one of French origin and one of German origin; both would appear to be viable options, but there can only be one winner!

The irony is that one might suggest that both of these options can trace their lineage back to a NATO programme that got underway in the Future Tank Main Armament (FTMA) programme in the late 1980s that involved France, Britain and Germany with the objective of developing a 140 mm NATO standard smoothbore tank gun. The US would later join this NATO effort, although major British involvement would cease at a later date.

This was the era of programmes such as the US Advanced Tank Cannon (ATAC) that developed the XM291 gun designed in both 140 mm and 120 mm calibres. Elsewhere, Germany had worked on a Leopard 2 upgrade, which was the multi-stage Kampfwertsteigerung (KWS) programme. Under KWS 1 the Rheinmetall 120 mm L44 smoothbore gun was replaced by the new Rheinmetall 120 mm L55, operating at higher pressures, providing increased performance. The KWS 2 programme integrated enhanced protection features (which would be used on the Leopard 2A5). While the far more ambitious KWS 3 would see a new turret fitted with the 140 mm NPzK smoothbore gun, an autoloader and a reduced crew of three, in the mid-1990s, the KWS 3 upgrade was cancelled. On the other hand, as we shall see, France continued with serious 140 mm tank gun work through the 1990s and beyond.

Meanwhile in Germany, Rheinmetall adopted a two-track approach to tank gun development. Following the development of the Rheinmetall 120 mm L55 gun, the next step was to design improved ammunition to take advantage of the increased performance, and this saw the development of the DM73 armour-piercing fin-stabilised discarding sabot (APFSDS) round that was said to offer an 8% performance boost over the previous generation DM53 and DM63 APFSDS rounds. Even more performance could be extracted from the L55 gun and this would be achieved by a new APFSDS round, the KE2020Neo, designed to offer a 20% performance improvement over current standard APFSDS 120 mm rounds.

Rheinmetall then decided to look at possible solutions for a next-generation tank gun that would significantly surpass 120 mm L55 performance. The first evidence of their efforts in this direction was the display of a new 130 mm gun system at the 2016 Eurosatory exhibition. This particular system had been used as a firing demonstrator to explore the performance parameters

The KF51-U prototype, armed with Rheinmetall's 130 mm gun integrated with their Concept Uncrewed Turret (CUT), was displayed at the Rheinmetall stand at Eurosatory 2024. [RecoMonkey]

of the new gun. The key objective was to have a gun system that delivered a round on to the target that had over 50% more energy than the equivalent 120 mm round. Other factors that influenced weapon design were finding the most effective combination of system weight, recoil force and barrel length. The gun system is also integrated with an autoloader, while new ammunition types are being developed such as a next-generation kinetic energy (KE) munition and a programmable multi-purpose high-explosive (HE) munition.

Rheinmetall has developed the KF51 Panther tank as an upgrade for the Leopard 2 family; Hungary is the first customer and will use the 120 mm L55A1 gun along with an autoloader system. The turret will also be able to support the integration of the 130 mm L51 gun as part of an upgrade programme at a later date. Meanwhile in Italy, a new joint-venture, Leonardo Rheinmetall Military Vehicles (LRMV), has been formed, which will use the KF51 as the basis for developing a new tank for the Italian Army, with the 130 mm gun part of the programme.

The other solution for the MGCS is from KNDS, based on French work on future tank armaments both nationally and in connection with FTMA. By the mid-1990s, a 140 mm smoothbore gun system had been integrated with a specially modified Leclerc turret with autoloader, which potentially could have paved the way for a future Leclerc modernisation programme. However, the size of the ammunition, being more than 50% longer, as well as heavier than a standard 120 mm APFSDS round, would make it complex to offer as a simple upgrade. This would eventually lead to work on developing a more dimensionally efficient ammunition solution and towards maximising gun performance.

By Eurosatory 2022, KNDS was showcasing the 140 mm ASCALON gun for the first time, a system previously rooted in FTMA development. However, at that point it was clear that the 140 mm gun was a work in progress, as KNDS looked at evolving MGCS requirements and both current and future threat assessments. One important element was the evolutionary capabilities of the gun, as the gun shown in 2022 had the capability to accommodate a significant increase in chamber pressure to provide higher projectile velocity and extended engagement range. To take full advantage of this would require ammunition enhancements, something that KNDS was working on in parallel.

▲ The EMBT-ADT 140 prototype vehicle armed with an ASCALON 140 mm gun was displayed at the KNDS stand at Eurosatory 2024. [RecoMonkey]

By Eurosatory 2024, the ASCALON gun had undergone two years of development work and the 140 mm version was joined by a 120 mm version. Though the ASCALON 120 mm L58 gun can use all existing 120 × 570 mm NATO ammunition, KNDS have a new SHARD APFSDS round which offers a considerable performance increase over current rounds of this type. The 120 mm ASCALON variant can be easily and rapidly upgraded to the 140 mm version. According to media reports, KNDS suggested that the 140 mm gun could, because of its higher muzzle energy, deliver a round with as much as 70% more energy on to the target than a standard 120 mm round. The rounds displayed in 2024 also appeared slightly shorter than those shown in the mid-1990s.

Complicated international programmes like the MGCS future tank programme and the SCAF combat air system are inevitably highly political. MGCS programme timings have already slipped and that inevitably adds uncertainty into the long-term health of the programme. Despite this, both KNDS and Rheinmetall appear capable of providing viable gun solutions for MGCS. In the meantime, upgrading existing tanks by replacing current generation 120 mm gun systems offers a potential market while an MGCS decision remains pending.

Both of the guns being suggested for MGCS will have the capability to engage targets at extended ranges, with beyond line-of-sight capabilities mentioned. This opens the way for the adoption of new GLATGMs, presumably one of the reasons why MBDA unveiled the Akeron MBT 120 system at the DSEI exhibition in September 2025. This is a non-line-of-sight missile for smoothbore 120 mm guns, featuring a low-smoke motor and a passive infrared (IR) seeker. The system is ITAR-free (allowing it to be exported without approval by Washington DC) and uses commercial-off-the-shelf components, meaning that an in-service variant of the missile could be rapidly developed to meet customer demand. Other GLATGM solutions are available from or being developed by India, Israel, Türkiye and the Republic of Korea, amongst others.

Marketing Report: PIK-AS Austria GmbH

PIK-AS Austria GmbH launches additional ‘Made in Austria’ products

[PIK-AS]

PIK-AS Austria GmbH continues its growth strategy and further expands its product portfolio with new high-quality solutions Made in Austria. This ongoing expansion represents an important contribution to strengthening market resilience and ensuring long-term supply security for customers.

Right at the turn of the year, product validations were successfully completed for several new components, including the STANAG Slave Receptacle, STANAG Blackout Position Lights, and the Convoy Cross Light, available in both standard and LED versions. All products meet the highest technical and quality standards and are specifically designed for use in land vehicles.

PIK-AS CEO Christina Polster expressed her pride in the entire project team:
“I am very proud of the outstanding commitment shown by our team under the leadership of Sebastian Wagner, who have worked intensively over the past months to expand our portfolio with additional high-quality products. With these new solutions, we once again deliver the reliability, performance, and quality our customers expect from PIK-AS.”

By expanding its portfolio, PIK-AS ensures that short lead times, excellent service, and consistent product quality remain available in the familiar PIK-AS manner. At the same time, the company reinforces its position as a reliable partner providing innovative and dependable solutions for military and governmental land vehicle applications.

With the successful validation of these new products, PIK-AS Austria GmbH once again underlines its commitment to quality, innovation, and manufacturing excellence within the heart of Europe.

From logistics to liability: Bridging the 'trust gap' in naval 3D printing

Dr Alix Valenti

Additive manufacturing (AM), also known as 3D printing, promises naval forces unprecedented autonomy at sea, such as the ability to print replacement parts in hours rather than wait weeks for resupply. However, a 2016 experiment that brought down a drone with corrupted design files exposed a critical vulnerability which poses risks to widespread operational adoption. Until navies can guarantee both digital security and physical reliability, 3D printing will likely remain confined to non-critical systems.

During RIMPAC 2024, USN crew successfully 3D-printed a replacement part onboard USS Somerset. [US Navy]

What if all it took to bring down a military drone was a corrupted 3D printer file? No explosives, no jamming, no physical interference—just a few lines of malicious code buried in a blueprint. That's exactly what a team of researchers demonstrated in 2016 when they hacked into and modified the digital design of a drone's 3D-printed propeller. The part looked flawless. But mid-flight, under load, it shattered and the drone dropped. The mission was over within minutes, not because of enemy fire, but because of a flaw no one could see, in a part no one ever physically touched.

AUTHOR

Dr Alix Valenti is a freelance defence journalist with 10 years' experience writing about naval technologies and procurement. From 2017 to 2019, she was Editor-in-Chief of Naval Forces. Alix holds a PhD in post-conflict reconstruction.

The 2016 Dr0wned experiment was not a fluke. It was a warning. As navies turn to AM for spare parts, mission-specific tools, and unmanned systems, the appeal is obvious: speed, autonomy, resilience. But its use remains limited to non-critical parts. Why? Trust. Trust that design files haven't been compromised. Trust that printed parts will hold under pressure, in unforgiving environments.

Beyond logistics: The strategic return on investment

In 2022, the US Navy (USN) launched its Additive Manufacturing Center of Excellence in Danville, Virginia. Two years later, sailors aboard USS Somerset 3D-printed a replacement part for the ship's desalination system mid-mission during RIMPAC 2024. The Royal Australian Navy (RAN) took things further with a full deployable 3D printing lab – the DAMR system – fielded during Talisman Sabre 2025. And every Royal Netherlands Navy (RNLN) ship now sails with onboard 3D printers as standard issue.

These examples reflect a broader shift. AM is becoming a practical tool for navies seeking greater independence, flexibility and responsiveness at sea. Where a failed bracket or worn pipe once meant weeks of delay, it can now be replaced in a matter of hours. "One of the main benefits is that it allows deployed ships to become more self-sufficient and reliant," said Max Nijpels, AM engineer at the RNLN Expertise Centre for Additive Manufacturing (ECAM). For navies that routinely operate far from home – including the RNLN, USN, RAN, Royal Navy (RN) and Marine Nationale (MN) – that self-sufficiency directly enhances operational availability.

Beyond logistical speed, AM offers a path through obsolescence. Where Original Equipment Manufacturers (OEM) ceased production or disappeared altogether, additive methods allow crews to reproduce components that would otherwise be unavailable. As Nijpels noted, the long-term aim is to embed AM into the naval supply chain – not as a last resort, but as a core capability that increases fleet readiness.

The economic case is no less compelling. A 2019 study by the US Naval Postgraduate School, titled 'Additive Manufacturing Laboratories at Sea and their Value to the Navy's Seagoing Warfighter', concluded that AM laboratories at sea could generate a 234% return on investment and a 334% return on knowledge. The analysis concludes: *"Because AM could potentially play a major role in manufacturing time-sensitive parts on demand for sustainment and readiness for entire Battle Groups at sea, AML installation on naval vessels clearly provides a value-added capability to the Navy."*

More recently, AM has also been used to experiment with rapid prototyping. At the Bold Machina 2025 exercise, held at the Nieuwe Haven naval base in Den Helder, The Netherlands, during September 2025, special forces from multiple nations collaborated on the design and deployment of an unmanned surface vehicle (USV).

The hull was printed on site by Dutch company CEAD using ruggedised thermoplastic composites, while commercial off-the-shelf components filled out the navigation, propulsion and sensor suite. "This was not just about printing parts, it was about proving that special forces can locally manufacture and deploy functional systems within hours, without relying on fragile supply chains" explained Charlene van Wingerden, Chief Business Development Officer at CEAD.

This provided flexibility and the ability to quickly iterate between designs. For instance, the officer overseeing the training told journalists: "One of the battery packs didn't fit quite right in the first version, so we just updated the Computer-Aided Design (CAD) file and printed a new one the next morning. That kind of iteration would take weeks in a normal setting." The goal was not simply to build a boat, but to demonstrate that functional, mission-specific platforms can be generated quickly and affordably – even by users with no robotics background. In doing so, the exercise underscored AM's growing potential to support rapid prototyping and tactical innovation at the edge.

Yet for all the benefits it offers and the promises it holds, AM remains largely experimental in most navies. The RNLN is among the few that have already integrated it more systematically. The technology itself is no longer the barrier, with large-format printers now producing USV hulls within hours, and smaller systems routinely accelerating supply workflows. Rather, the constraint is operational: most applications remain confined to non-critical systems. As with AI, broader adoption hinges on a single factor: trust.

The invisible saboteur: When the file is the weapon

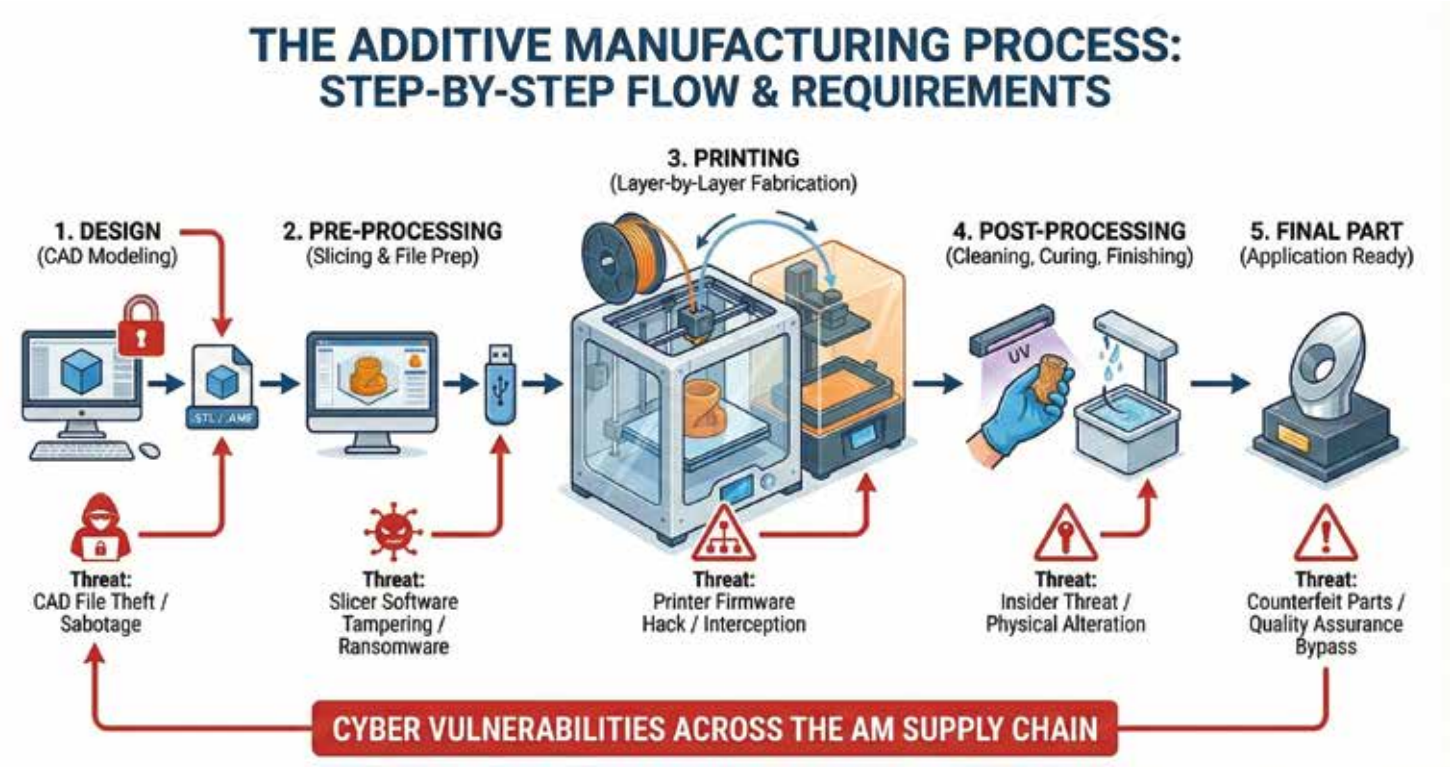
At its core, AM is a digital process. From design to print, a part exists solely in the digital space – first as a CAD file and then as a Technical Data Package (TDP). For navies, the process begins even earlier: the moment a deployed unit requests a TDP to replace a component, it steps into the digital domain – and creates a chain of potential cyber vulnerabilities.

The 2016 Dr0wned experiment illustrated this risk. Conducted by researchers from Ben-Gurion University, the University of South Alabama, and the Singapore University of Technology and Design, it demonstrated how a malicious actor could infiltrate the AM process for a USD 1,000 drone and introduce subtle flaws into one of its critical components. The attack began with a phishing email containing a malicious PDF. Once opened, it installed remote-access malware, allowing the attackers to locate the drone's blueprint, alter the propeller design, and let the 3D printer execute the rest. Visually, the defective propeller was indistinguishable from the original. But mid-flight, under basic aerodynamic stress, it shattered, bringing the drone down.

During exercise Bold Machina 2025, Special Forces 3D-printed (using CEAD's printer) and fitted a USV with COTS in just under one week. [Alix Valenti]

Nearly a decade later, cybersecurity awareness has advanced, especially within armed forces. Navies now operate cybersecurity centres and task specialists with managing digital risks aboard increasingly connected vessels. Still, within the broader force, the implications of system-of-systems integration and the Internet of Things (IoT) are not always fully understood.

A 2021 audit by the US Department of Defense (DoD) Inspector General, titled "Audit of the Cybersecurity of Department of Defense Additive Manufacturing," found



The AM process presents multiple cyber vulnerabilities across the AM supply chain. [Generated by Gemini]

that AM systems at several reviewed sites were not consistently secured or managed to prevent unauthorised modifications or protect the integrity of design data. One core issue was perception: AM systems were seen as tools to generate parts, not as networked IT systems requiring appropriate cybersecurity controls.

This is a critical gap. AM systems operate within broader naval networks. Misunderstanding this context opens multiple attack vectors. Beyond sabotaging a physical part, a network intrusion could enable intellectual property (IP) theft, allowing adversaries to reverse-engineer capabilities or identify structural weaknesses. Intercepting an unsecured TDP request could reveal mission-critical vulnerabilities. "Imagine sending a request for a weapon system's spare part TDP, or carrying out a remote survey to certify that spare part," Nijpels explained, "you definitely would not want your adversary to know that you are one weapon system down!"

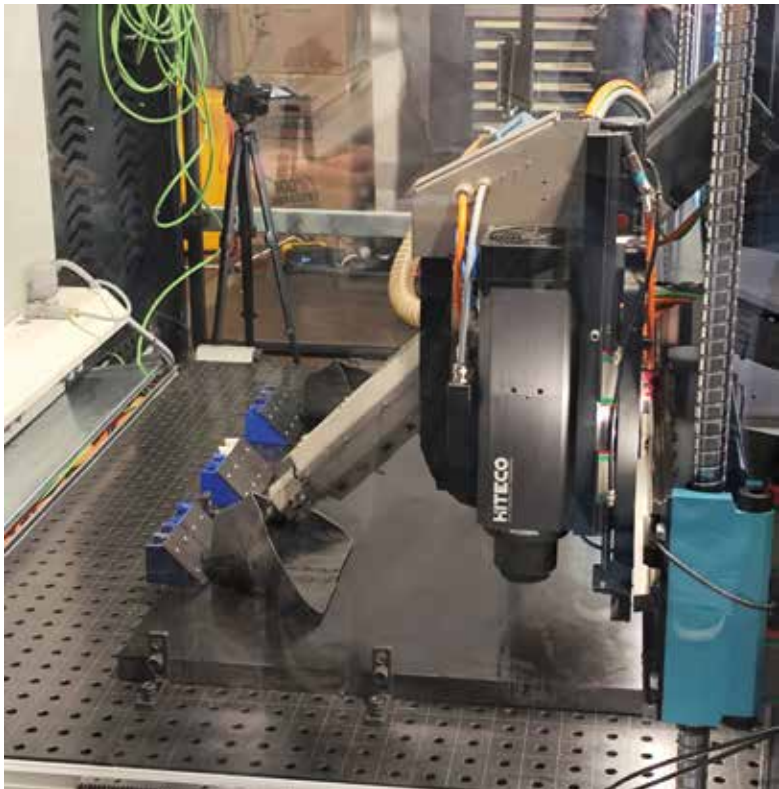
Perhaps even more worrying is the latest research from a team of researchers from the University of Louisiana and Auburn University. In a 2024 paper, "Decoding Intellectual Property: Acoustic and Magnetic Side-channel Attack on a 3D Printer", they demonstrated that direct intrusion with an AM process may not even be necessary to carry out IP theft. To translate a 3D model into layer-by-layer instructions, AM uses G-code, a programming language that dictates the printer's movements to create the object. Creative attackers could utilise a smartphone's built-in sensors – including the microphone – to capture this data and reverse-engineer the parts.

While such an attack might seem implausible in naval settings where smartphones are restricted or offline, it underlines a broader truth: cyber threats evolve quickly, and attackers are often more imaginative than expected. Cybersecurity remains a constantly moving target.

Securing the digital supply chain

Yet as with all things cybersecurity, all is not doom and gloom. As with most digital systems, the key lies in identifying potential vulnerabilities and developing effective mitigation strategies.

For the RNLN, the solution – at least for now – is very clear: to serve its fleet of 3D printers, files are stored and uploaded on secure internal communication networks and 3D printers are never connected to external networks. This is essential, explained Max Nijpels, because most of the RNLN fleet lacks digital twins – there is no comprehensive digital record of spare parts. "But we are working on creating a database for AM parts that will be available on all ships and will remove the need to contact ECAM when they need spare parts," he said.



Pictured is a CEAD 3D Printer used during Bold Machina 2025. [Alix Valenti]

In practice, when a ship requires a spare part, the crew submit a request to ECAM, which provides the TDP through the secure network. The part is printed onboard and fitted to the system. Building this database will take time, but the benefits are already clear. "Once a digital version of a part has been created, the entire RNLN and Marines fleet can benefit from it," Nijpels added. Ultimately, this will streamline workflows and enhance cybersecurity.

The US DoD took a similar step in 2020 by launching JAMMEX (Joint Additive Manufacturing Model Exchange), a secure, centralised web-based repository. It allows personnel to access pre-approved 3D models validated by engineering authorities such as DLA and NAVSEA.

they can use it with confidence. Had the Dr0wned experiment included a certification step, the flaw in the drone's propeller would likely have been caught, and the mission completed.

For shore-based production, certification is more straightforward. Classification societies like DNV (Norway), Lloyd's Register (UK), and ABS (US) are actively working with industry to streamline certification. Their efforts are guided by the International Association of Classification Societies (IACS), which released Recommendation 186 in 2025 – a framework for qualifying and certifying 3D-printed metal parts for marine use. This is how, when a chilled water pump cooling rotor failed aboard an *Arleigh Burke* class guided missile destroyer,

The RNLN's ECAM tested its UltiMaker FDM printers aboard the logistics support ship HNLMS *Pelikaan* under different sea conditions. [Dick Langer, via Wikimedia Commons; CC-BY-SA 4.0]

And to support secure interoperability across allied navies, NATO developed RAPID-e (Repository for Additively Manufactured Products in a Digital Environment), a digital library that enables the secure storage and exchange of TDPs. It ensures that a certified file retains its status when printed by a different nation. RAPID-e became operational in December 2024.

Of course, even a secure repository may present potential vulnerabilities. That is why the US National Innovation Advisory Council (NIAC) announced in 2017 that it would start exploring blockchain technology to secure 3D printing processes. It is however difficult to assess how far the NIAC efforts have gone as there appears to be no publicly available information past 2021.

The certification gap: Why 'good enough' isn't enough

Closely tied to cybersecurity is the question of certification. Without it, trust in 3D-printed parts remains limited. If crews can verify that a printed part or process has been certified,

it was replaced within weeks at a fraction of the cost: just USD 131.21 for the printed blade, versus USD 316,544.16 to replace the entire motor through conventional means.

But certification of parts that have been 3D printed while on deployment is tricky. A CAD design for a part may have been certified, but replicating it in a maritime environment introduces variables: salinity, humidity, vibration, and sea state can all affect print quality. The RNLN's ECAM tested its UltiMaker FDM printers aboard the logistics support ship HNLMS Pelikaan under different sea conditions. "At the time we found that, while sea states did not appear to affect the quality of the printing, engine vibrations did," Nijpels explained. The solution was simple: relocate the printer to a more stable area of the ship.

But these variables raise broader questions, particularly around liability. If a printed part fails and damages a critical system, who is responsible? The OEM that provided the original design? The printer manufacturer? The ship's crew?

Data-driven trust: Remote surveys and in-process monitoring

To some extent, certification bodies are beginning to confront the challenges of remote and in-situ validation. DNV's In-Process Monitoring standard, DNV-ST-B203, shifts focus away from certifying individual parts and toward certifying the process itself – including the machine and its feedstock. The rationale is straightforward: if the printer is calibrated and the material verified, the output can be trusted – within defined limits. Yet those limits may be challenged under conditions aboard naval vessels, where environmental factors such as vibration, salinity, and temperature variability challenge consistency.

In the commercial sector, remote surveys are advancing rapidly. In 2018, Lloyd's Register began collaborating with The Welding Institute (TWI) based in Cambridge, UK, to develop remote technologies and smart sensors for surface and subsurface inspections in hazardous environments. In the US, ABS has issued guidance for the safe use of remote inspection technologies.

As for industry, van Wingerden told ESD that certification always lags behind innovation, especially when new materials and new processes enter naval workflows. "What we do today is make the process as controlled and traceable as possible," she explained. "Our machines log extensive process data, monitor key parameters in real time and maintain strict repeatability. That foundation is essential, because once certification frameworks catch up, the question will be whether the process is trustworthy."

These tools promise agility and reach, but naval conditions add complexity. In an environment where connectivity can be spotty at best, and where the safe encryption/protection of that connectivity is paramount, can remote surveys really be the solution?

Nijpels pointed to a possible future where in-process monitoring is combined with artificial intelligence (AI). "Carefully developed algorithms could be used to detect if there is an issue, even a cyber issue, in the printing process or the integrity of the material," he explained. Such systems could offer real-time validation and deeper confidence in parts produced at sea.

Command trust: The final component

For all its potential, AM remains a capability in search of command trust. Cybersecurity and certification are not just technical hurdles – they are operational bottlenecks. Until navies can ensure that a part is both digitally secure and physically reliable, 3D printing at sea will remain largely confined to non-critical systems and non-mission-essential repairs.

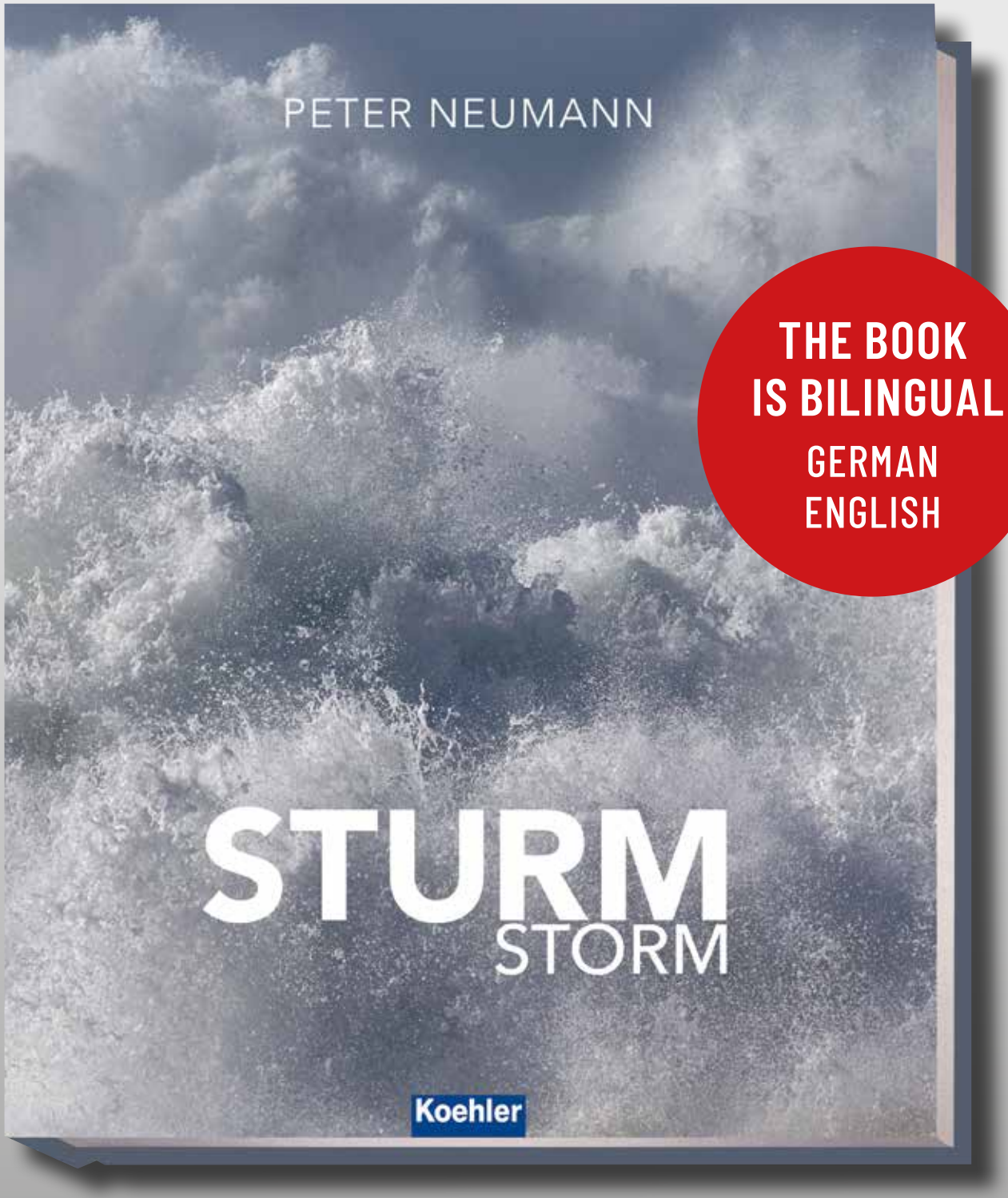
To address this, several organisations are developing tiered approaches to trust. The US' Naval Sea Systems Command (NAVSEA) has introduced a 'green box' system, a framework that works on a tiered model going from low-critical parts to highly-critical parts and, as such, delineates what can be printed, by whom, and under what conditions. The RNLN applies a similar concept, calibrating risk by type of part, application, and certification level. This tiered model helps commanders make informed decisions: they don't need to trust everything, just the right things, in the right context.

In the meantime, AM will continue to prove its value where the stakes are manageable. At the Bold Machina 2025 exercise, the goal was not to develop the state-of-the-art, but "the state of the possible," as one trainer put it. That mindset – experimenting within safe operational boundaries – may be the key to unlocking wider adoption.

Industry actors are also working toward the same end. Certain companies developing large-format naval AM systems see the path to wider adoption as running through process reliability. "If commanders can see exactly how a part was printed and if those parameters are consistent every time, then certification becomes an exercise in validating the process rather than re-inspecting every part," van Wingerden explained. Such data-rich workflows do not replace certification, but they can accelerate it once standards mature.

As navies move from pilot projects to scaled implementation, trust will remain the bridge between experimentation and doctrine.

Pictured: Multiple vessels of the RNLN operating together. All RNLN vessels now carry 3D printers aboard. [RNLN]



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Integrated logistics support data: Operational availability and lessons learned

Guy Langenaeken

Integrated logistics support (ILS) data connects engineering, procurement, and maintenance across a system's entire lifecycle. This article examines some of the key specifications, tools, and lessons learned in this sphere.

ILS data overview

ILS data are all logistical data that you need to operate and maintain your civilian or military system. Industry, armed forces, and NATO agencies use enterprise resources planning (ERP)

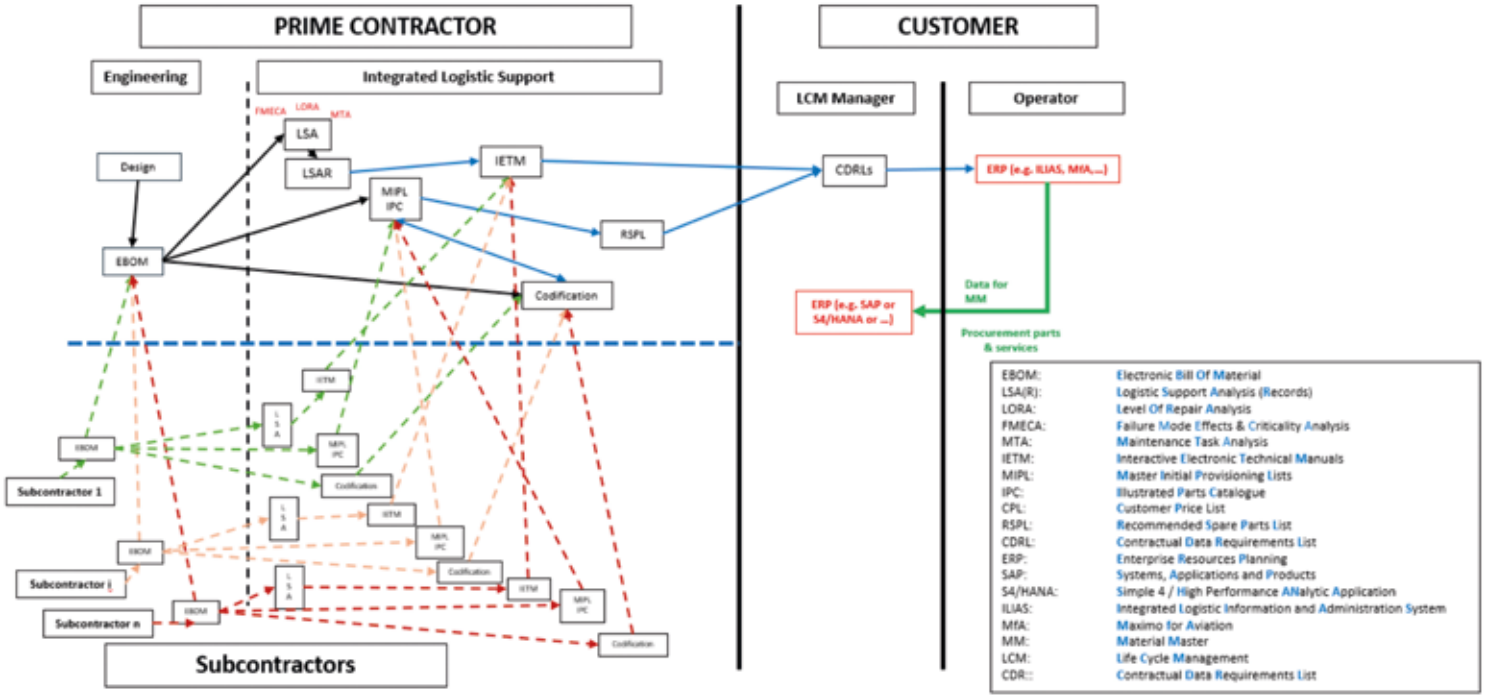

Fig 1: General data structure for a complex system of systems. [Guy Langenaeken]

AUTHOR

Guy Langenaeken has an MSC in Engineering and has started a PhD at the University of Liège in Belgium. He has over two decades experience of working with data for the Integrated Logistics Support of Alouette II & III, A400M, NH90 and the NATO RQ-4D. He has headed the Codification Department in the Belgian National Codification Bureau (NCB) and been Belgian NCB representative to AC135 (Codification), as well as AC135's representative in AC327 (Life Cycle Management). He currently works at the NATO Support and Procurement Agency (NSPA) in Luxembourg and is a member of AC327 Working Group 3, which concentrates on Life Cycle Cost.

software, which provides the integrated management of main business processes. It helps run core business processes in a single tool for departments such as engineering, finance, manufacturing, human resources, procurement, supply chain and others.

Industry, armed forces, and NATO agencies may use a product lifecycle management (PLM) tool: this is used to manage a product and its associated data through all stages of the product lifecycle. It includes data from requirements, documents, items, parts, products, engineering change orders, quality workflows, etc. Though primarily used by design and engineering teams working with computer-aided design (CAD) data, such a PLM tool can provide visibility into the product design process for all business stakeholders. Integrating ERP and PLM into a single software solution at company level would make sense – this approach has been implemented by some companies.

ILS data cover the data needed to field a system and its support system and to sustain them during the life cycle of the system. It is important to be aware of the difference between ERP/engineering data on the one hand and ILS data on the other hand, since they have different purposes. Both data sets should describe the same system and both data sets are created on industry side to be used by industry and the customer, in accordance with the agreed maintenance concept.

Configuration data may refer to specific modules of equipment bought from a subcontractor and being identified as such to allow manufacturing. They may not have a part number & manufacturer code that is being used in logistics.

Logistical data have a totally different purpose: they must provide all the necessary data to allow the system to be operated and to be maintained. They must of course be consistent among them and they must be representing the system described in the configuration data. Configuration and logistical data must be consistent among them. This is sometimes called DataBase Consistency (DBC).

The ASD S-Series of IPS specifications

The S-Series of IPS Specifications suite from AeroSpace and Defence Industries Association of Europe (ASD) and Aerospace Industries Association of America (AIA) covers the whole spectre of Integrated Product Support. The overarching document of this series is SX000i Issue 3.1. It is over 600 pages, but one should in first instance read the first chapters. Figure 19 from this document illustrates the interactions between the other specifications of this ASD series:

a) ASD S1000D: International specification for technical publications.
b) ASD S2000M: International specification for material management.
c) ASD S3000L: International procedure specification for logistics support analysis (LSA).
d) ASD S4000P: International specification for developing and continuously improving preventive maintenance.
e) ASD S5000F: International specification for in-service data feedback.
f) ASD S6000T: International specification for training analysis and design.

The most important feature of the S-Series is the Common Data Model described in ASD SX002D. It ensures data consistency among the ASD S-Series IPS Specifications.

Link to operational availability

When a new system enters service, the same recurring questions need to be answered, including, but not limited to:

- Which maintenance concept (preventive and corrective) to be applied? Who (Armed Forces or Industry) will do which level at which location employing how many maintenance staff having which training and disposing of which support equipment and which test equipment?
- Which spares (range) and how many of each (scaling) need to be procured and where to stock them to meet the requested operational availability for the planned utilisation (for instance, 600 Flying Hours per year) at a minimum cost?
- What is the best possible maintenance organisation?

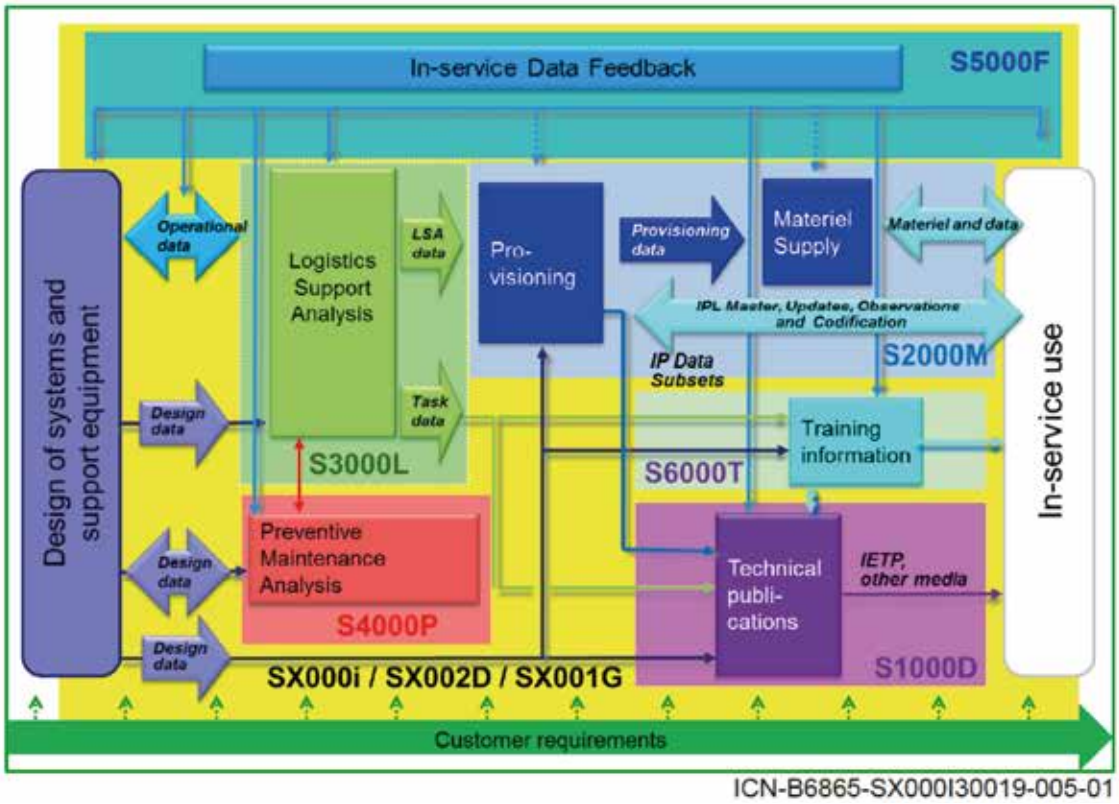

Fig 2: Relationships between ADS S-series IPS Specifications. [ADS]

- What is the impact if the predicted MTBFs / repair Turn Around Times / Provisioning Lead Times have been too optimistic?
- What would be the impact of changes (either positive or negative) of the parameters mentioned above? This is sometimes called 'sensitivity analysis' or the 'what if?'

Such questions can be answered in an optimal way by applying the system approach theory, which was first published in a RAND corporation publication in April 1964. Using system approach-based spares optimisation tools could lead to important (circa 20%, potentially even more) savings, while providing the same operational availability as the much more expensive previous item approach theory.

Lessons learned

- Data consistency is essential. Data consistency should be stated as a mandatory requirement in the request for proposal (RfP)/quotation and industry should be requested to prove this. Milestone payment(s) should be defined to guarantee data consistency in case a contract is granted.
- Logistics data should mandatorily have data formats compatible with the user ERP software and the LCM analytics logistics software.
- A logistics model reflecting the requested/proposed configuration (in line with the wanted maintenance concept) should be requested. This model should mandatorily be in the format of the logistical analytics software in use with the LCM manager on the user side.
- Item procurement prices , PLTs, applicable INCOTERMS, TAT, the reception cost and initial inspection cost of failed items to determine whether worth repairing or declaring it not economically repairable, should be in the logistics model and should be the prices and times to be used in a potential performance-based logistics (PBL) contract after selection – this should be a mandatory requirement.
- Necessary tooling in accordance with the maintenance concept should mandatorily be described in the ILS data set.
- Calibration requirements for such tooling should mandatorily be provided.

A means of compliance should be defined for each of the proposed mandatory requirements. The bids should not be considered if one or more of the abovementioned mandatory requirements are not met. All of the mandatory requirements should be linked to milestone payments if the contract is granted.

During contract negotiations there should be no reduction or weakening of ILS requirements for commercial or budgetary reasons.
In-service data capture at operational level is absolutely essential, especially now that artificial intelligence (AI) tools start to be used for analysis purposes. It should be used to improve the outputs of the analytics logistics model.

Conclusion

- Using system approach-based software allows determining an optimal spare parts list at minimum cost.
- Using system approach-based software allows potentially achieving the same operational availability at a substantial lower cost of the investment needed compared to item approach determined quantity for each individual item.
- Using system approach-based software allows users to optimise the yearly sustainment budget.
- The results of system approach-based software should be reviewed by maintenance experts before making decisions.
- Capturing real life in-service data is a must.
- AI tools should be used to analyse collected maintenance data.

The use of analytics logistics software is considered so important that their use has been made mandatory in 2024 by the UK Chief of Defence Logistics and Support. This is explained in the 'Support Modelling and Analysis Framework', published by the UK Strategic Command Defence Support in order to implement "Enhanced evidence based decision making to improve support to the front line".

Amplifying Your Life Cycle Management Impact: From Analysis to Influence

After nearly 20 years in Life Cycle Management (LCM) across rail and defence, I've seen brilliant analysis ignored, sound recommendations sidelined, and opportunities missed. The issue is rarely the analysis — it's influence.

Analysts and engineers do excellent work, but without shaping decisions, their efforts fall short. The same patterns repeat: strong data, clear logic, limited impact. This article reflects on that pattern and how to bridge the gap between analysis and influence.

From Analysis to Influence

LCM is too often treated as a technical process instead of a strategic one. Analysts produce robust studies, but short-term pressures or narrow KPIs often override long-term logic. This disconnect between insight and decision-making drains potential value.
Bridging it takes more than better data. It requires an intentional effort to ensure analysis drives choices — in design, budget, and strategy.

Four Foundations for Influence

Start early: The earlier LCM enters a program, the more impact it has. During the concept phase, requirements and support concepts are still flexible. That's when you can define availability, mission success, and life cycle cost together.
Sustain cost-effectiveness: LCC and availability require ongoing attention. Build regular checkpoints and use integrated logistics tools to adjust as contexts change — keeping guidance trusted and relevant.
Be proactive: Use mission reliability modelling, RAM analysis, and maintenance simulations to identify risks and optimise before failure occurs. Anticipation turns analysis into protection.
Elevate functional requirements: Technical specs aren't enough. Treat readiness, sortie rates, or turnaround times as primary requirements. Trace these outcomes back to design and support through RAM and IPS tools.

Why Good Analysis Sometimes Fails

Often, a preferred option is clear — higher build cost but lower LCC and greater uptime. Yet management picks the cheapest up-front choice. Why? Because governance structures still reward capex savings, short timelines, and technical delivery — not operational effectiveness or lifecycle value.
To overcome this, we must change the decision-making context, not just improve the model.

A Playbook for Greater Influence

1. Make LCM the governance language
   - Scope = operational outcomes
   - Cost = life cycle, not just capex
   - Time = readiness across the lifecycle
2. Tie every study to a decision
   Frame the analysis with a clear decision and deadline in mind.
3. Educate beyond the core team
   Help finance, sponsors, and procurement understand downtime costs and availability value.
4. Quantify real-world consequences
   Replace abstract terms with vivid impacts: "5–7 years of shutdown every 40 years" hits harder than "reduced availability."
5. Highlight inventory and maintenance trade-offs
   Use spare parts modelling and maintenance simulations to show the cost-benefit logic clearly.
6. Keep models simple and transparent
   Use the simplest valid model, but make logic traceable when complexity is needed.
7. Stay consistent under pressure
   Keep the lifecycle view alive during budget or schedule crunches. Influence is built through repetition.

Tools That Enable Influence

Logistics support software, RAM tools, and defence-specific fleet management systems make trade-offs visible and decisions defensible. These tools don't replace judgment — they amplify it.

Applying This with Opus Suite

Opus Suite supports this approach by providing the modelling, transparency, and structure to link analysis with decisions. It helps teams visualise how design and support choices drive cost, availability, and readiness.
With Opus Suite, analysts don't just show which option is better — they show why, at what cost, and in terms decision-makers can act on.

Final Thought

Influence isn't accidental — it's earned. Start early, define success in lifecycle terms, link analysis to decisions, educate broadly, and stay clear and patient. Do that consistently, and your analysis won't just be right — it will be used.

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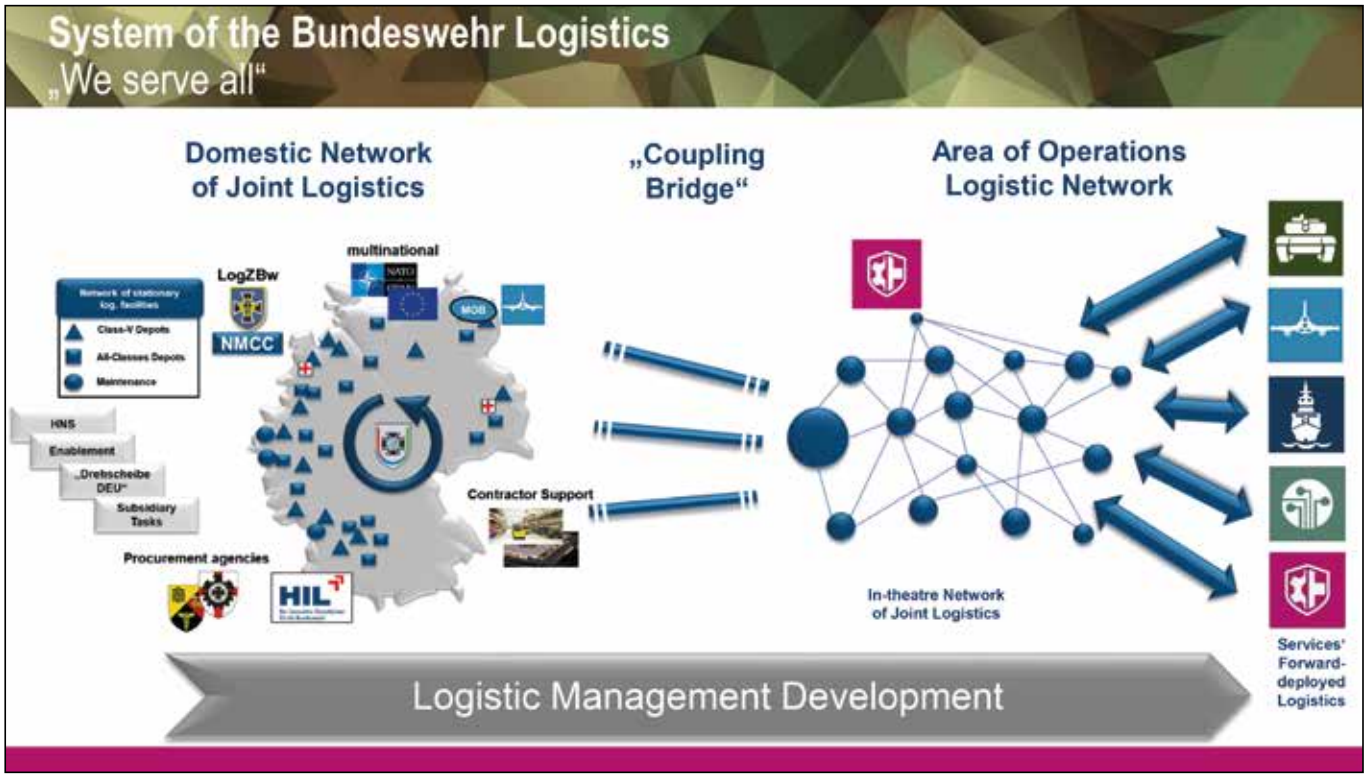
www.systecongroup.com

The role of logistics in the Bundeswehr: A foundation for the planning and conduct of operations

Lt Col Sebastian Mielke and Sebastian Gutjahr

In military practice, logistics is not an end in itself; rather, it is an essential foundation for all Bundeswehr combat forces to stand on, spanning all phases of the planning and conduct of operations. The scenarios that are currently considered most likely with regard to deployment within a NATO context call for the seamless integration and effective capabilities of a complex logistics network. Functionally, this network rests on three central pillars:

- First, the capabilities in the theatre of operations, which are provided by the mobile Bundeswehr Joint Support Command logistics forces; they support the service logistics of the combat units – be they Army, Air Force or Navy units or units of the Cyber and Information Domain Service or the Bundeswehr Joint Support Command (BwJSC).
- Second, the strategic "coupling bridge", which serves as an indispensable link between Germany and the theatre of operations abroad.
- Third, the capabilities of fixed BwJSC logistics facilities in Germany, including resource offices, as well as the integration of civilian commercial partners and the defence industry.



[Bundeswehr]

AUTHOR

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The strategic importance of a functioning and robust logistics concept has been thrown into stark relief by the ongoing war between Russia and Ukraine. Flexible and rapid operational support can be effective only if the underlying logistics network is robust and resilient. If the term "warfighting capability" is to be taken seriously in its true and full meaning, one must invariably be prepared to make substantial investments in the Bundeswehr logistics system.

At present, the Bundeswehr has about 182,000 military personnel, meaning that a smart mix of resources is necessary to accomplish these challenging tasks. This requires a joint, Bundeswehr-wide effort that also involves civilian and multinational third parties. The available quantities of numerous weapon systems have been reduced quite significantly. For historical reasons, the stockpiling of replacement and exchange items and ammunition has been geared towards routine operations and exercises as well as international crisis management. Now, stockpiling is gradually being adapted to meet the new requirements.

The Bundeswehr logistics system: structure and challenges

The Bundeswehr logistics system is well-established and available to all requesting agencies within the armed forces. Should there be an RSOMI operation for the purpose of collective defence, Germany would play a pivotal role as the central hub for Allied forces. However, the establishment of this 'coupling bridge' requires the use of commercial services because the military resources alone are not sufficient for this task.
The logistics network in the theatre of operations is characterised by great agility and the need for frequent redeployment due to the enemy's vast and rapid reconnaissance capabilities, especially in terms of service logistics. In theatre, a comprehensive logistics network is established that starts with the network of Bundeswehr Joint Support Command logistics in Germany and extends through the critical functionality of the 'coupling bridge' deep into the logistics network in the actual theatre of operations.

The term 'coupling bridge' entails much more than just the physical transfer of materiel to a different country. This bridge also serves to provide and make available services from third parties, including host-nation support (HNS), partners or private service providers.

A closer look at the logistics network in the theatre of operations

The core task of the mobile BwJSC logistics forces is to establish the BwJSC logistics network in the theatre of operations. They set up this network based on the schematic representation of a construct made up of logistical nodes. In the network, supplies are held available to support the various operational domains. These are quasi-stationary in the rear area but deployable closer to the forward area, so they can be made available to the service logistics organisations of the individual services as required.

To that end, the mobile logistics forces are employed in the form of both heavy and light logistics battalions. Depending on their specific mission and the theatre of operations, these battalions are able to ensure mobile, agile and situation-oriented resupply. Through these efforts, the mobile BwJSC logistics forces set the stage for the activities of the highly mobile service logistics forces in the various domains, thus ensuring their freedom of operation.

Which brings us to the final link in the Bundeswehr logistics system: the service logistics organisation. These forces receive supplies from the BwJSC logistics forces at agreed and designated interfaces and provide logistical services directly to the deployed forces of the respective domain (e.g. Army forces). Structured like this, the Bundeswehr logistics system has proven invaluable in operations abroad, domestic operations (e.g. disaster assistance) and exercises. The mobile BwJSC logistics forces are of particular and vital importance; without these forces, the deployed forces of the major military organisational elements would simply lack the crucial resupply route from Germany on which their lives depend, and they would also be unable to evacuate materiel to Germany.

The tasks of the mobile BwJSC logistics forces include logistical support to strategic deployment within the framework of the RSOMI (reception, staging, onward movement and integration) process as well as the integration of host nation services (HNS), of commercial services (contractor support to operations (CSO)) and of services provided by government institutions (for instance by HIL GmbH (Army maintenance logistics)).

The importance of integrated logistical support (ILS) and data management

The Bundeswehr approach to integrated logistical support (ILS; called 'Integrated Lifecycle Support' in NATO) is aimed at ensuring the logistical supportability of systems throughout their entire life cycle. This applies equally to all operational logistics business processes: materiel management, maintenance and production, and movement and transport.

The underlying master data, which is conveyed via the data models of the S-Series Integrated Product Support (IPS) specifications, forms the indispensable foundation of this system. Only because of this data is it possible to perform the logistical business processes of materiel management, maintenance and production, and movement and transport by means of the currently available software, SASPF (Standard Application Software Product Families).

Reliable master data is absolutely essential because it serves as the basis for decision-making and management with regard to the processes mapped in information technology (IT) systems. Without consistent master data, the results of IT-based automation or simulation would be flawed, leading to potentially incorrect deductions or decisions.

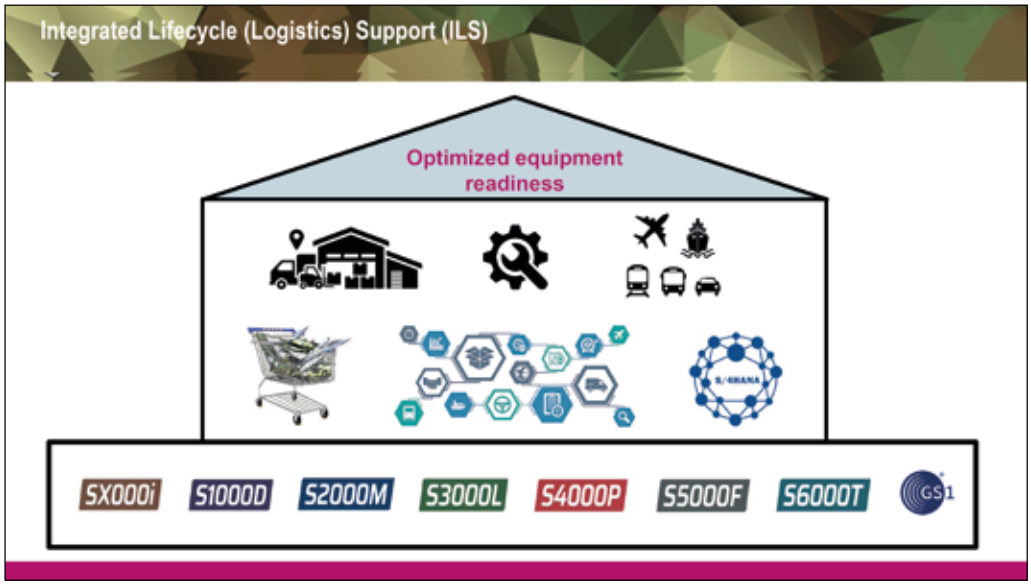
Currently, the following standards and specifications are to be used in the Bundeswehr and are linked to SASPF:

- S1000D: A specification covering technical documentation and the maintenance master data derived from it.
- S2000M: A specification covering materiel master data, cataloguing and materiel management, which also governs, among other things, procurement and management processes between the Bundeswehr and NATO defence agencies.
- Global Standard One: A standard for marking materiel to ensure it can be properly managed and tracked.

Future developments and benefits

Going forward, there are plans for the systematic application of the remaining IPS specifications (SX000i, S3000L, S4000P, S5000F and S6000T). This is directly related to Germany's ratification of NATO STANAG (Standardization Agreement) 4876 – the NATO regulation on the ILS process, also known as NATO GUIDANCE FOR INTEGRATED LIFE CYCLE SUPPORT (ALP-10).

As a result, there will be benefits for the Bundeswehr in several strategic areas:
Logistically optimal procurement and in-service use of defence products in the Bundeswehr relies on the standardisation of processes and data. It is therefore imperative that a uniform basis is provided for technical logistics management (TLM) and that consistent master data is made available in the IT systems (SASPF) and for the exchange of usage data. These digital and procedural



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standards provide the groundwork for the efficient and goal-oriented work of the operational business areas – namely materiel management, maintenance and production, and movement and transport – thus ultimately ensuring optimal operational readiness of material resources.

The comprehensive application of the ILS process is aimed primarily at maximising the operational readiness of weapon systems in the Bundeswehr, in addition to limiting life cycle costs (LCC).

Data governance forms the basis for all other activities. The goal of Bundeswehr logistical data management is to build a foundation strong and resilient enough to guarantee the efficiency and stability of all logistical processes. On a conceptual level, this foundation rests on four supporting pillars:

- The standards and specifications include mandatory guidelines on how data is to be generated, managed and used. International standards such as S1000D or S2000M are also included, and quite deliberately so. Strict adherence to standards such as these is the only way to ensure that data can be understood and used consistently, both internally and internationally – for example when cooperating with NATO partners.

- Cataloguing requirements are in place to guarantee unambiguous item identification. Use of the NATO Codification System (NCS) and the designated N-CORE tool ensure that materiel is catalogued without ambiguity throughout NATO. This creates indispensable transparency and maximum interoperability in the field of materiel management.

- For the day-to-day use of logistical data, processes are defined that specify how data is to be integrated into the various workflows. The task here is not just to establish rules but also to actively help with data maintenance, to manage interfaces with operational systems and to ensure that data is used correctly from the procurement of items to their segregation.

- Data quality management defines rules for data quality as well as specific actions that need to be taken in order to monitor and continuously improve these rules. Even the largest database is worthless if the data it contains is flawed or outdated. Therefore, processes are established to ensure the quality of the data through continuous review.
With such a solid foundation to stand on, it is possible to pursue two overarching strategic objectives:

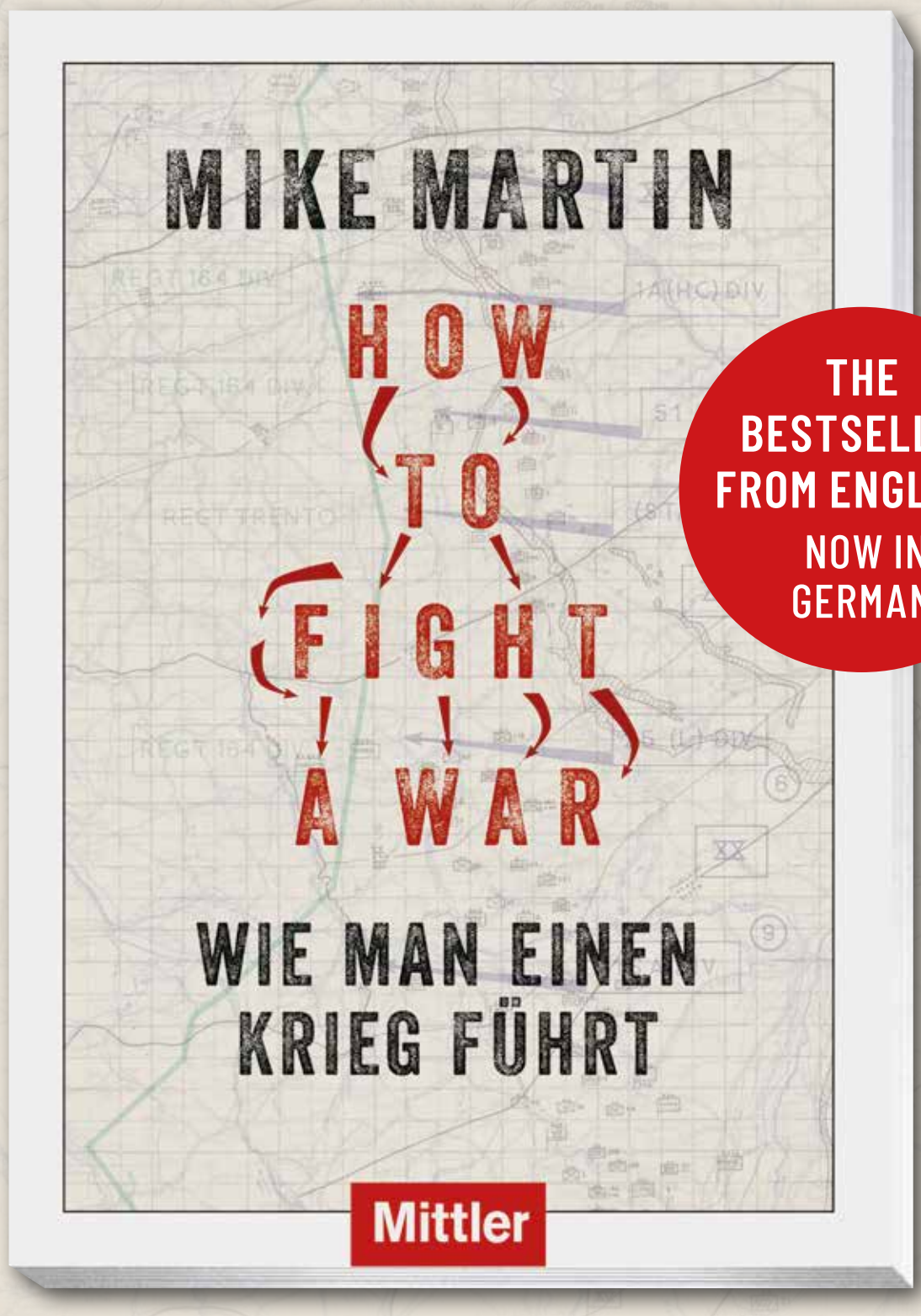
For one, there is TLM, where the product-related data is consolidated. TLM ensures that all technical information related to a system, such as a vehicle or weapon system, is complete, up to date and available in a standardised format.

Then, there is data governance within the logistics main process, which ensures that logistical data is used consistently and reliably throughout the process context.

Both areas go hand in hand. The structure created here is an essential prerequisite for the introduction of modern systems, such as SAP S/4HANA or predictive maintenance. Without it, there would be no way of guaranteeing effective cooperation between the various actors (military/civilian and national/international) or future-proofing logistical capabilities.

In summary, logistics is a strategic backbone for military operations, and its importance will continue to grow in light of current geopolitical instabilities, such as the war in Ukraine. The Bundeswehr logistics system is currently being transformed by the integration of national, civilian and multinational actors as well as by digitalisation via S-Series IPS specifications and modern IT systems (SAP S/4HANA). This transformation is crucial to optimising the operational readiness of material resources and reining in life cycle costs.

Data governance, unambiguous NCS identification, process integration and quality assurance form a foundation that is absolutely essential for the Bundeswehr as it seeks to meet the logistics challenges of tomorrow and to ensure that its network is robust and agile. The ability to efficiently and effectively provide the Bundeswehr with the supplies it requires – be it through fixed BwJSC logistics facilities in Germany, the 'coupling bridge' or highly mobile service logistics forces in theatre – is not an optional factor; it is a guarantor of strategic success. Therefore, it is essential for the Bundeswehr to continuously update its logistics strategy and invest in future-oriented technologies in order to ensure that it retains its capacity for action and meets its NATO commitments in the long term.



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Predictive maintenance and life cycle management for armoured vehicles

Manuela Tudosia

Europe is rapidly increasing the size of armoured vehicle fleets, but it is long-term readiness – not acquisition – that has become the key challenge. Recurring issues such as shortage of parts, technical-data gaps, and uneven maintenance capacity are also limiting availability across multiple fleets. Solutions, including predictive maintenance and AI-driven life-cycle management are only now addressing these gaps. Next-generation armoured capability depends as much on sustainment standards and data discipline as on mobility and protection.

▲ Here at the DSEI 2025, the Patria 6×6 vehicle represents the platform for the Common Armoured Vehicle System (CAVS) programme. [Patria]

AUTHOR

Manuela Tudosia is government affairs expert in defence, and contributor to the NATO Industrial Advisory Group and NIAG Industry Interface Group. She is also founder of the Pole CM [Civil-Military Innovation Network], initiative that provides strategic advice to Small- and Medium-Sized Enterprises in defence.

The development and acquisition of armoured vehicles will be a clear priority in Europe for the years to come. This is evident across multiple European Union (EU) and national initiatives, ranging from direct research and procurement programmes to strategic initiatives enabling the future deployment and operation of such capabilities.

At the forefront of the EU framework are targeted R&D programmes under the European Defence Fund (EDF); this includes the Future Highly Mobile Augmented Armoured Systems (FAMOUS 2), focusing on next-generation modular armoured platforms with advanced mobility and protection. The project ArmoURed Infantry Ground Assault (AURIGA) will design, develop and prototype key technology bricks. The Main Battle Tank Technologies (FMBTech) project focuses on innovative technologies within a modular main battle tank (MBT) system architecture, to support existing and future European MBTs.

Alongside R&D, joint procurement initiatives will further strengthen European capabilities, such as the Common Armoured Vehicle System (CAVS) programme, supported by the European Defence Industry Reinforcement through Joint Procurement (EDIRPA) initiative and based on the Patria 6×6 platform. Currently comprising seven European nations (Denmark, Finland, Germany, Latvia, Norway, Sweden, and the UK) and open for more to join, the programme includes "a jointly developed state-of-the-art new armoured vehicle system" as well as its Life Cycle Management (LCM), which is implemented through dedicated agreements among participating nations and Patria.

Alongside these EU-led initiatives, major investments in armoured vehicle capabilities are underway across Europe at the national level. France and Germany are jointly developing the Main Ground Combat System (MGCS) through the MGCS Project Company GmbH (MPC), aimed at replacing the Leopard 2 and the Leclerc MBT families with a multi-platform ground combat system.

Poland is advancing its Borsuk infantry fighting vehicle (IFV) programme through a March 2025 agreement with a consortium led by Polska Grupa Zbrojeniowa (PGZ) and Huta Stalowa Wola (HSW), following the 2023 framework establishing the

A Borsuk IFV for Poland's 15th Mechanised Infantry Brigade shown during a ceremony on 14 November 2022. [US ARNG/SSgt Matthew A. Foster]

Universal Modular Tracked Platform (UMPG; Uniwersalna Modułowa Platforma Gąsienicowa) as the basis for Borsuk and its family of tracked vehicles.

As part of its 'Army 35' modernisation plan, Spain is enhancing its armoured capabilities through modernisation of existing vehicles, such as the Pizarro IFV and the Leopard 2E MBT, and through the acquisition of new platforms via the VCR wheeled combat vehicle (vehículo de combate sobre ruedas) 8×8 Dragón programme. Other countries, including Greece, The Netherlands, and Romania are implementing national armoured vehicle modernisation programmes.

Several enabling instruments are expected to ensure the availability and operational readiness of armoured vehicle capabilities in Europe for decades. These include the European Union Security Action for Europe (SAFE) instrument, which supports the expansion of defence manufacturing capacity, and multiple EU military mobility initiatives that remove regulatory bottlenecks and strengthen infrastructure for rapid deployment of heavy platforms. Long-term enablers also include strategic policy frameworks such as the European Defence Industrial Strategy (EDIS) and the Defence Readiness Roadmap 2030. At the transatlantic level, NATO initiatives like the Defence Production Action Plan (DPAP) and the NATO Industrial Capacity Expansion Pledge are expected to play a strategic role.

While increased defence spending and the current international context place armoured vehicle capabilities high on the agenda, ensuring their operational availability at affordable costs over several decades to come is essential. Learning from lessons of the past and understanding emerging trends is key to achieving this, just as striking the right balance between readiness and total cost of ownership (TCO) represents both a challenge and an opportunity.

Old challenges

A 2025 report by the US Government Accountability Office (GAO) to the US House Committee on Armed Services analysed the sustainment challenges affecting the availability and maintenance of selected Army and Marine Corps ground vehicles from fiscal years 2015 to 2024.

Nine sustainment challenges were identified to have affected the ground vehicle fleets.

Two of them affected all 18 vehicles analysed:

1) **A lack of parts and materiel**, due for example to issues such as obsolete parts, diminishing manufacturing sources, or long lead-times for production. Aging fleets, like the M113 armoured personnel carrier (APC) and high mobility multipurpose wheeled vehicle (HMMWV), experienced significant difficulties in sourcing parts due to manufacturers ceasing production or being unwilling to produce small batches. While the old fleets faced diminished manufacturing sources, newly-fielded vehicles were also reported to face issues due to competition for parts with ongoing production lines.

2) **Outdated or unavailable technical data** hindered maintenance and repair efforts. It was reported that depot maintainers often had to send maintenance and repair work to manufacturers due to the proprietary nature of technical data. This concerned, for example, the M1 Abrams MBT, the Bradley IFV, and the Stryker family of wheeled armoured vehicles. To illustrate further, it was indicated that separate manufacturers own the technical data for the Abrams' engine, and transmission, preventing depot maintainers from performing repairs themselves. Even when technical data is purchased, updating it for new versions of components (for instance, engines or transmissions) can be time-consuming and can lead to delays in maintenance. Handmade drawings still in use for the older vehicles are complicating maintenance and repair efforts. Examples were given for both the M113 and the M109 Paladin self-propelled howitzer (SPH).

Several challenges were also identified regarding maintenance work. Lack of regular depot-level maintenance has led to skill degradation among maintainers, as experienced, for example with the Stryker programme. Complex design, like the Joint Light Tactical Vehicle's (JLTV) advanced digital architecture, also posed challenges for maintainers in the field due to its complexity and high learning curve.

A complex armoured vehicle system, even if legacy, can come with complex proprietary technical data. [US Army/Spc Kali Ecton]

A recurring issue was unplanned maintenance, where vehicles arrived at depots in far worse condition than anticipated, which forced additional repairs and parts procurement. In addition, the findings of the GAO report show that insufficient overhauls led to lower mission capable rates across the vehicle fleets, including the M1 Abrams, the M88 armoured recovery vehicle (ARV), or the family of medium tactical vehicles (FMTV). Depot-level overhauls are highlighted as critical not only for the old vehicle fleets but also for newly-fielded systems, like the Amphibious Combat Vehicle (ACV) family and the JLTV. These examples point to key challenges that are broadly acknowledged by the life cycle management community and for which there is no simple 'miracle' solution.

It is generally acknowledged that operating and support (O&S) costs during the in-service phase can account for 70–80% of total life-cycle costs, and that early design decisions significantly influence these costs as well as long-term operational availability. According to the US Department of Defense (DoD) 2025 Operating and Support Cost Estimating Guide, among the eight system types analysed, the average life-cycle costs for ground vehicles as a system type are of 3% for research, development, test and evaluation (RDT&E), 32% for procurement, and 65% for O&S.

The earlier examples also indicate that Integrated Product Support planning must include data rights and technical documentation from the start to ensure long-term supportability. Early acquisition and proper management of technical data during the initial stages of the acquisition process are therefore critical to ensuring long-term sustainment.

The examples also show that long-term and sustainable cost savings are not always achieved by cutting on the most obvious activities, such as scheduled maintenance or depot overhauls. On the contrary, reducing scheduled maintenance can lead to higher downstream costs and lower availability, while skipping depot overhauls often results in declining mission-capable rates, degraded vehicle conditions, increased unplanned maintenance, decline in specialised maintenance skills, and more.

Evolving solutions

Although these challenges are not new, the approaches to address them continue to evolve and demonstrate increasing effectiveness. Two complementary categories of solutions can be distinguished: one is driven by technological advancements, which offer new opportunities while simultaneously introducing additional complexities; the other is grounded in policies, standards, processes, and recommended best practices.

Condition-based maintenance (CBM) is a powerful complement to traditional preventive maintenance strategies, and its concepts have been integrated in military systems maintenance strategies for years, across NATO and its member countries. CBM relies on monitoring the actual, real-time, condition of equipment to determine the need for maintenance, performing it only when there is evidence of potential failure or degradation. CBM Plus (CBM+) enhances traditional CBM by integrating advanced technologies and processes to improve reliability, maintenance efficiency, and cost-effectiveness. Leveraging internet of things (IoT) sensors, health monitoring data, AI-driven analytics, and digital twins, CBM+ enables predictive maintenance actions that mitigate potential failures before they occur.

The US DoD mandates CBM+ as a primary sustainment strategy for weapon systems under DoDI 4151.22. Transitioning to CBM+, and thus to predictive maintenance, is progressively implemented, including in armoured vehicle programmes. For example, as part of their modernisation efforts, the US Marine Corps (USMC) announced the adoption of a CBM+ strategy for six key vehicle platforms and critical operational capabilities, including the armoured vehicle JLTV. This strategy involves advanced data collection and analytics to predict and pre-empt equipment failures, and to optimise maintenance schedules.

A wheeled vehicle mechanic assigned to the 25th Composite Truck Company, 25th Sustainment Brigade, addresses a radiator hose leak on an FMTV series vehicle, at Schofield Barracks, Hawaii, on 30 May 2018. [US Army]

In 2024, the Government of Canada launched a challenge to develop fleet-wide, automated, proactive Health and Usage Monitoring Systems (HUMS) for military platforms. The goal is to "support a movement to CBM, and ultimately, predictive maintenance, to optimise limited maintenance resources, and to increase the availability of operational platforms".

At the national level, in September 2025, in the UK Ministry of Defence (MoD) signed a GBP 320 million contract with IBM UK to develop the Defence Equipment Engineering Asset Management Systems (DEEAMS), a new AI-driven platform that will modernise and streamline the UK Armed Forces' equipment management. According to the UK Government press release, the new system will replace 17 fragmented applications and will provide "real-time information to predict maintenance and repairs, stock availability, and engineering planning across major equipment and platforms". It will serve over 65,000 users across more than 130 major military platforms and assets, and armoured vehicles are expected to be part of this.

Although France does not have a formal CBM+ policy like the US DoD, it actively pursues predictive maintenance and HUMS integration for land platforms, illustrated by initiatives within the SCORPION programme, or by the Tactical Evaluation Vérité

US Army Soldiers carry out Preventive Maintenance Checks and Services (PMCS) on a group of Joint Light Tactical Vehicles (JLTVs) in support of a deployment readiness exercise at Camp Carroll, South Korea, on 27 July 2024. [US Army/Sgt Eric Kestner]

(EVTA) trials, and the NumCo digital twin project for the armoured infantry fighting vehicle (VBCI).

While neither the EU nor NATO mandate a unified CBM+ policy, since this remains a trend driven by national implementation, both promote advanced maintenance strategies through research, funding, and standardisation efforts.

Industry is also embracing the predictive maintenance strategies, in the context of government strategies or independently. Only selected examples can be provided here. Information available on the CAVS programme's Life Cycle Management contract, signed between Patria, Finland, and Latvia, suggests that it is based on the Patria OPTIME service concept, which employs HUMS, maintenance records, and mission profiles to optimise performance.

On its website, Oshkosh Defense has announced that it has applied CBM and CBM+ methodologies across an array of defence platforms including JLTV, the British Army's wheeled tanker and the US Army 's FMTVs, Armor Level 1, Protection Level 2 (FMTV A1P2).

At the 2025 AUSA and MSPO exhibitions, the Israeli defence integrator IMCO Group showcased its HUMS, which supports predictive maintenance for military land, sea, and air platforms. In September 2025, the group announced the establishment of a new subsidiary in Romania as part of its strategy to enter European markets and expand the group's production capacity, and to operate as a "local supplier" for European projects. This strategy and IMCO's active pursuit of partnerships in Europe may indicate future use of its HUMS in European nations' armoured vehicle capabilities.

The importance of standards

Predictive maintenance appears to be an emerging trend that is here to stay, helping to increase operational availability and reduce O&S costs for armoured vehicle capabilities. However, this does not come without challenges, the most evident of which include whether systems are new or legacy platforms undergoing modernisation, how data is collected and organised to enable meaningful use of AI capabilities, and ensuring robust cyber defence.

Armoured vehicle systems and the enabling technologies currently in development benefit from a historically unprecedented opportunity: integrating sustainment planning and maintainability from the design phase as well as, from the outset, applying strategies and standards to collect structured data, which will significantly enhance the reliability and trustworthiness of AI capabilities supporting predictive maintenance. Strong cyber-security can also be integrated in the original design.

Much of today's technological advances and best practices can also be applied to legacy systems, which represents an opportunity especially in the context of modernisation programmes. However, limitations must be acknowledged principally in relation to implementing data-driven maintenance versus the costs that should be incurred to achieve this across an entire system. Since most of the legacy systems were not designed with data-driven capabilities in mind, data collected can be fragmented, and the temptation to rely upon unstructured data lakes may be strong, which can undermine predictive maintenance effectiveness.

Perhaps unexpected for some, but evident for many, process-oriented standards such as the NATO ALP-10, offer timeless solutions to constantly emerging challenges, while considering latest technological evolution. Promoting interoperability, ALP-10 aligns Integrated Life Cycle Support (ILS) activities with all System Life Cycle (SLC) stages, including design, acquisition, operation, and disposal, highlighting how ILS processes and activities are integrated into each stage.

While processes can be timeless, technical standardisation is driven by technology change, and standardisation of digitalisation in defence is the next challenge.

System life cycle management: The next step to ensuring performance

Andreas Kirchhofer

According to NATO's Systems Life Cycle Management (SLCM) policy the main goal of systems life cycle management is to deliver, use, and maintain NATO capabilities efficiently and effectively while ensuring a high level of Operational Availability (AO), reducing in-service costs. The application of System Life Cycle Management (SLCM) is based on the following principles: Commitment to Systems Life Cycle Management, Cooperation and Interoperability, Efficiency, Collaboration with Industry, and Quality. Nowadays, an important detail is that Interoperability is perceived at capability level as well as on maintenance and support level.

A presentation from the NATO LCM 2025 conference in Brussels. [MRV/Javier Bernal Revert]

Approximately 70% of the total cost of ownership will happen in utilisation/in-service/operations. On the contrary, roughly 80% of the decisions which influence maintainability, supportability and reduction of down-time are to be designed in concept/design stages, contractual, technical, and processual. Doing this on purpose or by chance or not at all, makes a significant difference. It is essential to influence requirements from the very beginning, design to reflect, next to technical needs, the needs for supportability as well as predictability. In this context, an AO driven business approach, as well as processes, methods and tools have to be set up in a coordinated way, robust and flexible enough for continuous optimisation to reflect an ever-changing operational and technical environment. Standardisation is key to facilitating re-use, acceptance and efficiency.

SLCM is a scientific methodology, an organisational business approach, focusing on the Life Cycle of a System which is determined to use a System to perform capabilities, in, with and by an organisation, as well as across organisations.

The application of SLCM is crucial to implement operational efficiency, that allows for more targeted actions, shortens adjustments to the ever-changing operational environment, and strengthens both the quality and flexibility of the systems and its operations. The transformation from product to services business, the modularisation into systems-of-systems and systems-of-subsystems, and share of risk and gain, as well as the establishment of sustainable processes and business models are crucial measures to establish and maintain the efficiency to survive.

AUTHOR

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The system concept of NATO AAP-20 (NATO's System Life Cycle Management Framework) defines a System as a System-of-Interest (SOI – equivalent to the term product, with all its product data, breakdown, configuration, life cycle) and all Enabling Systems (enablers, like infrastructure, material, personnel, training, documentation, etc.) for the SOI in its operational environment. The aim is to achieve and maintain AO of the SOI in an efficient and cost-effective way, supported by the enabling systems. Thus, in this concept the enabling systems are an integral part of the system along its design and development, production, utilisation, support and disposal. The SOI and its Enabling Systems cannot be divided. These are to be organised together in a most flexible way to directly reflect and react to technical changes, as well as to changes of the operational environment.

To use a System of Interest (SoI) in an economical way, reducing downtime to a minimum is the main goal. That means, there is to be a focus on the enabling systems to ensure economical AO. For that a mature organisation is necessary. This breaks down into an integrated/support optimised approach of:

- Contract management;
- Programme management;
- Organisational setup/alignment;
- Integrated, interrelated process-/information management;
- Design of supportability & predictability into the system including thorough configuration management based on a re-use strategy;
- Clear interfaces (IP) and information with suppliers and customers;
- Re-use of information, based on international standards such as: ISO/IEC 15288, NATO AAP-20 (NATO's SLCM Framework), AAP-48 (NATO SLCM Processes), ALP-10 (NATO Standard to Integrated Life Cycle Support), AQAPs (NATO Suite of Quality Assurance Standards), etc.

Delivering Operational Availability throughout the entire life cycle of a system — and doing so in a cost-effective way — represents a profound conceptual shift. Availability is no longer just a technical metric: it becomes a product in itself, enhancing the portfolio, flexibility, and performance of today's organisations. A sound processual, contractual, methodical, interoperable backbone provides a capability to react and deliver quickly.

To seize this opportunity, organisations must evolve from traditional non-efficient project to product-based approaches and finally towards service business models, grounded in classical, but optimised, as well as outcome- or performance-based contracting. This shift enables more competitive offers, helps to implement re-use strategies, reduces transactional efforts, secures intellectual property, and ensures sustainable long-term relationships.

From a NATO/countries perspective it is all about WHO, WHY, and HOW:

- WHO: the organisation, which wants to fill a capability gap, so plans to get a SOI in its organisation and makes itself mature and sustains this status to us a SOI;
- WHY: to plan and steer (control!) a System and to build up and sustain that System;
- HOW: by following the principles of SLCM (maturities, stages, processes activities), managing by decision making on controlling-data by responsible personnel.

System Life Cycle Management (SLCM) remains the key enabler in turning plans and investments into actual combat power in the hands of the warfighter. It is to support the warfighter in a most efficient, flexible, fast, and efficient way. Operational Availability of Systems and a sound System-of- Systems design, all across the value chain, are key elements for a sustainable allocation and use of capabilities.

The annual NATO LCM Conference will present new visions, innovative approaches, developments, lessons learned, and achievements made by representatives of government, military, industry, and NATO in applying SLCM as a basis for new and innovative approaches. The event will again be organised in cooperation with the NATO Life Cycle Management Group (AC/327) and the NATO Industrial Advisory Group at the Holiday Inn Brussels Airport on 20/21 January 2026.

Alongside presentations highlighting of recent trends in LCM, the NATO LCM conference in Brussels provides valuable opportunities for networking within the LCM space. [MRV/Javier Bernal Revert]

Exhibition Dates 2026

Date	Event	Location
January		
13.-15.1.26	**Navy SNA Symposium**	Crystal City/USA
19.-22.1.26	**DIMDEX- Doha Intern. Maritime Defence Exh./Conf.**	Doha/Katar
19.-22.01.26	**Umex- SIMTEX -Unmanned Systems Exhibition & Conference**	Abu Dhabi/UAE
20.-22.01.26	**IAV -International Armoured Vehicles**	Farnborough/ United Kingdom
20. - 23.01.26	**Shot Show**	Las Vegas/USA
21.-22.01.25	**Surface Warships**	London/United Kingdom
26. - 27.1.26	**Mobile Deployable Communications**	Prague/Czech Republic
27 - 28.1.26	**Perspektiven der Verteidigungswirtschaft**	Bonn/Germany
27.-28.01.26	**APEX Defense**	Washington/USA
27.-28.01..26	**Maritime Reconnaisance & Surveilance Technology**	London/United Kingdom
February		
02.-03.02.26	**UAV Technology USA**	Arlington VA/USA
03.-05-02.26	**Seabed Defense/ Navy Tech**	Gothenburg/Sweden
03-08-02-26	**Singapore Airshow**	Singapor/Singapore
08. - 12.02.26	**World Defense Show**	Riyadh/Saudi Arabia
10.-12.02.26	**CEL 26 - Combat Engineer & Logistics**	Warszawa/Poland
13. - 15.2.26	**Münchener Sicherheitskonferenz**	München/Germany
23.-25.2.26	**DGI Geospatial Intelligence for Defence & Security**	London/United Kingdom
23.- 25.2.26	**EnforceTac**	Nünrberg/Germany
24. - 26.02.26	**Int'l Military Helicopter**	London/United Kingdom
26.2. -01.03.26	**IWA Outdoor Classics**	Nünrberg/Germany
late February 2026	**Future Indirect Fires**	Bristol/United Kingdom
March		
03.-05.03.26	**Angewandte Forschung für Verteidigung & Sicherheit in Deutschland**	Bonn/Germany
11.-12.03.26	**LOGnet**	Koblenz/Germany
09.-11.03.26	**Future Soldier Technology**	London/United Kingdom
24-26.03.26	**Xponential Europe**	Düsseldorf/Germany

Date	Event	Location
30.03.-1.04.26	**Egypt Air Show**	El Alamein/Egypt
31.3. - 2.04.26	**Mlitary Flight Training**	Lucern/Switzerland
April		
07. - 12.4.26	**FIDAE**	Santiago/Chile
13.-15.04.26	**Military Robotics and Autonomous Systems**	London/United Kingdom
14.-16.4.26	**IT2EC 2024**	London/United Kingdom
14.-16.4.25	**UDT 2024**	London/United Kingdom
19.-22.04.26	**Sea Air Space**	National Harbour/USA
20.-22.04.26	**Counter UAS Technology Europe**	London/United Kingdom
20.-23.04.26	**D.S.A. -NATSEC**	Kuala Lumpur/ Malaysia
22.-23.4.26	**Verteidigung Readiness**	Berlin/ Germany
22.-23.04.26	**Future Armoured Vehicles Situational Awareness**	London/United Kingdom
22. - 25.04.26	**Aero**	Friedrichshafen/ Germany
27.-29.04.26	**Military Space Situational Awareness**	London/United Kingdom
28. - 29.4.26	**Multi Domain Operations III**	Bonn/Germany
28.-30.04.26	**Milipol Asia-Pacific**	Singapore/Singapore
28.-30.04.26	**The Security Event**	Birmingham/ United Kingdom
28. - 30.4.26	**Infopol l XPO 112**	Kortrijk / the Netherlands
May		
05.-09.05.26	**SAHA Expo**	Istanbul/Turkeye
12.-13.05.26	**AFCEA Fachausstellung**	Bonn/Germany
13.-15.05.26	**BSDA**	Bucharest/ Romania
13.-15.05.26	**World Police Summit**	Dubai/UAE
14.-16.5.26	**IDEB**	Bratislava/Slovakia
18.-19.5.26	**Future Armoured Vehicles CEE**	Prag/Czech Republic
18 - 21.05.26	**SOF Week**	Tampa/USA
19.-22.5..4.24	**Xponential**	Detroit/USA
19.-21.05.26	**Aerospace & Defence Meetings Sevilla**	Sevilla/Spain
19.-21.05.26	**Future Artillery**	London/United Kingdom

Exhibition Dates 2026

Date	Event	Location
19.-21.05.26	**Combined Naval Event**	Farnborough/ United Kingdom
19.-21.05.26	**AOC Europe**	Helsinki/Finland
20. - 21.5.26	**Helicopter Technology CEE**	Prag/Czech Republic
24 -26.5.26	**DEFEXPO**	Chennai/India
26 - 27. 05.26	**SSD Expo**	Talin//Estonia
26. - 28.05.26	**Airspace World 2026**	Lisbon/Portugal
27.-28.05.26	**Energieversorgung der Streitkräfte**	Bonn/Germany
June		
02. - 04.06-26	**SEDEC**	Ankara/Turkeye
23.06.26	**Im Dialog mit Militärattaches**	Schloss Diedersdorf/ Germany
03.-06.06.26	**Hemus**	Plovdiv/ Bulgaria
10. - 14.6.26	**ILA**	Berlin/ Germany
15. - 19.6.26	**Eurosatory**	Paris/France
July		
July 26	**Close Combat Shrivenham**	Shrivenham/ United Kingdom
20.-24.7.26	**Farnborough Airshow**	Farnborough/ United Kingdom
01.-02.07.26	**Hubschrauberforum**	Bückeburg/Germany
August		
August 26	**DALO Industry days**	Ballerup/Dänemark
September		
Sept. 2026	**DVD Millbrook**	Millbrook/ United Kingdom
01-02.09.26	**BWI Industry Days**	Berlin/Germany
01.- 04.9.26	**SMM**	Hamburg/GY
04.-05.09.26	**Airpower Austria**	Zeltweg/Austria
08-11.09.26	**MSPO**	Kielce/Poland
09.-11.09.26	**Land Forces**	Melbourne /Australia
15.-16.09.26	**AFCEA Technet**	Berlin/Germany
16.-20.09.26	**AAD- Aerospace & Defence Expo**	City of Tshwane/SAA
22.-24.09.26	**AD2S**	Bordeaux/France
22.-25.09.26	**Euro Defence/Security Essen**	Essen/Germany
23.-25.09.26	**ADAS**	Manila/Philippnes

Date	Event	Location
28. - 30.09.26	**Marineworkshop**	Linstow/Germany
30.09.-2.10.26	**ADEX**	Baku/Azerbaijan
October		
October 26	**Dismounted Close Combat**	London/United Kingdom
October 26	**International Dismounted Soldier Conf.**	London/United Kingdom
06.-07.10.26	**Surface Warships**	Troia/ Portugal
07. - 08.10.26	**Bonner IT-Dialog**	Bonn / Germany
12.-14..10.26	**AUSA**	Washington DC/USA
21.-23.10.26	**Future Forces**	Prag/Czech Republic
20.-22.10.26	**Milipol Quatar**	Doha/Katar
20.-22.10.26	**GSOF**	Rome/Italy
27.-29.10.26	**it-sa**	Nürnberg/Germany
27. - 29.10.26.	**SOFEX**	Aquaba/ Jordan
28.10.-1.11.26	**IADE Tunisia**	Djerba/ Tunisia
Okt 26	**KADEX**	Gyeryongdae/ Südkorea
November		
Nov 26	**MAST Australia**	Adelaide/Australia
Nov 26	**International Fighter Conf.**	tbc
03.-06.11.26	**Euronaval**	Paris/France
04.-05.11.26	**Readiness Europe**	Nürnberg/Germany
18.-20.11.26	**Bahrain International Airshow**	Bahrain
18.-21.11.26	**IndoDefence**	Jakarta/Indonesia
24-27.11.26	**IDEAS**	Karachi/Pakistan
28.11. - .12.36	**I/ITSEC**	Orlando/USA
December		
Dec 26	**VietNam Defence Expo**	Hanoi/Vietnam
01.-03.12.26	**Expo Naval**	Valparaiso/Chile
03.-04.12.26	**LandEuro Europe**	Wiesbaden/Germany
03-04.12.26	**2nd Homeland Security Expo**	Stockholm/Sweden
08-09.12.26	**IT Konferenz**	Bonn/ Germany

MITTLER REPORT

US foreign policy as a patchwork: Trump's approach to peace

Dr Gayane Novikova

In his second term in office, Donald J. Trump has presented himself as a global peacemaker: A slogan "Stop the wars" has become a new mantra since his inauguration in January 2025. In October 2025, President Trump claimed that he had "ended eight wars." This article analyses the Trump administration's approach in attempting to resolve three conflicts, each of which has significant and wide-ranging inter-regional implications: Armenia-Azerbaijan, Russia-Ukraine, and Israel-Palestine. In the process, it highlights some trends in current US foreign policy.

The Armenia-Azerbaijan road to peace. Deal!

As a consequence of the 2020 Nagorno-Karabakh war, followed in September 2023 by the forced exodus of the entire ethnic Armenian population from Nagorno-Karabakh, Azerbaijan not only reestablished full control over its internationally recognised territory but also took over some parts of Armenian territory. Armenia's significantly weakened position in the region has allowed Azerbaijan to repeatedly demand concessions in the ongoing negotiations around a peace treaty.

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Against this background, President Trump initiated a high-level summit with the leaders of Armenia and Azerbaijan in Washington DC, where on 8 August 2025 all three signed a joint Declaration. The first paragraph of the Washington Declaration confirmed that Armenia and Azerbaijan agreed upon a text of The Agreement on Establishment of Peace and Inter-State Relations. The signatories reaffirmed the importance of the opening of communications between Armenia and Azerbaijan with reciprocal benefits "on the basis of respect for the sovereignty, territorial integrity, and jurisdiction of the States."

As for now, the implementation of the bilateral Armenian-Azerbaijani Agreement formally depends upon the willingness of the Armenian side to remove from the Constitution a referral to the Declaration of Independence which includes a statement on "Reunification of the Armenian SSR and the Mountainous Region of Karabakh [December 1, 1989]." Azerbaijan views it as Armenia's territorial claims and the main remaining obstacle to a lasting peace with Armenia.

The most intriguing part of the Washington Declaration is a proposed "Trump Route for International Peace and Prosperity" (TRIPP) as a segment of the so-called 'Middle Corridor' connecting Europe to Central Asia. Concisely, implications of TRIPP for the interested parties are the following:

1) For Azerbaijan, the establishment of a direct connection with its Nakhichevan Autonomous Republic and Türkiye through Armenia's sovereign territory, the Syunik region, which has strategic importance for Armenia;
2) For Türkiye, a cementing of its presence in the South Caucasus and a direct connection with Azerbaijan and Central Asia;
3) For Armenia, open borders with Türkiye and Azerbaijan, and a connection through the Azerbaijani territory to the 'Middle Corridor'.

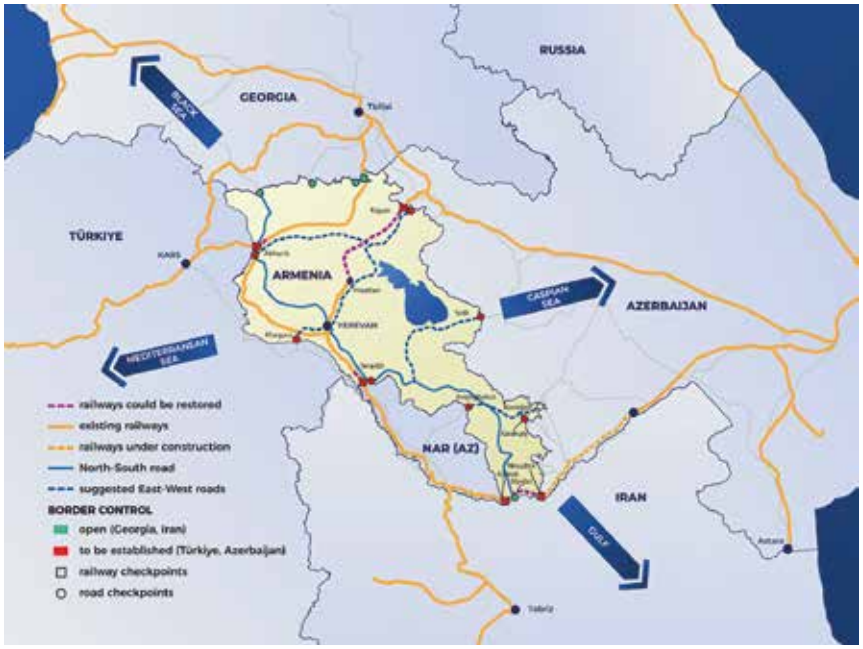
President Trump (centre) signed a Trilateral Joint Declaration with President of Azerbaijan, Ilham Aliyev (left), and Prime Minister of Armenia Nikol Pashinyan (Right) at the White House, on 8 August 2025. [White House]

For the US, TRIPP creates an opportunity for a broader involvement in the South Caucasus and correspondingly in the Greater Central Asia. It is notably viewed as leverage to reduce Russia's space for manoeuvring, to isolate Iran, and – to some degree – to constrain China.

According to available information, Armenia will lease a 43 km-long piece of its land for 99 or 49 years to the US; the American private companies as subcontractors, presumably

with their security personnel, will receive exclusive development rights along this route, including a construction of a railway and a highway and necessary infrastructure. No third country can deploy its military force along this route.

In addition to the Declaration, Armenia and Azerbaijan signed bilateral Memoranda of Understanding (MoU) with the US. Armenia's three MoUs cover the capacity-building of Pashinyan's 'Crossroads of Peace' project, a partnership in energy security sector, including civil nuclear energy, and in AI and semiconductor innovation sectors. These MoUs complement the Armenia–United States Strategic Partnership Charter signed on 14 January 2025.



▲ A map of the routes planned in Armenia under the 'Crossroads of peace' project. [Office of the Prime Minister of Armenia]

The US-Azerbaijan MoU is a first step toward an Azerbaijan–United States Strategic Partnership Charter. Its three areas include in particular regional connectivity in energy, transit, and trade, investments in AI and digital infrastructure, security cooperation in defence sales and counterterrorism cooperation with strong mutual commitments. In addition, the Azerbaijani state oil company SOCAR signed a second MoU with American ExxonMobil which holds a 2.5% stake in the Baku-Tbilisi-Ceyhan (BTC) and 6.79% in the Azeri–Chirag–Gunashli (ACG) pipelines.

Challenges:

a) The Washington Declaration does not contain any legal obligations;
b) Russia and Iran can take steps to protect their strategic interests, in particular in the North-South Corridor;
c) It is not clear whether the Armenian-Iranian border will remain under joint Armenian-Russian border guard protection;
d) The financial aspect of the deal is not announced. The real estimate of the TRIPP-related expenses and its profitability are lacking;
e) Internal political turbulence in Armenia before and after the 2026 parliamentary elections can postpone the implementation of TRIPP for an indefinite period.

According to Armenian sources, President Trump intended to ask his Azerbaijani counterpart to release "23 Christian prisoners" who were captured after the Armenians exodus from Nagorno-Karabakh, and who are on trial in Baku.

The Israel-Palestine enigma: A new deal?

President Trump's first term in office was marked in the Middle East by a recognition of the Israeli occupation of the Syrian Golan Heights, the signing of the Abraham Accords, and a relocation of the US Embassy from Tel Aviv to Jerusalem. The main goals were to bring some Arab states (Bahrain, UAE, Morocco, Sudan) and Israel closer to each other, to please the president's pro-Israeli donors, and to eliminate any chances to call East Jerusalem a capital of the future Palestinian state.

The two-year Israeli-Hamas conflict has seriously influenced US domestic policy, becoming one of the dividing lines between the US and its allies. It has divided Israeli society, had catastrophic consequences for the Palestinians, and has also shaped the entire Middle East. Therefore, a cessation of hostilities, which would be followed by a ceasefire agreement, became a priority for President Trump. His vision and statements regarding the future of Gaza has varied from the Gaza Strip as the "Riviera in the Middle East" (February 2025) to a vague promise of a "Palestinian self-determination and statehood as the aspiration of the Palestinian people," in a 20-point Comprehensive Plan to End the Gaza Conflict (29 September 2025).

Phase One of the Plan, which went into effect on 10 October 2025, includes a return of all Israeli hostages and the bodies of the deceased in exchange for a release of Palestinian prisoners and remains of Gazans, an opening of passage for humanitarian aid, and a withdrawal of Israeli troops to a 'yellow line' inside the Gaza Strip. However, implementation of even this phase faces real obstacles on the ground.

The crucial part of the Plan combines a withdrawal of the Israeli Defense Forces (IDF) from Gaza with the disarmament of Hamas and the establishment of a "transitional governance of a technocratic, apolitical Palestinian committee." This committee would act under the supervision of a "new

▼ President Trump at the Sharm El Sheikh Peace Summit in Sharm el Sheikh, Egypt, on 13 October 2025. [White House]

international transitional body, the "Board of Peace", which will be headed and chaired by President Donald J. Trump". A temporary International Stabilization Force (ISF) should be immediately deployed to Gaza and remain there until their replacement by vetted Palestinian police forces. US troops will not be deployed in the area of the conflict. Interestingly, the US Administration did not insist on an immediate disarmament of Hamas: on 14 October, President Trump acknowledged that Hamas needs "to take out a couple of gangs".

To receive international support, the US Administration needed to first bring on board Arab and Muslim-majority states and to reduce criticism from European states, Russia, and all others who recognised the Palestinian statehood and condemned the Israeli actions in Gaza. Therefore, and despite the fierce pressure from the Israeli government, the Plan could not avoid mentioning Palestinian statehood. Second, the American side needed to assure the potential participants, especially those who could secure a military presence in Gaza, that their presence and actions are legitimate. The US team of negotiators (Steve Witkoff, Jared Kushner, JD Vance) warned both sides that if its efforts failed, the fragile ceasefire in Gaza would collapse immediately. These efforts resulted in the adoption of UNSC Resolution 2803 (2025) on 17 November 2025.

The key elements of the Resolution include brief mention of a possible "Palestinian self-determination and statehood" after the implementation of several preconditions, such as a demilitarisation of Gaza, the fulfilment of the Palestinian Authority's reform programme, a redevelopment of Gaza, the establishment of a transitional governance administration of a "technocratic, apolitical committee of competent Palestinians from the Strip", and the establishment of a "temporary International Stabilization Force (ISF) in Gaza under unified command acceptable to the BoP [Board of Peace; whose mandate extends to 31 December 2027]". The main tasks of the ISF are the demilitarisation of Gaza, "including the destruction and prevention of rebuilding of the military, terror, and offensive infrastructure, as well as the permanent decommissioning of weapons from non-state armed groups." The West Bank was not mentioned in the Resolution.

Israeli Prime Minister Netanyahu (left) meeting with US President Donald Trump (right) at the White House on 29 September 2025. [White House]ented [RecoMonkey]

Prior to the UNSC vote, the US took an important step to ensure some success of its stabilisation efforts. On 17 October 2025, US CENTCOM opened a Civil-Military Coordination Center in southern Israel, near the Gaza border. It will serve as a "main coordination hub for Gaza assistance," which is crucial for reducing an Israeli control over the humanitarian aid entering the Palestinian territory.

However, on 14 November, the US and Israel announced a decision to divide the Gaza Strip into 'red' and 'green' zones. The former, where the overwhelming majority of Gazans is currently concentrated, will be left in ruins; the latter will be established to the east of the 'yellow line' and will be reconstructed under Israeli and international military control. An established trust fund will supervise the reconstruction, and the necessary financing will be provided by the World Bank and – presumably – by the Gulf Arab States.

Challenges:

a) A permanent strong opposition of the Israeli government to the establishment of Palestinian statehood;
b) Hamas' rejection to disarm voluntarily;
c) Continuous attacks of the Israeli military in Gaza despite a ceasefire, and attacks by Israeli settlers on Palestinians in the West Bank;
d) A lack of enthusiasm from possible contributors to the ISF: Egypt, Indonesia, the UAE, Türkiye, and Azerbaijan refer to security threats prior to a complete demilitarisation of Hamas; Israel rejected the participation of Turkish military forces; Jordan, as a home for approximately three million Palestinians, was apprehensive to participate due to moral concerns around their troops potentially being required to use force on Gazans to enforce peace. Italy is the only European state considering its participation in ISF.

Russia – Ukraine stalemate. No deal (so far).

President Trump's approach to the Russia-Ukraine War was marked by a swift U-turn from Biden's "nothing about Ukraine without Ukraine" to 'almost everything about Ukraine without Ukraine'. In Trump's view, Ukraine and its defence is primarily a problem for European states. He is also against direct US military supplies to Ukraine unless NATO allies want to buy the weapons from the US and transfer them to Ukraine. Trump also rejects direct participation of US military either in Ukraine's defence or in peacekeeping operations there, and – last but not least – President Trump himself has shown a willingness to negotiate the conditions of peace directly with President Putin, to the exclusion of President Zelenskyy and European allies.

Several important nuances should be considered:

1) The erratic policy of President Trump is in contrast to President Putin's strong vision of post-war Ukraine and Europe, in general;
2) Ukraine appeals to international law while Russia refers to a resolution of the "root causes";
3) The US mediators' team has been divided into two groups to hold separate discussions with Russian and Ukrainian counterparts; however, members of both groups, with little or no diplomatic experience, have conflicting views on the resolution of the war. Hence, something can be 'lost in translation.'

President Vladimir Putin (left) and President Donald Trump (right) conducted joint discussions aimed at ending the Russia-Ukraine War, at Joint Base Elmendorf–Richardson in Anchorage, Alaska, on 15 August 2025. [White House]

For Kyiv, the most significant and painful consequences of Washington's changed approach are related to US military supplies and President Trump's view of Ukrainian territorial integrity. The potential loss of access to US intelligence became a permanent threat to Ukraine after the US suspended intelligence sharing for two weeks in March 2025. Military aid was completely frozen between March and July 2025, followed by limited supplies of some types of weapons. On 14 July, the US Administration introduced the Prioritised Ukraine Requirements List (PURL), a new package of military assistance to Ukraine making clear that there will be no direct and, especially, unconditional US military supplies to it; NATO member states should buy modern American weapons and deliver them to Ukraine. In parallel, President Trump has threatened Russia with sanctions and once – after he was "disappointed" by President Putin after a round of negotiations in October 2025 – imposed them.

President Trump's approach to the issue of Ukraine's territorial integrity contradicts the Crimea Declaration which he signed in July 2018, and which rejected "Russia's attempted annexation of Crimea". At that time, the US pledged to maintain this policy until a restoration of Ukraine's territorial integrity. Currently Washington is attempting to convince Kyiv that territorial concessions are unavoidable and that Ukraine should review its 'maximalist' demands.

On 19 November 2025, a US 28-point peace plan on Ukraine was announced. The EU leadership was not consulted; according to Axios, Zelenskyy was informed about its launch joining remotely the phone conversation initiated by Steve Witkoff, Jared Kushner, together with Donald Trump. The resignation of Keith Kellogg, a special envoy to Ukraine (stepping down in January 2026), who was seen as largely sharing the Ukrainian (and European) position, signalled that a pro-Russian camp in Trump's team had gained the advantage.

The US 28-point plan was met with deep scepticism by Ukraine and European allies, who broadly saw the plan as caving in to Russia's demands. The plan envisaged Ukraine's de facto (though not de jure) recognition of all currently occupied territories, surrender of some areas not yet occupied, strict limits on Ukraine's armed forces (600,000 personnel), no NATO membership, and no NATO troops in Ukraine. The plan did however not oppose Ukrainian EU membership, and stated that Ukraine would receive security guarantees. The plan also stated that Ukraine will be rebuilt through joint efforts, including through an investment of USD 100 billion drawn from frozen Russian assets, and a further USD 100 billion provided by European countries. Furthermore, according to the proposal, the US would receive 50% of profits from US-led efforts to rebuild and invest in Ukraine using Russian frozen assets, as well as compensation for providing its guarantees. The agreement will be legally binding and will be monitored by a Peace Council under President Trump's leadership.

In response to the US plan, on 23 November, France, Germany and the UK tabled a counter-proposal peace plan for Ukraine as an alternative. While multiple versions have been

President Trump met with Ukrainian President Volodymyr Zelenskyy and a group of European leaders at the White House to negotiate an end to the war in Ukraine, on 18 August 2025. [White House]

making the rounds (a 24-point version was published by The Telegraph), the European draft broadly aligns more closely with Ukrainian expectations and previously stated red lines. It preserves Ukraine's right not to declare neutrality, guarantees full territorial integrity, allows a larger peacetime force (800,000 rather than 600,000), does not exclude the possibility of future NATO membership, and permits flexibility on foreign troop deployments.

US–Ukraine negotiations took place in Geneva on 23 November. In a joint statement, Washington and Kyiv described the talks as "highly productive" and committed to further discussions. While the US highlighted "extensive and productive" dialogue, President Zelenskyy struck a more cautious tone, welcoming "reinvigorated" diplomacy and noting signals that Trump's team "is hearing us". Ukrainian officials reaffirmed that territorial integrity is not up for negotiation and stressed that Ukraine will not accept any deal crossing its red lines."

Presumably, the US-Ukraine agreement on the Establishment of a United States-Ukraine Reconstruction Investment Fund (RIF), which was announced on 30 April 2025, will also contribute to the "long-term reconstruction and modernization of Ukraine" and to some degree to Ukraine's security. Among the most important achievements of the Ukrainian side in these negotiations are preservation of its sovereignty over the natural resources and related infrastructure, an equal 50%-share contribution to RIF, an extraction of Ukraine's main oil and gas producers – Naftogaz and Ukrnafta – from a contribution to the RIF. Any debt obligations to the US as compensation for previously provided support will be removed. According to Article VI of the Agreement, "if after the Effective Date, the Government of the United States of America delivers new military assistance to the Government of Ukraine in any form (including the donation of weapons systems, ammunition, technology or training), the capital contribution of the US Partner will be deemed to be increased by the assessed value of such military assistance."

Challenges:

a) Mutually exclusive ultimate goals of the belligerents;
b) An absence of direct Russia-Ukraine negotiations;
c) An understanding of both the Ukrainian and European sides that without full-scale US military, economic, and diplomatic support, reaching a peace agreement that addresses even a significant portion of Ukraine's security needs seems impossible;
d) Differences and disagreements between the US and European states; and
e) An ongoing high-level corruption scandal in Ukraine.

Deal or no deal: Make your choice

Initiating and moving toward the resolution of the three conflicts, the US Administration first of all weighs the economic benefits for Donald Trump's "America First" project. Any philanthropic or humanitarian approach is generally excluded, as is any reference to a violation of human rights. US economic benefits are essential in each of the analysed peace proposals.

The US is interested in an expanded strategic partnership and a multilayer engagement with Azerbaijan. Its involvement into the resolution of the decades-long Armenia-Azerbaijan tensions (after the elimination of the Nagorno-Karabakh factor) cannot influence developments on the ground per se. It fails to provide security guaranties to Armenia in a situation where Azerbaijan combines bellicose rhetoric with increased military spending, keeping Armenia under constant pressure.

The US modus operandi in the Israel-Palestine and Russia-Ukraine wars is more forceful. Washington applies a disproportionate amount of pressure on the two sides of these conflicts – lesser on the stronger and more on the weaker. Thus, the provisions of the UNSC Resolution on Gaza and the steps toward its implementation suggest that the very idea of the two-state solution is buried. In the case of Russia-Ukraine, the inclusion of the US Army Secretary D. Driscoll in the US delegation during the Geneva meeting can be read as the Trump administration increasing the pressure on Kyiv to accommodate the US peace proposal.

Preseident Trump (left) and President Zelenskyy (right) during a meeting at the White House on 18 August 2025. Thus far, the Trump administration has exerted more pressure on Ukraine to accept a deal than on Russia, and this trend does not appear likely to change much. [White House]

Both the Gaza and Ukraine peace plans have similar provisions prepared by the same group of people. The introductions of both Plans were accompanied by deadlines and threats of "possible harsh consequences," if any of the sides reject it. These ultimatums reduce the time for a proper consultation period and meaningful counter-proposals by potential opponents. Despite this, the Israel-Gaza Peace Plan became a legal document after its approval by the UNSC. As for now, the peace plan for Ukraine is still in progress, but the chances that the Russia-Ukraine War may become a frozen conflict are high.

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